THE OSAGE OIL FIELD, WESTON COUNTY, WYOMING.

By A. J. Collier.

INTRODUCTION.

Location and production.—Oil seeps along the western front of the Black Hills have been known for many years, and between 1885 and 1900 there were temporary oil booms at Newcastle and Moorcroft, Wyo. In September, 1919, the discovery of high-grade oil in commercial quantities adjacent to a railroad again attracted many searchers for oil to that region and led to the development of what is known as the Osage oil field. This field was named from the flag station of Osage, on the Chicago, Burlington & Quincy Railroad, and is in Weston County about 15 miles northwest of Newcastle, the county seat. (See index map, fig. 6.)

In 1921 there were about 100 oil wells in the field, which were yielding from 1 to 50 barrels a day; several gas wells, yielding from 500,000 to 1,000,000 cubic feet a day; eight or nine flowing water wells; and many dry holes. The productive wells ranged in depth from 100 to 1,600 feet. Early in 1921 the field had an output of about 550 barrels of oil a day.

Within a year after the field was discovered a town of about 1,500 persons grew up (see Pl. X), roads were built and improved, a refinery with a capacity of 500 barrels a day[1] was established, about 200 wells were drilled, and pipe lines were laid. All this work probably cost about $3,000,000. In addition to the developments in the immediate vicinity of Osage the discovery stimulated prospecting elsewhere along the western front of the Black Hills. Whether or not these developments will be commercially profitable can not be stated. It seems unlikely that the Osage field will ever be a great producer of oil, at least from the sands that are now productive, but it will probably yield a moderate quantity for many years.

History of discovery.—The first attempt to find oil in wells on the west flank of the Black Hills was made at some time before 1887[2] in the Moorcroft field, about 40 miles northeast of Osage, and somewhat later the Newcastle field was drilled.[3] In both these fields a small

[1] Oil and Gas Jour., Oct. 1, 1921.

[2] Ricketts, L. D., Wyoming Territorial Geologist Ann. Rept., 1888, p. 43.

[3] Darton, N. H., Geology and water resources of the southern half of the Black Hills: U. S. Geol. Survey Twenty-first Ann. Rept., pt. 4, p. 586, 1901.

quantity of heavy oil was obtained. About 1915 light high-grade oil was discovered near the railroad between Thornton and Moorcroft.[4]

In 1910 John Nefsy discovered the oil seep on Poison Creek near the quarter corner between secs. 17 and 18, T. 46 N., R. 63 W., and in 1913 he and others located it as an oil claim. The same year he and his brothers bought the Nefsy town site, on which much of the town of Osage is located. Early in 1919 Mr. Kennedy, of the Mike Henry Oil Co., began drilling in sec. 5, T. 46 N., R. 63 W., and in

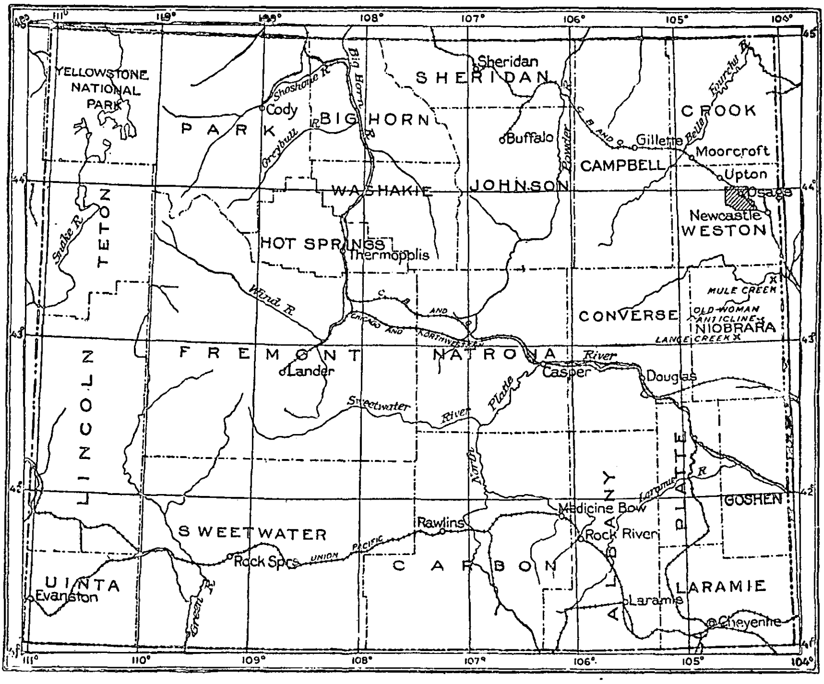
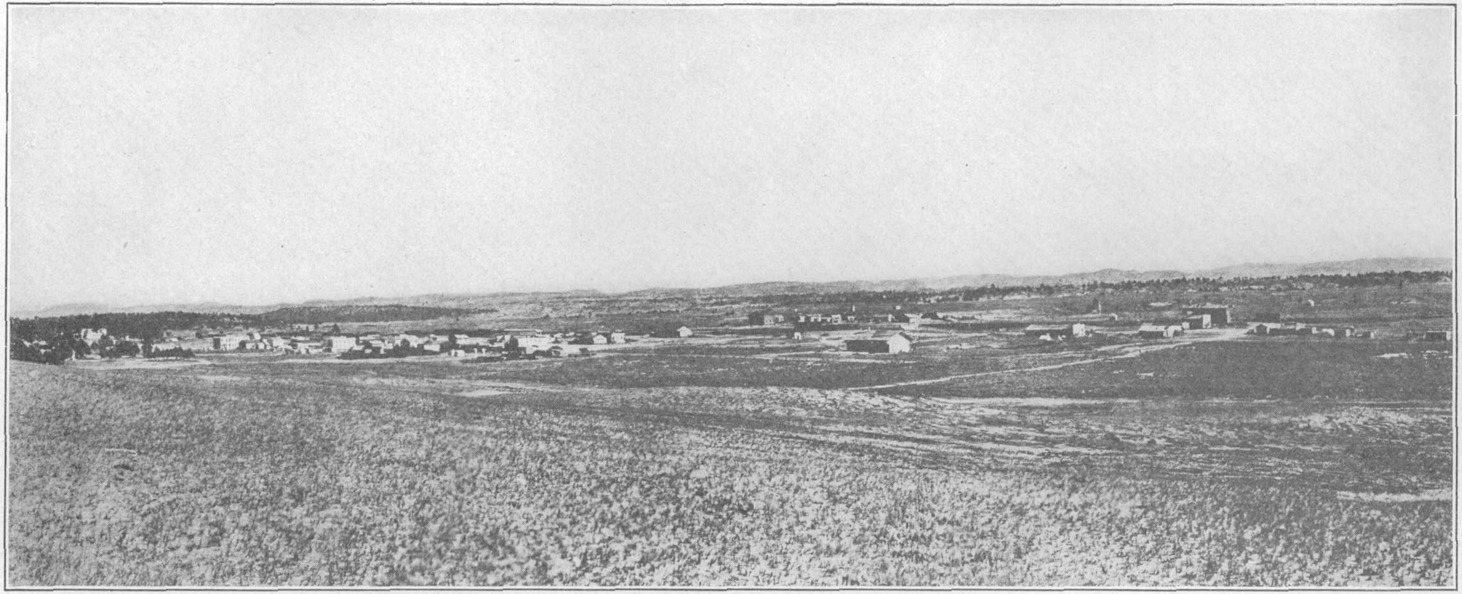


FIGURE 6.—Index map of Wyoming showing position of the Osage oil field.

September of that year he brought in the first shallow well. Soon after this discovery was made the Alliance Oil Co., represented by J. S. Adams, began drilling the first deep well, which came in as a gusher in March, 1920, and which was sold soon afterward to the Sinclair Oil Corporation and is now known as the pioneer well of the field.

Field work.—The field work on which this report is based was done in May and June, 1920, by the writer, assisted by M. G. Gulley. The season was a very bad one, for on April 18 Wyoming was visited by a blizzard and the whole of the western part was covered by deep snow. Very little work could be done before the 1st of June, but the relations and thickness of the formations exposed in the field

[4] Hancock, E. T., The Upton-Thornton oil field, Wyo.: U. S. Geol. Survey Bull. 716, p. 18, 1914.



GENERAL VIEW OF THE TOWN OF OSAGE, WYO., IN SEPTEMBER, 1920.

and the general position of the productive areas were determined approximately before it was possible to make exact measurements. The field was then surveyed with plane table and telescopic alidade. A base line was measured, and from it triangulation was carried to all parts of the field. From the points thus established the positions of many wells and minor points were determined by stadia readings. The altitude above sea level, determined by the Geological Survey, is given on several bench marks, and from these marks altitudes in all parts of the field were determined by vertical angles.

Although most of the field work was completed by the last of June, the writer kept in touch with the field, revisiting it several times during the summer, to note later developments.

Acknowledgments.—Credit is due to the topographers of the Geological Survey, who made a general map of the Black Hills region that was published in 1903, and to N. H. Darton, from whose report on the geology of the Black Hills most of the formation names and some of the descriptions in this report are taken. Without this assistance the interpretation of many observations made during the field work would be difficult. The writer wishes to thank the oil operators and drillers met in the field for their courtesy in furnishing well data and other necessary information. He would also recommend the work of Robert E. Clark and his associates, deputy county surveyors of Weston County, who unraveled an almost hopeless tangle of land lines and furnished a reliable plat of T. 46 N., R. 63 W. The present paper has been constructively reviewed by K. C. Heald, who visited the field late in the season of 1920.

SURFACE FEATURES.

Topography.—The Osage field lies on the western front of the Black Hills, and its surface consists of long asymmetrical ridges caused by the outcrops of harder beds and long valleys caused by softer beds, which dip slightly to the west. Both ridges and valleys are parallel to the Black Hills front. Near the east line of T. 46 N., R. 63 W., the land rises to the east on the dip slopes of the Dakota and Lakota sandstones. West of this line there is a rather indefinite valley from half a mile to 2 miles wide which is drained by Skull Creek. East of Osage an area of dissected hills which have gentle slopes on the west sides and steep slopes on the east sides and which are covered with a scattering growth of pine trees marks the outcrops of the Newcastle sandstone and Mowry shale, which extend across T. 46 N., R. 63 W., from secs. 24 and 25 northward to secs. 3 and 4. West of these hills there is a shale valley from 1 to 3 miles wide, and farther west is a pronounced ridge, made by the Greenhorn limestone. This ridge extends northward across the township from sec. 36 to the south side of sec. 1 and is unsymmetrical, having in many places a steep slope on the northeast side and a more gentle slope on the southwest side. On the southwest slope of this ridge there is a second ridge formed by the Wall Creek (?) sandstone, which varies in position with the variations in the dip of the underlying rocks. The valley of Beaver Creek, which is about 4 miles wide, lies southwest of the Greenhorn limestone and Wall Creek (?) sandstone ridges and is underlain by the shales in the Pierre and Niobrara formations and the upper part of the Carlile formation. All the land in this valley is low except a group of low buttes in secs. 20, 29, and 32, which are capped with concretionary zones in the upper part of the Carlile shale. The outcrop of the Fox Hills sandstone, which lies southwest of Beaver Creek valley, is marked in some places by a low escarpment. A profile about 8 miles long, running from east to west through Osage, would show the altitude of the Dakota sandstone on Skull Creek to be about 4,350 feet, the highest points on the Newcastle sandstone about 4,500 feet, Osage 4,317 feet, the low places on Poison Creek in sec. 17 about 4,250 feet, the high points on the Greenhorn limestone ridge about 4,350 feet, Beaver Creek about 4,000 feet, and the base of the Fox Hills sandstone about 4,050 feet.

Drainage and water supply.—Beaver Creek, which flows southeastward across the western part of the field, is a permanent stream, though the flow is small during dry seasons. This stream drains a large area north of the field. The only other permanent stream is Skull Creek, which flows southward near the east side of T. 46 N., R. 63 W. Poison Creek drains the part of the field near Osage and flows southwestward, crossing the Greenhorn limestone ridge in a comparatively narrow canyon in sec. 18, T. 46 N., R. 63 W. Just above the canyon the stream divides, and the converging streams flow approximately parallel with the strike of the Greenhorn limestone ridge. A part of the field northwest of Osage is drained by Turner Creek, which flows northward and crosses the Greenhorn limestone ridge in sec. 35, T. 47 N., R. 64 W. Water was impounded in these streams for use in drilling. Water for domestic use at Osage is obtained from several deep artesian wells that were drilled to the Dakota and Lakota sandstones near Osage. The Mike Henry artesian well, in sec. 8, T. 46 N., R. 63 W., usually had several wagons waiting to take on water for the camps.

Late in the season of 1920 a deep well in sec. 11, T. 46 N., R. 64 W., brought in a very large flow of water, which is piped to many of the wells and used for drilling. A well with a strong flow of somewhat salty water from the Newcastle and Dakota sandstones was brought in late in August in sec. 4, T. 45 N., R. 63 W.

Fuel supply.—The first fuel used in the field was coal from Sheridan, Wyo., which was delivered at the railroad station in Osage for $9 a ton and which probably cost twice that much at the wells. In June and July, 1920, oil was used as fuel at many of the rigs. Early in August the first gas wel was struck, and the wells drilled since that time have used gas where it was not too far away.

Climate.—This part of Wyoming has a somewhat arid climate, and being situated near the Black Hills it is an almost perfect place for well drilling from the first of June to the last of September. In ordinary seasons drilling operations can continue with some interruptions until Christmas. Through January and February the climate is ordinarily too cold for such work, and in March, April, and May the work is likely to be interfered with more or less by severe storms.

Settlement and agricultural value of the land.—The lands covered by the Osage oil field are not considered of great value for agriculture, and farms are very few. This is due to the character of the gumbo soil above the shale bedrock and to the lack of good water for domestic use. Farther west, however, beyond the outcrop of the Fox Hills sandstone, the soil is more sandy, good water can usually be found in shallow wells, and the lands have been taken up by dry-land farmers. Much of the higher land east of the Osage field has been held by farmers for many years.

Roads.—The prevalence of shale and shale soil makes the building of roads that will be good at all seasons of the year very difficult. During the wet weather in the spring the roads become almost impassable and are badly cut up. When dry weather comes they are very rough and must be scraped. A notable exception to the above statement is the Mowry shale, over which roads good at all seasons are easily maintained. A fairly good dry-weather road was built through Osage parallel to the railroad, and several roads were built running west across the field.

STRATIGRAPHY.

GENERAL SECTION.

