THE UPTON-THORNTON OIL FIELD, WYOMING.

By E. T. Hancock.

INTRODUCTION.

LOCATION OF THE FIELD.

The territory here designated the Upton-Thornton oil field (see Pl. VI) includes two small dome-shaped folds and a small tract that yields a moderate quantity of oil of excellent quality and is entirely separate from either of these domes. One of these domes will be referred to as the Upton dome and the other as the Thornton dome. The productive territory lies in Weston and Crook counties, Wyo., near the Chicago, Burlington & Quincy Railroad, about 3 miles northwest of Thornton. It is about 20 miles southeast of the Moorcroft oil field, 90 miles northeast of the Salt Creek field, and 80 miles almost due north of the very promising Lance Creek field. Most of the producing wells are in sec. 33, T. 49 N., R. 66 W., and sec. 4, T. 48 N., R. 66 W. The Upton dome is about half a mile southwest of the town of Upton, in secs. 34 and 35, T. 48 N., R. 65 W., and secs. 2 and 3, T. 47 N., R. 65 W. The Thornton dome, which lies about 2½ miles southeast of Thornton, is included mainly in secs. 7, 8, 17, and 18, T. 48 N., R. 65 W.

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The writer was assisted in the field work by Mr. Robert M. Campbell, for whose aid he desires to express his appreciation. He is also indebted for hearty cooperation to many of the citizens of Upton, especially to Messrs. R. C. Chappell and F. W. Palis, of the Southwest Oil Co., for valuable well data and for courtesies shown in many ways.

PURPOSE OF THE INVESTIGATION.

The purpose of the present investigation was to assist in the development of the field by making a detailed study of the stratigraphy in order to determine the stratigraphic position of the oil-bearing sands and the possibility of obtaining oil and gas in other sands, also to discover and locate such structural features as have elsewhere been found to have a definite relation to accumulations of oil and gas.

METHOD OF FIELD WORK.

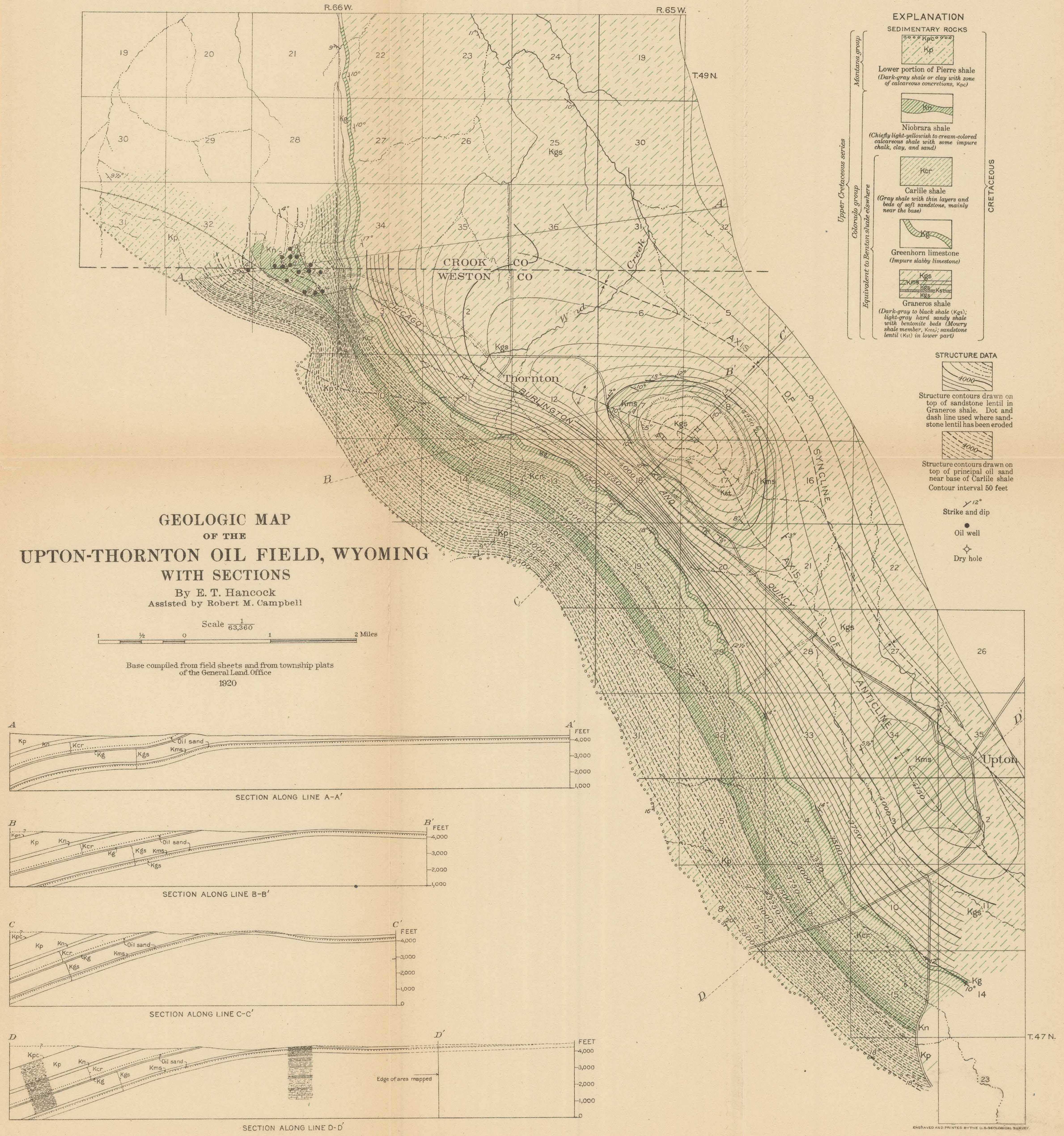
The investigation that furnished a basis for the present report was made in July and August, 1918. The field observations were made and the maps prepared under the immediate supervision of the writer. In the process of mapping nearly all locations were made by triangulation, and elevations were determined by means of vertical angles. A line 10,400 feet long was measured on the railroad track southeastward from the station at Thornton, and with this as a base, a system of triangulation was extended over the area. Beginning with the known elevation of the railroad track at Thornton the elevation of each of the stations was determined by vertical angle.

