THE DE SOTO-RED RIVER OIL AND GAS FIELD, LOUISIANA.

By G. C. Matson and O. B. Hopkins.

LOCATION.

The De Soto-Red River oil and gas field lies in De Soto and Red River parishes, La., in the northwestern part of the State, in Tps. 12 and 13 N., Rs. 10, 11, 12, and 13 W. Louisiana meridian. It is 30 miles southeast of Shreveport, the principal business and railroad center in the northwestern part of the State, and extends from a point near Naborton in a northeasterly direction across Red River to Crichton, on the line of the Louisiana Railway & Navigation Co. The east end of the field is accessible also over the Natchitoches branch of the Texas & Pacific Railway, which follows the west bank of Red River and crosses the field near Abington. Naborton, the center of development in the western part of the field, may be reached over the Frost-Johnson Lumber Co.'s branch road from Mansfield. In relation to the neighboring productive fields of Louisiana, the De Soto-Red River field is 45 miles slightly east of south of the Caddo oil and gas field, 30 miles south of the Shreveport gas field, and 12 miles north of the small oil pool near Pelican. (See Pl. VII.)

HISTORY.

The development of the Caddo field, which began in 1904, and the drilling of large gushers there some years later called the attention of oil prospectors to northwestern Louisiana as favorable territory. Drilling in and near the area called by Harris[1] the Sabine uplift finally led, in 1912, to the discovery of gas in De Soto Parish near Naborton at a depth of about 800 feet, or about the same depth as the shallow gas wells of the Caddo field. The locations of some of the gas wells were selected by J. Y. Snyder after field observations of the local structure.

The presence of the gas-bearing Nacatoch sand in De Soto Parish and the belief that deeper productive sands corresponding to those

[1] Harris, G. D., Oil and gas in Louisiana: U. S. Geol. Survey Bull. 429, p. 27 (map), 1910.

in Caddo Parish were also present led to deep drilling, which resulted in the discovery of small quantities of oil, and on May 10, 1913, the completion of the Gulf Refining Co.'s Jenkins well No. 2 proved the presence of a notable oil pool. Within a few months all the large oil companies operating in northern Louisiana had become active here, and during the following 12 months the Naborton district experienced its greatest activity.

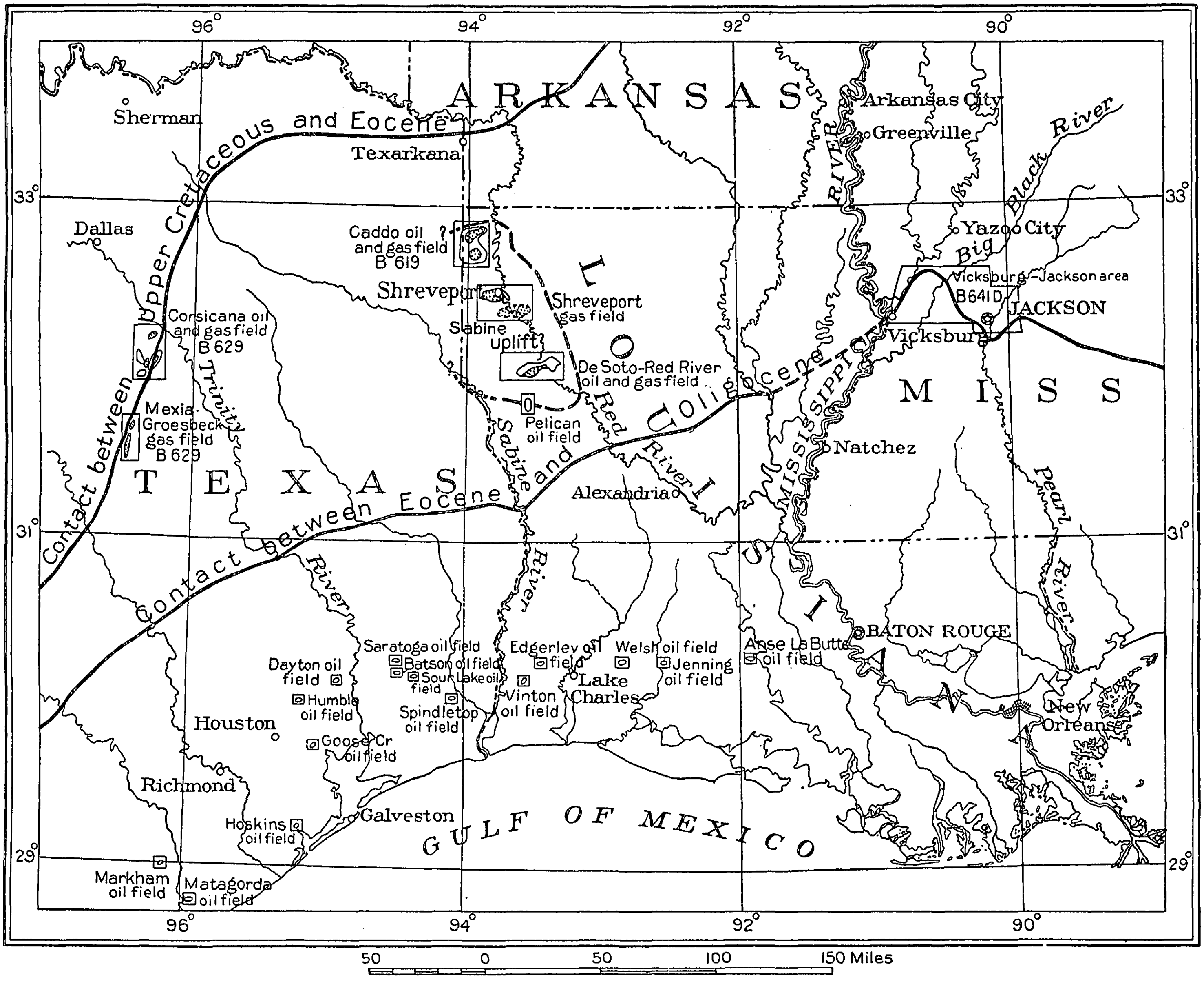
In the Abington district of Red River Parish the discovery well, Marston No. 1, was drilled in April, 1914. By the fall of that year the center of interest had moved from Naborton to the northeastern continuation of the field, where leasing and drilling became active. In November, 1914, the first well was completed in the Crichton district, on the east side of Red River. Interest in this extreme northeast end of the field was brought to a climax by the completion of a large gusher on the Weiss property, in sec. 18, T. 13 N., R. 10 W., on January 27, 1915. The Crichton district was the center of activity during 1915, and in it one of the most productive oil pools in the United States has been developed.

FIELD WORK.

During the spring of 1913, before the discovery well in De Soto Parish had been completed, G. C. Matson made a short trip to this field and outlined the general structural features. With the view of obtaining more detailed knowledge of the structure and of the occurrence and distribution of oil and gas, he returned in the autumn of 1914, and with O. B. Hopkins and E. H. Finch spent part of November and most of December and January making a survey of the district.

In general, the field work consisted in collecting data from exposures of the strata and information concerning development work, such as well logs, altitudes of the wells, and well samples, It was not possible to outline the structure of the entire field from the well logs alone, because they were not uniformly distributed over it; neither was it possible to make a satisfactory structural map of the entire field from the rock exposures, as in more than half of the area no rocks are exposed. Consequently it was necessary to collect all available data from both sources.

Stadia traverses and level lines were carried over the field in order to locate the exposures and determine their altitudes. There are no key rocks exposed at the surface which can be traced over the field and from which the structure can be unraveled; furthermore, it is not possible to trace a particular horizon over any considerable area, as the exposures are too poor and the lithology too varied. Consequently it was necessary in determining the dip to use different beds



INDEX MAP OF A PART OF THE GULF COASTAL PLAIN SHOWING THE LOCATION OF THE PRODUCTIVE OIL FIELDS AND THE LOCATION AND IN PART THE EXTENT OF THE SABINE UPLIFT.

or horizons in different parts of the field, such as the contact between a sand and clay bed, a particular bed of clay, or a sandstone ledge.

ACKNOWLEDGMENTS.

So many citizens of northwestern Louisiana have contributed material for use in this report or have assisted the authors in other ways that it is impossible to mention all of them. Special acknowledgments are due to the officials of the oil companies operating in the field for maps showing locations of wells, lists of altitudes, and logs of wells. The following list, which is far from complete, contains the names of those to whom the authors desire to express special thanks: W. B. Pyron, O. A. Wright, Judge R. E. Brooks, A. G. Curtis, M. B. Carmody, C. D. Keen, William C. Wolfe, S. A. McCune, J. C. McCue, W. C. Ribb, C. C. Averrill, George Beard, S. S. Hunter, W. B. McCormick, R. B. Allison, Sam Mason, McCann & Harper, and J. S. Richardson.

The following geologists and engineers have not only furnished valuable information but also offered suggestions that were useful in the prosecution of the field work: Mowry Bates, E. G. Woodruff, L. C. Chapman, J. Y. Snyder, F. E. Chalk, C. M. Bennett, L. B. Philip, and J. W. Anderson.

The manuscript for this report has been read by E. W. Shaw and G. S. Rogers, geologists of this Survey, and the authors desire to express appreciation for their helpful criticism.

TOPOGRAPHY.

The De Soto-Red River oil and gas field is in what have been called the "hill parishes" of Louisiana. It extends from the hills of De Soto Parish eastward across the broad valley of Bayou Pierre and Red River to the hills in Red River Parish beyond the river. (See Pl. VIII, in pocket.) Approximately half of the field, as outlined, is in the hills to the west of the valley, and the other half is in the broad valley itself. The width of the valley decreases from about 8 miles in the northern part of the area to 5 miles in the southern part. The greater width to the north is due to the greater area covered by old Bayou Pierre Lake, which is now drained.

Topographically the area may be conveniently divided into three parts—the low lands along Bayou Pierre and Red River, the area of comparatively level land between the low lands and the hills, and the hilly region. The first division consists of comparatively recent stream terraces. The lowland on the east side of Red River in the neighborhood of Crichton ranges from 130 to 135 feet in altitude; on the west side of the river near the Marston wells the general altitude is between 150 and 155 feet. Farther west along the margin of old Bayou Pierre Lake the altitude is about 140 feet.

From the low area mentioned above the country rises gradually toward the west to a well-defined plain which has an altitude of 190 to 210 or probably 220 feet along the tributary streams. This plain, though somewhat dissected, is well developed; in the northeast corner of T. 12 N., R. 12 W., east of Naborton; in the southeast corner of T. 13 N., R. 12 W.; and in sec. 32, T. 12 N., R. 11 W., along the Naborton and Seven Forks road south of the Lakeside wells. It is on the surface of this plain that the so-called "gas mounds" are most prominent. Little information about the structure can be gained from a study of this comparatively flat area, for although the underlying strata are exposed over the greater part of it the exposures are poor. Along the eastern edge of the field, however, there is a bluff which separates the low bottom lands from this higher plain, and along it there are some exposures that are useful for determining the structure of the underlying formations.

The highest hills in the field rise a little more than 400 feet above sea level, the range in altitude or relief being therefore little more than 250 feet. In view of this slight relief, the hilly district is particularly rough, especially in the region of the Dolette Hills, in the south-central part of the district. These hills have been carved by small streams, which carry little or no water except in rainy seasons, into V-shaped hollows with steep slopes. The slopes bordering the broad, flat bottoms of the large streams are equally steep. Owing to the thick covering of vegetation and the widespread mantle of sand, the exposures of the underlying strata are not good even on the steep slopes and in the bottoms of the deep ravines.

GEOLOGY.

STRATIGRAPHY.

GENERAL FEATURES.

The alternating beds of sand, shale, limestone, clay, etc., that form the Coastal Plain dip gently seaward but at a greater angle than the general slope of the country; thus the older beds gradually disappear under more recent ones and become progressively more deeply buried toward the coast. As the dip is slight, the outcrops of the various beds, or the formations into which they are divided, are relatively wide, and in any particular locality only a small section of the strata that form the Coastal Plain can be seen at the surface. This is particularly true of the Sabine uplift, an area over which the beds, except for small irregularities, are almost horizontal, so that only one formation is exposed at the surface, with remnants of a thin covering of recent deposits. The De Soto-Red River field, which is on the Sabine uplift, is thus at a considerable distance from the surface outcrops of strata that underlie the field at no great depths. The variations in lithology and thickness of the different formations, both along the outcrops and particularly from the ancient shore line seaward, make the correlation of the formations from well records, where fossils are not available, very difficult and in places impossible. Although it is safe to assume that the older formations which crop out to the northwest and north, in Texas and Arkansas, underlie this field, the beds shown in the well logs of De Soto and Red River parishes can be correlated only tentatively with the strata as studied and divided into formations along the outcrops, and for some well logs even this can not be done, because the information supplied by the logs is not sufficient. Good samples are not easily obtainable where the rotary method of drilling is used, because fragile shells are ground up by the drill and the material from the bottom of the hole is mixed with the material washed from its walls.