The principal oil sand in the Osage field is the Newcastle sandstone, commonly known as the Muddy sand, a member of the Upper Cretaceous Graneros shale about 200 feet above its base. The rocks below the Dakota sandstone are not exposed in this field but crop out within a few miles to the east. As it is possible that where the structure is favorable there may be oil in the Pahasapa, Minnelusa, Minnekahta, Sundance, Lakota, and Dakota formations, all of which underlie the Newcastle sandstone, a brief description of these formations, adapted from N. H. Darton's account in the Newcastle folio of the Geologic Atlas of the United States, is inserted to enable drillers and oil operators to make a quick reference to them. The descriptions of the Graneros, Greenhorn, Carlile, and Niobrara formations (all Upper Cretaceous), which are either oil bearing or must be drilled through in the search for oil in the Osage field, are given in as much detail as the work done will justify. The Pierre and Fox Hills formations, also Upper Cretaceous, and the Lance formation, of Tertiary (?) age, are described very briefly.

UNEXPOSED ROCKS.

PAHASAPA LIMESTONE (MISSISSIPPIAN).

The Pahasapa limestone is about 700 feet thick and probably underlies the country surrounding the Black Hills for many miles. It is essentially a massive light-gray limestone, which in places contains many marine fossils of Mississippian types and is approximately equivalent to the Madison limestone of the Northwest. Although it is not thought to be oil bearing, it may have been the source from which the heavy dark oil found in the Minnelusa sandstone was derived. According to Washburne [5] the Madison limestone of the Big Horn Basin is noticeably bituminous in many places, giving an odor of oil when freshly broken and in a few localities containing solid hydrocarbons of asphaltic appearance. Its potentialities have not been tested in the Osage field.

MINNELUSA SANDSTONE (PENNSYLVANIAN).

The Minnelusa sandstone in the southwestern part of the Black Hills is, according to Darton, more than 600 feet thick. It is of Pennsylvanian age and consists for the most part of white to red or brown calcareous sandstone, but it contains some red shaly sandstone near the base and some rather thin beds of limestone and of gypsum distributed through the formation. The upper part of the formation was examined by the writer in the canyon of Rocky Ford Creek in T. 52 N., R. 61 W., where below the Opeche shales there is a hard light-colored "cap rock" consisting essentially of limestone but containing many siliceous concretions, below which is about 100 feet of sandstone that was originally light gray but has been largely colored dark brown by asphaltic oil. This coloration may not show on the surface but is immediately apparent when the rock is broken and is particularly conspicuous in shallow prospect pits that have been dug in the face of the bluff. Underlying the asphaltic sand is a lens about 60 feet thick of snowy-white gypsum. The Minnelusa formation carries small amounts of heavy asphaltic oil in the Rocky Ford field, 30 miles north of Osage,[6] and in the Old Woman anticline, 60 miles

[5] Washburne, C. W., U. S. Geol. Survey Bull. 340, p. 361, 1908.
[6] A report on the Rocky Ford oil field is in preparation.

Geologic formations in the Osage oil field, Wyo.

System.	Series.	Group.	Formation and member.	Thickness (feet).	Character.	Oil possibilities.
Tertiary(?).	Eocene(?).		Lance formation.	Not measured.	Massive cross-bedded light to buff sandstones, containing large sandy concretions of various shapes, and gray sandy shale. Fragments of dinosaurs and turtles.	
Cretaceous.	Upper Cretaceous.	Montana.	Fox Hills sandstone.	50±	Light-gray sandstone and sandy shale, with thin regular bedding, containing calcareous concretions in some places. Marine invertebrate fossils.	
			Pierre shale.	1,250±	Dark-gray clay shale, with indistinct bedding, containing many bands of calcareous concretions. Many invertebrate marine fossils usually contained in concretions. Prevailing forms *Baculites*, *Ammonites*, and *Inoceramus*.	This formation has yielded oil in the Salt Creek, Big Muddy, and Pilot Butte fields of Wyoming and flows of gas near Pierre, S. Dak., and Wray, Colo.
		Colorado.	Niobrara shale.	200	Light-yellowish to cream-colored calcareous shale, with some sandstone and impure chalk. Very readily distinguished wherever exposed by its light color.	
			Carlile shale.	610	In upper part dark-gray shale, containing many bands of concretions; in lower part about 80 feet of shaly calcareous sandstone, probably the Wall Creek sandstone member. Marine invertebrate fossils and a 1-foot sandstone containing shark teeth in the lower part.	Showings of oil in lower part of formation in Osage field. Oil sand in Wakeman and Upton-Thornton fields.
			Greenhorn limestone.	100	Very fossiliferous shaly limestone at the top. Shale below contains several lines of calcareous concretions, also fossiliferous. At the base a second layer of shaly limestone in places.	Showing of oil near bottom of formation in one well.
			Graneros shale. Belle Fourche shale member.	560	Dark-gray shale. Calcareous concretions near the top; zone of Mowry-like shale about 100 feet below the top; many clay-ironstone concretions in lower part; thick bed of bentonite near base. Very few fossils.	Oil seep in upper part of member in Osage field. Showings of oil in several wells.
			Mowry shale member.	150	Hard light-colored siliceous shale; a fair road metal. Contains many fossil fish scales. Several thin beds of bentonite.	Showings of oil in wells in Osage field.
			Nefsy shale member.	25–50	Soft dark shale and thin sandy lenses.	
			Newcastle sandstone member.	40–60	From one to four layers of sandstone separated by beds of shale, bentonite, and impure coal. The lower sandstone bed contains more or less coal in fragments. Called Muddy sand and Oil sand by drillers.	Principal oil sand of the Osage, Newcastle, and Moorcroft fields.
			Skull Creek shale member.	200	Dark-gray shale containing a few calcareous concretions. A stray oil sand 2 inches to 1 foot thick near middle. Siliceous shale near base. Very few fossils. Called Thermopolis shale by drillers, but represents only basal part of true Thermopolis shale.	Showing of light oil 100 feet below top in Osage field.
			Dakota sandstone.	50–100	Light-reddish sand and sandy shale, usually water sand. Upper Cretaceous fossil plants.	Showing of light oil in top of formation in Osage field. Heavy oil in Moorcroft field. Light oil in Lance Creek field.
	Lower Cretaceous.		Fuson formation.	30	Gray to red shale and thin sandstone.	
			Lakota sandstone.	200	Massive cross-bedded coarse sandstone, gray to buff, interbedded with shale. Lower Cretaceous fossil plants.	Principal oil sand in Mule Creek field.
Cretaceous (?).	Lower Cretaceous (?).		Morrison formation.	150	Massive buff, pale-green, and maroon sandy shale.	
Jurassic.	Upper Jurassic.		Sundance formation.	350	Greenish-gray and dark-gray shale, with thin limestone and buff sandstone. Many *Belemnites* and other fossils.	Possibly an oil showing in Moorcroft field.
Triassic (?).			Spearfish formation ("Red Beds").	500	Red sandy shale and soft red sandstone with beds of gypsum. No fossils.	The Chugwater formation of the Big Horn Basin, which is probably equivalent, in part, to the Spearfish formation, yields a small amount of oil.
Carboniferous.	Permian(?).		Minnekahta limestone.	40	Thin-bedded gray limestone. A few scattering small fossils.	Specimens collected in the Rocky Ford field have a fetid odor thought to be oil.
			Opeche formation.	75	Red sandy shale and shaly sandstone. No fossils.	
	Pennsylvanian.		Minnelusa sandstone.	600+	Hard white sandstone and buff and gray limy sandstone, more or less cross-bedded. Some thin beds of limestone and gypsum. Very few fossils.	Yields heavy oil in Rocky Ford field and Old Woman anticline, Wyo.
	Mississippian.		Pahasapa limestone.	700	Massive light-gray limestone. Very fossiliferous in places.	The Madison limestone, which is the Big Horn Basin equivalent of the Pahasapa, gives oil in the Soap Creek field, Mont.

to the south.[7] It is probably equivalent to the Amsden and Tensleep formations and possibly part of the overlying Embar formation in the Big Horn Basin. The Embar carries heavy oil at several places in the Big Horn Basin, and the writer often heard prospectors at Osage speak of the Minnelusa sandstone as the Embar and Tensleep. Several deep wells drilled in and around the Osage field in 1920 attempted to find oil in the Minnelusa. One drilled by the Union Oil Co. in sec. 28, T. 47 N., R. 64 W., passed through a 10-foot sand (the Newcastle sandstone member) at a depth of 360 feet and struck the Dakota sand, 80 feet thick, at 720 feet; both sands yielded water. Drilling was discontinued late in the season, after the Minnelusa was reached. The test was not satisfactory, for the structure is monoclinal and the water in the overlying beds shows that it is outside of the oil field.

OPECHE FORMATION (PERMIAN?).

The Opeche formation consists of about 75 feet of red shale and shaly sandstone. In appearance it resembles the Spearfish formation, from which it is separated by the Minnekahta limestone. Like the Spearfish formation it has yielded no fossils by which its age can be determined, but as it lies between the Pennsylvanian Minnelusa sandstone and the Permian or Triassic Minnekahta limestone it is regarded as probably Permian.

MINNEKAHTA LIMESTONE (PERMIAN?).

The Minnekahta limestone consists of a very persistent layer, about 40 feet thick, of thin-bedded gray limestone in which the beds are so tightly cemented together that the rock appears massive. It contains a few fossils which were regarded by Schuchert as Permian but which Girty regards as possibly Triassic. When freshly broken some specimens of the rock have a fetid odor suggestive of petroleum. Though no oil has been found in the Minnekahta limestone, small quantities may ultimately be found in it or in the overlying Spearfish formation.

SPEARFISH FORMATION (TRIASSIC?).

The thickness of the Spearfish formation, or the "Red Beds," as it is often called, is given in the Newcastle folio as 500 feet. The formation is readily recognized by its red color and is distinguished from the Opeche formation by its greater thickness. It consists essentially of soft red sandstone and red sandy shales, but it contains several beds of gypsum. The Spearfish formation is regarded as probably of Triassic age, because it overlies the Permian(?) Opeche formation and underlies the Upper Jurassic Sundance formation. The Chugwater formation of the Big Horn Basin, about 200 miles

[7] Darton, N. H., Structure of parts of the central Great Plains: U. S. Geol. Survey Bull. 691, pp. 24–25, 1918.

west of the Black Hills, which is probably in part the equivalent of the Spearfish formation, carries small quantities of oil in several localities.[8] It is not believed that the oil originated in that formation, but that it will be found there only where the Chugwater is in contact with the Embar, which is known to carry large amounts of oil. The Spearfish formation is not thought to be oil bearing in the vicinity of the Black Hills.

SUNDANCE FORMATION (UPPER JURASSIC).

The Sundance formation, according to the Newcastle folio, is 350 feet thick. It consists of greenish-gray shale, thin limestone, reddish sandy shale, and buff sandstone. The formation is of Upper Jurassic age and carries several layers of distinctive fossils, the most striking of which is *Belemnites densus*, a black cigar-shaped body from 1 inch or less to 4 inches in length. This formation may be oil bearing in places, and a showing of oil that may perhaps come from this formation is reported in the log of a well in the Moorcroft field.[9]

MORRISON FORMATION (CRETACEOUS?).

The Morrison formation is described in the Newcastle folio as consisting of 150 feet of massive pinkish sandy shale. It is regarded as of fresh-water origin, having been deposited when this region was above sea level in either Jurassic or Lower Cretaceous time, and has yielded a dinosaur fauna. This formation has not been found to be oil bearing in the vicinity of the Black Hills.

LAKOTA SANDSTONE (LOWER CRETACEOUS).

The Lakota formation is described by Darton in the Newcastle folio as being about 200 feet thick and consisting principally of coarse-grained sandstone, part of which is conglomeratic. It contains several shaly beds and, near the base, beds of coal that are thick and pure enough for mining at Cambria, 10 miles east of Osage. The materials that make up the Lakota formation are variable, and sections measured a few miles apart are generally unlike. Wells drilled to the Lakota in and about the Osage field have produced rather strong flows of relatively pure water. The formation has not been found to be oil bearing in this field but contains the principal oil sand of the Mule Creek field.[10]

FUSON FORMATION (LOWER CRETACEOUS).

The Fuson formation, according to Darton, consists of 15 to 30 feet of gray to red shales with thin layers of sandstone.

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[8] Collier, A. J., Oil in the Warm Springs and Hamilton domes, near Thermopolis, Wyo.: U. S. Geol. Survey Bull. 711, pp. 69–70, 1920.

[9] Barnett, V. H., The Moorcroft oil field, Crook County, Wyo.: U. S. Geol. Survey Bull. 581, p. 87, 1913.

[10] Hancock, E. T., The Mule Creek oil field, Wyo.: U. S. Geol. Survey Bull. 716, p. 52, 1920.

EXPOSED ROCKS.

UPPER CRETACEOUS.

DAKOTA SANDSTONE.

The Dakota sandstone, like the Lakota formation, is composed mainly of gray to buff sandstone and is from 50 to 100 feet thick. It has been reached in several wells in the Osage field, where it yields water that usually has a sulphur odor, gives a slight showing of gas, and contains various impurities, notably iron. The logs of some of the wells report a showing of oil in the top of the formation, and in the well bored with a diamond drill at Osage the formation surely carried oil in thin layers of sandstone and shale at the top. The oil appears to be of about the same grade as that found in other parts of the Osage field. The Dakota sandstone shows a seep of heavy dark oil, accompanied by asphalt and asphalt-stained sandstone, at Bird Spring, in the Moorcroft field.[11] It is probably the principal oil-bearing sand of the Lance Creek field.

The Dakota and Lakota formations are essentially massive coarse-grained sandstones separated by the Fuson formation, which consists of thinner sandstone and shale. The fossil plants contained show that the Dakota is of Upper Cretaceous age, and the Lakota and Fuson are Lower Cretaceous. The shale members are usually thick enough to prevent any oil that may be present from passing from the lower sandstones to the upper ones, and on this account some of the sands may yield water and others oil or gas.

GRANEROS SHALE.

The Graneros formation comprises about 1,000 feet of shale, in which several members can be distinguished.

Skull Creek shale member.—The lowest member of the Graneros consists mainly of dark bluish-gray shale and is about 200 feet thick. It is well exposed along Skull Creek southeast of Osage, between the outcrops of the Dakota and Newcastle sandstones. It is commonly called the Thermopolis shale by the oil operators, but as the Thermopolis shale in its typical locality includes all the beds between the Mowry shale and the Dakota sandstone, the name Skull Creek shale member is here adopted for this basal member. The upper part of this shale makes a soft dark mud on weathering, but the lower part has a tendency to break into thin hard plates. Throughout the member there are a few calcareous concretions and thin lenses of impure calcareous material which on weathering shows cone-in-cone structure. The diamond-drill core obtained at Osage shows a thin layer of sandy shale and sandstone containing light oil 100 feet below the top of the member.

[11] Barnett, V. H., op. cit., pp. 89-94.