HISTORY OF DEVELOPMENT.

An attempt was made to test the Thornton dome several years ago. Two holes were drilled near the top of the dome, and from the appearance of the cuttings near the holes the drill must have penetrated the red beds. The first apparent discovery of oil was made by the Southwest Oil Co. in its No. 2 well about three years ago. Since that time the company has drilled 12 more wells and has obtained oil in every one of them.

TOPOGRAPHY.

This field has no very conspicuous surface features. It lies along the southwest flank of the Black Hills uplift, and its topography is mainly the result of the action of wind, rain, and running water on the long, narrow outcrops of beds that present different degrees of resistance. For example, the Greenhorn limestone, which occurs between the great body of soft shale in the upper part of the Graneros formation and that of the Carlile shale, forms a continuous ridge from one end of the field to the other. Near Upton and about 2½ miles southeast of Thornton local uplifting of the strata has given rise to relatively high areas exhibiting a reversal of dip along the east side. The doming of the strata near Upton has produced an elliptical hill nearly 100 feet higher than the surrounding area. That about 2½ miles southeast of Thornton has given rise to a similar hill whose top is approximately 170 feet above the surrounding flat.



GEOLOGIC MAP OF THE UPTON-THORNTON OIL FIELD, WYOMING WITH SECTIONS

By E. T. Hancock
Assisted by Robert M. Campbell

Scale $\frac{1}{63,360}$

Base compiled from field sheets and from township plats of the General Land Office
1920

The drainage channels in this field occur, for the most part, in the valleys between the outcrops of the more resistant beds. The uplifting of the strata in the formation of the Thornton dome has given rise to a somewhat elevated tract from which the streams flow in opposite direction. A portion of the sediment that is picked up by running water near the top of this divide is carried southeastward and another portion goes northwestward. These two portions together completely encircle the Black Hills, one on the south and the other on the north. After being transported several hundred miles the sediment is again mingled in eastern Meade County, S. Dak., where Belle Fourche River joins the South Fork of the Cheyenne to form Cheyenne River.

GEOLOGY.

STRATIGRAPHY.

GENERAL SECTION.

No sedimentary beds crop out in this field which are lower in the stratigraphic column than those about 100 feet above the Dakota sandstone, the oldest formation of the Upper Cretaceous series in this region, but in attempting to determine the possibilities of the accumulation of oil and gas it is necessary to consider all the beds that lie within reach of the drill. In this field the principal known concentration of oil is in beds that reach the surface a short distance from the center of accumulation, but in most other fields the greatest accumulations are in porous sands which are sealed by the overlying impervious beds, especially where the entire series has been arched upward. Inasmuch as the beds in this field have been arched in two different localities outside of the productive area it is necessary to consider the relations, composition, and depth of some of the underlying beds. The following table shows the rock formations which crop out in this field, as well as those which were penetrated in the bore hole at the Antelope mine at Cambria, Wyo., and in the deep well at Cambria. The same formations from the Morrison down are represented graphically in figure 1.