In the following table is given a list of the formations into which the strata of the field are divided on the basis of their surface outcrops in Louisiana and adjoining States:

Generalized section of formations supposed to underlie the De Soto-Red River oil field, La.[a]

System.	Series.	Group.	Formation.
Quaternary.	Recent.		
	Pleistocene.		
Tertiary.	Eocene.		Wilcox formation. Midway formation.
Cretaceous.	Gulf (Upper Cretaceous).		Arkadelphia clay. Nacatoch sand. Marlbrook marl.
		Austin.	Annona chalk. Brownstown marl.
			Eagle Ford shale (including Blossom sand member). Woodbine sand.
	Comanche (Lower Cretaceous).	Washita.	Denison formation. Fort Worth limestone. Preston formation.
		Fredericksburg.	Goodland limestone.
			Trinity sand.

[a] The Upper Cretaceous formations do not crop out in the De Soto-Red River field and are known from well logs only. The Lower Cretaceous formations have not been reached in the wells of this field, but the formations enumerated in the table probably underlie the field.

In the De Soto-Red River field only the Wilcox formation and the Pleistocene and Recent deposits are found at the surface; the lower formations down to the Woodbine sand are known from well records only. It is probable that no wells have penetrated the Lower Cretaceous in this field. In the following discussion brief descriptions of the thickness and lithologic character of the different formations at their nearest known localities are given and tentative correlations suggested so far as possible. The Nacatoch sand is the most easily recognizable unit in the logs of the wells of this and adjoining regions. The "chalk," which includes the Marlbrook and Annona and part or all of the Brownstown, is recognizable as a whole over a large area but is inseparable into formations.

CRETACEOUS SYSTEM.

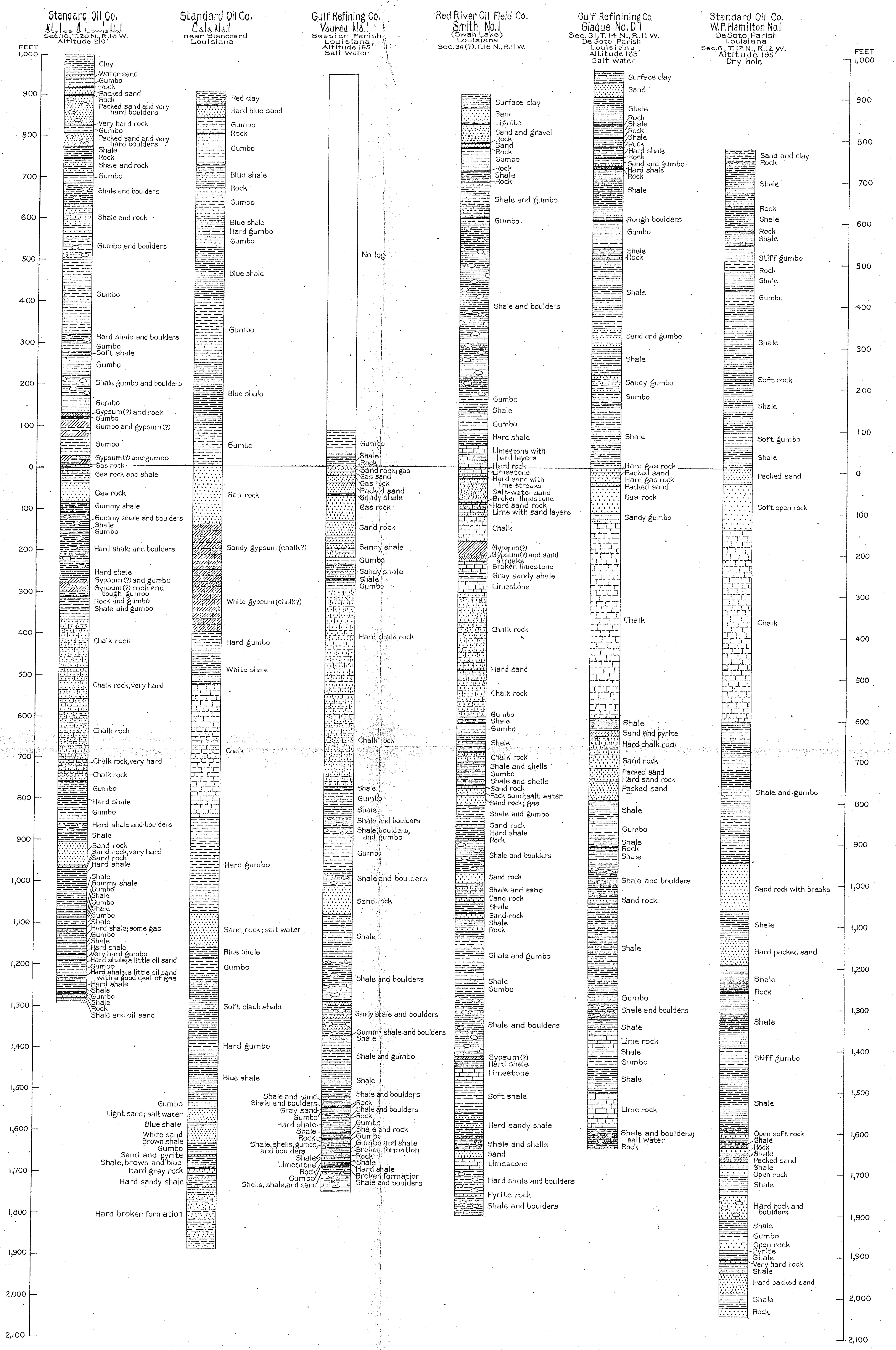
COMANCHE SERIES (LOWER CRETACEOUS).

The presence of beds of Lower Cretaceous age in southern Arkansas and northeastern Texas, together with the fact that they are known to pass beneath the younger formations toward the south, makes it safe to infer that these formations are present in the De Soto-Red River field, though they are so deeply buried there that even the uppermost formation of this age may not have been reached by the oil and gas wells. In the absence of definite information concerning the character of the materials in these beds, it is difficult to tell in advance of drilling their nature and thickness. In southern Arkansas and northeastern Texas the Lower Cretaceous has been divided into the Trinity, Fredericksburg, and Washita groups, named in the order of their age, beginning with the oldest. In that region the Trinity group is represented by sand alone and is known as the Trinity sand, but farther southwest in Texas it includes two sands separated by about 300 feet of limestone.

The Trinity sand was deposited on the older geologic formations after they had been subjected to considerable weathering and erosion, and the materials incorporated in its lower portion were derived from these older formations. It is probable that the lower portion of the Trinity in the De Soto-Red River field, if present there, is similar to the phases exposed in northeastern Texas, which, according to Gordon,[1] consist of quartz sand with scattered pebbles and boulders of quartz, lenses and layers of clay and remains of vegetable matter, together with fossil remains of animals that lived in brackish water.

In southwestern Arkansas the Fredericksburg group is represented by the Goodland limestone, which is 25 feet thick, but in northeastern Texas this group is thicker and contains some shale interbedded with

[1] Gordon, C. H., Geology and underground waters of northeastern Texas: U. S. Geol. Survey Water-Supply Paper 276, p. 14, 1911.



REPRESENTATIVE WELL LOGS ARRANGED ALONG A NORTH-SOUTH LINE FROM THE CADDO TO THE DE SOTO-RED RIVER FIELD, LOUISIANA

ENGRAVED AND PRINTED BY THE U.S. GEOLOGICAL SURVEY

the limestone. Two or three formations consisting of limestones and shales and having a thickness of several hundred feet constitute the Washita group in Texas and Oklahoma.

The total thickness of all the formations belonging to the Lower Cretaceous in the De Soto-Red River oil field is a matter of speculation, but at Dallas, in northeastern Texas, the thickness exceeds 1,300 feet, and the top of the Trinity group, as recognized there, is about 800 feet below the base of the Upper Cretaceous. Estimates of thickness based on published statements of the thickness of the different formations in southwestern Arkansas give the depth of the upper part of the Trinity group below the base of the Upper Cretaceous as scarcely more than half this amount.

GULF SERIES (UPPER CRETACEOUS).

The beds shown in the logs of wells in the De Soto-Red River field (see Pls. IX, X) are not readily separable into formations that can be correlated with those recognized in the well logs of the Caddo field and described from their outcrops in southwestern Arkansas and northeastern Texas. The Upper Cretaceous formations that have been recognized at their surface outcrops[1] in northeastern Texas are the Woodbine sand, Eagle Ford shale (including the Blossom sand member), Brownstown marl, Annona chalk, Marlbrook marl, Nacatoch sand, and Arkadelphia clay. The Nacatoch sand is the only one of these formations that can be recognized in well logs in the De Soto-Red River field, and for this reason exact correlations between the Upper Cretaceous formations of the two regions are impossible.

The Upper Cretaceous section in southwestern Arkansas differs from the one just given, the lower portion, including the Woodbine sand and Eagle Ford shale, with the Blossom sand member, being represented by beds of sand (the Bingen sand) having a total thickness of 500 feet.[2] That portion of the section in De Soto and Red River parishes that lies below the chalk resembles the Bingen sand, though it contains more clay and less sand.

WOODBINE SAND AND EAGLE FORD SHALE.

The lower portions of the sections penetrated in the wells in the De Soto-Red River field consist of shale and clay with many thin beds of sand and sandstone, 950 to 1,150 feet in total thickness. These beds include both the Woodbine sand and the Eagle Ford shale of

---

[1] Matson, G. C., The Caddo oil and gas field, Louisiana and Texas: U. S. Geol. Survey Bull. 619, pp. 17–19, 1916. Harris, G. D., Oil and gas in Louisiana: U. S. Geol. Survey Bull. 429, p. 125, 1910.

[2] Veatch, A. C., Geology and underground water resources of northern Louisiana and southern Arkansas: U. S. Geol. Survey Prof. Paper 46, pp. 23–24, 1906.

the wells in the Caddo field,[1] together with some deeper beds of shales and sands that underlie a bed of hard limestone. It is difficult to obtain samples of this limestone from the drillings, because it is so hard that it is ground to a fine powder. It resembles in character some of the limestone beds in the upper part of the Lower Cretaceous but can not be correlated with them if the fossils that have been obtained from wells in this field came from the deep sands. The information on this subject is summarized in the discussion of the generalized section and the correlation of the sections in the De Soto-Red River and Caddo fields (pp. 113–116).

BROWNSTOWN MARL, ANNONA CHALK, AND MARLBROOK MARL.

From 450 to 650 feet of chalk, containing thin beds of shale, is encountered in the wells in the De Soto-Red River field. This chalk is believed to represent the Brownstown marl, Annona chalk, and Marlbrook marl.[2] In some parts of Red River Parish a bed of shale from a few feet to 100 feet thick occurs between the chalk and the overlying Nacatoch sand, and this shale probably belongs to the Marlbrook marl.

NACATOCH SAND.

The Nacatoch sand is distinct from the calcareous shale and chalk below and the dark-colored shales above it. As a rule its base is more sharply defined than its top, owing to the fact that there are some thin sandy layers in what is supposed to be the base of the Arkadelphia. However, this sand and the chalk below are the most persistent and easy recognizable formations in the field. Of the two the sand can probably be most clearly recognized, for it is a prominent salt water and gas bearing formation.