Newcastle sandstone member.—The next member is the productive oil sand in the Osage field and is often referred to as the Muddy sand. As it is well exposed at Newcastle and is not believed to be in the exact stratigraphic position of the Muddy sand of the Big Horn Basin, the name Newcastle was applied to it by Hancock.[12] The Newcastle sandstone is exposed immediately east of Osage. It consists of one to four layers of sandstone from 1 to 15 feet thick separated by beds of more or less sandy shale, bentonite, and impure coal. Unlike the Newcastle and Moorcroft fields, the Osage field shows no positive indications of the presence of oil, such as seepages and sandstone stained with asphalt, in the croppings of the oil sand. The dark sandy shale common in the Osage outcrops, when subjected to the heat and carbon tetrachloride tests described by Erickson,[13] shows the presence of bitumens or resin which may be derived either from oil or from the coaly matter of the shale. The following sections of the Newcastle sandstone and the underlying Skull Creek shale have been measured:

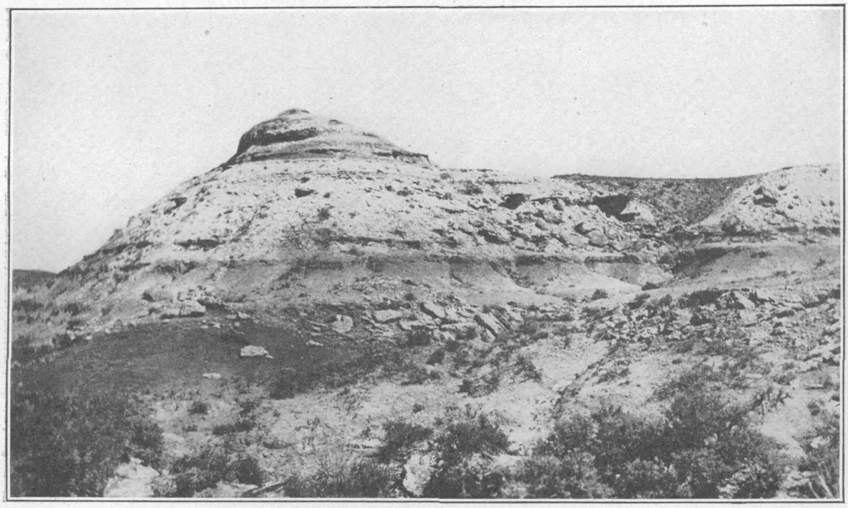
Log of diamond-drill hole in sec. 9, T. 46 N., R. 63 W.

	Ft.	in.
Mixture of alluvium and Mowry shale	38	
Newcastle sandstone member:		
First sand; oil	4	
Bentonite	1	1½
Dark-gray sandy shale	1	
Light-gray sandy shale; streaks of coal	3	6
Bentonite	1	
Gray sandy shale	3	
Dark-gray calcareous shale	4	6
Second sand; oil	13	
Coal, impure	5	
Hard dark sandy shale	10	
Coal, impure	2	
Third sand; oil	13	
	61	1½
Skull Creek shale member:		
Shale	91	
Sand and sandy shale; oil	6	
Shale (base of Graneros shale)	103	
	200	
Dakota sandstone:		
Sandy shale; oil	5	
Sandstone.		

[12] Hancock, E. T., The Mule Creek oil field, Wyo.: U. S. Geol. Survey Bull. 716, p. 39, 1920.

[13] Erickson, E. T., Tests to determine the presence of small quantities of oil and bitumens (U. S. Geol. Survey press bulletin), 1920.

A. SANDSTONE LENS NEAR THE BASE OF THE NEWCASTLE SANDSTONE, SEC. 10, T. 46 N., R. 63 W., WYO.



B. GENERAL VIEW OF THE NEWCASTLE SANDSTONE, SEC. 10, T. 46 N., R. 63 W., WYO.

Section of Newcastle sandstone in sec. 10, T. 46 N., R. 63 W.

	Feet.
Sandy shale.	
Hard sandstone	2
Bentonite	3
Carbonaceous shale	7
Sandstone	5
Bentonite	10
Carbonaceous shale	5
Sandy shale	10
Lens of sandstone	5
	47

Section of Newcastle sandstone, from log of a diamond-drill hole in sec. 8, T. 47 N., R. 64 W.

	Ft.	in.
Coal, impure, and shale	2	
Soft light shale	1	4
Coal	1	6
Sand		8
Bentonite		6
Fine-grained sandstone	2	3
Light shale; specks of coal	4	8
Dark sandy shale	1	
Light shale	2	
Sand	1	6
Sandy shale	2	8
Light sandstone	1	6
Dark sandstone with specks of coal	5	6
Gray shale	6	
Fine-grained sandstone		4
Dark-gray shale	7	
Sandstone	4	
	45	5

Section of Newcastle sandstone in sec. 9, T. 45 N., R. 63 W.

	Ft.	in.
Hard sandstone	1	8
Dark shale and bentonite, not well exposed	14	
Hard sandstone, ripple marked	2	10
Dark shale and bentonite, not well exposed	10	
Soft sandstone	12	
	40	6

These sections show that the Newcastle sandstone is highly variable and that it consists of several lenticular beds of sandstone separated by more or less impervious beds of shale. The coal content, ripple marks, and cross-bedding indicate that this member was deposited in shallow water. Some of the lower sandstone layers change into sandy shales within very short distances. Some of the sandy shale contains fragments of coal and petrified wood, as if the deposit were made not far from an exposed land surface covered with forests.

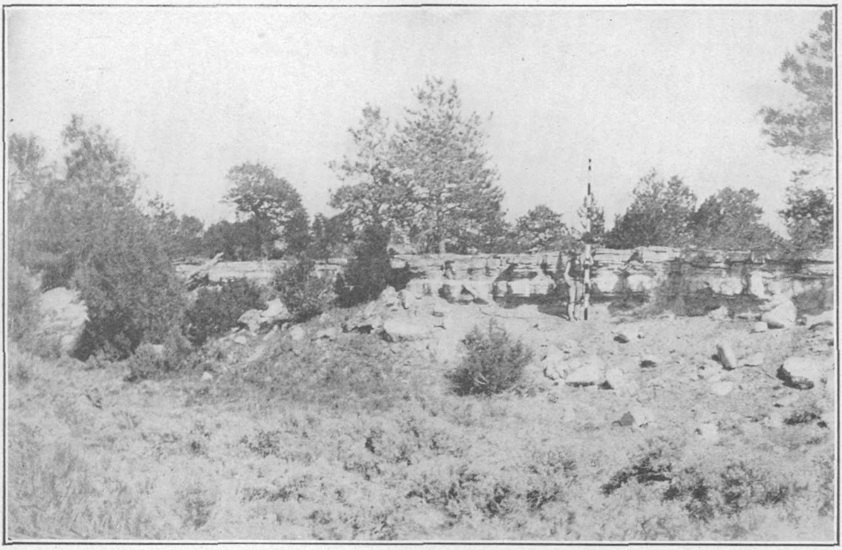
In a few places the layers of sand are clearly lenses and the boundaries between them and the shale are distinct, as is shown in Plate XI. Such features are common in the deposits seen along modern sea beaches and lagoons back of beaches, and it is the writer's opinion that in Newcastle time in this region beach and lagoon conditions must have prevailed in some places while in other places not far away the water was deeper and the sediment deposited was more or less sandy mud, now sandy shale. No fossils that can be identified were found in this member in the Osage field. A lens of sandstone about 1 foot thick containing many nearly vertical burrows made by worms or other animals can be seen east of the railroad near Osage. A well-preserved fragment of the femur of a dinosaur found in the Newcastle sandstone in sec. 2, T. 56 N., R. 66 W., supports the writer's opinion that the Newcastle is not entirely of marine origin. A general view of the Newcastle sandstone at the outcrop east of Osage is shown in Plate XI, *B*, and the appearance of one of its sandstone beds at the outcrop southeast of Osage is shown in Plate XII, *A*.

Along the outcrops of the upper sand of the Newcastle member east of Osage are a great many slickensided fragments. The slickensides are planes cutting across the bedding, usually at low angles. These planes are grooved in one direction, and usually a thin layer of calcite, which is also grooved, has been deposited over them. They represent breaks or joint planes along which movement has occurred. Such features are developed in rocks by faults, and their presence here is taken as an indication of many minor faults. As only the flatter-lying parts of the Newcastle sandstone are exposed near Osage it seems probable that in the zone of steeply dipping rocks southwest of Osage the slickensides may be much more abundant.

Nefsy shale member.—Above the Newcastle sandstone at many localities lies from 25 to 50 feet of soft dark shale interbedded with lenses of sandy shale. This shale can be distinguished from the underlying Newcastle member by the absence of hard sandstone layers and from the overlying Mowry member by the character of the shale, which disintegrates into sticky mud. As a large part of the Nefsy town site at Osage is underlain by this shale, the name Nefsy is here adopted for it.

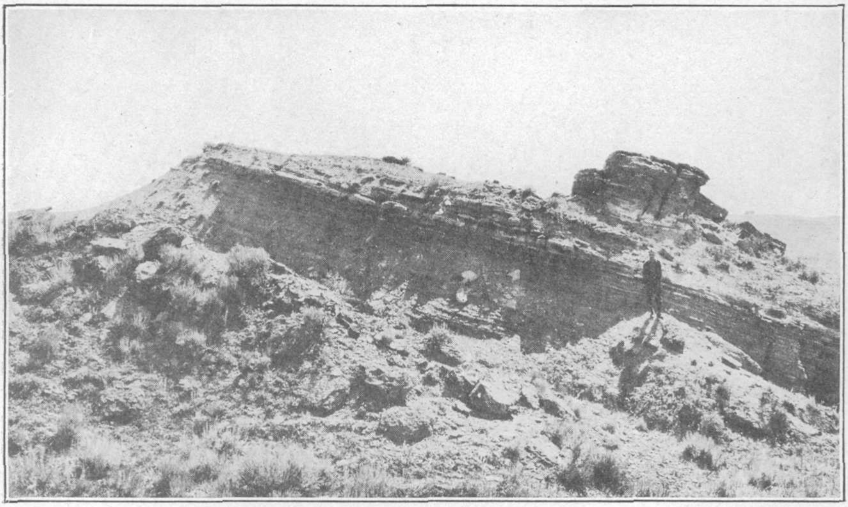
Mowry shale member.—The Mowry shale member of the Graneros formation is about 150 feet thick in the Osage field. It is a hard shale, dark when fresh but white like broken porcelain when weathered. Roads over the Mowry shale are very good in this region, where most of the rocks make very poor road metal. In the neighborhood of Osage its outcrop is usually marked by a low ridge covered with pines and other trees.

The rock is sometimes described by drillers as a sandy shale, but although the Mowry is a hard shale, it is fine grained and contains



A. A BED OF SANDSTONE IN THE NEWCASTLE SANDSTONE, SEC. 14, T. 46 N., R. 63 W., WYO.

Probably the second sandstone.



B. OUTCROP OF THE LOWER PART OF THE CARLILE SHALE, SEC. 20, T. 46 N., R. 63 W., WYO.

Probably the Wall Creek sandstone member, which makes a jagged ridge across the field.

less grit than the softer shales that lie above it. A thin section of a specimen of Mowry shale collected a short distance south of Osage, when examined under the microscope, shows a very fine, probably siliceous groundmass in which there are a few larger grains of quartz and many opaque fragments of organic remains. The groundmass may be colloidal silica.

This member can usually be recognized by the abundance of fish scales preserved in it, though the finding of a few imperfectly preserved fish scales in other shales makes this criterion of somewhat doubtful value. In the Mowry shale in the Osage field there are several thin beds of bentonite, or "Denver mud," as it is sometimes called by the drillers. Bentonite is a light-colored clay shale which is distinguished by its property of absorbing several times its bulk of water. According to Hewett [14] and Wherry,[15] it is clay derived from volcanic dust. The presence of many beds of bentonite in the Upper Cretaceous rocks indicates that when the oil-bearing rocks were being deposited there were occasional violent volcanic eruptions, either in the Black Hills or to the west in the Rocky Mountains, from which volcanic dust was scattered by the wind.

Belle Fourche shale member.—The uppermost member of the Graneros shale is named the Belle Fourche shale member on account of its exposure along Belle Fourche River in the neighborhood of Wind Creek, Crook County. It consists of dark-gray shale which varies in hardness but is all softer than the underlying Mowry shale. It is about 560 feet thick. Just above the Mowry shale there is a zone of very soft shale 20 to 30 feet thick which is permeated with water along its outcrop in the Osage field. Near the top of this zone there is a bed of bentonite from 2 to 10 feet thick which has been noted in many drill holes. This bed is mined [16] from strip pits in sec. 30, T. 47 N., R. 63 W., and the product is shipped on the Chicago, Burlington & Quincy Railroad. The well drillers frequently have trouble with caving in passing through this part of the section. In the next 100 feet there are many nearly black concretions composed for the most part of iron carbonate or clay ironstone. The concretions range from 1 to 5 feet in horizontal diameter and are somewhat flat. They range in shape from round to oblong and owing to their peculiarly corrugated surfaces are often mistaken by prospectors for fossil turtles. About 300 feet above the Mowry shale the Belle Fourche shale is sandy and on weathering appears to be very similar to the Mowry, but it breaks up into somewhat thicker flakes and weathers to a soft mud. A thin section of a specimen taken near

[14] Hewett, D. F., The origin of bentonite: Washington Acad. Sci. Jour., vol. 7, pp. 196–198, 1917.
[15] Wherry, E. T., Clay from volcanic dust: Washington Acad. Sci. Jour., vol. 7, p. 576, 1917.
[16] Darton, N. H., U. S. Geol. Survey Geol. Atlas, Sundance folio (No. 127), p. 12, 1905.

the oil seep in sec. 17, T. 46 N., R. 63 W., shows under the microscope a groundmass similar to that of the Mowry shale but containing many grains of quartz and opaque organic material and in addition shells of *Textularia* and *Globigerina.* Thin lenses of calcareous shale showing cone-in-cone structure are not uncommon in the Belle Fourche member. The upper limit of the Graneros formation and of the Belle Fourche member is somewhat indefinite, there being in many places no change in the character of the shale at this horizon. In a few places, however, there is a rather thin bed of slabby limestone containing fragments of fossils similar to those in the overlying Greenhorn limestone, and the base of this slabby limestone is here taken as the boundary line between the Graneros and Greenhorn formations. Where the slabby limestone is absent its approximate horizon is made the division line.

GREENHORN LIMESTONE.