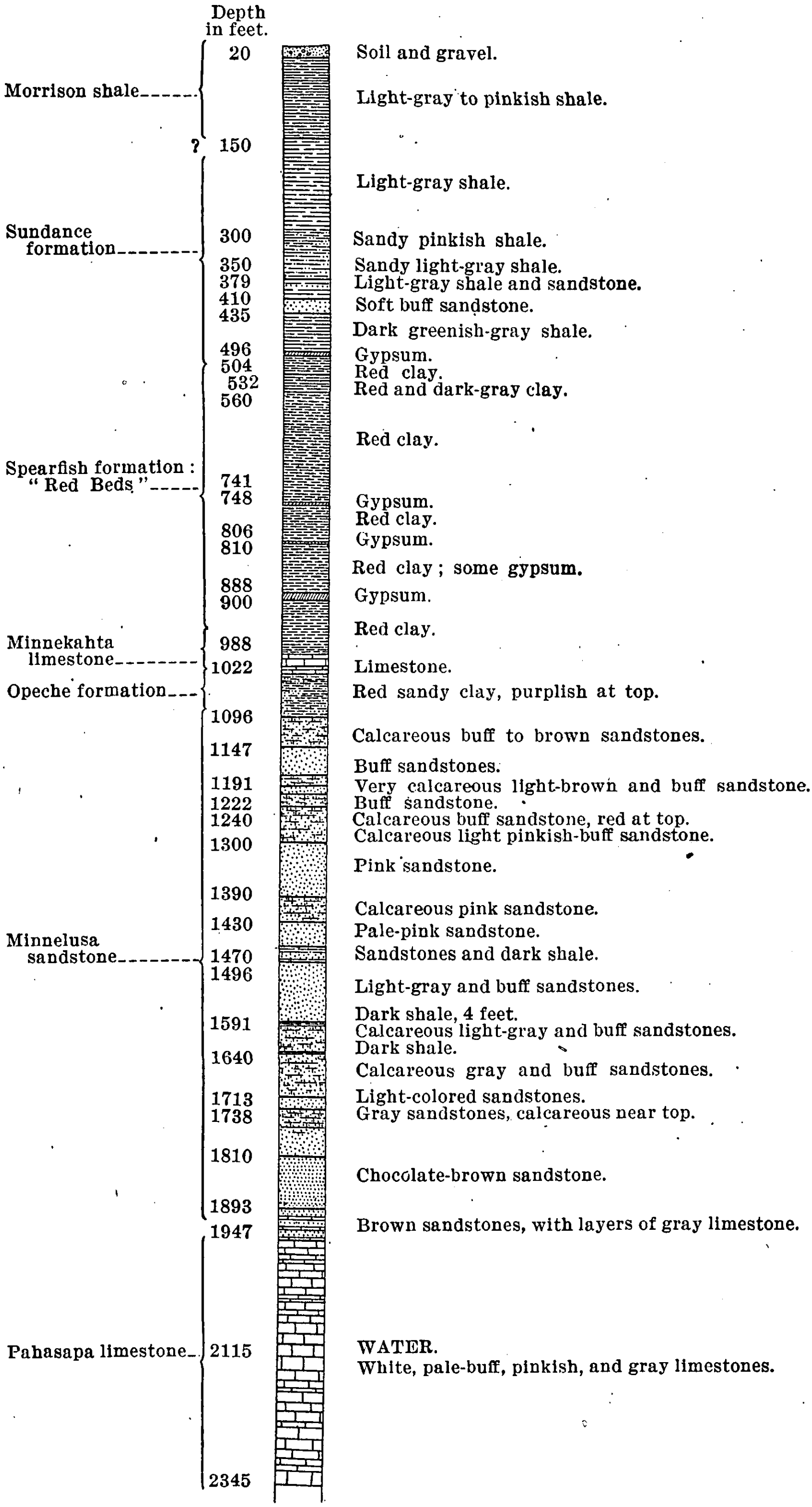


FIGURE 1.—Log of well at Cambria, Wyo. From Darton, N. H., U. S. Geol. Survey Geol. Atlas, Newcastle folio (No. 107), p. 8, 1904.

Section of rock formations in the Upton-Thornton field.

System.	Series.	Group.	Formation and member.	Character.	Thickness (feet).
Cretaceous.	Upper Cretaceous.	Montana.	Pierre shale.	Dark shale including a zone of calcareous concretions near middle and a few thin beds of bentonite. Only lower 1,200 feet to top of zone of calcareous concretions is mapped.	2,500±
		Colorado.	Niobrara shale.	Chiefly light-yellowish to cream-colored calcareous shale, with some impure chalk, clay, and sand.	200
			Carlile shale.	Dark shale with thin beds of soft sandstone mainly near the base.	700
			Greenhorn limestone.	Impure slabby limestone.	50
			Graneros shale.	Dark-gray to black shale, including many large calcareous concretions, especially in the upper part.	800
			Mowry shale member.	Hard, light-gray, sandy shales containing numerous fish scales. Bentonite beds near the top and to some extent near the base.	150
				Dark sandy shale grading upward into typical Mowry shale.	50
				Reddish to light-yellow sandstone associated with black carbonaceous shale.	3 to 15
				Dark-gray to black shale.	225
			Dakota sandstone.	Thin-bedded to massive hard buff sandstone.	60
	Lower Cretaceous.		Fuson formation.	Shale and thin-bedded sandstone.	20
			Lakota sandstone.	Sandstone, in part conglomeratic, with some coal beds near the base.	200
Cretaceous(?).	(?)		Morrison formation.	Light-gray to pinkish shale.	130
Jurassic.	Upper Jurassic.		Sundance formation.	Light-gray to dark greenish-gray and pinkish sandy shale with a 25-foot sandstone near the base.	346
Triassic (?).			Spearfish formation.	Gypsum and red clay beds in alternating succession. Popularly known as the "Red Beds."	492
Carboniferous.	Permian (?).		Minnekahta limestone.	Light-gray to pinkish or purplish limestone.	34
			Opeche formation.	Red sandy clay, purplish at the top.	74
	Pennsylvanian.		Minnelusa sandstone.	Light gray to buff calcareous sandstone.	851
	Mississippian.		Pahasapa limestone.	White, pale-buff, pinkish, and gray limestone.	398±

FORMATIONS NOT OUTCROPPING BUT WITHIN REACH OF THE DRILL.

The section from the top of the Dakota sandstone down into the Morrison is well shown in the bore hole of the Antelope mine, at Cambria, about 23 miles southeast of Upton.

Section in bore hole of Antelope mine at Cambria, Wyo.[1]

	Feet.
Dakota:	
Sandstone, thin bedded, at top of table	20
Sandstone, hard, massive, buff colored	40
Fuson:	
Shale and talus	20
Lakota:	
Sandstone, light colored, conglomeratic in part	60
Talus and sandstone ledges	70
Sandstone, light gray, soft, fine grained	50
Coal	7
Sandstone, hard, light brown	5
Sandstone, soft, dark brown	2
Sandstone, light gray, moderately hard	1½
Coal with sandstone, shale, and pebbly layers	½
Sandstone, dark gray, soft	1
Coal, shales, and sandstone	2
Morrison:	
Fire clay, gray	3
Sandstone, light gray, moderately hard	1½
Fire clay	7½
Sandstones, gray, upper half very hard	4
Shales with some thin sandstones	54

The deep-well boring at Cambria probably furnishes as detailed and reliable information regarding the underlying formations as can be obtained. The well was begun just below the 7½-foot bed of fire clay in the above section and was continued to a depth of 2,345 feet. The log of the well, as shown in figure 1, was compiled by N. H. Darton from samples sent to Washington and from a set of borings admirably preserved in glass tubes by Mr. Mouck, the superintendent of the Cambria mines.