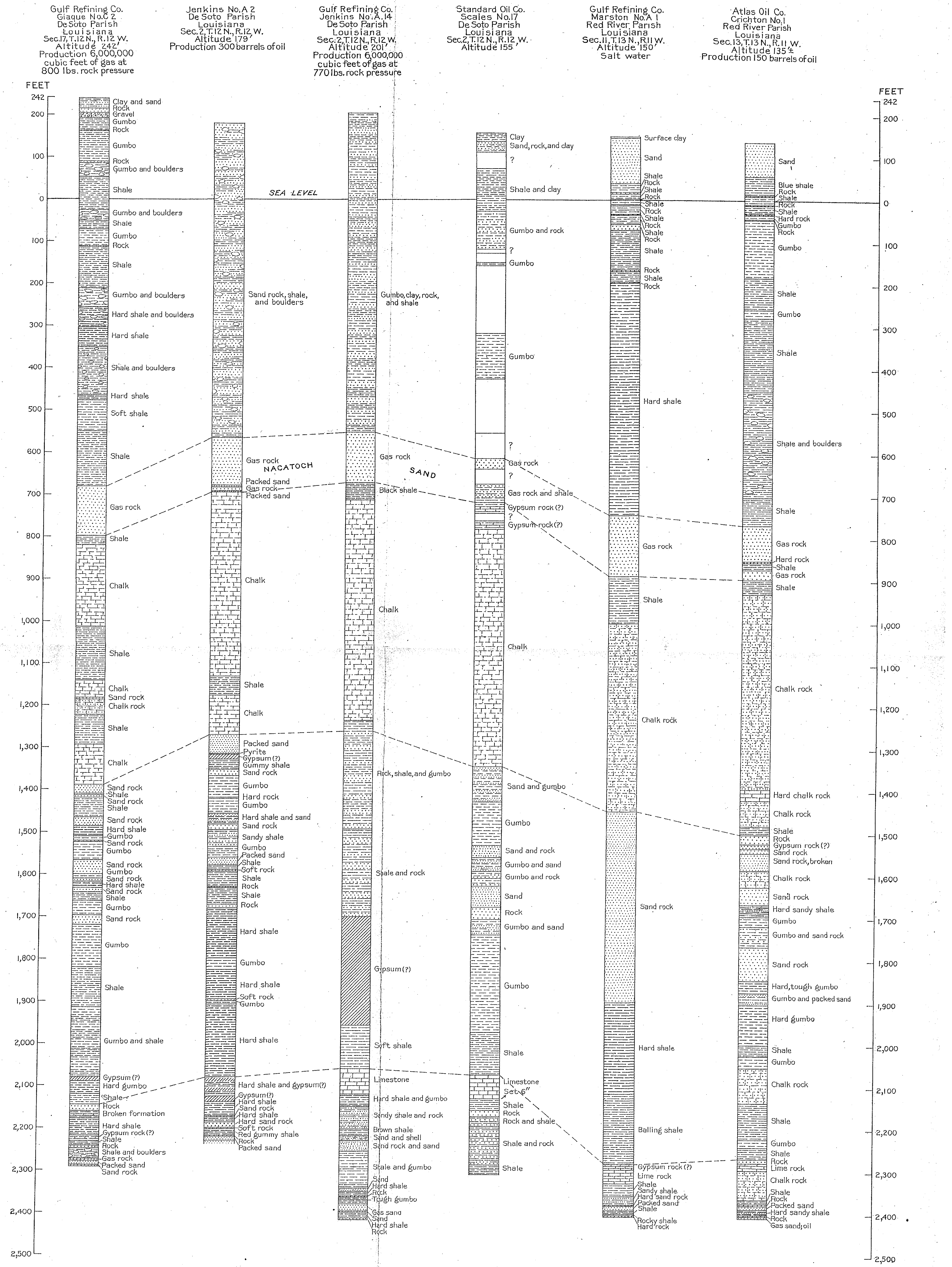
The thickness of the Nacatoch sand, recognized as a lithologic unit, ranges from 50 to 150 feet and averages 125 feet. As described by the driller it consists of "gas rock," which in some logs is divided into a number of units, as in the following section:

Section of Nacatoch sand in a well in De Soto Parish, La.

	Feet.
Gas rock	10
Packed sand	13
Hard gas rock	12
Packed sand	10
Gas rock	65
Sandy gumbo	25

The lowest unit in the above section may not properly belong to the Nacatoch sand, although a part of that formation is sometimes

[1] Matson, G. C., op. cit., pp. 17–19. Harris, G. D., op. cit., p. 125.
[2] Matson, G. C., op. cit., pp: 20–23. Harris, G. D., op. cit., pp. 123–124.



LOGS OF WELLS ARRANGED IN A NORTHEAST-SOUTHWEST DIRECTION ACROSS THE DE SOTO-RED RIVER FIELD, LOUISIANA

ENGRAVED AND PRINTED BY THE U.S. GEOLOGICAL SURVEY described as sandy shale. The recognition of hard and soft layers in the sand is common. There seem to be slight regional differences in the thickness or character of the formation as recorded in the well logs; many of the greatest differences shown are in neighboring wells, and these are attributed to inaccuracies of recording the character and thickness of the beds. The Nacatoch is therefore remarkably persistent and uniform.

This sand is an important gas-bearing formation, as might be inferred from its character as described above and its position between "impervious" beds. In the Caddo field this formation contains heavy oil as well as gas, but in the De Soto-Red River field it has furnished nothing but gas.

ARKADELPHIA CLAY.

Above the Nacatoch sand lie several hundred feet of clay and shale that are described by the well drillers as shale and gumbo. The lower portion of these beds belongs to the Arkadelphia clay,[1] but in the well logs this formation can not be separated from the overlying formation, of Eocene age. A small amount of sand occurs in this formation just above the Nacatoch sand. The Arkadelphia clay forms an impervious cap for the Nacatoch sand and prevents the escape of gas from it.

TERTIARY SYSTEM.

EOCENE SERIES.

MIDWAY FORMATION.

The first definitely recognizable formation in the wells of the De Soto-Red River field is the Nacatoch sand, which is reached at a depth of 700 to 900 or even 1,000 feet, the depth depending on the local structure. In penetrating to this sand the drill passes through part of the Wilcox and all of the Midway and Arkadelphia formations. It is not possible to distinguish these formations in the well records, because of the close similarity of the materials composing them. This is especially true of the Midway and Arkadelphia. In the absence of definite information the approximate base of the Wilcox may be considered to be at the base of sandy beds and layers of sandstone or concretions. On this arbitrary assumption the Midway and Arkadelphia are composed of about 500 to 600 feet of what the driller calls shale and gumbo and in some places boulders. How much of this thickness belongs to the two formations respectively can not be stated.

The Midway formation contains in southern Arkansas, according to Harris,[2] beds of hard light-gray limestone alternating with beds

[1] Matson, G. C., op. cit., pp. 25–26. Harris, G. D., op. cit., p. 122.

[2] Harris, G. D., The Tertiary geology of southern Arkansas: Arkansas Geol. Survey Ann. Rept. for 1892, vol. 2, pp. 8, 22–35.

of light-yellow sand. Deussen[1] describes this formation in Texas as composed of a series of clays and limestones of marine origin containing in the lower part micaceous clays and clayey sands and having a thickness of 250 to 500 feet. In the Caddo field[2] the Midway is known from well logs to consist predominantly of clay, thin layers of glauconite and sand, and thin beds of rock which are probably in part sandstone and in part limestone, with a total thickness of 200 to 300 feet. To judge from the logs of the wells in the De Soto-Red River field the Midway in this field is composed of clay with thin layers of limestone.

WILCOX FORMATION.

The Wilcox formation underlies the entire field and is exposed in more or less weathered form over more than half of it. In general the formation crops out in the hilly area and is concealed in the lowlands along the main streams and their tributaries. It is composed of alternating beds of lignitic sands and clays, together with ferruginous sandstone, calcareous sandstone concretions, and lignite. As exposed in this district the formation may be divided into two members—a clayey member below and a sandy member above.

The lower member consists largely of clay interbedded with thin lenticular layers of sand. In a fresh condition it consists of gray sandy laminated clay containing more or less comminuted plant remains and bluish-gray or drab hackly clay. On weathering the sand does not appear to be so abundant, and the material develops into a deep-red plastic clay, as exposed in and around Naborton. It contains calcareous concretions, and in its upper part ferruginous sandstone layers with plant impressions.

The sandy member is well exposed near Shreveport. It is composed of extensive lenticular beds of sand and subordinate beds of clay. Lignite, ferruginous sandstone and limonite pebbles are very abundant, and in some places clay pebbles and clay boulders. Ferruginous sandstone with leaf and other plant impressions is more plentiful in the lower part than in the upper part of this member. Limonite pebbles are also more numerous in the lower part, the iron being derived from the leaching of the ferruginous sands. These pebbles are formed most abundantly at the base of a sand bed that overlies clay, which prevents the downward circulation of the water. Silicified wood is common in both members, especially in the upper part of the clayey member and the lower part of the sandy member.

The general character of the Wilcox formation is shown in the following composite section:

[1] Deussen, Alexander, Geology and underground waters of the southeastern part of the Texas Coastal Plain: U. S. Geol. Survey Water-Supply Paper 335, p. 31, 1914.

[2] Matson, G. C., op. cit., p. 26.

Composite section of Wilcox formation near Naborton, De Soto Parish, La.

	Feet.
Section 1 mile southwest of Zion Hill.	
Sand, of medium grain, orange-colored or yellow to gray	22
Sand, of medium grain, pure, orange-colored	17
Sand, same as below, with small pebbles of light-gray shale	13
Sand, of medium grain, pure, orange-colored to yellow	5
Lignite and bone	1
Sand	10
Clay, red	2
Sand	5
Shale, gray, arenaceous, weathering to red clay	7
Sandstone, concretionary; forms prominent, hard layers	1
Arenaceous shale or laminated sandy clay; weathers to deep-red fine sandy sticky clay	20
Concretionary layer, calcareous, sandy	1
Shale, arenaceous, grading upward into clay, carbonaceous clay, and laminated sandy clay, containing fossil leaves on top	24
Section 1 mile southeast of Naborton.	
Sandstone, hard, ferruginous, with fossil leaves; two collections, obtained in the SW. ¼ sec. 14	1
Clay, stiff, red, granular	25
Lignite and carbonaceous shale	2
Shales, arenaceous, weathering to red clay	10
Shales, gray, arenaceous, some with carbonaceous layers in lower part	13
Sand, yellow, hard, of medium grain	8
Sandstone, hard, ferruginous	2
Arenaceous shale or laminated gray sandy clay, with large concretions; carbonaceous in lower part	15
Shale	2
Sandstone, hard, ferruginous	2½
Sandstone, soft, grading into arenaceous shale below	9½
Shale, dark gray, with sandy layers	6
Shale, gray, arenaceous	2
Sandstone and shale; ferruginous pebbles and concretions	5
Sandstone, yellow, of medium grain, soft	3
Shale, gray, sandy, fine grained	6
From the log of a well near Naborton.	
Gumbo	15
Rock	3
Sand and boulders	4
Gumbo	7
Shale and rocks	123
Shale, gumbo, and rock	259
Gumbo and boulders	45
Base of Wilcox formation (?).	
	696

The lenticular character of the different beds of this formation may be recognized from a comparison of the logs of neighboring wells. Although there is always a close similarity in the nature of the materials found, the several beds do not show the same intervals or the same arrangement in wells only a fraction of a mile apart; sandstones and coal beds in one well can not be correlated definitely with similar beds in another.

The thickness of the Wilcox formation as penetrated by the drill in this field ranges from 300 to 500 feet, depending on the local structure, but farther south the thickness may amount to 800 or 1,000 feet. The formation is of no commercial importance in this district, and, although it contains a small amount of gas farther south, attempts to develop the gas have been unsuccessful. In this field the lower part of the Wilcox contains no thick beds of sand, and it is unlikely that either oil or gas will be obtained from it in commercial quantities.

QUATERNARY SYSTEM.

The early part of the Pleistocene time was a period of erosion, during which the major topographic features of the present day were beginning to form.[1] This period of erosion culminated when the general altitude of the region was probably slightly lower than it is now and the stream bottoms were relatively shallower. A gradual subsidence in later Pleistocene time made the streams more sluggish and therefore incapable of carrying as great a load as formerly; for this reason they began to fill the valleys and to build up the bottom lands. This condition continued until broad flood plains were formed on the large streams at altitudes of 190 to 210 feet. The relative position of the land and sea appears to have remained stationary for a considerable length of time, for this plain was extensively developed as a broad terrace covered by a thin veneer of fine sands and clay. In this particular area over part of this plain the Wilcox occurs at the surface with little or no covering of terrace deposits.

Late Quaternary or Recent time has been a period of erosion in this area; the streams have been sinking their beds into the plain previously formed. The overloading of the streams with silt and the formation of rafts which blocked the courses of the streams complicated their history; lakes, cut-offs, and minor terraces were thus formed, and these conditions have existed until the present time.

GENERALIZED SECTION.

Plates IX and X show the succession of strata as they are encountered in the wells of this field and are described by the driller. It will be noticed that there is a marked similarity, notwithstanding

[1] Veatch, A. C., Geology and underground water resources of northern Louisiana and southern Arkansas: U. S. Geol. Survey Prof. Paper 46, pp. 46–55, 1906.

some more or less important differences, in these various well records. The greatest differences are probably due to errors in keeping the records and to misuse of the descriptive terms; thus the limestone of one driller may be the sandstone of another.

Between the surface and the top of the gas sand there are from 725 to 975 feet of strata, the thickness depending on the altitude of the surface and the local structure; the average is slightly more than 800 feet. Of this material the upper 300 feet is commonly described as shale, sand, and gumbo, and the lower 500 feet as shale and gumbo with a little sand. The gas sand has a thickness of 50 to 150 feet, averaging 124. The thickness of the chalk ranges according to different records from 450 to 650 feet and averages 565 feet. It is encountered at an average depth of about 940 feet. Between the base of the chalk and the oil sand there are about 970 feet of strata. Of this material the upper 400 feet is composed largely of sand with smaller quantities of gumbo and shale; the lower 570 feet is composed of shale, gumbo, and limestone, with minor amounts of sand, except near the bottom. Between the oil sand and the deep gas sand there are 150 to 200 feet of shale, gumbo, and sand.

Contours on the top of the gas sand or the top of the chalk make the oil sand appear about 25 feet lower in the Red River district than in the De Soto district, and thus either the thickness of the interval between the oil sand and the top of the gas sand or the chalk is 25 feet less in the east end of the field, or else the oil sand occurs there 25 feet higher stratigraphically. As this change appears to be gradual from the western to the eastern part of the field it is attributed to a slight thinning of the strata in that direction.

COMPARISON OF DE SOTO-RED RIVER AND CADDO SECTIONS.