The Greenhorn limestone is marked topographically by a ridge running from the southeast corner of T. 46 N., R. 63 W., to the west line near the northwest corner of the township. Its upper layers are distinctive, and its top can be definitely mapped, for it consists of about 15 feet of slabby limestone composed of fragments of fossils, the most abundant of which is *Inoceramus labiatus.* The top of the Greenhorn limestone is about 860 feet above the Newcastle sandstone. Below the upper bed the Greenhorn consists of bluish-black shale having two well-marked zones of lime concretions that contain numerous Greenhorn fossils. About 100 feet below the top there is in some places a lenticular bed of limestone which is similar to the limestone at the top of the formation and which has been considered by the writer as marking its base. Probably no two geologists will agree as to the exact thickness of the Greenhorn limestone. Though this formation is hard enough to form a conspicuous ridge along its outcrop, it is nevertheless not usually noted by drillers in making up well logs, and it is the writer's opinion that the formation becomes hard on exposure to the air. It is very conspicuous southeast of the Osage field, but a few miles to the northwest it is hardly noticeable.

CARLILE SHALE.

The Carlile shale in the Osage field is about 610 feet thick and consists of several parts which can be distinguished rather readily. The lower 100 feet of the formation consists of dark sandy shale. Above this is a somewhat lenticular bed of coarse-grained sandstone or conglomerate which is nowhere more than 2 feet thick and is usually less but which can be traced almost without a break across the field and is an ideal horizon marker. It is about 1,000 feet above the principal oil sand in the Osage field. In places this sandstone contains many fossil shark and other fish teeth, in a collection of which J. W. Gidley has identified four sharks (*Scapanorhynchus rhaphiodon*, *Lamna appendiculata*, *Lamna* sp., *Corax falcatus*) and a large ray fish with rounded teeth (*Ptychodus whipplei*). Thin lenses of calcareous shale showing cone-in-cone structure are developed in some places above or below this bed. For about 25 feet above the bed containing the shark teeth the formation consists of brownish sandy shale, and above this is a conspicuous outcrop of calcareous sandy shale and large sandy concretions some of which on weathering appear like cart wheels 2 to 5 feet in diameter, the center being softer than the rim and being represented by a hole. This exposure, which makes a jagged ridge across the productive part of the field, is shown in Plate XII, *B*. The upper boundary of the sandy member is not well defined, but near it there is a line of very fossiliferous concretions that weather light red. The upper 430 feet of the formation is dark-gray shale, but its outcrop is marked in many places by fragments of light-gray limestone concretions. There are at least seven zones of such concretions in this part of the Carlile formation. The concretions are from 6 inches to 3 feet in diameter and are nearly round. After they were formed cracks were developed in them, and veins of crystalline calcite, half an inch or more in thickness, have been deposited in the cracks. When exposed the concretions separate along the veins, leaving the fragments covered by pointed crystals of calcite of various colors.

The sandy member at the base of the Carlile formation carries oil in the Upton-Thornton field, and a slight showing of oil from it is reported in the logs of some of the wells in the Osage field. As it is at about the horizon of the principal oil sand of the Muddy and Salt Creek fields, it is called by drillers familiar with these fields the Wall Creek sand. It is apparently the same as the sand in the Mule Creek field that was identified by Hancock as the Wall Creek sandstone member.

NIOBRARA SHALE.

The Niobrara formation is nowhere well exposed in the Osage field, and the description given here is the result of several observations made in this and adjoining areas. It is about 200 feet in thickness and consists of soft white to yellow shale, with some sandstone and impure chalk. Owing to its yellow color it can be readily identified and distinguished from the dark-gray shales above and below it wherever it is exposed, and in some places southwest of the Black Hills it is a most important horizon marker. It is usually described as containing slabs of *Ostrea congesta*, but none were found in the Osage field. In the townships south and southeast of the Osage field, in the neighborhood of Pedro, a thick bed of bentonite just above the Niobrara has been stripped and was mined to some extent.[17] Although the outcrops of the Niobrara are recognized by their light-yellow color, the formation below the surface is probably light gray and not easily recognized in drill cuttings. Where it is exposed in sec. 31, T. 46 N., R. 63 W., there is a rather well marked vein of calcite trending across the strike for about 100 feet. The base of the Niobrara is about 1,500 feet above the Newcastle sandstone.

PIERRE SHALE.

The Pierre shale is a thick formation in which bedding planes are not easily found, and on this account its exact thickness is very difficult to measure. It contains a number of concretion zones, but many of these can not be traced very far. The base and top of the formation seem to be clearly marked by the Niobrara and Fox Hills formations, and the dips can easily be taken there. Darton, in the Newcastle folio, gives the thickness as 1,250 feet. Hancock[18] has recently stated that the thickness of the Pierre shale is more than 2,500 feet. The writer from several unsatisfactory measurements made between the Niobrara and the Fox Hills outcrops is of the opinion that the thickness of the Pierre shale exposed west of the Osage tfield can not be more than 1,250 feet, and it is so represented on the structure map (Pl. XIII). The thickness can be determined accurately only by a drill starting at the base of the Fox Hills and penetrating to the Niobrara. The Pierre formation consists of gray shale only a little lighter in shade than the shales below the Niobrara. It can be identified by its great thickness and by the presence of *Baculites*. In many of the concretions and in places scattered over the surface these fossils are very abundant throughout the Pierre shale, but they are also found near the top of the Carlile shale in the Osage field. They are described by prospectors as pieces of fossil fish. No sign of oil in the Pierre shale has been observed in the Osage region, but the possibility of a commercial oil or gas content must be admitted. This formation has yielded oil in commercial volume in the Salt Creek, Big Muddy, and Pilot Butte fields of Wyoming, and good flows of gas in a number of places, particularly near Pierre, S. Dak., and Wray, Colo.

FOX HILLS SANDSTONE.

The Fox Hills formation, which lies conformably upon the Pierre shale, consists of regularly bedded soft sandstone interspersed with thinner layers of hard sandstone. Its lower part in the vicinity of Osage consists of rather thin beds of soft light-colored sandstone, marked with worm tracks and containing a few sandy fossil-bearing

[17] Darton, N. H., U. S. Geol. Survey Geol. Atlas, Newcastle folio (No. 107), p. 9, 1907. Wherry, E. T., Clay derived from volcanic dust in the Pierre in South Dakota: Washington Acad. Sci. Jour., vol. 7, p. 579, 1917.

[18] Hancock, E. T., The Upton-Thornton oil field, Wyo.: U. S. Geol. Survey Bull. 716, p. 21, 1920.

concretions. Higher in the formation the sandstone appears to be more massive, but this may be due to the fact that it is more thoroughly indurated. There are in a few places beds made up almost entirely of marine fossils. Some of the species represented are also found in the Pierre shale; others occur only in the Fox Hills sandstone. The Fox Hills is about 50 feet thick, but as it is overlain by rocks that differ from it lithologically only in the nature of the bedding, it was not possible to determine its exact thickness. Some geologists are of the opinion that the Fox Hills formation of the Black Hills region is in nearly the same stratigraphic position as the Mesaverde formation of the Big Horn Basin.

TERTIARY (?).

LANCE FORMATION.

The Fox Hills sandstone is overlain by the Lance formation (called Laramie formation by Darton in the Newcastle folio and other papers relating to the geology of the Black Hills). In the Osage region the Lance is composed of soft massive cross-bedded sandstone and sandy shale. It contains fossil fragments of many species of reptiles, the most striking of which is the gigantic herbivorous dinosaur *Triceratops*, though fragments of turtle shells found in it are much more easily identified by the layman. The formation is evidently nonmarine, and the massive sandstones are so intricately cross-bedded and contain so many irregular beds and concretions that its structure can be determined only by very careful study. Work of this kind has not been attempted in the Osage region, but a casual examination suggests that the Lance formation may be unconformable with the Fox Hills sandstone. Darton and other Federal geologists, however, have regarded these formations as conformable.

THE STRUCTURE MAP.

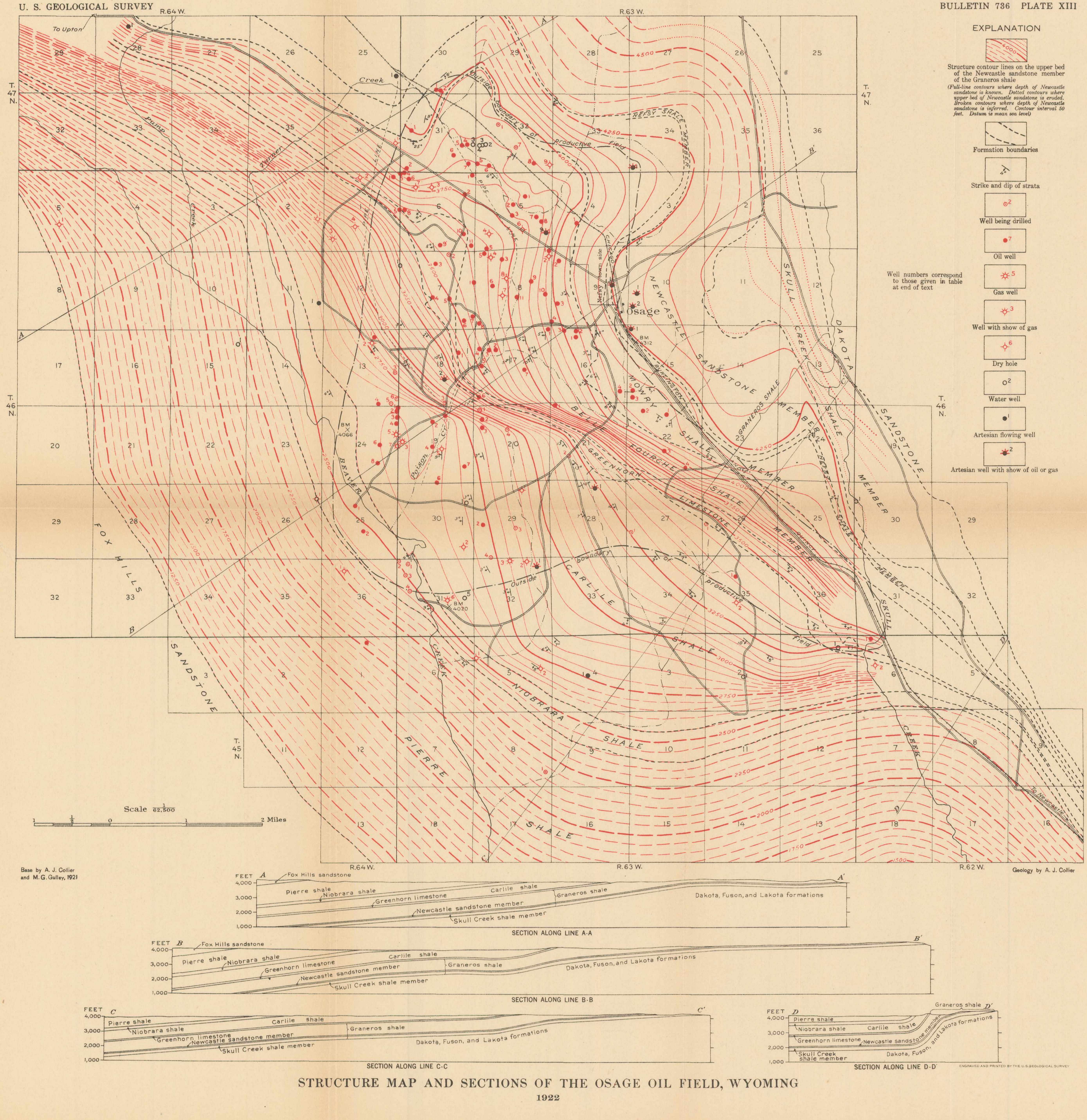
Area covered.—Plate XIII shows the known productive field, which covers parts of T. 46 N., Rs. 63 and 64 W., and T. 47 N., R. 63 W., an area somewhat smaller than a township (36 square miles). The work of surveying and compiling the portion of the map representing the productive area has been done as accurately as possible. Very little field work has been done northwest, southeast, and west of the productive area, but the approximate positions of such features as roads, towns, and outcrops are known and the approximate structure is indicated by broken lines. All the land covered by the map, as well as that for many miles along the Black Hills front, was considered possible oil land by prospectors in 1920, and wells were being drilled in many places.

Condition of the land net.—The area of the Osage field was surveyed by agents of the General Land Office in 1881, but very few of the original monuments can be found. When oil was struck and the lands became prospectively valuable private surveyors were employed, and, starting from several supposed section corners, they staked off the ground. In the vicinity of some section corners there were many such stakes covering an area of 2 or 3 acres. Late in the summer of 1920 the several claimants employed a firm of deputy county surveyors to make an official survey of T. 46 N., R. 63 W. On the accompanying structure map (Pl. XIII) the writer has attempted to place the section lines and corners in the position indicated in the plat furnished by this survey.

A large part of the Osage field lies in the Newcastle quadrangle, of which the United States Geological Survey published a map in 1903 showing the topography by 50-foot contours. A small part of the productive area is included in the Sundance quadrangle, which joins the Newcastle quadrangle on the north, and the region northwest of the productive area lies in the Moorcroft quadrangle.

Structure contours.—The strata were originally deposited one above another in a nearly flat position, but in the long ages since they were laid down they have been more or less disturbed by the forces of nature. As the beds in a conformable series are parallel, the present attitude of the whole series can be shown by structure contour lines connecting points of equal elevation on one of the beds. On the accompanying map (Pl. XIII) the structure contour lines represent the altitude above sea level of the top of the Newcastle sand, and the vertical interval between the contours is 50 feet. Structure contours furnish a means by which it is possible to show on the map the forms of anticlines, synclines, terraces, and monoclines. If the contour lines are near together, they indicate that the dip of the beds is steep; if far apart, that the dip is gentle.

In field work to determine the structure a base line was first measured and from its ends triangulation was carried to many points over the field. From the points thus located measurements were made by means of stadia readings to near-by localities. The altitude above sea level is given on several bench marks placed by topographers of the United States Geological Survey; two of these marks were located, and from them the altitude of the other points was determined by vertical angles. In this way the positions and altitudes of more than 300 points in and about the Osage field were determined. The depth of the Newcastle sand was known or could be estimated at many of these points, either by drill records or by the position of the surface at these points with reference to well-marked beds, such as the top of the Mowry shale, the top of the Greenhorn limestone, the sandstone in the Carlile shale that carries



STRUCTURE MAP AND SECTIONS OF THE OSAGE OIL FIELD, WYOMING

1922

the shark teeth, and the base of the Niobrara shale. In addition to this information the dips of the outcropping rocks were determined at many intermediate points. The dip and strike can be determined with considerable accuracy at many places in the Graneros and Niobrara shales by digging down until a definite bedding plane is found. This method was followed by many geologists in the Osage field, and it was possible to determine where they had worked by noting the small excavations they left behind. In the upper part of the Carlile shale the bedding planes are not well defined, but the dips can in places be determined approximately from the zones of concretions. In the Pierre shale it is possible to determine the dip only at very few places.