Inasmuch as the beds exposed at the top of the Thornton dome lie about 100 feet above the Dakota sandstone, it follows that the beds at the bottom of the deep well at Cambria are about 2,830 feet stratigraphically below the top of the Thornton dome. The Upton dome is not eroded as deeply by about 200 feet, and consequently the same beds are about 2,930 feet below the top of that dome.

A careful analysis of the logs of the bore hole in the Antelope mine and the deep well at Cambria shows that the principal sand-

[1] Darton, N. H., U. S. Geol. Survey Geol. Atlas, Newcastle folio (No. 107), p. 4, 1904.

stones beneath the surface in this region are included in the Dakota, Lakota, and Minnelusa formations. At the Antelope mine the Dakota is composed of an upper thin-bedded sandstone and a lower hard, massive buff sandstone. The Lakota is composed mainly of sandstone, in part conglomeratic, with coal beds near the base. The Morrison consists mainly of light-gray to pinkish shale, with beds of sandstone and fire clay near the top. The Sundance formation is composed mostly of light-gray to dark greenish-gray and pinkish sandy shales but includes near its base one soft buff sandstone about 25 feet thick. Extending from the base of the Sundance formation down to the Minnekahta limestone is the Spearfish formation, commonly known as the "Red Beds," including gypsum and red clay in alternating succession. The Permian series is probably represented by the Minnekahta limestone, about 34 feet thick, and the underlying Opeche formation, composed of 74 feet of red sandy clay, somewhat purplish at the top, although the Permian age of these formations has not been established. The Carboniferous from the base of the Permian series to the bottom of the well is composed essentially of sandstones and limestones. The Minnelusa formation consists almost entirely of light-gray to buff calcareous sandstones, the total thickness of which is 851 feet. From the base of this formation to the bottom of the well there is 398 feet of massive limestone.

OUTCROPPING FORMATIONS.

UPPER CRETACEOUS ROCKS.

COLORADO GROUP.

GRANEROS SHALE.

Overlying the Dakota sandstone in this field is a mass of soft, fine-grained deposits about 1,225 feet thick. The greater part of the mass consists of dark-gray to black shale which is very soft and yields readily to the ordinary agencies of erosion. About 225 feet above the base of the formation is a reddish-brown, moderately soft sandstone, the outcrop of which encircles the central portion of the Thornton dome and occurs in isolated patches near the top of the dome. It is apparently only 2 or 3 feet thick around the northwest end of the dome, but on the east side of sec. 17 it is considerably thicker. In that locality there is about 15 feet of reddish to light-yellow sandstone associated with some black carbonaceous shale, somewhat resembling a section of the sandstone member and associated beds of the Graneros shale measured on the west side of a gully about 4 or 5 miles northeast of Upton and oneeighth of a mile east of the main road. At that locality some prospecting has been done, apparently in a search for coal, and a 12-foot bed of light-yellow massive sandstone overlain by dark shale is exposed. The sandstone is underlain by 5 feet of black carbonaceous shale, which in turn is underlain by 3 feet of sandy shale and sandstone. Underlying the 3-foot bed is 16 feet of somewhat sandy carbonaceous shale. East of the gully is a long dip slope rising toward the east on the surface of a sandstone which weathers reddish brown and which is believed to be a few feet higher than the 12-foot massive sandstone on the west side of the gulch.

From Stockade Beaver Creek, about 5 miles southeast of Newcastle, northwestward to the north side of T. 45 N., R. 62 W., the sandstone member of the Graneros is much thicker and is so hard and resistant that it gives rise to very prominent hogbacks southwest of the main ridge formed by the Dakota sandstone, from which it is separated by a line of narrow valleys eroded out of the intervening black shale. In the vicinity of Newcastle, where it contains more or less petroleum, it is about 35 feet thick, and a short distance west of that town it forms a ridge about 500 feet above the railroad.

Encircling the outcrop of the sandstone member of the Graneros in the Thornton dome is an area underlain by dark shale. This shale, which overlies the sandstone and gradually merges upward into the typical Mowry shale, is about 50 feet thick. This shale area, which sustains a rank growth of sagebrush, can readily be distinguished because it lies between the barren dip slope formed on the top of the sandstone member of the Graneros and the outer encircling area underlain by the Mowry shale and characterized either by a stunted growth of grass or by an abundance of evergreens.

The narrow zone of dark shale described in the preceding paragraph merges upward into the typical Mowry shale member of the Graneros. The Mowry shale underlies at the surface the outer narrow belt in the Thornton dome and the entire central portion of the Upton dome. It comprises about 150 feet of hard light-gray sandy shales that contain numerous fish scales. These shales weather nearly white, in strong contrast with the softer dark-colored shales above and below. Owing to their superior hardness they do not erode as rapidly as the overlying and underlying shales. The soil derived from them is in places entirely barren, as is well shown by the upper portion of the Upton dome. Although the outcrops of the Mowry shale are rarely grass covered, it is very common to find them covered by a moderately dense growth of evergreens. In the upper part of the Mowry shale there are several thin beds of bentonite. This mineral is a hydrous silicate of alumina with certain other constituents in small proportions. It is characterized by its high absorbent qualities, having the power of absorbing three times its weight of water. It is a light-gray to yellowish fine-textured soft massive clay. One of the beds occurs about 15 feet above the top of the typical Mowry shale and is exhibited as a light-colored band around many of the low banks of shale between the Thornton dome and Upton and for some distance north of the Thornton dome. It was especially valuable as a horizon marker in the determination of structure, because it shows a striking contrast to the rusty, iron-stained beds a few feet above the Mowry shale and was therefore very easily recognized. When wet the material is exceedingly sticky, but on drying it shrinks and breaks up into small irregular-shaped lumps.