The well logs shown on Plates IX and X are arranged in their geographic position and represent the strata encountered in a series of borings extending from the Caddo field to the De Soto-Red River field. The upper part of the section down to the base of the gas sand is very similar throughout this area, but below that horizon there are some marked differences.

In the Caddo field about 250 feet of shale and gumbo with some chalky layers immediately underlie the Nacatoch sand and overlie the thick chalk beds. To the south the sequence is somewhat different, and in De Soto Parish the sand rests in general directly upon the chalk or is separated from it by not more than 50 feet of shale, which increases in thickness to about 100 feet in Red River Parish. The thickness of the material described as chalk by the driller is much greater in the De Soto-Red River field, and in four places out of five the chalk rests directly on sand; in the Caddo field, however, 150 to 200 feet of gumbo and shale intervene between the chalk and the sand. On the assumption that these sands, including the Blossom sand member in the Caddo field, are of the same age, the relation of the strata in the two fields appears to be normal, for the more southern field is farther away from the source of the sediments and would be expected to contain deposits formed in clearer water, such as limestone and chalk.

Whether this correlation is correct or whether the shale and gumbo above the Blossom sand in the Caddo field are the equivalent of part of the sands and shales in the De Soto-Red River field can not be definitely stated. In either case this portion of the section is more sandy in the southern field, and part of the 400 feet of dominantly sandy deposits here must represent the well-defined Blossom sand of the northern field, which has a thickness of 50 to 200 feet.

The thickness of the strata between the Nacatoch gas sand and the oil sand is 300 to 350 feet greater in this field than in the Caddo field, and the difference is explained by the increased thickness of sand mentioned above, the greater thickness of shale, and the presence of one or two moderately thick limestone beds. This difference in interval between the sands in the two fields suggests that they may not represent the same stratigraphic horizon and that the deep oil sand in the Caddo field may be higher and geologically younger than the deep oil sand and deep gas sand of the De Soto-Red River field. Most of the deep wells show a limestone bed ranging in thickness from 20 to over 100 feet that is stratigraphically below the oil sand in the Caddo field and above the oil and deep gas sands in the De Soto-Red River field. Some of the logs of the wells that lie between the two fields have been examined to determine whether they show this limestone. Few of the wells in the Caddo field reach the limestone, because most of them are finished at the oil sand, which lies 100 feet or more above it. But some of the wells drilled on the outskirts of the field that failed to obtain oil in the deep sand were continued to greater depths and encountered the limestone. Among these are Peak No. 1, in sec. 23, T. 22 N., R. 15 W.; the Douglass & Glassell No. 1, in sec. 30, T. 20 N., R. 14 W.; and the well of the Clover Leaf Oil Co., on the north side of Caddo Lake, about 1 mile west of the boundary between Louisiana and Texas. Among the wells between the two fields that encountered the limestone are the Allen No. 1, in sec. 11, T. 18 N., R. 11 W.; Page No. 1, in sec. 25, T. 18 N., R. 16 W.; Scott No. 1, in sec. 11, T. 18 N., R. 13 W.; McCutcheon No. 1, in sec. 3, T. 17 N., R. 14 W.: Youree No. 2, in sec. 18, T. 17 N., R. 13 W.; Cooper No. 2, in sec. 14, T. 17 N., R. 14 W.; and the well at Grand Cane, near the middle of T. 13 N., R. 14 W. This limestone is recorded in most of the logs of wells that have been drilled in the De Soto-Red River field, and although it is not recorded in the others or in some of the logs of the wells in the area between this field and the Caddo field, its apparent absence may be due to the fact that it has been described by other terms. Most of the logs that show no limestone record shale and boulders at the horizon where the limestone should be found, and the mistake would be very natural, because the limestone is hard and is usually ground to a very fine powder that may appear dark when mixed with the mud-laden fluid used in drilling.

Through the kindness of Mr. William C. Ribb, of the Producers Oil Co., the Geological Survey was supplied with some collections of fossils that came from the deep oil and gas sands in the De Soto-Red River field. These specimens were submitted to L. W. Stephenson, of the Survey, who reports as follows:

Producers Oil Co. Sample C 10, depth 2,430 feet:

Corbula aff. C. carolinensis Conrad.

A gastropod (not identifiable).

This type of Corbula ranges throughout the zone of *Exogyra ponderosa* Roemer in the Chattahoochee region. In terms of the section in the vicinity of Austin, Tex., the age would be that of the Austin chalk or of the Taylor marl. In terms of the section in northeastern Texas and southwestern Arkansas it probably corresponds in age to some part of the Brownstown marl or of the Annona chalk. It is probably older than the Marlbrook marl, with the possible exception of its basal beds.

Producers Oil Co. Sample C 14, depth 2,870 feet:

Ostrea lugubris Conrad.

Volutoderma sp. (probably a new species).

Prionotropis hyatti Stanton?

Prionotropis sp.

Callianassa sp. (a crayfish, identified by Miss M. J. Rathbun).

Mr. Stanton has assisted me in identifying and correlating this lot. *Prionotropis hyatti* Stanton was found by him in the upper part of the Benton (*Pugnellus* sandstone) of the western interior. Young specimens belonging to this genus occur in the Eagle Ford shale in northeastern Texas. The *Volutoderma* is similar to though not identical with any one of the species of this genus found associated with *Prionotropis hyatti* Stanton in the western interior. *Ostrea lugubris* Conrad is a characteristic species of the upper part of the Eagle Ford shale of northeastern Texas and occurs also in association with *Prionotropis hyatti* Stanton and with the species of *Volutoderma* in the western interior.

We regard this lot as indicating a stratigraphic position corresponding to the upper part of the Eagle Ford formation of Texas and to the upper part of the Benton formation of the western interior.

Mr. Stephenson has also examined a specimen from the Producers Oil Co.'s Wemple "B" 1 well, in sec. 22, T. 12 N., R. 11 W., from a depth below 2,626 feet.

Prionocyclus sp. (probably an undescribed species). The genus has been reported only from the Colorado group of the western interior. At localities where the stratigraphic position is definitely known it is below the Niobrara limestone. The evidence indicates that, in terms of the Gulf Cretaceous nomenclature, the specimen came from either the Austin chalk or the Eagle Ford shale, and I am inclined to the opinion that it is from the latter.

These fossils furnish satisfactory evidence, provided there is no mistake as to the depths from which they came, that the oil sand and the deep gas sand in the De Soto-Red River field are of Eagle Ford age, and from the evidence that is summarized on page 114 it is apparent that these sands are stratigraphically lower than the deep oil sand of the Caddo field. Hence, if they are of Eagle Ford age, the sand of the Caddo field must be at least as young as the Eagle Ford.

STRUCTURE.

CONTOUR MAP.

Most sedimentary rocks, such as sandstone, shale, and limestone, are deposited from water in approximately horizontal, parallel beds. Such beds or strata may remain in that position or they may be bent and broken. Bending produces folds, and breaking and slipping of the strata produce faults. The upward folds are known as anticlines and the downward folds as synclines. The economic importance of folds is due to the fact that oil and gas are commonly associated with anticlines. The attitude or position of the rock beds with reference to a horizontal plane is called structure.

Structure may be represented diagrammatically, the arrangement and inclination, or dip, of the strata being shown along a particular line; or by contour lines, as on Plate VIII (in pocket), where the shape and areal extent of the folds are represented by lines that connect points of equal altitude on one particular bed, called the key rock. The mode of interpreting a structure-contour map may be best understood by a consideration of the method by which it may be prepared.

It is necessary to select as a key rock some bed that can be recognized over the area to be mapped. In the preparation of the accompanying map the top of the shallow gas sand (Nacatoch sand) was selected. The depth of the top of the gas sand was determined from the logs of the wells. The altitude of the wells above sea level was determined from level lines run to the wells, and by subtracting the altitude of the well from the depth to the top of the gas sand, the depth of this key rock below sea level was determined for each well. With these data it was possible to draw contour lines connecting points where the oil sand has approximately the same depth below sea level. As these lines represent depths below sea level the direction from one contour line to the adjacent one marked with a larger number indicates the direction of the dip; the rate of dip is greatest in the area for which the contour lines are closest together and least in the area for which they are farthest apart. The beds dip in opposite directions away from the crest or axis of an anticline and toward the axis of a syncline. By representing the direction and rate of dip the contour lines outline the shape and areal extent of anticlines and synclines.

If the beds above the gas sand were removed and its surface exposed to view, the anticlines or upward folds would represent hills and the synclines or downward folds would represent valleys. In following the path indicated by one of these contour lines around a hill or a valley the traveler would remain always at the same altitude.

One of the commonest mistakes, however, is to assume that the upfolds and downfolds of the formations underground are the same as the hills and valleys of the surface. Round hills, for example, are often mistaken for domes, and ridges are often thought to be long anticlines. Because of mistakes of this character, it should be borne in mind that the visible hills and valleys may bear no relation to the structure of the formations beneath the surface; in fact, the relation may be exactly the reverse of what might naturally be expected, the anticlines lying beneath valleys instead of beneath hills.

GENERAL STRUCTURE.

The De Soto-Red River oil field is on the southern part of the Sabine uplift, which is outlined in part on the diagram (Pl. VII) by a line indicating the area over which the top of the Nacatoch sand is less than 1,000 feet below sea level. The contour lines on Plate VIII (in pocket) show the minor structural features in as great detail as was possible with the information available from well logs and examination of surface exposures. These lines represent the top of the Nacatoch sand (gas sand), and the figures accompanying them show the depth of the surface of this sand below sea level.

The folds as represented by these contour lines are very irregular in shape, but probably a great part of this irregularity is due to lack of sufficient information to represent the details of structure. The height of the principal folds is comparable with that of the highest part of the folds in the Caddo field.[1] The highest part of the Nacatoch sand in the Caddo field east of Mooringsport is, as shown by the contour lines, 550 feet below sea level, and the highest part of the folds in the De Soto-Red River field, as shown by contour lines on the same formation, is 525 feet below sea level.

The mapping of the structure on Plate VIII is not as detailed as that shown on the contour map of the Caddo field, because the wells in this field are fewer and not as evenly distributed over the area, and therefore there is less information to supply details of the structural features. Probably if sufficient data could be ob-

[1] Matson, G. C., op. cit., pl. 7.

tained more subordinate anticlines and synclines could be shown. The structural features as represented include a broad, irregular, dome-shaped fold—the Naborton dome—showing well-defined general dips away from its highest part. North of this dome-shaped area is a more definite anticlinal fold—the Smithport anticline—that follows the general direction of the Smithport road southwestward from a point near Bayou Pierre Lake. The northern and western margins of the central dome are made irregular by a number of small anticlines that project from it. South of the central area is the Bice anticline, but the amount of information available does not permit accurate contouring of this fold. Northeast of the central area, in Red River Parish, there are low anticlines and a broad structural terrace called the Crichton terrace. The most productive anticline in this part of the field is the Gusher Bend anticline. The structural terrace has not been contoured along its southern extension and is represented as terminating against a fault that extends from the south-central part of the field eastward to a small oil pool in the hilly region east of Red River.

The depth of the Nacatoch sand below sea level ranges from 525 feet on the crest of the Naborton dome to 875 feet in the lowest area contoured. The rate of dip in the different parts of the field varies widely, from a few feet to 200 feet or more to the mile.

FORM AND AGE OF FOLDS.

In considering the folds in the Caddo oil field[1] it was noted that there had been folding in two different directions, one set of folds extending in a northeasterly direction and another, consisting of a broad axial fold with minor folds parallel to it, in a northwesterly direction, at nearly right angles to the northeasterly folds. These sets of folds are probably represented in a general way on the entire surface of the Sabine uplift, though their shapes and sizes, as well as their altitudes, are variable. The northwesterly arch that forms the axis of the Sabine uplift probably extends in a more or less direct course southward beyond the De Soto-Red River field. Its extension toward the northwest has not been traced, and its course may not be as straight in that direction as farther south, though it probably connects with the axis in the Caddo field. From this axis the minor folds that cross it pitch both to the northeast and southwest. That these two sets of folds were produced by pressure exerted approximately parallel to the bedding is inferred from the fact that where the folds can be examined at the surface they consist of a series of parallel anticlines and synclines such as would be formed if the beds were subjected to lateral pressure. The forma-

[1] Matson, G. C., op. cit., pp. 35–37.

tion of the two sets of folds was not simultaneous, as is well illustrated in the Caddo field, in which the northeasterly folds are bent where they are crossed by the northwesterly folds. Apparently the northeasterly folds are the older, and were distorted by the later folding. The exact time of folding can not be determined from the study of one small area. Both sets of folds affected beds of Wilcox age in the De Soto-Red River field, and must, therefore, have been formed in post-Wilcox time; the general folding that produced the Sabine uplift involved the youngest Eocene beds farther south, and it is therefore safe to conclude that the folding is, in part at least, post-Eocene.