The geologic structure as shown on the map may appear to disagree with the results of drilling in some places, owing either to the lenticular character of the Newcastle sand or to the occurrence of oil in the shale overlying the Newcastle sand. Should the upper lentils of the Newcastle sand be absent or very shaly the driller might not detect their presence and in consequence might record a lower bed as the top of the sandstone member. The occurrence of oil in tke overlying shale might lead to the erroneous belief that the sandstone had been reached.

Structure sections.—The structure sections, also placed on the map, illustrate the position and dip of the different strata as they would actually appear in the sides of deep trenches cut across the field. Such sections bring out the structure along the lines indicated much more graphically than structure contours, but they must be considered in connection with the contours to determine the horizontal extent of the structural features they show.

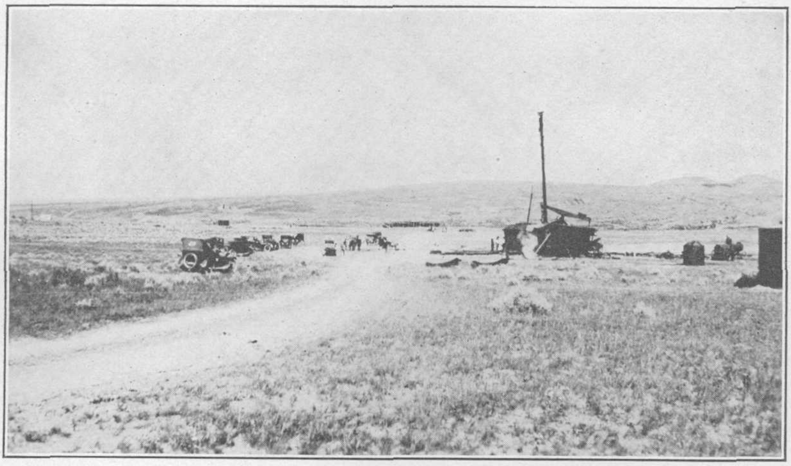
Degree of accuracy in different parts of the map.—The oil field in T. 46 N., Rs. 63 and 64 W., and a small part of T. 47 N., R. 63 W., was surveyed as accurately as possible, and on Plate XIII the structure contours for this field are shown by solid lines except for the area where the Newcastle sand has been removed by erosion, for which they are shown by dotted lines. The mapping was extended for several miles northwest, southeast, and west of the oil field, but the structure contours in these areas are rather hypothetical and are represented by broken lines. In the parts covered by the Upper Cretaceous formations below the Niobrara the contours are approximately accurate, for the position of the Greenhorn, Niobrara, and Newcastle outcrops is known. In the part covered by the Pierre shale they are much more uncertain, for, although the outcrop of the Fox Hills is known approximately, the Pierre shale is a thick formation in which there are few beds that will serve as key rocks, the dips of the beds are not determinable, and the exact thickness of the shale is not known, though it is assumed to be about 1,250 feet. It is probable that in the broad expanse of Pierre shale south of the productive oil field there may be several terraces like those shown in the oil field or that anticlines or domes may be present.

STRUCTURE.

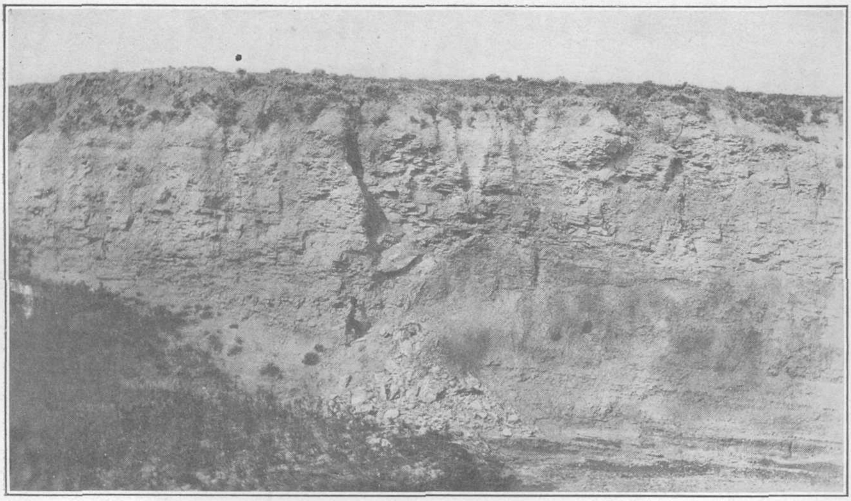
As the Osage field lies on the southwestern flank of the Black Hills, and as these hills represent a great dome-shaped uplift, it naturally follows that the rocks beds exposed in this field must dip to the southwest, away from the center of the uplift. There are minor folds and crumplings, however, which greatly modify the general dip and which have undoubtedly played a part in determining where the oil should be collected. In general the dip is about 5°, but in a zone extending northwestward across the center of the field the dips are as high as 20°. Northeast of this zone there is a structural terrace with relatively low dips, in which the oil is reached in wells from 100 to 500 feet deep; and south of the zone of steeply dipping beds there is another structural terrace in which the wells are from 1,300 to 1,600 feet deep. Wells drilled on this southern terrace show that the oil sand is warped into a dome, probably with a slight closure near its northeast side, in sec. 19, T. 46 N., R. 63 W., and sec. 24, T. 46 N., R. 64 W.

Narrow zones of steeply dipping beds and broad nearly flat-lying structural terraces of this character are rather common features of the southwestern slope of the Black Hills—for example, the broad terrace in the Upton-Thornton field, which lies northwest of the Osage field, and the broad lower terrace with sharply upturned beds along its northwest side which occurs southeast of the Osage field, in the vicinity of Pedro. The zones of steeply dipping rocks extend for considerable distances in nearly straight lines and suggest that deep down in the earth the schists that underlie the sedimentary rocks may be affected by very pronounced faults that have not reached the surface but have nevertheless produced the folds in the surface rocks.

The rocks exposed are almost free from faults of appreciable size. The only fault seen in the Osage field by the writer is a small one (see Pl. XIV, *B*) having a vertical displacement of about 13 feet which appears at the base of the Niobrara strata in the right bank of Beaver Creek in sec. 30, T. 46 N., R. 63 W. This fault could not be traced far, because the surface is covered with alluvium consisting of decomposed shale. It probably strikes nearly due east and is not thought to extend very far. A small fault of undetermined throw is exposed in the railroad cut northwest of Thornton, in the Upton-Thornton field. The Newcastle sandstone exposed northeast of Osage has a great many slickensided fragments scattered over the surface, indicating a movement across the bedding. Similar slick-



A. BRINGING IN THE THIRD DEEP WELL IN THE OSAGE FIELD, WYO., AT LOCATION 2, SEC. 19, T. 46 N., R. 63 W.



B. FAULT IN THE NIOBRARA SHALE, SEC. 30, T. 46 N., R. 63 W., WYO.

ensides are to be seen in thicker beds of the Newcastle sandstone exposed in sec. 32, T. 46 N., R. 62 W., and in the Greenhorn limestone exposed in sec. 9, T. 45 N., R. 62 W. In the last-mentioned locality the dip of the limestone is about 53°. The abundant slickensides undoubtedly indicate minor faulting due to crumpling and crushing of the beds, and probably there are many faults of small throw that were not detected because of the lack of continuity in the outcrops of prominent beds. This possibility is strengthened by the observation of the faults mentioned.

CONDITIONS AFFECTING PRODUCTION.

THE PRODUCTIVE AREA.

Although the developments show that small quantities of light oil are to be found in the top of the Dakota sandstone, the middle part of the Skull Creek shale, the Newcastle sand, the Belle Fourche shale, the Greenhorn limestone, and the Wall Creek (?) sand, and that the whole of the Graneros shale will yield some oil on distillation, the oil obtained in nearly all the wells has come from the Newcastle sand. The producing oil field is commonly divided by the operators into an area of shallow wells, most of which are less than 500 feet deep and in the Graneros formation, and an area in which the wells begin in formations above the Graneros and have an average depth of about 1,400 feet. The zone of more steeply dipping beds lies between these two areas and is from half a mile to a mile wide. Although this zone is known to be oil bearing in some places, the depth of the wells is from 800 to 1,300 feet, and the comparatively small production obtained has thus far prevented very thorough development. Wells in this zone will probably yield as much oil on an average as the shallow wells.

The location of the wells visited by the writer is shown on the structure map, and a brief statement of the conditions found at each locality is given on pages 107–110. These notes are arranged by townships from the northeast to the southwest, and for convenience the statements are given by sections in regular order from sec. 1 to sec. 36. The wells in each section are arbitrarily numbered, starting in the northeast quarter and ending in the southeast quarter.

The shallow wells are on an upper terrace, which is separated from the deep-well terrace by a zone of steeply dipping beds that extends southeastward across secs. 19 and 20. The area proved by shallow wells is equal to about 8 square miles and includes parts of secs. 30, 31, and 32, T. 47 N., R. 63 W.; parts of sec. 36, T. 47 N., R. 64 W.; part of sec. 1, T. 46 N., R. 64 W.; and parts or all of secs. 5, 6, 7, 8, 9, 15, 16, 17, 18, 21, and 22, T. 46 N., R. 63 W. The presence of small quantities of oil has been proved in sec. 34, T. 47 N.,

R. 63 W., and secs. 4 and 10, T. 46 N., R. 63 W. The area can be best described roughly as that covered by the outcrops of the Belle Fourche and Mowry members of the Graneros shale in the northern part of T. 46 N., R. 63 W. It is about 2½ miles wide in its widest part but is much narrower at the northwest and southeast ends, owing to steepening of the dip. The limits given in this paragraph may be considerably extended to the north, northeast, and southeast, as no definite margin of the oil-bearing area has been estabished in these directions. On the northwest several wells drilled to the Newcastle sand in sec. 36, T. 47 N., R. 64 W., failed to find paying quantities of oil, and a well still farther northwest encountered water at this horizon. On the southeast a well in the SE. ¼ SE. ¼ sec. 22, T. 46 N., R. 63 W., which reached the Newcastle sand at about 410 feet, is a productive well, although its exact output is not known to the writer. About 3 miles farther southeast, near the southeast corner of T. 46 N., R. 63 W., several wells have been drilled and reported productive, so there is at least a possibility that the producing field will extend this far or perhaps farther.

In this area of production from shallow wells the beds lie in a monocline, dipping to the west and southwest at the comparatively gentle average rate of 5°. This monocline is modified by two shallow synclines whose axes pitch south and southwest and which join and merge with the monocline in the S. ½ sec. 6, T. 46 N., R. 63 W. West of these synclines the strata dip about 8° SW.

The depths of the shallow wells range from about 100 feet near the eastern margin of the producing area to 800 feet or more near the outcrop of the Greenhorn limestone on the west. Their output per day ranges from less than a barrel to 15 barrels or a little more, but the average is probably not more than 5 barrels. The oil comes from the Newcastle sandstone and the overlying Belle Fourche shale. There is good reason to believe that drilling stopped in many of these shallow wells when they encountered small showings of oil in the Belle Fourche, because the drillers believed that the Newcastle sand had been reached, and that a number of the wells that obtain oil from the top bed of the Newcastle sandstone might have had better outputs if drilling had been continued to tap deeper lenses.

Efforts to obtain oil from beds underlying the Newcastle sand in the shallow area have been unsuccessful. Most of the deep wells are outside the area in which oil is obtained from the Newcastle sand. Three of these deep wells were started on the outcrop of the Newcastle sand east of Osage. They passed through the Dakota and reached the Lakota sandstone, without finding a commercial amount of oil in either of these beds, although a showing was reported from the top of the Dakota. However, absence of oil in the deep sands in these wells is little more significant than the barrenness of the Newcastle at the same location. A moderate flow of water was obtained from the Lakota sandstone in these wells. A well on the townsite of Nefsy, bored with a diamond drill, is closer to the productive area. The core of this well, which was placed at the disposal of the writer by the owners, W. E. Talbert and J. F. Mahoney, showed three oil-bearing sands in the Newcastle sandstone, a 1-foot stray oil sand 100 feet below the Newcastle sandstone, and 6 to 10 feet of oil-bearing sand at the top of the Dakota. Thus the showings in the Dakota were practically as good as those in the Newcastle, which is elsewhere productive. More discouraging results were obtained in a well drilled by the Mike Henry Oil Co. in sec. 5, T. 46 N., R. 63 W. This well reached the Lakota sandstone without finding oil in either Dakota or Lakota. It is flowing water, which is hauled to many parts of the field. A deep well drilled by the Union Oil Co. in sec. 28, T. 47 N., R. 64 W., started just above the Mowry shale and was drilled to the Minnelusa sandstone. Water was found in the Newcastle sand at 360 feet, and no showings of oil were reported. The water in the Newcastle sand showed that this well is outside the oil-producing area, and here as in most of the other deep tests the barrenness of the deeper beds has no particular significance with respect to their possible productivity in areas where the structural conditions are more favorable.

The area that contains the deeper wells and is the more productive part of the Osage field is on the lower terrace southwest of the zone of steeply dipping rocks and includes parts or all of secs. 19, 20, 29, 30, 31, and 32, T. 46 N., R. 63 W., and parts of secs. 13, 24, and 25, T. 46 N., R. 64 W. The limits of the productive area as shown on Plate XIII are not established on structural considerations but have been determined by actual drilling. It is not believed that the producing area of the Osage field will be extended far beyond the limits indicated on the map, but it must be recognized that there are considerable stretches where no drilling has been done to indicate whether the Newcastle sand is productive of oil or whether, as is expected outside of the outlined productive area, it contains water.