The upper 800 feet of the Graneros formation is composed essentially of dark-gray to black shale, including many large concretions, especially in the upper part.

GREENHORN LIMESTONE.

Immediately overlying the upper dark shale of the Graneros formation is a thin but very persistent series of beds of impure limestone known as the Greenhorn limestone. In most places the entire formation does not exceed 50 feet in thickness, but these limestone beds and the sandstones in the lower portion of the Carlile shale are so much harder than those above and below that they give rise to a continuous ridge or northeastward-facing escarpment extending the entire length of the field. On weathering the thin beds of limestone become very hard and resistant, and in consequence the outcrop of the Greenhorn limestone is in many places marked by a series of thin slabs projecting above the surface. These slabs are commonly characterized by numerous impressions of *Inoceramus labiatus*, a fossil which rarely occurs in the Carlile and Graneros formations.

CARLILE SHALE.

The Carlile formation consists mainly of shales with some thin beds of sandstone near the base. The entire formation is about 700 feet thick. The lower portion of the formation is best exposed in the railroad cut about 2 miles northwest of Thornton. Although it was rather difficult to measure the beds accurately along the railroad, nevertheless the separate units in the following section were examined carefully and the description should convey a rather definite notion regarding the composition of the lower third of the formation.

Section of the lower portion of the Carlile shale and the Greenhorn limestone in the railroad cut about 2 miles northwest of Thornton, Wyo.

	Ft.	in.
Sandstone, soft and unconsolidated	4	
Shale, dark gray	6	
Sandstone, soft, brown	1	4
Shale, dark, inclined to be sandy in places	20	
Sandstone, in thin beds forming a shelving ledge; strike N. 20° W., dip 25° S. 70° W	3	
Shale, dark gray	33	
Shale, including some very thin beds of sandstone	15	
Shale, dark, containing a few sandstone concretions and belts of very sandy shale. These shales and sandy shales were examined at several horizons and with few exceptions gave a very distinct odor of petroleum. The sandy shales near the base are in places nearly saturated with oil	90	
Sandstone		10
Sandstone, soft, unconsolidated, and shale in alternating bands, giving distinct odor of petroleum	2	6
Sandstone, hard		6
Soft sand and dark sandy shale in thin alternating layers; distinct odor of petroleum throughout	15	
Shale, dark, somewhat sandy	20	
Soft sandy beds of yellowish-brown color, including seams of dark sandy shale	20	
Shale, very sandy, and soft sandy layers including large calcareous concretions cut by irregular branching veins of calcite. Probably represents the Greenhorn limestone	20	
Shale, very sandy	40	

In many places the sandstone in the lower part of the Carlile shale gives rise to sharp ridges, and if the dips are very steep these ridges have very ragged crest lines.

NIOBRARA SHALE.

Owing to the softness of the constituent materials and the consequent lack of good exposures, the Niobrara shale is the most indefinite of all the formations in this field, and consequently the boundaries as shown on the geologic map (Pl. VI) are subject to the greatest amount of error. The formation is about 200 feet thick and is composed of soft calcareous shale with some impure chalk, clay, and sand. Where the formation is unweathered it is generally light gray, but upon weathering it acquires a bright-yellow color. It sometimes contains hard, limy beds made up largely of an aggregation of shells of *Ostrea congesta*, a fossil very distinctive of the formation. Owing to the softness of the beds it commonly occupies a more or less shallow valley at the foot of the slope formed by the harder rocks of the Carlile shale.

MONTANA GROUP.

PIERRE SHALE.

This field (see Pl. VI) includes only the lower portion of the Pierre shale, or from the base up to the top of a well-defined zone of calcareous concretions, which, on the basis of the structure sections, appears to be about 1,200 feet above the base of the formation. The formation in general is made up of a rather uniform mass of dark-colored shale, but at certain horizons the shale contains more or less admixed sand. There are also other horizon markers in the shale, such as thin beds of bentonite and zones of calcareous concretions, some of which are very fossiliferous. The first well-defined ridge southwest of that formed by the Greenhorn limestone and overlying beds is developed along the outcrop of one of these zones of concretions, which is shown on Plate VI.

STRUCTURE.

METHOD OF REPRESENTATION.

In order to obtain a fairly adequate notion of the lay of the sedimentary rocks in the Upton-Thornton field the reader should carefully examine Plate VI, which shows the long, linear outcrops of the different formations and by structure contours and structure sections their angle of inclination and distance above sea level. The following explanation is offered for the benefit of those who are unfamiliar with the interpretation of structure sections and structure contours.

A structure section is based mainly on the degree of inclination of the beds at the surface, on measured stratigraphic thicknesses, and on data derived from deep borings. It shows how a portion of the earth's crust would appear if it were cut along a vertical plane and the rocks on one side of the plane were entirely removed and exhibits the angle of inclination as well as the relation of the different formations to the surface and also to sea level. Four sections showing the structure along lines A–A′, B–B′, C–C′, and D–D′ are given on the map, and section D–D′ shows the formations given in the table on page 21.

Structure contours are lines drawn on a map to show the elevation of a chosen horizon or stratum above or below a certain datum plane, as, for example, mean sea level. They are like topographic contours in that every part of any one contour is at the same elevation above the chosen datum plane. They are designed to show the shape and magnitude of the folds and in general the irregular warping of the beds. In the preparation of the accompanying map, it was decided to use two sets of structure contours, as shown under "Explanation." One set is drawn on the top of the sandstone lentil in the lower part of the Graneros shale. The contours in this set are indicated by the unbroken lines, and each contour is 50 feet either above or below the adjacent one. The contours of the second set are represented by the broken lines and are drawn on the top of the principal oil sand in the lower part of the Carlile shale. It follows, therefore, that any particular contour is the line of intersection between the top of the sand which is contoured and a horizontal plane a certain distance (for example, 4,000 feet for the 4,000-foot contour) above sea level.