In preparing the structural map of the De Soto-Red River field it was found that the axes of folds drawn by means of different formations as key rocks did not coincide, and this characteristic is also shown on the structural map of the Caddo field. It is suggested that the folding began during the deposition of the Upper Cretaceous formations, and that this may account for a certain erratic lack of parallelism of the formations in the Upper Cretaceous and also for some differences in position of the axes of folds contoured on different formations, though some of these differences may be explained in other ways.

LOCAL STRUCTURAL FEATURES.

NABORTON DOME.

The broad, flat-topped dome that lies south of the town of Naborton is elongated in a northeasterly direction, its major axis extending across the major axis of the Sabine uplift. The highest part is in secs. 5 and 7, T. 12 N., R. 11 W. There is a gentle dip away from this apex which increases gradually and becomes much steeper at distances of a few miles. The northern flank of the Naborton dome is crossed by a shallow syncline that separates the apex from the oil-producing areas near Naborton, and the western margin is made irregular by a number of small pitching anticlines and synclines. The eastern margin is much more regular than the western and extends down to the area where the dip is low, west of the oil pools in Red River Parish. The south edge of the Naborton dome is formed by the Gusher Bend fault, which carries all the formations abruptly downward toward the south.

SMITHPORT ANTICLINE.

A long, narrow anticline that extends from a point near the Sample wells of the Producers Oil Co., at the west edge of Bayou Pierre Lake, southwestward across secs. 22, 28, and 32, T. 13 N., R. 12 W., is here called the Smithport anticline. This fold is much lower than the Naborton dome, and from the meager information available it apparently has gentle dips except near the east end, where it plunges steeply toward the northeast. It is separated from the Naborton dome by a shallow syncline that deepens both toward the northeast and the southwest, the higher part being along the line of the major axis of the Sabine uplift.

BICE ANTICLINE.

Some distance south of the Naborton dome, in secs. 4, 5, and 6, T. 11 N., R. 11 W., and secs. 34, T. 12 N., R. 11 W., there is a long, narrow fold called the Bice anticline. The detailed information about this anticline is scanty, but it is apparently low, having much gentler dips than the higher folds to the north. Its axis is curved, possibly as a result of the same forces that produced the Gusher Bend fault.

CRICHTON TERRACE.

The Crichton terrace, in secs. 19, 20, and 30, T. 13 N., R. 10 W., occupies an area where the dip of the formations is very low, and although the structure immediately east of it could not be contoured, the arrangement of the surface formations indicates that the dip increases toward the northeast. It is also possible that this terrace is separated by a broad, shallow syncline from the area of higher folding southwest of it, but there is no information concerning this area aside from that supplied by a few scattered dry holes, and these data are not sufficient to show the details of the structure. The Crichton terrace is crossed by a number of shallow synclines and anticlines that pitch toward the northeast.

GUSHER BEND ANTICLINE.

Associated with the Crichton terrace is a low, broad anticline that trends slightly east of north. This anticline is in secs. 24, 25, and 36, T. 13 N., R. 11 W., at the bend of the river where large yields were obtained in many wells, and is called the Gusher Bend anticline.

GUSHER BEND FAULT.

The southern margin of the Crichton terrace and the Gusher Bend anticline, as outlined on the map, is formed by the Gusher Bend fault, a break in the strata which near Red River has carried the formations downward on the south side of the fault between 200 and 225 feet below their position on the north side. This fault is marked on the eastern wall of the Red River valley by a nearly vertical contact between the clays in the lower part of the Wilcox formation and the sands forming the upper part of the Wilcox. The best information concerning the amount of movement along this fault plane was obtained on the Armistead lease of the Gulf Refining Co., where it was from 200 to 225 feet, and the amount of movement is supposed to diminish westward to the point where the fault terminates. Toward the east this fault may extend to a small pool that has been developed on the property of the Globe Lumber Co. and beyond.

OTHER FAULTS.

No attempt has been made to locate all the small faults in the De Soto-Red River field, though it is believed that there are several minor ones that extend in the same general direction as the Gusher Bend fault. Probably none of these faults are of very great magnitude, and their effect on production is likely to be local. Among the places where such faults have been suspected is a locality on the Christine lease of the Producers Oil Co., where a producing well was obtained in the chalk rock, and another on the lease of the Wilson-Broach Oil Co. in the Naborton pool, where a showing of oil was obtained in the chalk.

OIL AND GAS.

OIL AND GAS BEARING FORMATIONS.

GEOLOGIC POSITION.

The producing oil and gas bearing sands of northwest Louisiana are found in the Gulf series or Upper Cretaceous, which includes in this region the following formations, arranged in order of superposition:

Formations of Gulf series (Upper Cretaceous) in De Soto River oil and gas field, La.

Formation.	Character.	Oil or gas.	Range in depth.
Arkadelphia clay.	Stiff, gummy clay, with some sandy layers in lower part.		
Nacatoch sand.	Sand, with some layers of clay and hard sandstone.	Prominent gas sand.	Top at 725–975 feet.
Marlbrook marl.	Shale or marl above; white chalk below.	Some oil, supposedly derived from lower formations through faults.	Top at 850–1,050 feet.
Annona chalk.	Chalk.		
Brownstown marl.	Probably marl and chalk above; shale and sandy shale, with some sand, below.		Showings of oil and gas below base of chalk.
Eagle Ford shale.	Shales, sands, and probably limestone beds.	Principal oil sand of field; also deep gas sand.[a]	Oil sand at 2,450–2,550 feet; deep gas sand at 2,650–2,750 feet.
Woodbine sand.	Not definitely recognized in this field.		

[a] Exact correlation uncertain; may be older than indicated. (See pp. 115–116.)

All the sands of these formations appear to be saturated and usually yield a flow of salt water where oil and gas are absent.

NACATOCH SAND.

Because of its porous character over wide areas, the Nacatoch sand is particularly suitable as a reservoir for the collection of oil and gas and for their accumulation in areas of favorable structure. It is composed of 50 to 150 feet of sand of variable porosity, with a number of irregular indurated layers. This sand is the shallowest productive formation in the field and occurs at a depth of 725 to 975 feet, the depth depending on local structure and the altitude of the surface. It has been tested at a number of widely separated places in the field and has yielded, so far, large quantities of gas but little or no oil. The wells in this sand have capacities reaching 15,000,000 cubic feet of gas a day and rock pressures of 300 to 350 pounds to the square inch.

CHALK.

Oil is found sporadically in the chalk, and at least one well has been finished in it. The oil may occur in a porous layer of chalk or sand, but it is much more probably contained in cracks and crevices, having migrated upward along a fault plane.

OIL SAND.

The principal oil-bearing formation of this field is approximately 1,660 feet below the top of the Nacatoch sand, and, as stated on pages 115–116, its exact age is not known. The productive sands are found below one or more beds of limestone which seem to be persistent but which are variously described as limestone, chalk, shale, boulders, etc. The sands are relatively thin and lenticular and are interbedded with shale and some hard layers. They do not occur at a very definite horizon but extend through an interval of 50 or 100 feet. The greater variability in the character of these sands, as compared with that of the Nacatoch sand, makes them less regular in production, especially in De Soto Parish. In Red River Parish the sand appears to be more persistent and consequently more uniformly productive.

Over the greater part of the productive area wells drilled in this sand have a strong initial flow ranging from less than 100 to 6,000 or 8,000 barrels in 24 hours. Wells producing 1,000 barrels or more are common, especially in the east end of the field. (See figs. 19, 20.) The wells decline gradually as the pressure is relieved and finally cease to flow; they are then pumped until exhausted.

These sands are also a minor source of gas, and some wells of good volume and pressure have been completed in them. The wells have a maximum volume of 15,000,000 cubic feet and rock pressures of 700 to 1,000 pounds to the square inch.

DEEP GAS SAND.

Between the oil-bearing sands just described and the deep gas sand there is an interval of 150 to 200 feet, which is occupied by shale, hard layers of sandstone or shaly limestone, and thin beds of sand. The amount of sand increases in the lower part. The gas in the deep sand occurs in well-defined beds of considerable thickness, which are probably of greater persistence than the higher sands, because these lower beds are more uniformly productive. Some wells that are unproductive in the oil sand have been developed as "gassers" of considerable volume in this deep sand.

The capacity of the wells in the deep gas sand reaches 35,000,000 cubic feet or more, and the rock pressure ranges from 1,000 to more 1,200 pounds to the square inch.

ORIGIN.

A discussion of the theories that have been advanced to explain the formation of oil and gas is beyond the scope of this paper. In seeking for a source for these materials in the De Soto-Red River field it was found that the shales associated with the sands and in some places the sands themselves contain considerable organic matter which was apparently derived chiefly from vegetation, and it is believed that the oil and gas were formed from this organic matter by slow chemical changes, which may have been facilitated by moderately high temperature and the pressure caused by the load of sediments that overlie them, and by the thrusts to which they have been subjected. The gas from the Nacatoch sand is chiefly methane, and is almost identical in composition with some of the gas formed from decaying vegetable matter in present-day swamps where there is enough water to exclude the air from the decomposing vegetation.

The gas in the deeper sands has a different composition, but this may be explained by the fact that it was probably formed at greater depths, where the temperature was higher and the pressure greater. The theory that oil and the higher hydrocarbons in the deep gases may have been derived from bituminous shales is supported by results of recent examination of oil shales in the Western States.[1] There is no doubt that clays and shales similar to these oil shales have a comparatively wide distribution, because oil can be distilled from

[1] Woodruff, E. G., and Day, D. T., Oil shale of northwestern Colorado and northeastern Utah: U. S. Geol. Survey Bull. 581, pp. 1–21, 1915. Winchester, D. E., Oil shale in northwestern Colorado and adjacent areas: U. S. Geol. Survey Bull. 641, pp. 139–198, 1916 (Bull. 641–F).

most carbonaceous shales. Although the temperatures used in distilling the oil shales are higher than temperatures ordinarily found at the depths of the oil and gas sands, the distillation might be accomplished during long periods of time at lower temperatures.

RELATION TO STRUCTURE.

GENERAL RELATIONS.

The early investigations in oil fields revealed the fact that the occurrence of oil and gas is related to the structure of the oil sands and associated formations. In some of the older fields the relations to structure were very clear, the oil and gas having accumulated in anticlines, in which gas occupied the higher parts of the folds and beneath that in regular succession came oil and salt water. In some places where the gas was absent the oil occupied the top of the fold. It was noted that these substances were arranged in the anticlines in the order of their specific gravity, the lightest substance, gas, being at the top, and the heaviest, salt water, being the lowest. It was supposed that these substances had originally been mixed and that they had separated and taken up their relative positions under the influence of gravity. This explanation was satisfactory for a great many oil and gas fields and for a long time it remained unmodified.

The condition of the water, whether stationary (hydrostatic) or moving (hydraulic), was not discussed in presenting the earlier explanations of the relation of oil and gas to structure. The important points were that these substances had originally been mixed with the salt water and had been separated out. Later investigations threw some doubt on the adequacy of the anticlinal hypothesis of separation under the influence of specific gravity alone and experiments[1] were undertaken to determine whether such separation would take place. In investigations lasting several months oil did not rise through sands saturated with salt water, and although the period covered by the investigators was short the results suggested the inadequacy of the older hypothesis. A newer and modified form of this hypothesis is that the separation took place while the fluids were circulating through the porous beds, the accumulation being facilitated by the movement of these fluids and the arrangement being determined by the gravity of the substances. It might be urged against this explanation that there is probably very little circulation of water in deeply buried sands and that the character of the water associated with the oil and gas indicates that no great amount of circulation has taken place. However, it is probable that there are very few sands in which there is no movement of water and it is not

[1] Munn, M. J., Reconnaissance of the Grandfield district, Okla.: U. S. Geol. Survey Bull. 547, pp. 78, 79, 1914.

necessary that this movement be sufficiently great to permit the incursion of fresh water into the field in order to cause the accumulation of the oil and gas. Probably the major portion of the circulation is everywhere under the influence of gravity and its direction is away from the place where the porous formation is at the surface. Circulation may have taken place in folded beds at the time of folding, water having been squeezed out of the porous beds as the result of pressure and consequent decrease in volume of pore space in the formation. Accumulation as the result of hydraulic pressure will take place where there are anticlines to trap the lighter fluids or where there are local barriers to the migration of the fluids. These local barriers may be either lenticular beds of fine sand, indurated sandstone, or lenses of clay. It is probable that in many places accumulation is the result of the combined effects of folds and relatively impervious barriers in the oil sands.

In the examination of the western oil shales[1] it was found that a small amount of the oil existed as such in the shale before distillation. If it is assumed that oil is formed in the shales and sands, as has been outlined in discussing the origin, the principal problem involved is to explain its accumulation in porous sands under the influence of structure and variations in the texture of the sands. Probably the first process is a slow interchange in position of water and oil, the oil moving into the more porous beds and the water into those of finer texture. This interchange would be facilitated by the slow earth movements that are probably constantly in progress and would be hastened by the processes of deformation that produce the folds. The final process would be migration of the oil under hydraulic pressure and accumulation in the large productive pools under the influence of the water circulation and gravity.

RELATIONS IN THE DE SOTO-RED RIVER FIELD.