It is reported that a small quantity of oil was obtained in the NW. ¼ NE. ¼ sec. 13, T. 46 N., R. 64 W., about 1½ miles northwest of the Pioneer well, the first deep well of the field (No. 1 in sec. 19, T. 46 N., R. 63 W.), and that farther northwest, at the Midwest Co.'s well in sec. 11, T. 46 N., R. 64 W., the Newcastle sand is dry, but the Dakota sandstone produces a strong flow of water, which is piped and sold to other wells. The water is lukewarm but otherwise not objectionable for drinking. West of the Pioneer well the field is productive for about 1 mile to the north quarter corner of sec. 24, T. 46 N., R. 64 W. Southwest of the Pioneer well the field is productive for about 1¾ miles. The Producers & Refiners Oil Co. has several wells that yield an average of about 20 barrels a day in sec. 25, T. 46 N., R. 64 W., but the wells a short distance beyond these are reported to be dry. The field probably extends south from the Pioneer well about 2 miles, or to about the middle of sec. 31. The Glen Oil Co. has several productive wells in sec. 30, T. 46 N., R. 63 W. About 2 miles southeast of the Pioneer well, near the north quarter corner of sec. 32, a well was producing about 500,000 cubic feet of gas when visited in September, 1920, and one drilled near the northeast corner of sec. 32 had reached the Newcastle sand and found water and a little gas. That the limit of the productive field is not far south of these wells is shown by a well in sec. 4, T. 45 N., R. 63 W., which found a strong flow of salt water in the Newcastle sand. East-southeast of the Pioneer well the limit of the field has not been definitely determined, but the field extends in that direction for at least half a mile and perhaps for several miles. A well drilled by the Producers & Refiners Oil Co. in sec. 28, T. 46 N., R. 63 W., found a small showing of oil in the Newcastle sand at a depth of about 1,000 feet. This well was afterward drilled to the Dakota sandstone and yielded a good flow of water before it was abandoned. Another deep well drilled with a standard rig by the Niobrara Oil Co. (No. 1 in sec. 35, T. 46 N., R. 63 W.) is shown on a map published by the Clark, Haste & Hill Co. as a producing well, and probably it yielded a showing of oil from the Newcastle sand. A short distance to the south a well in sec. 2, T. 45 N., R. 63 W., struck alkali water at a depth of 80 feet. Northeast and north of the Pioneer well, in secs. 17 and 18, are two wells drilled in the zone of steeply dipping beds by the Ohio and Midwest companies. The Ohio well, in sec. 17, reached the Newcastle sand at a depth of about 900 feet; the Midwest well, in sec. 18, at 1,000 to 1,050 feet. Neither of these wells was dry, but they did not produce more than the average wells in the shallow part of this field.

The interpretation of the structure in this portion of the field is based largely on the drill records, for much of the surface is covered with more or less disintegrated shale, so that outcrops are very hard to find south of the zone of steeply dipping rocks. Along a line running southwest from the Pioneer well for about 2½ miles the rocks lie nearly flat. Near the northeast end of this line the Newcastle sand dips about 6° SW., but farther southwest the sand rises at an angle of about 2° to the west line of sec. 19, near which is the crest of a slight anticline or dome. This feature, shown by wells drilled late in the season, is not clearly defined, but it probably covers about 200 acres, and its highest point is near the west quarter corner of sec. 19. On the west side of the crest the sand again dips about 3° SW. for a distance of about 1½ miles. Somewhere southwest of Beaver Creek the dips must be steeper, for within 3 miles the top of the Pierre shale and the Fox Hills sandstone are exposed, showing a moderate dip to the southwest.

The Pioneer well, in the NW. ¼ NE. ¼ sec. 19, T. 46 N., R. 63 W., found a flow of oil estimated at about 200 barrels a day at a depth of 1,335 feet. This well is probably the most productive one in the field. In August, 1920, it was producing about 50 barrels of oil a day. The second well, near the center of sec. 19, is about 1,440 feet deep and produced only about 20 barrels a day; the third well, in the NE. ¼ NE. ¼ sec. 19, drilled late in July, was also 1,440 feet deep and had an estimated yield of 20 barrels a day. A photograph of the third well is shown in Plate XIV, *A*. Since that well was put down drilling has been extended in all directions. Near the west quarter corner of sec. 19, T. 46 N., R. 63 W., several wells reaching the sand at a depth of about 1,400 feet have brought in rather strong flows of gas. These wells are apparently on the low dome mentioned above. It is reported in a Newcastle paper that the first of these gas wells has since been shot and that it now produces oil. A well near the north quarter corner of sec. 32, T. 46 N., R. 63 W., also brought in a gas flow, but at this place there is no anticlinal structure known that will account for it. A well drilled by the Wyoming Petroleum Co. in the NE. ¼ sec. 1, T. 45 N., R. 64 W., which is reported to have found some oil in the Newcastle sand at a depth of 2,082 feet, should be noted, for it is outside the boundary of the productive field as shown on Plate IV. The oil was encountered in July, 1921, and the well was shot about October 10, but its productive possibilities have not yet been determined. The Newcastle sand is reported to lie at a depth about 600 feet below that found in the wells in sec. 25, T. 46 N., R. 64 W., and this well may indicate the position of a third terrace or dome not detected from the surface outcrops.

RELATION OF PRODUCTION TO STRUCTURE.

The structure map of the Osage field shows that the oil has accumulated in an area where the beds dip much more gently than in the surrounding region. This area of gentle dips is interrupted by a belt of very steep dips, and it is apparently significant that the wells of large production are confined to the territory west of this zone of steeply dipping beds. A study of the map gives the general impression that the oil moved eastward up the steeply dipping beds from the synclinal Powder River basin to the west. This eastward movement was probably arrested in part by the flat-lying strata west of the steeply tilted zone and was perhaps further arrested by the presence of faults and fractures in porous beds that had been displaced and brought into contact with impervious beds. The oil presumably gathered to the west of the steeply tilted zone, until a fairly large quantity had accumulated. This was perhaps followed by the escape of a portion of this oil through more permeable channels in the steeply tilted formations to form secondary accumulations of smaller volume in the area of flattened beds east of the disturbed belt. If this hypothesis is correct, it might be reasonable to expect the oil in the northeastern part of the field to be of slightly higher quality than that in the southwestern part, as it is generally believed that the migration of oil through a fine-grained medium has a slight refining influence upon it, provided there are no contaminating solutions, such as water containing a high content of sulphur, to retard or entirely neutralize this influence. It may be significant that the quality of the oil in the shallow wells northeast of the disturbed belt, as shown in analysis 4 (laboratory No. 0383, p. 104), is slightly better than that of the oil in the deep wells west of the belt, as shown in analysis 3 (laboratory No. 0380, p. 103).

FLOW OF ARTESIAN WELLS.

Artesian wells have been drilled to the Dakota and Lakota sandstones at several places in the vicinity of Osage, and though the available data regarding the flow of such wells are rather meager, they may be of interest. The wells east of Osage all yield moderate flows of water; those northwest and south of the field yield strong flows, as might be expected from their lower altitude. The well northwest of the discovery well in sec. 18, T. 46 N., R. 63 W., was drilled to the Dakota sandstone but found very little water. If the water under hydrostatic pressure came up from the large body of water underlying the basin to the west, its movement to this well was interfered with by the proximity of the dome and the zone of small faults due to the abrupt steepening of the dip. The water, however, may have come down the dip from outcrops on the east.

POROSITY OF THE NEWCASTLE SAND.

The Newcastle sand varies greatly from place to place, not only in the number and character of its beds but in the capacity of its sand members to hold oil. A set of samples taken in the Osage field and several fields near by was examined by A. F. Melcher[19] to determine the pore space of the oil sand. His results are as follows:

[19] For method of examination see Melcher, A. F., Determination of pore space of oil and gas sands: Mining and Metallurgy, No. 160, sec. 5, pp. 1-22, April, 1920.

Samples from diamond-drill core, well in sec. 9, T. 46 N., R. 63 W. (see p. 109); average specific gravity, 2.68:

Depth (feet).	Sand.	Pore space (per cent).	Average diameter of grains (millimeter).	Sample shows.
40	First sand	22.6	0.106	Oil.
64	Second sand	26.0		Do.
70	.....do	14.7		Do.
87	Third sand	15.3		Do.
95	.....do	19.8	.103	Do.
96	.....do	14.0		Do.
153	Skull Creek shale	15.3		No oil.
185	Stray sand in Skull Creek shale	19.5		Oil.
195	.....do	15.4		Do.
197	.....do	11.3		No oil.
300	Top of Dakota sandstone	15.2		Oil.

Samples of drill cuttings from producing sand of second deep well of Sinclair Oil Corporation (well No. 4, sec. 19, T. 46 N., R. 64 W.), at a depth between 1,415 and 1,450 feet: Pore space, 23, 24, and 21 per cent.

Samples from Midwest Co.'s well No. 1, NE. ¼ sec. 24, T. 46 N., R. 64 W., taken between 1,435 and 1,446 feet after well was shot: Pore space, 19 and 19.5 per cent; average diameter of grains (second sample), 0.130 millimeter; both samples show oil.

Outcrop samples of Newcastle sand in sec. 10, T. 46 N., R. 63 W., east of Osage: Pore space, hard calcareous sand at top of member, 8.8 per cent; middle sand, 22.3 and 23.5 per cent; lower sand, 23.2 and 21.4 per cent. All samples dry.

Sample of Newcastle sand from outcrop at Newcastle: Pore space, 19 per cent; specific gravity, 2.65.

Samples of asphalt-stained sand from outcrops near oil seep in Moorcroft field: Pore space, 23.9, 24.8, and 23.9 per cent; specific gravity (one sample), 2.65; average diameter of grains, one sample, about 0.19 millimeter; another sample, less than 0.074 millimeter.

Samples of oil sand from deep well that produced 60 barrels a day in Lance Creek field: Pore space, 20.7 and 14.9 per cent; specific gravity, 2.646.

By far the most reliable of the samples tested are those taken from the drill core at Osage, which show an average porosity of about 19 per cent. It will be seen that some of the shale samples have a porosity as high as some of the oil sands, but this can probably be accounted for by the fact that the size of the grains and therefore of the pores in the shales is very much smaller than in the sands and consequently the permeability is very much lower, though the total porosity may be the same. It seems probable that most of the oil is produced from the parts of the sands that show a porosity of 19 per cent or more. One of the samples taken from the outcrop at Osage was a very hard sandstone which when tested in the office was found to be cemented with calcite and showed only 8.8 per cent porosity. It is thought probable from this showing that some of the wells in which the driller has been disappointed may have struck local phases of sand of this character. The oil sand from the Moorcroft field has a very high porosity, making it possible for the lighter portion of the oil to evaporate readily at the outcrop, leaving only the heavier portion remaining.

The porosity of the samples from the Lance Creek field, which may not be strictly representative of the field, averages only 17.1 per cent. Probably the most productive wells of that field will be found to be in places where the porosity is 20 per cent or more.

Samples of the oil sand obtained from wells always contain some oil which can be detected by the odor, and the sand from the Moorcroft field has also the dark color of oil. This oil represents part of the nonrecoverable residue of the oil field. The samples tested for porosity were weighed, heated to burn off the petroleum contained, and again weighed. The loss in weight by this treatment is probably in the main that of the oil which they contained. Of the highly porous samples from the drill core at Osage an average of 6 per cent by volume was residual oil; those from the Midwest well No. 1, in the NE. ¼ sec. 24, T. 46 N., R. 64 W., show 8 per cent; and those from the Sinclair well, in sec. 19, T. 46 N., R. 63 W., show 10 per cent. Before the test the samples were much more thoroughly drained of oil by exposure to the air for several months than it is conceivable that they could be underground, and the test shows that probably there is considerably more than half the oil left in the ground when the wells are finally abandoned. The fact that specimens taken from the outcrops of the Newcastle sand at Osage contain only traces of oil suggests that when the rocks are long exposed to the weather the oil may be completely evaporated or washed from them.

CHEMICAL CHARACTER OF THE GRANEROS SHALE.

Samples were collected at several places in the Graneros shale and were investigated chemically with the following results:

Coal analysis.—A sample of coal was taken from a diamond-drill core obtained west of the railroad in Osage and submitted to E. T. Erickson, a chemist of the United States Geological Survey, for proximate analysis, in the belief that it might have a bearing on White's theory[20] regarding the presence of oil in rocks that have been slightly metamorphosed. The sample came from the Newcastle sand at a depth of about 70 feet.

Analysis of coal from Newcastle sand.

Moisture	2.9
Volatile matter	23.5
Fixed carbon	28.6
Ash	45.0
	100.0
Percentage of fixed carbon in dry ash-free coal	54.9
Fuel ratio	1.22

[20] White, David, Some relations in origin between coal and petroleum: Washington Acad. Sci. Jour., vol. 6, pp. 189-212, 1915.

The sample was extracted by successive treatments with chloroform at ordinary room temperature for two weeks. The final extract, of several days' standing, was faintly colored with the dissolved sample. The combined extracts were evaporated at as low a temperature as possible to evaporate the chloroform slowly, and the product obtained (chloroform extract) was 0.58 per cent of the original sample. This extract may be considered resinous matter, a normal constituent of bituminous coal, and not free petroleum. The sample was also tested for phosphate, but none was found. According to White's paper, oil in commercial quantities is never found in coal regions in which the fixed carbon in dry ash-free coal is as high as 70 per cent or the fuel ratio 2.23 and is seldom found where the fixed carbon is as high as 60 per cent or the fuel ratio 1.50. The percentage of fixed carbon in dry ash-free coal from the Newcastle sand and its fuel ratio agree very well with those of the coal found in the large productive oil fields of the United States.

Tests of the shale.—Samples of shale were taken from several members of the Graneros shale and were tested by Mr. Erickson for oil and other bitumens by the heat and chloroform method.[21]

Tests of Graneros shale.

	Free hydrocarbon by $CHCl_3$ test.	Total bitumen by heat test.
Skull Creek member	Slight	Slight.
Mowry member	do	Do.
Shale in lower part of Belle Fourche member about 30 feet above Mowry member.	Trace	Trace.
Shale in Belle Fourche member about 300 feet above Mowry member.	Slight	Slight.
Shale in Belle Fourche member about 320 feet above Mowry member.	Trace	Trace.
Shale in Belle Fourche member near oil seep about 350 feet above Mowry member.	Distinct amber-colored residue left by evaporation of $CHCl_3$ extract.	Small amount of oil condensed from a moderately strong vapor cloud produced in the heat test.

The results given above show that a little oil occurs throughout the Graneros shale and that this oil is probably in large part in a free state—that is, the shale is not an oil shale in the same sense as the Green River shale or any other shale from which oil may be obtained in appreciable quantity by destructive distillation. It seems rather that the oil in the Graneros shale is free to migrate, provided avenues for migration are available, and this would signify the probability that commercial accumulations of oil are to be expected wherever in this shale there are porous beds that provide space for the storage of the oil.

[21] Erickson, E. T., Tests to detect the presence of small quantities of oil and bitumens (U. S. Geol. Survey press bulletin), 1920; Detecting small quantities of petroleum: Eng. and Min. Jour., July, 1921.

THE OIL.

ORIGINAL SOURCE.

Geologists do not all agree as to the ultimate origin of petroleum, for though most of them believe that it is a product of organic remains buried in stratified rocks, a few still adhere to the inorganic theory that oil is produced by deep-seated chemical reactions in the earth. That the oil of the Osage field was once disseminated through the Graneros, Greenhorn, and Carlile formation is proved almost conclusively by the small quantities of oil found in sandy beds at several horizons throughout these formations and the traces of oil present in the shale wherever it has been tested. Microscopic examination reveals much organic material scattered through the shale along with the oil. The Newcastle sandstone contains a great deal of organic matter, including beds of impure coal, and it overlies about 200 feet of dark shale that contains organic fragments and disseminated oil.