STRUCTURE OF THE UPTON-THORNTON FIELD.

The Upton-Thornton field as a whole occupies a portion of the southwest flank of the Black Hills uplift, and hence the prevailing dip is toward the southwest, but as the structure sections clearly show, the dip increases as the distance from the Black Hills increases. In the eastern part of the field the beds rise toward the Black Hills at a uniformly low angle, but in the western part the dips range from 10° to 25°. The bedding in the Pierre shale is not as easily recognized as that in some of the lower formations, but by careful observation thin layers of sandstone, belts of concretions, and yellow beds of bentonite can be detected in many places. Such beds indicate a southwesterly dip in the southern part of the field of 17° to 20°, and the Pierre shale is inclined at a similar angle as far north as Thornton. From that place northward, however, the beds flatten out very materially. The true angle of dip can be determined with greatest accuracy from thin beds in the Greenhorn limestone. South of Thornton that formation is inclined southwestward at angles ranging from 10° to 15°, but in the vicinity of the Chicago, Burlington & Quincy Railroad, where the strike changes abruptly, the Greenhorn limestone and overlying beds are inclined as steeply as 25°. North of the railroad the beds soon flatten and the dip is as low as 10°. South of the railroad in secs. 3 and 4, T. 48 N., R. 66 W., the entire series from the Greenhorn limestone to the zone of concretions in the Pierre shale dips very steeply, but the structure contours, which are based solely on the depth of the principal oil sand in the wells, indicate an abrupt flattening of the beds north of the railroad. Structure section A–A′, which is based on the dip of the Greenhorn limestone at its outcrop, on the elevation of the principal oil sand in the wells, and on the total thickness of beds between the principal oil sand and the zone of concretions in the Pierre shale, shows a well-defined structural terrace, or perhaps, to judge from the shape of the structure contours, an abrupt flattening along the axis of a low anticline.

In line with the strike of the beds in this field and about where the beds begin to flatten in approaching the Black Hills were developed two rather well-defined domes which, owing to their situation, are here named the Upton dome and the Thornton dome. The surface at the top of the Thornton dome is about 180 feet higher than it is at the top of the Upton dome, but the beds exposed at the top of the Thornton dome are about 250 feet nearer the Dakota sandstone than those at the top of the Upton dome, so that corresponding beds are about 430 feet higher in the Thornton than in the Upton dome. The beds at the top of the Upton dome are about 100 feet higher than the corresponding beds at the axis of the syncline a mile to the east and about 50 feet higher than the same beds at their lowest point between the Upton and Thornton domes, so that the amount of closure in this dome is small. The Thornton dome, on the other hand, is much higher, and the beds which crop out at the top are approximately 500 feet higher than the corresponding beds at the axis of the syncline between the Thornton dome and the Black Hills uplift.

The writer was unable, for lack of time, to study the structure far north of the line between Crook and Weston counties. The work there was confined mainly to the mapping of the Greenhorn limestone, and although structure section A–A′ shows the beds dipping westward from the top of the Mowry shale at a very low angle, nevertheless the wide belt of outcrop and the few dips recorded near the north edge of the field indicate the necessity for further study.

OIL.

OCCURRENCES OF OIL NEAR THE UPTON-THORNTON FIELD.

Some of the beds that crop out along the southwest flank of the Black Hills have for many years been known to contain oil in small quantity. The most pronounced seepages occur in the vicinity of Newcastle and in the Moorcroft field, which extends northward from Moorcroft, in a general way from Belle Fourche River to the center of T. 52 N., R. 67 W.

The sandstone that occurs about 225 feet above the base of the Graneros shale ranges from 10 to 30 feet in thickness in the vicinity of Newcastle. A small quantity of excellent petroleum oozes from this sandstone in at least two places. One of these oil springs is near the railroad about 2 miles west of Newcastle, where the sandstone underlies the long dip slope extending southward from the top of the high ridge west of Newcastle and dips beneath the surface in a small gully immediately north of the railroad. At the time of the writer's visit the oil had collected to considerable extent in an old cistern-like structure immediately southwest of the railroad, and from all appearances it was being freely used as a lubricant by those living in the vicinity. The other spring is said to be about 2 miles farther northwest and a little farther north of the railroad. Several attempts have been made to develop the oil-bearing sand in its extension underground by means of wells a short distance west and southwest of Newcastle, but apparently these operations have not yielded a large supply of oil. The oil is very heavy and even in its crude state is reported to be a high-grade lubricant.