The gas and oil in the De Soto-Red River field were probably accumulated under hydraulic pressure. This hypothesis is supported by the relations of these substances to the structure and by the occurrence of the oil in very productive pools of small area. The amount of oil in these pools is too great to be satisfactorily explained by assuming a local source on the flanks of the gentle folds that exist in this region.

NACATOCH SAND.

The Nacatoch sand in the De Soto-Red River field has furnished considerable gas but no oil, though drilling has not been extended around the gas-producing area, and therefore it is not safe to say that oil will not be found in this sand. Because of its wide distribution

[1] Woodruff, E. G., and Day, D. T., op. cit., pp. 6–7.

and notable porosity, the Nacatoch sand presents ideal conditions for the accumulation of oil and gas under the influence of gravity; in other words, it favors accumulation according to the anticlinal theory. However, it is unlikely that the salt water that is abundant in the sand below the level where gas occurs has been stationary during the gas accumulation. This sand furnishes gas at many places in northwestern Louisiana, and, so far as has been noted, the gas occurs invariably in high parts of the folds. In the Caddo field the lower limits of the gas-bearing portion of the sand follow very closely the course of one of the structure contours, and although the volume of gas in the De Soto-Red River field is not as great as in the Caddo field, it is probable that the lower margin lies at a nearly uniform level in this field also, though somewhat higher than in the Caddo field. If any oil is found in this sand it will be around the margins of the gas-producing area.

CHALK.

Very few wells encountered any showings of oil in this chalk, and the only one that has proved an important producer is on the Christine lease of the Producers Oil Co., but wells in chalk rock are much more common in the Caddo field, and the distribution of the oil, as shown by the drilling of many wells in close proximity to large wells in this formation, indicates that the oil comes either from a porous bed of slight extent or from crevices. It is therefore suggested that the oil in the chalk may have been derived from the deeper sands by migration along fault planes. A showing of oil has been noted in the sands immediately below the chalk, but no oil has been produced from these sands, and it is impossible to say whether the oil in the chalk has accumulated from local sources or has migrated to its present position from some distant source.

OIL SAND.

The oil sand in the De Soto-Red River field does not present favorable conditions for accumulation in the higher parts of the folds, because the beds are more or less lenticular and the formation is thin. An examination of the relation of the oil pools to the structure shows that they occur considerably below the tops of the highest structural features, probably because of minor structural features and because the upward migration has been interrupted by barriers in the form of fine-grained sands or beds of shale. It is difficult to get reliable information concerning the thickness and character of the sands from the samples obtained in drilling by the rotary method, but many of the wells that are outside of the producing areas and between those areas and the high parts of the folds show considerable porous sand, and it is unlikely that the migration of the oil is prevented by continuous barriers of fine-grained sediments. The principal areas of production in this field are all in places where there is a flattening of the dip on the slopes of the major folds, and it is probable that the accumulation was influenced more by this flattening, which in the area containing the pools in Red River Parish forms a a well-defined structural terrace, than by increase in the fineness of the sand. There can be little doubt that the oil in the larger pools has been brought to its present position, in part at least, by movements of the water through the sand, and it will be observed that the producing areas lie where the circulation would be first impeded by the change in structure.

The producing areas near Naborton are on the north flank of the Naborton dome, above the bottom of the syncline that separates this dome from the Smithport anticline, in the locality where this syncline is rendered shallow by crossing the major axis of the Sabine uplift. The pools in Red River Parish are on the east edge of the Sabine uplift, and although little information is at hand about the dip to the northeast beyond the productive area, it is probably much steeper there than in the producing areas.

On page 107 it was noted that there is a resemblance between the formations penetrated in the lower parts of the wells in this field and those in southern Arkansas, and it is believed that this resemblance is to be explained by the facts that the drainage which brought these materials to their present position came from the northeast and that the sands are therefore continuous between this field and southern Arkansas. This circulation of the water from the northeast would favor the accumulation of oil on the northeast side of the folds, whereas circulation from the northwest, such as clearly occurred in the Caddo field, would favor accumulation on the northwest side of the folds and would present conditions that were unfavorable for large pools on the east side, where the most productive areas in the De Soto-Red River field are located.

DEEP GAS SAND.

The deep gas sand is productive more uniformly and over a wider area than either the oil sand or the shallow gas sand. Many wells that have been drilled to the oil sand without success have obtained gas in the deep gas sand. Moreover, the relation between the structure of the rocks and the accumulation of gas in this sand is closer than that between the structure and the accumulation of oil in the oil sand.

The wider distribution of the gas in this sand is shown by the occurrence of gas farther down the slopes of folds and on lower folds than in the higher sands, as is illustrated by the large gas wells on the Sample lease of the Producers Oil Co., in sec. 23, T. 13 N., R. 12 W., and by McCormick-Nabors well C-2 of the Gulf Refining Co., in sec. 28, T. 13 N., R. 11 W. It is necessary to conclude, therefore, that the ratio of the volume of the gas to the salt water in this sand is greater than that of the oil and gas to the salt water in the overlying sands. These facts and the general occurrence of gas in the deep sand in areas of favorable structure lead to the conclusion that this sand is more uniform in thickness and porosity than the oil sand above.

COMPOSITION.

OIL.

ANALYSES.

The analyses shown in the accompanying table were made of small samples from individual wells, and the results may not be characteristic of the oils of the different fields. The gravity of northwestern Louisiana oils, in degrees Baumé, is given by J. W. Smith[1] in a recent report, as follows: Caddo light, 38–45.5; Caddo heavy, 19–38; De Soto, 38–41.5; Red River, 40.5–42.5. The gravity of the different samples as shown in the tables differs only slightly from the figures given by Smith, though in comparing individual fields it will be noted that none of the samples from the Caddo field approach the maximum gravity for that field. It must be inferred, therefore, that these samples do not include a representative of the lightest oil of the Caddo field.

[1] Louisiana Conservation Comm. Rept. from Apr. 1, 1914, to Apr. 1, 1916, p. 73.

Analyses of oil from the De Soto-Red River field and neighboring fields in Louisiana and Texas.

Formation and well.	Location.	Depth of sand (feet).	Total depth of well (feet).	Crude. Cubic centimeters.	Crude. Gravity. Specific.	Crude. Gravity. Baumé.	To 150° C. Cubic centimeters.	To 150° C. Specific gravity.	150°–300° C. Cubic centimeters.	150°–300° C. Specific gravity.	Residuum. Cubic centimeters.	Residuum. Specific gravity.	Unsaturated hydrocarbons. Crude (per cent).	Unsaturated hydrocarbons. 150°–300° C. (per cent).	Asphalt (per cent).
Chalk rock.															
De Soto Parish:															
Christine No. 16	Near Naborton, La		1,186	100	0.7973	45.6	27	0.7200	55.5	0.7990	17.5	0.9050	8.8	6	0.09
Caddo field:															
Leonard No. 1, Richardson Oil Co.	Near Oil City, La	1,460	1,473	100	.9138	23.2	1		40.5	.8800	58.5	.9300	23.2	10	2.95
Oil sand.															
De Soto Parish:															
Scales No. 1	Sec. 35, T. 13 N., R. 12 W	2,382		100	.8069	43.5	19	.7230	50	.7960	31	.8870	8.8	6	.0
Red River Parish:															
McClelland No. 6	Sec. 13, T. 13 N., R. 11 W	2,540	2,550	100	.8226	38.94	6		67	.7990	27	.8930	8.4	4	.09
Robinson No. 3	Sec. 25, T. 13 N., R. 11 W		2,535	100	.8154	41.7	11.5	.7400	64.5	.8000	25	.8890	8	1	
Marston No. 15	Sec. 13, T. 13 N., R. 11 W		2,554	100	.8202	40.7	12	.7510	70.5	.8075	17.5	.9390	6.4	4	.18
Globe Oil & Gas Co. No. 1	Sec. 16, T. 13 N., R. 10 W	2,614		100	.8299	38.7	4.5		68.5	.8000	27	.8910	9.6	5	.3
Caddo field:															
McCue Levee Board No. 2	Sec. 36, T. 21 N., R. 16 W	2,180–2,221	2,221	100	.8969	26.1	2.5		35	.8540	62.5	.9130	21.2	7	2.01
Allen No. 1	Sec. 18, T. 20 N., R. 15 W., near Oil City, La.		2,328	100	.8313	38.38	16	.7265	43	.8025	41	.8980	11.2	6	.45
Pelican field:															
Logan No. 6	Sec. 16, T. 10 N., R. 12 W			100	.8154	41.7	16.5	.7355	57.5	.8070	26	.8870	8	8	
Joiner No. 1	Sec. 28, T. 11 N., R. 12 W		2,970	100	.8107	42.7	13.5	.7200	56	.7980	30.5	.8820	6.4	1	
Nacatoch sand.															
Caddo field:															
Dawes No. 1[a]	Sec. 36, T. 22 N., R. 16 W		1,050	102.9	.9253	21.3			17.0	.8406	82.9	.9302			.22
Corsicana field (Powell pool):															
Wright No. 6	5 miles southeast of Corsicana, Tex	860			.9109	23.7	1		33	.8680	66	.9260	30	13	1.14
Corsicana sand.															
Corsicana field:															
Robbins Nos. 7 and 12	2 miles southeast of Corsicana, Tex		{1,131 / 1,155}		.8304	38.6	21	.7238	48	.8150	31	.9130	12.8	4	.83

[a] Harris, G. D., Oil and gas in Louisiana: U. S. Geol. Survey Bull. 429, p. 131, 1910.

In discussing the analyses it is assumed that the product up to 150° C. is gasoline, that between 150° and 300° C. is kerosene, and the remainder is residuum. In refining the amount of gasoline may be increased by distilling to a somewhat higher temperature, provided the requirements of the trade do not call for a high-gravity gasoline, and it is probable that in practice some of the oil that distills above 150° is included with the gasoline. This would result in a decrease in the amount of kerosene unless the oil is distilled at a higher temperature than 300° C. in producing the kerosene. With increased temperatures the gravity of the product is lower. It is important to know the percentages of unsaturated hydrocarbons, especially those of the kerosene, because thorough refining necessitates their removal, which adds to the cost of producing the kerosene and decreases the quantity.

OIL FROM CHALK ROCK.

Two samples were obtained from wells that procured oil in the chalk rock. One of these, from the Christine well, in De Soto Parish, has a specific gravity of 0.7973 (46.6° B.), which indicates that it is one of the very light oils of northwestern Louisiana and not a heavy oil such as is characteristic of the chalk rock. The sample from the Leonard well No. 1, in the Caddo field, is much more representative of the oil from the chalk rock than that from the Christine well. The percentage of unsaturated hydrocarbons in these two samples is very different, but there is a closer agreement in the percentage of unsaturated hydrocarbons in the kerosene. The two samples also differ notably in their percentages of asphalt.

OIL FROM OIL SAND.

The oil from the deep sand in De Soto Parish is represented by a single analysis, but the deep sand in Red River Parish is represented by three samples that show a small variation in the gravity and the content of lighter hydrocarbons and considerable variation in the percentages of kerosene and residuum. The percentages of unsaturated hydrocarbons in the crude samples from De Soto and Red River parishes were comparatively low, and those in the kerosene were too low to be important. None of these samples showed high percentages of asphalt.

In the Caddo field the deep sand is represented by two samples, one of which, from the McCue Levee Board well, was of exceptionally low gravity for deep-sand oil in this field, and its percentage of gasoline was correspondingly low. The gravity of the sample from the Allen well was only a fraction above the lowest gravity given by Smith for the light oils of this field, but this sample furnished a high percentage of gasoline. The yield of kerosene from these two samples was relatively low. The percentages of unsaturated hydrocarbons were apparently high for the deep-sand oils, and there was a wide variation in the asphalt.

Two samples from the deep sand in the Pelican field showed little variation in the gravity and in the amounts of light hydrocarbons. They averaged slightly higher in gravity and in the contents of gasoline than the samples from Red River Parish, but their kerosene yield was somewhat lower. The percentages of unsaturated hydrocarbons were relatively small and neither of these samples showed any asphalt.

OIL FROM SHALLOW SAND.

In northwestern Louisiana the only shallow sand that has furnished oil is the Nacatoch sand in the Caddo field, but in northeastern Texas two or three shallow sands have been productive. The relations of these sands to the Nacatoch sand in Louisiana have been determined, the one at Powell being of the same age as the Nacatoch sand, the one at Corsicana being older, and the one at Angus being doubtfully correlated with the Nacatoch sand. For purposes of comparison some analyses of samples from these shallow sands have been inserted in the table. The sample from the Nacatoch sand (Dawes well) is much heavier than most of the samples obtained from the deep sand in northwestern Louisiana, but only slightly heavier than the sample from the Leonard well, in the Caddo field. The Wright well, in the Powell field, furnished a sample that was a little lighter than the one from the Dawes well. The sample from the Corsicana field was a composite of the oil supplied by two wells. This oil was much lighter than that from the Powell field, and its gasoline yield exceeded that of any of the samples from northwestern Louisiana except the one from the Christine well. The amount of kerosene was somewhat lower than in the samples from De Soto and Red River parishes, but higher than in those from the deep sand of the Caddo field. The percentages of unsaturated hydrocarbons in the crude samples from the Corsicana field were relatively high, and those in the kerosene were high in one sample and low in the others. The asphalt in one sample, that from the Dawes well, was low.