It is the writer's opinion that the oil originated in the organic matter included in the shale and sandstone. This material was probably altered to oil while the beds were being compressed, faulted, and warped into monoclines, anticlines, and synclines. Simultaneously much of the oil and also of the water with which the beds were saturated when they were deposited under the sea was forced from the shale into the more porous sandstone. A part of this fluid must have found its way to the surface and escaped, but where the structure is favorable and porous beds are present the oil has been retained. Such bodies of oil are presumably hemmed in by water, which is held from mixing with the oil by difference of specific gravity and other physical factors. The structural feature that is most favorable to trap and retain oil is the anticline, but the Osage occurrence is duplicated in many places where the oil has been arrested on gently sloping beds adjacent to more steeply tilted portions of the same beds by a change in the porosity of the sand, by minor faults, by the sealing of pores in the containing beds by solid hydrocarbons such as asphalt or paraffin, or by some cause not determined.

PROBABLE EXPLANATION OF OCCURRENCE.

The shallow wells are on a broad structural terrace that slopes about 5° SW. On the east margin of this terrace the Newcastle sand has been eroded, allowing most of the gas and oil to escape but leaving part of the gas and oil behind under slight gas pressure. The more productive parts of this area will be found where the sand is either very thick, very porous, or so lenticular that the escape of the oil has been hindered. When the oil-bearing rock is tapped by wells, the oil flows out of it very slowly and may continue to flow for a considerable length of time.

The deep discovery well is in sec. 19, T. 46 N., R. 63 W., near the edge of the zone of steeply dipping rocks, a short distance up the slope from the lower terrace. This well, when first drilled, had a strong gas pressure, which forced the oil to flow periodically. The well is so situated that the gas and oil would appear to have a free passage up to the shallow-well terrace if it were not interfered with either by the lenticularity of the sand or by the peculiar folding or faulting of the strata. Inasmuch as the sands of the upper terrace do not show marked gas pressure at any place where they have been drilled, it is the writer's opinion that the gas pressure in the discovery well is due to the presence of faults or folds—in other words, that the oil and gas are trapped locally by a series of small faults such as are represented by the slickensiding found in some places along the outcrops of the Newcastle sandstone. The gas wells near the west side of sec. 19, T. 46 N., R. 63 W., are clearly due to the low anticline already noted and shown approximately on the structure map (Pl. XIII). The gas well in sec. 32, T. 46 N., R. 63 W., may be due to either of the causes noted, but the evidence is not complete enough to enable the writer to form an opinion.

The beds northwest of the productive area in the neighborhood of the Midwest well, in sec. 11, T. 46 N., R. 64 W., dip almost uniformly southwest from the outcrop of the Newcastle sandstone to the outcrop of the Fox Hills sandstone and apparently do not have either steeply dipping or flat portions—at any rate, they have not yet been found to be petroliferous, and in one well in this area the Newcastle sand yields water. South of the Osage field the Newcastle sandstone lies nearly flat at considerable depth until it is turned up abruptly and crops out with a southwest dip along a line running southeastward from the southeast corner of T. 46 N., R. 63 W., for about 15 miles. The oil seeps near Newcastle are on this upturned outcrop of the Newcastle sandstone.

The small dome in secs. 19 and 24, T. 46 N., Rs. 63 and 64 W., must be so situated with regard to the structure of the rock beds to the west and south that it has collected the oil and gas from a comparatively large area and has been filled with gas, some of which has passed the closure of the dome and been caught locally in such structural traps as that at the discovery well (No. 1, sec. 19), but a large part of the gas has flowed up the dip and is held in the comparatively flat-lying beds of the upper terrace, and some has undoubtedly escaped at the outcrop of the Newcastle sandstone.

If this explanation of the occurrence of oil and gas in the small dome on the west line of sec. 19 is correct, it may be possible, by drilling the wells near the dome down to the Dakota sandstone, to find a pool of either oil or gas entrapped there, for a small amount of oil has been found in the top of the Dakota sandstone at Osage, and the thickness and character of the Dakota would enable it to hold a large quantity if the structure permitted. Such a well would penetrate the Dakota sandstone at about 1,600 feet, or 200 feet below the Newcastle sand.

QUALITY.

The oil obtained in the Osage field has a light olive-green color, a rather low specific gravity, and a rather high percentage of gasoline. Four samples taken in different parts of the field were analyzed by N. A. C. Smith at the Washington office of the Bureau of Mines. The first two of these samples were bailed from shallow wells that had not been pumped, and they had probably lost part of their more volatile constituents. Sample 3 was taken from a tank into which oil was flowing from the discovery well in sec. 19, T. 46 N., R. 63 W., and it represents the oil from the deep wells. Sample 4 was taken from one of the Whedon wells in sec. 16, T. 46 N., R. 63 W., while pumping was in progress and is thought to be representative of the oil from the shallow wells. The gravity of fresh samples ranged from 39.1° to 40.3° B.

Sample 1. Laboratory No. 0381. Taken within 15 feet of the top of an open well (No. 3) near west line of sec. 9, T. 46 N., R. 63 W. Specific gravity at 15° C., 0.857 (33.4° Baumé, modulus 140). First drop at 85° C.

Temperature (°C.).	Air distillation, with fractionating column.			Vacuum distillation, without column (pressure, 40 millimeters).		
	Fraction (per cent by volume).	Total (per cent by volume).	Specific gravity.	Fraction (per cent by volume).	Total (per cent by volume).	Specific gravity.
100-125	3.9	3.9	0.751			
125-150	5.4	9.3	.766			
150-175	6.4	15.7	.784	1.5	42.9	
175-200	5.6	21.3	.798	5.8	48.7	0.850
200-225	6.1	27.4	.811	8.0	56.7	.857
225-250	7.0	34.4	.825	7.3	64.0	.867
250-275	7.0	41.4	.838	6.7	70.7	.879
275-300				6.8	77.5	.892

Sulphur, 0.09 per cent.

Approximate summary:	Per cent.
Gasoline and naphtha (distills below 200° C.)	21.3
Kerosene (distills between 200° and 275° C.)	20.1
Gas oil	15.3
Light lubricating distillate	14.0
Medium lubricating distillate	6.8

Sample 2. Laboratory No. 0384. From well No. 4, near northwest corner of sec. 6, T. 63 N., R. 64 W. Specific gravity at 15° C., 0.826 (39.5° Baumé, modulus 140). Amount distilled, 200 cubic centimeters. First drop at 25° C.

Temperature (°C.).	Air distillation, with fractionating column.			Vacuum distillation, without column (pressure, 40 millimeters.		
	Fraction (per cent by volume).	Total (per cent by volume).	Specific gravity.	Fraction (per cent by volume).	Total (per cent by volume).	Specific gravity.
Up to 50	3.3	3.3	0.642	....	....	....
50-75	2.7	6.0	.671	....	....	....
75-100	5.9	11.9	.716	....	....	....
100-125	6.0	17.9	.740	....	....	....
125-150	5.6	23.5	.758	....	....	....
150-175	5.2	28.7	.776	1.0	51.4	0.847
175-200	5.1	33.8	.793	4.3	55.7	
200-225	4.7	38.5	.809	6.5	62.2	.854
225-250	5.7	44.2	.820	6.4	68.6	.865
250-275	6.2	50.4	.833	6.4	75.0	.877
275-300	....	....	....	4.0	79.0	.890

Sulphur, 0.13 per cent.

Approximate summary: Per cent.

Gasoline and naphtha (distills below 200° C.)	33.8
Kerosene (distills between 200° and 275° C.)	16.6
Gas oil	11.8
Light lubricating distillate	12.8
Medium lubricating distillate	4.0

Sample 3. Laboratory No. 0380. First deep well (No. 1) in sec. 19, T. 46 N., R. 63 W. Specific gravity at 15° C., 0.828 (39.1° Baumé, modulus 140). Amount distilled, 200 cubic centimeters. First drop at 24° C.

Temperature (°C.).	Air distillation, with fractionating column.			Vacuum distillation, without column (pressure, 40 millimeters.		
	Fraction (per cent by volume).	Total (per cent by volume).	Specific gravity.	Fraction (per cent by volume).	Total (per cent by volume).	Specific gravity.
Up to 50	2.3	2.3	0.641	....	....	....
50-75	2.3	4.6	.680	....	....	....
75-100	6.0	10.6	.721	....	....	....
100-125	6.9	17.5	.746	....	....	....
125-150	6.2	23.7	.765	....	....	....
150-175	5.7	29.4	.782	0.7	51.7	0.852
175-200	5.1	34.5	.798	4.6	56.3	
200-225	4.8	39.3	.812	7.1	63.4	.858
225-250	5.5	44.8	.827	7.8	71.2	.872
250-275	6.2	51.0	.839	4.9	76.1	.882
275-300	....	....	....	5.1	81.2	.892

Sulphur, 0.13 per cent.

Approximate summary: Per cent.

Gasoline and naphtha (distills below 200° C.)	34.4
Kerosene (distills between 200° and 275° C.)	16.5
Gas oil	12.4
Light lubricating distillate	12.7
Medium lubricating distillate	5.1

Sample 4. Laboratory No. 0383. Dr. Earle Whedon's well (No. 4), in the SE. ¼ SE. ¼ sec. 16, T. 46 N., R. 63 W. Specific gravity at 15° C., 0.822 (40.3° Baumé, modulus 140). Amount distilled, 200 cubic centimeters. First drop at 24° C.

Temperature (°C.).	Air distillation, with fractionating column.			Vacuum distillation, without column (pressure, 40 millimeters).		
	Fraction (per cent by volume).	Total (per cent by volume).	Specific gravity.	Fraction (per cent by volume).	Total (per cent by volume).	Specific gravity.
Up to 50	3.5	3.5	0.640			
50–75	4.0	7.5	.662			
75–100	6.0	13.5	.720			
100–125	6.7	20.2	.746			
125–150	5.3	25.5	.767			
150–175	6.2	31.7	.785	0.9	52.9	0.851
175–200	4.2	35.9	.800	4.7	57.6	
200–225	4.8	40.7	.813	6.2	63.8	.858
225–250	5.4	46.1	826	5.3	69.1	.868
250–275	5.9	52.0	838	5.7 4.1	74.8 78.9	.879 .891

Sulphur, 0.10 per cent.

Approximate summary:

	Per cent.
Gasoline and naphtha (distills below 200° C.)	35.9
Kerosene (distills between 200° and 275° C.)	16.1
Gas oil	11.8
Light lubricating distillate	11.0
Medium lubricating distillate	4.1

A sample of oil taken by Mr. Tuff from the four showings of oil found above the Newcastle sand in the Quin Oil Co.'s well No. 2, in sec. 20, T. 46 N., R. 63 W., was tested by E. T. Erickson and found to have at 25° C. a specific gravity of 0.8435 (36° Baumé). The high specific gravity may be due to the higher source of the oil, but it is the writer's opinion that the sample was affected by the drilling operations and had lost some of its lighter constituents before it was taken from the well.

SIGNIFICANCE OF THE OSAGE FIELD.

The fact that scattered showings of oil occur for about 60 miles along the southwest flank of the Black Hills seems to indicate that the oil comes from some source in the adjacent region to the southwest that is capable of yielding large volumes of oil. The wide distribution of these showings and their independence of local anticlines indicate that the source of the oil is widespread. The oil in the Newcastle, Osage, Upton-Thornton, Wakeman, and Moorcroft fields and the gas found 20 miles north of the Moorcroft field occur in flat-lying beds or structural terraces, usually adjacent to zones of steeply dipping beds. In the Newcastle, Moorcroft, and Upton-Thornton fields seepages occur along the outcrops of rather steeply dipping upturned beds, but in the Osage and Wakeman fields there were no surface indications of oil. In the Osage field most of the oil is found on an upper and a lower structural terrace separated by a zone of steeply dipping beds. In the Wakeman and Upton-Thornton fields the Newcastle sand is thin and the oil is found in the Wall Creek (?) sand, which is stratigraphically higher, being in the lower part of the Carlile shale. If the reasoning from these facts is correct, there may be along the Black Hills front many small undiscovered pools of oil in flat-lying terraces on either side of zones of steeply dipping beds, providing the Newcastle or some other sand is present. In such areas the more promising places to drill would be on the lower terrace west of the steeply dipping rocks, providing the depth of the sand is not too great. The structure sections of the Black Hills published in the Devils Tower, Newcastle, and Edgemont folios of the United States Geological Survey show many zones of steep dips but do not show the local thickening or thinning of the Newcastle sand.

In the region southwest of the zone of steeply dipping beds near the source from which the oil has come there may be local domes and anticlines which can not be detected by the examination of the surface but which retain large quantities of oil. This region is very largely covered by the Lance formation, which may not be conformable with the Fox Hills sandstone, as it is at present supposed to be, and should it be found to be unconformable the discovery of such hidden domes would be very expensive if not impossible.

POTENTIAL OUTPUT.

The quantity of oil recoverable from the Newcastle sand in the Osage field depends on so many factors, many of them imperfectly understood, that it is doubtful if the estimates made by two independent observers will check more than approximately until the rate of production and life of wells is established by statistics covering three years or more. If it is assumed that the oil sand is uniformly saturated and has an average thickness of 15 feet and an average porosity of 20 per cent over an area of 12 square miles, and that the field will be so completely drilled that 20 per cent of the total oil content will be recovered, the oil extracted would amount to about 35,000,000 barrels. To extract this oil would demand about 256 wells in the deep-sand area and about 2,560 wells in the shallow-sand area. These figures are based on the assumption that gas pressure in the deep-sand area is sufficient to permit one well to drain 10 acres, and that in the shallow-sand area one well will drain about 2 acres. If the average cost of the deep wells is considered $20,000 and of the shallow wells $2,000, this drilling will entail an expenditure of approximately $10,000,000, or about 30 cents a barrel. Accordingly, even though other development and operating expenses might be high, the extraction of the oil from the field, considered as a whole, should be profitable if the uniform conditions postulated above are present.

Absence of uniform sand conditions, failure to drill the area systematically, and possible inability to operate with profit in much of the area owing to lack of gas pressure to force the oil to the wells will greatly reduce the above estimate. The last factor mentioned will affect to a greater or less degree five-sixths of the 12 square miles assumed to be productive. In considering the field as a whole, and not some small favored unit of it, a reduction or safety factor of four-fifths will probably have to be applied to the estimate, and the total oil extracted from the Newcastle sand by present methods of production in this field is therefore unlikely to exceed 7,000,000 barrels. Indeed, even this will probably be regarded by most of the operators in the field as a wildly optimistic estimate.

The lamentable inefficiency of even the best methods of production now in use is startlingly brought out by this calculation. There can be little doubt that the Newcastle sand underlying 12 square miles of the Osage field contains at least 175,000,000 barrels of oil, and of this amount 168,000,000 barrels, or 96 per cent, is at present unobtainable.

METHODS OF DRILLING.