A high-gravity oil also finds its way to the surface at several localities in the Moorcroft field, and in order to convey some notion regarding the nature of the seeps, the probable source of the oil, and the efforts that have been made to develop the field, the following is quoted from a previous report:[1]

> In the SE. ¼ sec. 2, T. 51 N., R. 67 W., at a small spring seeping from the shale and sandstone of the Fuson shale, oil collects on the surface of the water; in the NE. ¼ NE. ¼ sec. 34, T. 52 N., R. 67 W., a very small amount of oil occurs in a ravine in the sandstone member of the Graneros shale; in the NE. ¼ SE. ¼ sec. 27, T. 52 N., R. 67 W., there is a spring of water on the surface of which oil collects in sufficient quantity to be dipped up with a ladle; and about one-quarter of a mile farther north, in the next ravine, at another spring of water, oil collects in very small quantities. In the sandstone member of the Graneros shale exposed in a ravine in the SE. ¼ sec. 22, T. 52 N., R. 67 W., there is oil in sufficient quantity to give a brownish color to the rock and impart a distinct odor of petroleum. Oil also seeps to the surface in three of the old drill holes along the west flank of the anticlinal ridge, as follows: Well No. 4, in sec. 36, T. 51 N., R. 67 W.; well No. 14, in sec. 12, T. 51 N., R. 67 W.; and well No. 30, in the NE. ¼ sec. 34, T. 52 N., R. 67 W. Oil is obtained at a depth of about 600 feet from six wells in the NW. ¼ sec. 34, T. 52 N., R. 67 W., where it occurs either in the sandstone member of the Graneros shale or in the Mowry shale member of the Graneros and is reported to have been struck at a depth of about 600 feet.
>
> Of the 65 seeps and wells described in the following pages, 3 are oil springs, 21 are shallow holes which should not be considered wells, and 41 are wells which are perhaps fair tests for oil at the localities where they were drilled. Of these 41 test holes 15 are reported to have struck "showings" or small quantities of oil. One well is reported to have yielded a small amount of gas, and four wells gave flowing water. All the wells in the field but seven have been abandoned as oil wells.

The map accompanying the report on the Moorcroft field shows that the beds dip westward away from an irregular anticlinal axis at an angle of about 12°. Most of the wells were begun either in the Mowry shale or in the upper dark shale between the Mowry and the Greenhorn limestone, apparently with the hope of obtaining considerable oil in the sandstone member of the Graneros shale. The sequence of beds is apparently the same as in the Upton-Thornton field, but the reader should bear in mind that the oil which is at

[1] Barnett, V. H., The Moorcroft oil field, Crook County, Wyo.: U. S. Geol. Survey Bull. 581, p. 86, 1915.

present being obtained in the Upton-Thornton field comes from beds much higher in the sedimentary column than those so thoroughly tested in the Moorcroft field.

OIL NEAR THORNTON.

The soft sandy shales and more or less pure sandstones near the base of the Carlile shale come to the surface and are well exposed in the railroad cut about 2 miles northwest of Thornton. These beds are petroliferous throughout and in places are thoroughly saturated with oil. It is reported that oil has been known to seep from these beds in sufficient quantity to accumulate in small pools in the bottom of the ditch along the railroad track. During the last two years considerable drilling has been done north of the railroad, mainly by the Southwest and High Gravity oil companies, for the purpose of testing these sands, and at present a small quantity of high grade light oil is being obtained from the wells by pumping and also by bailing. The Southwest Oil Co. has erected a small refinery near the center of the field and is able to supply local trade with gasoline and other products. The wells are all shallow, their depth, of course, depending on their distance from the outcrop. The oil is obtained mainly from a sand which ranges in thickness from 29 to 47 feet and is reached at depths ranging from 448 to 843 feet. The depth of the wells and the depths at which the principal oil sand was reached are shown below. A good showing of oil was also obtained in some of the wells from a sand 6 to 30 feet thick which occurs from 22 to 50 feet above the principal oil sand. The productive capacity of the wells that have already been drilled will probably range from 5 to 10 barrels a day.

Depth of wells and depth to principal oil sand in Upton-Thornton field, Wyo.

Well No.	Depth of well (feet).	Depth to principal oil sand (feet).	Well No.	Depth of well (feet).	Depth to principal oil sand (feet).
Southwest Oil Co.:			North Central Oil Co.:		
2	657	620	11	575	533
3	737	708	12	480	448
4	880	843	13	612	565
5	622	590	High Gravity Oil Co.:		
6	655	621.5	14	655	616
7	590	547	15	Drilling.	676
8	638	602	16	770	730
9	641	603			
10	585	585			

QUALITY OF THE OIL.

The oil that is being obtained near Thornton is of medium light olive-green color and has a low specific gravity. Six samples of oil taken from wells 2 to 7, inclusive, of the Southwest Oil Co. were analyzed with the results shown below.

Analyses of oils from wells of the Southwest Oil Co., Upton-Thornton field, Wyo.

[Made in the laboratory of the Bureau of Mines. Distillation in Bureau of Mines Hempel flask. Amount distilled, 200 centimeters.]

Well No.	Gravity at 15° C.		Air distillation, with fractionating column.						Vacuum distillation, without fractionating column.			
					To 150° C.		150° to 300° C.			175° to 300° C.		
	Specific.	Baumé (°).	Barometer reading (millimeters).	Distillation begins (°C.).	Total percentage distilled by volume.	Specific gravity at 125°-150° C.	Total percentage distilled by volume.	Specific gravity at 275°-300° C.	Pressure (millimeters).	Total percentage distilled by volume.	Residuum (per cent).	Sulphur (per cent).
2	0.823	40.1	734.8	25	19.4	0.770	32.4	0.843	38	22.0	26.2	0.10
3	.882.	40.3	734.8	25	23.1	.770	31.4	.846	38	21.5	24.0	.083
4	.826	39.5	739.1	25	23.6	.770	32.1	.847	38	20.0	24.3	.083
5	.822	40.3	739.1	25	24.9	.774	34.4	.843	40	20.0	20.7	.094
6	.822	40.3	739.1	26	23.6	.779	31.5	.848	38	22.0	22.9	.095
7	.820	40.7	740.0	24	25.6	.764	31.0	.846	38	21.5	21.9	.093

ORIGIN OF THE OIL.