GAS.

The analyses in the subjoined table show the composition of the gas obtained in a number of wells in northwestern Louisiana from different sands, and in one well in the Mexia-Groesbeck field, Texas, from the Nacatoch sand, the substantial equivalent of the shallow gas sand of northwestern Louisiana. The analysis of a sample obtained from the Mackey lease, near Corsicana, is also included, though the sand containing this gas is probably slightly older than the Nacatoch.

Analyses of gas from Louisiana and Texas.

[Made by Bureau of Mines; G. A. Burrell, analyst. Samples collected by O. B. Hopkins, except as otherwise stated.]

	1	2	3	4	5	6	7	8	9	10	11	12
Carbon dioxide (CO_2)	1.6	1.5	1.0	0.0	0.0	0.6	Tr.	1.7	1.2	0.2	0.9	0.3
Oxygen (O_2)	.3	2.0	.0	.1	.0	1.0	0.0	1.1	.0	.1	.0	.0
Methane (CH_4)	95.6	89.3	98.5	96.9	96.5	94.3	98.5	91.9	98.7	92.4	91.9	97.5
Ethane (C_2H_6)	......	......	......	......	......	......	......	......	......	3.4	6.2	.0
Nitrogen (N_2)	2.5	7.2	.5	3.0	3.5	4.1	1.5	5.3	.1	3.9	1.0	2.2
	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Specific gravity:												
Determined	0.58	0.58	0.57	0.58	0.57	0.59	0.56	0.60	0.58	0.60	0.62	0.57
Calculated	......	.57	.57	.57	.57	.58	......	......	.57	.59	.60	......
Oil absorption (per cent)	10.6	4.6	......	......	10.0	10.0	......	......	11.2	......	11.8	......
Heating value (British thermal units per cubic foot at 0° C. and 760 millimeters pressure)	1,018	1,044	1,050	1,031	1,027	1,052	1,052	979	1,051	......	1,095	1,038

Nos. 1 to 7 from Nacatoch sand; No. 8 older sand in Corsicana field; Nos. 9 to 11 from oil sand; No. 12 from deep gas sand.
1. Well No. 28 of Arkansas Natural Gas Co., sec. 6, T. 21 N., R. 15 W., 2½ miles south of Vivian, Caddo Parish, La.
2. Well No. 29 of Arkansas Natural Gas Co., 2½ miles south of Vivian, Caddo Parish, La.
3. Edwards well No. 1 of Southern Oil & Gas Co., sec. 28, T. 22 N., R. 11 W., near Vivian, Caddo Parish, La.; depth, 1,040 feet.
4. Well No. 130 of Southwestern Gas & Electric Co., SE. ¼ NW. ¼ sec. 34, T. 18 N., R. 14 W., near Shreveport, La.; depth, 1,000 feet.
5. Well on L. B. Phillips lease of Southwestern Gas & Electric Co., sec. 12, T. 17 N., R. 15 W., 10 miles west of Shreveport, La.; depth, 1,000 feet.
6. Well No. 2 on Mosely lease of Southwestern Gas & Electric Co., sec. 9, T. 12 N., R. 12 W., 1 mile west of Naborton, La.
7. Well on Anglin lease of Robinson Oil & Gas Co., Mexia-Groesbeck field, Tex. Collected by G. C. Matson; see U. S. Geol. Survey Bull. 629, p. 102, 1916.
8. Well No. 1 on Mackey lease, near Corsicana, Tex. Collected by G. C. Matson.
9. Well No. 1 of Caddo Oil Fields Co., near Oil City, La., depth, 2,260 feet.
10. P. H. Youree well No. 3 of Gulf Refining Co. of Louisiana, sec. 33, T. 17 N., R. 14 W., south of Shreveport, La.
11. Casing-head gas from well No. 15 on Marston lease of Gulf Refining Co., sec. 13, T. 13 N., R. 11 W. near Abington, Red River Parish, La.
12. Well No. A-1 on Sample lease of Producers Oil Co., De Soto Parish, La. Collected by C. A. Dally, jr. of Reserve Natural Gas Co.

The samples from the Nacatoch sand are all of dry gas and show a remarkable uniformity of composition, though the true uniformity is partly obscured by the presence of air, which increases the oxygen and nitrogen content of some of the samples and decreases the methane, which is the important combustible constituent in all the gases. The air-free samples (Nos. 3, 5, and 7) which contain no oxygen, carry methane in remarkably uniform amounts. The heating value of the air-free samples is also fairly uniform. The sample from the older sand in the Corsicana field contains some air, and its proportion of the combustible constituent methane and heating value are consequently lower.

In general composition the samples from the deep sands in northwestern Louisiana are similar to those from the Nacatoch sand with the exception of Nos. 10 and 11, which show small amounts of ethane. The methane content of the sample from the deep-oil sand in the

Caddo field (No. 9) is slightly higher than that of the best gases from the Nacatoch sand. The amount of methane in the sample from the deep gas sand (No. 12) is about the same as the average amount in the samples from the Nacatoch sand. The heating values of the gases from the deep sands are also about the same as those of the gases from the Nacatoch sand. The sample that represents casing-head gas (No. 11) has a somewhat higher heating value than any of the other samples, but this is to be expected from the fact that it contains considerable ethane in addition to the methane, for the ethane has a higher heating value than the methane.

The presence or absence of ethane (C_2H_6) has sometimes been used as a means of determining whether a sand contains oil in addition to the gas, it being assumed that if no ethane is present in the gas the sand is likely to be barren of oil, and that if ethane is found in the gas the same sand is likely to be oil producing. The unreliability of these conclusions is shown by the analyses, sample 9, which shows no ethane, having been obtained from the principal oil sand in the Caddo field; sample 10, which contains ethane, having been obtained from the sand that has furnished no oil within a radius of several miles of the gas well; and samples 1 and 2, which contain no ethane, having been obtained from a sand that supplies oil within a short distance from the gas wells.

At the senior author's request Mr. G. A. Burrell, of the Bureau of Mines, has furnished the following explanation of the importance of the test for oil absorption (see table):

The absorption test is an arbitrary test that the bureau uses for determining the adaptability of natural gas to the making of gasoline by the compression method. We have found, for instance, that only one plant working on natural gas shows an absorption of less than 28 per cent, and this is an exceptional case where the quantity of gasoline is very low. The test is simply conducted by shaking 100 cubic centimeters of gas with 35 cubic centimeters of mineral seal oil, claroline oil, straw oil, rape-seed oil, or some similar oil. Many of these oils have the same absorption capacity. The natural gas is shaken with the oil until absorption is complete, and the percentage of oil that goes into solution is measured and called the absorption.

The gases of northwestern Louisiana compare favorably with those of California,[1] whose heating value, in British thermal units, is from 724 to 934 in the McKittrick-Sunset field, 937 in the Coalinga field, 1,047 in the Kern River field, 1,019 in West Los Angeles, 1,042 to 1,044 in the Santa Maria field, 1,100 to 1,117 in Orange County, and 1,240 in the Torrey field, in Ventura County. Two analyses of Oklahoma gases show 1,025 and 1,271 British thermal units, the former being somewhat lower than that of the northwestern Louisiana gases and the latter somewhat higher. Most of the gases obtained in Pennsyl-

[1] Hill, B., U. S. Geol. Survey Mineral Resources, 1913, pt. 2, pp. 1460–1461, 1914.

vania and West Virginia have a higher calorific value than those in northwestern Louisiana, many of them exceeding 1,200 British thermal units. The northwestern Louisiana gas, however, shows a much higher heating value than the gases of northern Texas, which range from 300 to 929 and average probably less than 775 British thermal units.

PRODUCTION.

OIL.

It was not possible to obtain data for determining the average or total production of oil wells in the De Soto-Red River field, but this field is made up of many small areas containing numerous large wells surrounded by barren areas. This condition, although it has made some leases unusually valuable, has resulted in the expenditure of a large amount of money in drilling dry holes. In De Soto Parish much money was spent before oil was discovered in commercial quantities, although almost every one of the earlier wells gave a showing of oil. From statistics compiled by Northrop,[1] supplemented by unpublished data by the same author, a diagram has been drawn showing the number of productive wells and dry holes in De Soto Parish from August, 1913, to June, 1916. (See fig. 19.) The incomplete statistics show that in 1915 the number of dry holes was nearly equal to the number of producing wells in that parish, but in 1913 and 1914 the number of producing wells was considerably greater than the number of dry holes, as shown by the diagram.

The total production of the De Soto and Red River fields has probably exceeded 12,000,000 barrels, but exact figures of production have not been obtained because the statistics for De Soto Parish in 1913 were combined with those for another field to avoid disclosing individual operations. The production for De Soto Parish in 1914, including a small quantity from the Pelican district, amounted to 3,834,593 barrels, and in 1915 it amounted to 1,797,175 barrels. The total production from Red River Parish has been somewhat larger, amounting to 401,622 barrels in 1914 and 6,802,349 barrels in 1915.

The diagram (fig. 19) shows the average initial daily production of new wells in De Soto Parish from August, 1913, to June, 1916. This diagram illustrates the great variation in the initial production and shows, in a general way, the effect of periodic discoveries of new areas where gushers were obtained.

The diagram showing the number of producing wells and dry holes in Red River Parish (fig. 20) indicates a much higher percentage of successful wells than in De Soto Parish. This is the natural result of the character of the sand, which is more uniform in distribution in Red River Parish than in any of the other pools in

[1] Northrop, J. D., U. S. Geol. Survey Mineral Resources, 1914, pt. 2, pp. 1036–1038, 1915.

northwestern Louisiana, except on the northwest side of the Caddo field. The average initial production of new wells by months is shown on the same diagram from the time of the drilling of Marston well No. 1 to the end of June, 1916, and this diagram also shows the effect of opening new pools at intervals. The first well, Marston No. 1, had a much better yield than the average for any of the fol-

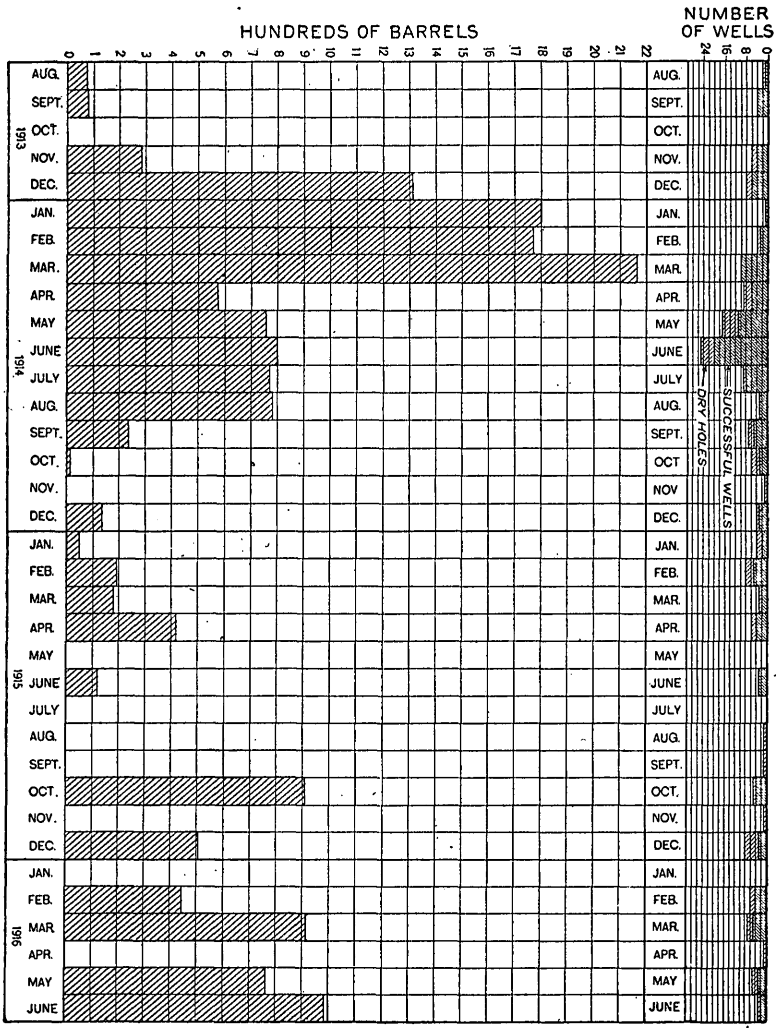


FIGURE 19.—Diagram showing number of productive wells and dry holes and average initial daily production of new wells drilled in De Soto Parish, La., from August, 1913, to June, 1916. From statistics by J. D. Northrop.

lowing months, though much larger individual wells were drilled in some of the other pools. After the average production of the wells in the Marston district began to decline, the opening of the district on the east side of Red River and the drilling of the large wells on the Weiss tract raised the average initial production to new high points in February and March, 1915. The decline from these high points was again arrested by the drilling of many good wells in the