Most of the shallow wells of the Osage field were drilled with light portable rigs such as are used for water wells, and the cost of drilling such wells in 1920 was from $6 to $8 a foot. The first deep wells were drilled with somewhat heavier rigs of the Star and National type, but by July 1, 1920, several standard rigs had been set up. The average cost of drilling and equipping the deep wells with casing and other needed appliances in 1920 was estimated at about $10 a foot. Some of the first wells undoubtedly cost much more than that—for example, the total expense of drilling the first well in sec. 19, T. 46 N., R. 63 W., to a depth of 1,335 feet was given to the writer as $37,000, or nearly $28 a foot.

After the writer left the field the practice of shooting the wells when the production was small was begun, and it is reported that the production of some wells treated in this way has been increased by 100 per cent.

All the rigs described are essentially churn drills, in the use of which the driller determines the character of the rock penetrated by its hardness and composition as shown by the nature of the impact and its effect on the drill. It can be determined more closely by careful examination of the drill cuttings. A diamond drill was used in a well drilled for water by E. W. Talbert and T. E. Mahoney west of the railroad in the Nefsy town site at Osage, and from the core obtained it was possible to measure the exact thickness and determine the character of the several layers penetrated. Although the diameter of the hole bored by the type of diamond drill most commonly in use is too small to permit much production from the ordinary oil sand, it is of unquestioned value for prospecting. A diamond-drill core informs the prospector concerning the exact nature of the beds through which he has drilled, and there is practically no possibility of passing without noting even very small showings of oil, provided adequate precautions are taken. By using bits and core barrels of a proper kind, it is possible to drill as fast with a diamond drill as with a churn drill, and the expense should actually be less for drilling a hole of prospecting size—that is, one which will yield a core 2 inches in diameter. It is true that if oil is encountered it will be necessary to drill a hole of larger diameter, presumably with a churn drill; but if oil is actually present in notable amount the operator can stand the additional expense without inconvenience, whereas if oil is absent the cost of prospecting should be kept as low as possible. In drilling the second well with a churn drill the operator will have the advantage of exact knowledge concerning the thickness and character of the beds he must penetrate, the proper points at which to set his casing, and the position of the top of the oil sand.

WELL DATA.

Wells visited in the Osage field.

No. on map.	Location.			Owner or driller.	Altitude (feet).	Depth to Newcastle sand (feet).	Showing.	Remarks.
	Sec.	T.	R.					
1	28	47	64	Union Oil Co.		360	Water	Well drilled to Minnelusa sandstone; no oil found.
1	25	47	64				do	A moderate flow of water from Newcastle sand and Dakota sandstone.
1	36	47	64		4,195			Probably a dry well.
1	30	47	63	F. W. Mondell	4,221		Oil	Being drilled when visited.
2	30	47	63	do	4,214	176	do	3 barrels a day reported.
1	31	47	63		4,631	200	do	
2	31	47	63		4,211	300	do	
3	31	47	63		4,207			Being drilled at 145 feet.
4	31	47	63	Moody, driller	4,212	275	Oil	
5	31	47	63		4,201		do	
6	31	47	63		4,202		do	
7	31	47	63		4,187	290	do	
8	31	47	63		4,204		do	
1	32	47	63		4,241			Being drilled; 18 feet deep when visited.
2	32	47	63		4,220			Being drilled; 200 feet deep when visited.
3	32	47	63		4,225			Being drilled; 145 feet deep when visited; showing of gas.
4	32	47	63		4,218			
5	32	47	63		4,187	205	Oil	Oil reported; 15 barrels a day.
6	32	47	63		4,196		Oil showing.	Struck white water sand at 485 feet.
7	32	47	63	Gillette Oil Syndicate.	4,252			Being drilled at 200 feet.
8	32	47	63		4,260		Oil	
9	32	47	63		4,275			Dry hole.
1	34	47	63				Oil, small show.	Struck 20 feet of Dakota sandstone at 380 feet. Lakota sandstone at 420 feet. Depth when visited, 520 feet.
1	1	46	64	W. E. Hall	4,209	296	Oil	Drilled into sand 1 foot.
2	1	46	64		4,217			Dry well, abandoned.

Wells visited in the Osage field—Continued.

No. on map.	Location. Sec.	T.	R.	Owner or driller.	Altitude (feet).	Depth to Newcastle sand (feet).	Showing.	Remarks.
3	1	46	64		4,177			Well 800 feet deep; showing of gas; abandoned.
4	1	46	64		4,236	1,100	Dry	Abandoned.
5	1	46	64	Gates & Marquis	4,273			Being drilled; 500 feet deep when visited.
1	2	46	64		4,169			Dry hole, abandoned.
1	5	46	64	Quin Oil Co.	4,171			Being drilled; 1,225 feet deep when visited.
1	11	46	64	Midwest Co.	4,072	1,500	Dry	Midwest Co. afterward drilled to the Dakota sandstone and struck a strong flow of artesian water.
1	12	46	64		4,282			Being drilled; 400 feet deep when visited.
1	13	46	64		4,128		Oil	Small amount of oil struck in September, 1920.
2	13	46	64		4,122			Unfinished well, abandoned.
3	13	46	64		4,122			Being drilled when visited.
4	13	46	64	Midwest Co. No. 1.	4,097		Oil	
5	13	46	64	Midwest Co. No. 2.	4,091		do	
6	13	46	64	Foster	4,101		do	
1	15	46	64		4,103			Being drilled when visited in September; abandoned later as dry hole.
1	24	46	64	Midwest Co.	4,086	1,450	Oil	Being drilled when visited in June.
2	24	46	64	Midwest Co. No. 4.	4,093			Being drilled when visited in October; 660 feet.
3	24	46	64	Midwest Co. No. 5.	4,106			
4	24	46	64	Midwest Co. No. 6.	4,107		Oil	
5	24	46	64	Midwest Co.	4,104		Gas	
6	24	46	64	Inland Oil Co.	4,106		Oil	
7	24	46	64	Mississippi Delta Co.	4,096	1,393	Gas	
8	24	46	64	Inland Oil Co.	4,107		Oil	
1	26	46	64				Dry	Well abandoned in September.
1	25	46	64	Producers & Refiners Oil Co.	4,085	1,527	Oil	
2	25	46	64	do	4,031		do	Well completed in October.
1	36	46	64		4,032		Dry	Well completed in September.
1	4	46	63		4,242		Oil	Well in Mowry shale.
1	5	46	63		4,249			Incomplete when visited in June.
2	5	46	63	Mike Henry Co.	4,208		Oil	
3	5	46	63	do	4,230		do	
4	5	46	63		4,284			Abandoned, hole probably dry.
5	5	46	63		4,292		Oil	
6	5	46	63	Mike Henry Co.	4,228		do	
7	5	46	63	do	4,230		do	
8	5	46	63	do	4,229		do	
9	5	46	63	do	4,235	360	Oil show	Showing of oil in the Newcastle sand at about 385 feet; depth of well, 600 feet; water well.
8	5	46	63		4,220			Abandoned, probably dry hole.
1	6	46	63		4,204		Oil	
2	6	46	63	Bridger Oil Co.	4,261	300	do	
3	6	46	63		4,267			Dry hole, abandoned.
4	6	46	63		4,214	300	Oil	
5	6	46	63		4,212		do	
6	6	46	63		4,232		do	
7	6	46	63		4,257			Do.
8	6	46	63	Gates & Marquis	4,262		Oil	Oil struck at 390 feet; probably near the oil-seep horizon.
9	6	46	63	Briggs	4,295		do	Oil found at 400 feet.
10	6	46	63		4,355		do	
11	6	46	63		4,323			Probably dry hole.
1	7	46	63	Friel	4,275			Being drilled when visited.
2	7	46	63		2,327			Being drilled when visited in June.
3	7	46	63		4,267		Oil showing.	A few gallons of oil from seep horizon at 560 feet.
4	7	46	63		4,300			
5	7	46	63		4,320			Being drilled when visited in June.
6	7	46	63		4,189		Oil	Probably showing at oil-seep horizon.
7	7	46	63		4,254		do	Do.
1	8	46	63		4.240		do	
2	8	46	63		4,238			Dry hole, abandoned.
3	8	46	63		4,261		Oil	
4	8	46	63		4,272		do	

Wells visited in the Osage field—Continued.

No. on map.	Location. Sec.	T.	R.	Owner or driller.	Altitude (feet).	Depth to Newcastle sand (feet).	Showing.	Remarks.
5	8	46	63	....	4,284	....	Oil.......	
6	8	46	63	....	4,242	....	...do......	
7	8	46	63	....	4,227	....	....	Dry hole, abandoned.
8	8	46	63	....	4,229	....	Oil.......	
9	8	46	63	Wyoming Southern Co.	4,252	375	...do......	
10	8	46	63	....	4,260	....	...do......	Oil standing within 4 feet of surface.
11	8	46	63	....	4,233	....	...do......	Do.
1	9	46	63	....	......	40	...do......	Diamond-drill well. At least five showings of oil in first 260 feet.
2	9	46	63	....	4,245	....	...do......	
3	9	46	63	....	4,284	....	...do......	Oil standing within few feet of surface.
4	....	....	....	Friel..............	4,259	300	...do......	
1	10	46	63	....	4,325	0	...do......	Water well 683 feet deep; showing of oil reported near top.
2	10	46	63	....	4,320	10	....	Water well; oil showing near top.
1	15	46	63	....	4,294	0	....	Do.
2	15	46	63	Earle Whedon....	4,250	....	....	Being drilled when visited in June
3	15	46	63	.....do............	4,255	170	Oil.......	
1	16	46	63	Chugwater........	4,313	240	...do......	Did not recognize upper sand.
2	16	46	63	....	4,313	220	...do......	Struck oil at 220 and 240 feet.
3	16	46	63	American Oil Co..	4,286	....	...do......	Log similar to that of well No 2.
4	16	46	63	Earle Whedon....	......	....	...do......	
1	17	46	63	....	4,241	....	...do......	
2	17	46	63	....	4,242	....	...do......	
3	17	46	63	....	......	....	...do......	
4	17	46	63	....	4,244	....	...do......	
5	17	46	63	....	4,234	....	....	Oil seep.
6	17	46	63	Ohio Oil Co.......	4,186	900	Oil.......	Estimated production 3 barrels a day.
7	17	46	63	....	4,308	....	...do......	
1	18	46	63	....	4,174	....	...do......	
2	18	46	63	Midwest Co.......	4,173	1,050	...do......	Small production from Newcastle sand; later drilled to Dakota sandstone.
3	18	46	63	National Oil Co...	4,097	....	....	Incompleted well reached a depth almost to the Newcastle sand before it was shut down.
1	19	46	63	Drilled by Alliance Co; sold to Sinclair.	4,079	1,335	Oil.......	Discovery well in deeper part of field; called the Pioneer well.
2	19	46	63	Sinclair Oil Syndicate.	4,094	1,440	...do......	
3	19	46	63	.....do............	4,102	1,400	Gas.......	Well completed in October, 1920.
4	19	46	63	.....do............	4,072	1,415	Oil.......	Second deep well drilled in the field.
5	19	46	63	....	4,083	....	....	Well abandoned before reaching Newcastle sand.
6	19	46	63	Glen Oil Co.......	4,089	1,400	Oil.......	Being drilled when visited.
7	19	46	63	Sinclair Oil Syndicate.	4,144	1,394	...do......	
1	20	46	63	Quin Oil Co.......	4,079	....	....	Being drilled when visited in May.
2	20	46	63	.....do............	4,140	....	Oil.......	Being drilled when visited in September; four showings of oil within 840 feet of the top.
3	20	46	63	.....do............	4,150	....	...do......	Producing well.
4	20	46	63	Burton & Stowe..	4,199	....	....	Being drilled when visited in May; had reached water sand at 225 feet.
1	21	46	63	Earle Whedon....	4,226	510	Oil.......	400 feet of oil in well.
2	21	46	63	R. B. Pierce......	4,295	....	....	Being drilled; water at 188 feet.
1	22	46	63	....	4,281	....	Oil.......	Oil standing within 7 feet of surface.
2	22	46	63	....	4,257	....	....	Probably dry hole in Mowry shale.
3	22	46	63	Alaska-Wyoming Oil Co.	4,295	414	Oil.......	
4	22	46	63	.....do............	4,325	410	...do......	
1	26	46	63	Warren Wilson...	4,432	....	....	Being drilled; 360 feet deep when visited.
1	27	46	63	Brigs..............	4,252	....	....	Being drilled when visited.
1	28	46	63	Producers & Refiners Oil Co.	4,217	1,000	Oil.......	Showing of oil in Newcastle sand; well drilled to Dakota sandstone and flow of water found before it was abandoned.
1	29	46	63	....	4,135	....	....	Probably dry hole; well has a standard rig but was capped and, apparently abandoned when visited in September.

Wells visited in the Osage field—Continued.

No. on map.	Location.			Owner or driller.	Altitude (feet).	Depth to Newcastle sand (feet).	Showing.	Remarks.
	Sec.	T.	R.					
2	29	46	63	Quin Oil Co.	4,122	1,340	Oil.	
3	29	46	63		4,095			Being drilled when visited in September; standard rig burning gas piped from well No. 3, sec. 32.
1	30	46	63	Glen Oil Co.	4,028		Oil.	Being drilled when visited; oil struck in September.
1	31	46	63		4,031			Being drilled when visited; abandoned later in season.
2	31	46	63		4,042			Standard rig when visited in June.
3	31	46	63		4,026		Oil.	Being drilled in October; probably Producers & Refiners Co.
4	31	46	63		4,042			Being drilled in October.
5	31	46	63		4,058			Alkali water at 80 feet.
6	31	46	63		4,020			Well 300 feet deep struck gas, which flowed for a few days.
1	32	46	63	Oil & Refining Co.	4,064	1,205	Water.	Water and some gas.
2	32	46	63		4,066			Well being drilled at 300 feet when visited in May; said to have oil showing in the Wall Creek (?) sand.
3	32	46	63		4,187		Gas.	Well being drilled in June; about 500 cubic feet of gas in September.
1	35	46	63	Frank Renolds.	4,346			Being drilled; 500 feet deep in June.
2	35	46	63	Niobrara Oil Co.	4,331		Oil.	Being drilled when visited in June.
1	30	46	62				Water.	Artesian well drilled to Dakota sandstone.
1	6	45	62		4,164		Oil.	Being drilled when visited in June; depth reached 450 feet; oil showing in Belle Fourche shale.
2	6	45	62	Fletcher, driller.	4,161			Being drilled in September.
1	1	45	63		4,189			Being drilled; 65 feet deep in June.
1	2	45	63		4,167			Water at depth of 80 feet.
1	4	45	63			1,375	Water.	Salt water struck in Newcastle sand; strong flow of water in Dakota sandstone.
1	5	45	63		4,028			Shallow well, abandoned.