The primary source of petroleum is not definitely known, but most oil geologists believe that it is of organic origin. It seems probable that most of the petroleum in the earth's crust has originated from plants rather than animals, for two reasons—in most rocks the carbonaceous remains of plants are far more abundant than those of animals, and the hydrocarbon-bearing portions of animals decompose more readily than the corresponding parts of plants. It has been estimated that more than 99 per cent of the carbonaceous material in the earth's crust is of plant origin. Aside from the water which they contain, plants consist mainly of the elements that enter into the composition of petroleum and natural gas, namely, oxygen, hydrogen, and nitrogen. It is true that the soft parts of animals are composed mainly of the same elements, yet they decompose much more readily and therefore are much more likely to be dissipated into the atmosphere or to be picked up by running water before being buried so deeply that oxidation and decomposition cease. In certain localities petroleum and natural gas have been found intimately associated with plant remains; in others they are more directly associated with the hard parts of animals, as, for example, the shells of mollusks. The great accumulations of petroleum and natural gas, however, indicate migration on a large scale, hence it is in general very difficult to say whether these substances originated where they now occur or whether they originated elsewhere and gradually migrated to their present position as a result of the chemical and physical processes that are continuously going on within the earth's crust.

The oil-bearing sands near Thornton lie immediately above the Greenhorn limestone, in which the shells of mollusks are abundant.

The limestone itself overlies a thick mass of dark shales, and the oil-bearing sands are overlain by similar material containing calcareous concretions many of which are very fossiliferous. It seems to the writer reasonable to suppose that the oil now present in the sands originated, to some extent, from the soft parts of these sea animals but also in part from carbonaceous material included in the dark shales themselves.

CONDITIONS GOVERNING THE ACCUMULATION OF OIL AND GAS.

A careful examination of the structure of the rocks and its relation to concentrations of oil and gas in many parts of the world has given rise to the structural or anticlinal theory. The conditions that control the accumulation of oil and gas, according to this theory, are briefly as follows:

1. A reservoir rock. This is commonly known as an oil sand, although it may be a very sandy shale, a fractured rock of some kind, a loose conglomerate sufficiently porous to allow the accumulation of oil or gas, or a porous limestone composed largely of interlocking crystals of calcite.
2. An impervious cap rock, to seal over the reservoir rock and prevent the upward escape of the oil and gas.
3. Folds in the rock favoring the accumulation of oil and gas in certain localities, these substances migrating from more extensive areas of adjoining beds less favorably situated for their retention.
4. Saturation of the rocks by ground water, on which the oil and gas will move on account of their lower specific gravity and be forced into the upper parts of the folds. According to the anticlinal theory, if a porous rock containing gas, oil, and water is folded between other rocks which are nonporous, these substances, under the influence of gravity, separate and arrange themselves according to density. Gas, being the lightest, rises to the crest of an anticline, the oil separates out below, and the water seeks the deepest portions of the beds. Detailed field observations have shown not only that many of the concentrations of oil and gas are intimately related to anticlines and domes, but also that gas, oil, and water are related in the manner indicated. Although the recognition of these facts has caused most geologists to accept the anticlinal theory in its broader aspects, many of them are willing to accept it only in a modified sense, as recent study has shown that accumulations of oil and gas occur not only in the crowns of the arches but also in many places on the flanks of the folds where the dips are interrupted for some distance, the interruptions forming structural terraces.

The accumulation of oil near Thornton bears a definite relation to such an area of local flattening of the beds, and the writer believes that this flattening is the principal cause of the accumulation. Inasmuch as the oil sands, where exposed at the surface, contain very little organic material, it seems reasonable to assume that the oil which they now contain had its origin in the dark shales and impure fossiliferous limestone above and below. It is believed that the surrounding shales and impure limestone far from the outcrop and for some distance along the strike have contributed toward the present accumulation. If the assumption is correct that the oil and a little gas originated in the surrounding beds, they must have gradually migrated through these beds into the porous sands, which were probably pretty thoroughly saturated with water. As the oil, gas, and water become mingled in the steeply dipping porous sands they in all probability separated and arranged themselves in the order of density, for although intermolecular attraction no doubt plays an important part in the movement of these substances it is the writer's belief that where the sands dip steeply gravity is probably the dominant force. The oil, being less dense than the water was borne upward, but as it entered the sands that were nearly flat-lying the viscosity of the oil and the adhesion of the oil and sand were probably almost equal to the greatly diminished force of gravity. In the gently dipping beds, where the opposing forces were active, the upward movement of the oil was retarded and the result was a greater concentration, but where a local flattening of the beds does not occur it is doubtful if the upward movement has been sufficiently retarded to produce any considerable concentration of oil.

SUGGESTIONS FOR DRILLING.

The close relation which has been observed between anticlinal structure and accumulations of oil and gas suggests that the Upton and Thornton domes should be carefully tested with the drill. From the description of these domes given under the heading "Structure" it is evident that the Thornton dome offers the greatest possibilities for oil and gas accumulation, mainly for the reason that it is a much higher fold, the closure being about ten times that of the Upton dome.

The sandstone lentil that occurs about 225 feet above the Dakota sandstone and is commonly oil bearing in this region has been eroded from the Thornton dome, but it lies beneath about 150 feet of cover in the Upton dome. Owing to its thinness in this locality, however, and the lack of a sufficiently impervious cap rock there is little probability of finding much oil in that sand in the Upton dome. The Thornton dome has been drilled at two points with apparently unfavorable results, and both of the holes seem to have been well located. The writer was unable to obtain the logs of the wells, but from the appearance of the dried sludge the drill must have entered the red beds. Owing to the fact that considerable oil was encountered in the Minnelusa sandstone in the Old Woman anticline, about 75 miles to the south, the writer feels that the Carboniferous beds should also be thoroughly tested in so promising a fold as the Thornton dome.