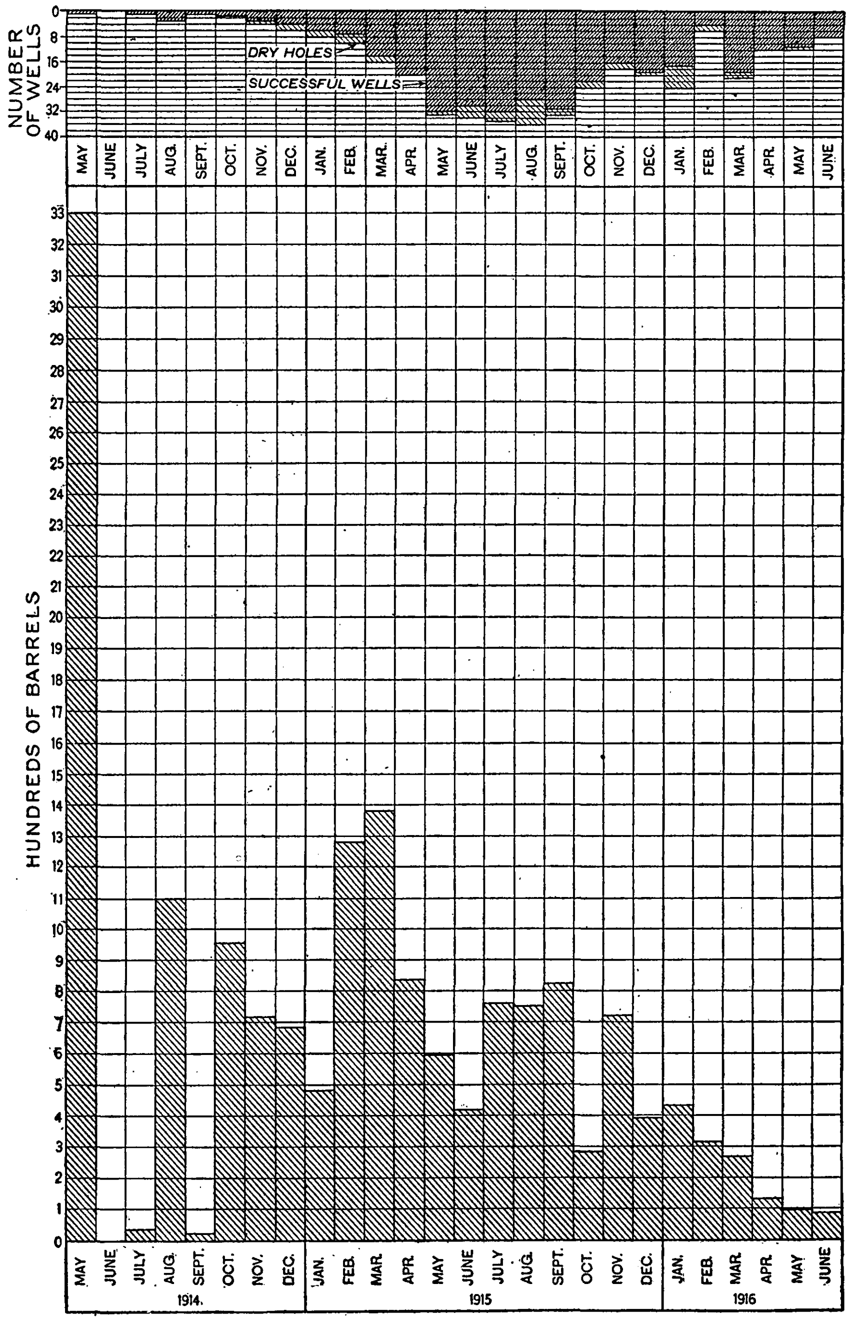


FIGURE 20.—Diagram showing number of productive wells and dry holes and average initial daily production of new wells drilled in Red River Parish, La., from May, 1914, to June, 1916.

Gusher Bend district during the later part of the summer and the early part of the autumn of 1915. In 1916 the pools in Red River Parish had all begun to decline in pressure, and the initial production fell off rapidly, the decline being uninterrupted to the close of June.

GAS.

Although natural gas was discovered at Shreveport more than a quarter of a century ago, its production in Louisiana on a commercial scale dates from the development of the Caddo oil field and the building of pipe lines to the towns and cities of northwestern Louisiana and southwestern Arkansas. The first of these lines, the one to Shreveport, was completed in the spring of 1906, and the line to southern Arkansas, which was completed to Texarkana during the following year, was subsequently extended to other towns and cities as far north as Little Rock.

Many of the early wells in the Caddo field had a very large yield, some of them being reported as having capacities of more than 50,000,000 cubic feet a day, and the large number drilled during the early history of the field led to the formulation of plans for piping the gas to New Orleans and the discussion of a project for piping it as far north as St. Louis.

The lack of an immediate market for the gas produced, together with the greater value of the oil from the same sands or from deeper sands, caused a large amount of gas to be wasted into the air in attempts to obtain oil from the wells. Gas was also used for raising oil from some of the wells that failed to flow by extending pipes into the wells and allowing the gas pressure and flow to be utilized in the same way that air is sometimes employed in pumping.

In addition to these wastes, much gas was lost through wild wells that became uncontrollable where the gas escaped around the casing. There were several of these wells. The most conspicuous was the one a short distance south of Oil City, which was finally closed in 1913 through the efforts of the Louisiana Conservation Commission. It is impossible to say what percentage of the gas from the Caddo field was allowed to escape into the air, but it was unquestionably very large.

In the summer of 1912 a well drilled at the State Fair Grounds at Shreveport obtained gas in commercial quantities, and the completion of this well was followed by the drilling of many others. The drilling of the Fair Grounds well marks the beginning of the commercial exploitation of gas from the Shreveport anticline, but this anticline has not justified the optimistic opinions that were held during the early stages of development. Most of the wells drilled on it had daily yields of only 4,000,000 to 5,000,000 cubic feet—much smaller than those of the earlier wells in the Caddo field. The maximum yield of even the best wells fell far below that of some of the early Caddo wells.

About the time that development began in Shreveport the rock pressures had fallen so low in the Caddo field that the early depletion of the supply was evident and plans were made for installing compressors in order to obtain enough gas to supply the wants of the consumers.

The early production from De Soto Parish was obtained from the same sand (Nacatoch sand) that supplied large quantities of gas in the Caddo field and at Shreveport, but the De Soto wells were more nearly comparable in yield to those of the Shreveport anticline than to those of the Caddo field. The gas from this field was first utilized by the Mansfield Gas Co. It became evident during the early stages of development that the Nacatoch sand would not supply enough gas to warrant piping to great distances from the field.

A new source of supply was discovered in De Soto Parish in the first well drilled by the Producers Oil Co. on its Sample A lease. This well, which was drilled for oil, encountered gas in a deep sand under a pressure so enormous that it could not be controlled, and the well was allowed to flow into the air for several months before it was connected with the pipe line. Subsequent drilling resulted in the completion of a number of other deep gas wells in De Soto Parish, and this led to the construction of the 16-inch pipe line from this field to Oil City, in the Caddo field. This pipe line, built by the Reserve Natural Gas Co., was completed during the autumn of 1914. Plans have recently been discussed for a pipe line to Houston, Tex., to utilize a portion of the gas from the deep sand.

The details of production of gas in northwestern Louisiana from 1909 to 1915, inclusive, are shown in the following table:

Record of natural-gas industry in Louisiana, 1909–1915.

[From U. S. Geol. Survey Mineral Resources, 1915.]

Year.	Number of producers.	Number of consumers.		Total value of gas produced.	Wells.		
		Domestic.	Industrial.		Drilled. Gas.	Drilled. Dry.	Productive Dec. 31.
1909	11	4,034	164	$326,245	26	10	70
1910	21	8,547	320	[a] 509,408	23	4	91
1911	27	[b] 17,964	442	[a] 858,145	36	18	116
1912	41	[b] 24,087	474	[a] 1,747,379	50	20	155
1913	57	[b] 26,424	550	[a] 2,119,948	53	24	191
1914	54	[b] 29,751	618	[a] 2,227,999	52	26	238
1915	57	[b] 30,144	597	2,163,934	35	10	253

[a] Includes the production of Alabama.
[b] Includes consumers supplied with gas piped from Louisiana to Arkansas and Texas.

AREAS OUTSIDE OF THE DE SOTO-RED RIVER FIELD.

The only folds near the De Soto-Red River field that have proved productive are in sec. 16, T. 13 N., R. 10 W., where a few wells have been drilled on and near a tract of land belonging to the Globe Lumber Co. and a few miles southwest of Pelican, near the northern boundary of Sabine Parish, where several small wells have been obtained. Neither of these pools has had a large production of oil, and the possibilities of future development do not warrant the prediction that they will ever become sources of production comparable with the best pools in the De Soto-Red River field.

In addition to these oil pools, gas has been obtained from the deep sand as far west as Spider and at various points between the Shreveport gas field and the northern boundary of the De Soto-Red River field, as well as south of the Gusher Bend fault. It is not at present possible to make a satisfactory prediction as to where the most favorable structure may be found, because a large part of this area has not been studied.

GLOBE LUMBER CO.

A few successful wells have been drilled in sec. 16, T. 13 N., R. 10 W., on and adjoining a tract of land belonging to the Globe Lumber Co. The production of most of the wells was comparatively small, ranging from 10 barrels to a few hundred barrels.

The structure of this pool has not been contoured in detail because of lack of information, but it appears to lie on the north side of the Gusher Bend fault and above the 750-foot contour on the top of the Nacatoch sand. The quality of the oil obtained from one of the Globe Oil & Gas Co.'s wells is shown in the table of analyses on page 129. There appears to be no reason for expecting a great extension of the area of production in this particular pool, because it is doubtless located on a small fold formed at about the same time as the Gusher Bend fault. There is, however, a possible extension of this fault farther to the northeast.

MANSFIELD.

In a press notice issued by the Survey in October, 1915, attention was called to some of the structural features in the vicinity of Mansfield, where it was recognized that the folds were lower and the sands deeper than in the De Soto-Red River field. In suggesting that these folds be tested by drilling, it was hoped that the conditions there might be comparable with those on the west side of the Caddo field, where the producing sand extends far below the level of the sand at the south end of the field. The well that was drilled on the anticline at Mansfield encountered the Nacatoch sand within less than 10 feet of the depth predicted in the press notice, but apparently the sand was barren of oil and gas. Further drilling on this anticline does not seem warranted unless the locations are made farther northeast, where the sand is higher.

PELICAN DISTRICT.

About 16 wells have been drilled in the southern part of De Soto Parish and the northern part of Sabine Parish, opening a small oil pool in the vicinity of Pelican. The productive wells are scattered over an area extending from a point 2 miles northwest of Pelican southward for a distance of 7 miles, in Tps. 10 and 11 N., R. 12 W. About half of the wells drilled have been productive, but they have yielded only a small amount of oil.

The stratigraphic section in this district is in every way similar to that in the De Soto-Red River field, although the section shows a smaller amount of sand. The Nacatoch sand is reached at a depth below sea level ranging from 900 feet in the northern part of the district to about 1,350 feet in the southern part. In this area it consists largely of hard sandy shale and sandstone with only a relatively small amount of loose sand. It has been productive

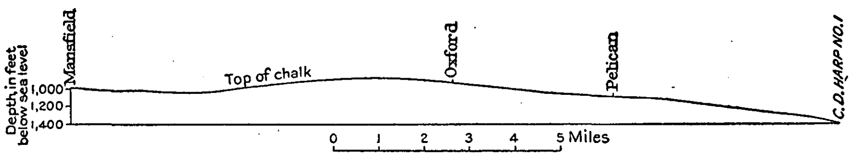


FIGURE 21.—Generalized profile showing slope of the top of the chalk and its depth below sea level from Mansfield to Pelican, La.

in this area only in the Davis & Atkins well No. 1 of the Standard Oil Co., which produced heavy oil in small quantities for a few weeks. In none of the wells has it yielded a commercial flow of gas.

The productive oil sand in this field is the equivalent of the oil sand in the De Soto-Red River field, and here as there it occurs below a bed of limestone 100 feet or more thick. This sand occurs at a depth ranging from 2,800 feet in the northern part of the district to 3,200 feet in the southern part and yields from a few barrels up to 30 or 40 barrels a day. Joiner well No. 1 of the Producers Oil Co. was the best well that has been drilled in the field, and it made about 25 barrels a day six months after it was drilled. Logan well No. 2 of the Producers Oil Co. is the only gas well in the field, and the gas, which is accompanied by a large volume of salt water, is used in pumping the neighboring oil wells.

No study has been made of the surface exposures to determine the structure of the field. The wells are too far apart to admit of a determination of the details of structure from the well logs, which show a fairly uniform dip to the south of 50 to 60 feet to the mile. (See fig. 21.) From the information available, the structure is not considered favorable for the concentration of oil in large quantities.