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GEORGE C. BRANNER

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BULLETIN 2

Oil and Gas Geology of the Gulf Coastal Plain in Arkansas

By

W. C. SPOONER

With a Chapter on

Upper Cretaceous Ostracoda

BY

MERLE C. ISRAELSKY

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LETTER TO PUBLISHER

ARKANSAS GEOLOGICAL SURVEY
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PARKE-HARPER COMPANY,
Little Rock, Arkansas.

Gentlemen:

In response to your request of October 1, 1934, we are lending you the manuscript of our Bulletin 2, entitled, "Oil and Gas Geology of the Gulf Coastal Plain in Arkansas," and written by W. C. Spooner of Shreveport, Louisiana. We are including in our loan the zinc etching of 117 drawings which are part of the report. It is our understanding that you wish to publish this bulletin at your own expense, and that any edition you issue is, in its entirety, to be your property for distribution as you see fit.

I have conferred with the Attorney General regarding the legality of permitting a firm to print, as a private undertaking, information which has been assembled at the expense of the state. He has assured me that no legal barriers exist, so long as the publication is not designated as a state report. Therefore, it canot, technically, be considered as such, although the material is essentially the same we would publish if funds were available for the purpose.

Work on this bulletin was initiated in 1927 but its completion was very materially delayed by the serious and protracted illness of the author. Although the work has been nearly ready for publication during the last three years, this department has lacked the required funds, and as there is not immediate prospect of securing them, I am glad to turn the bulletin over to you so that the information may be made available to the public. Maps and portions of the text of this bulletin have been available at this office for the last three years.

It should be stated that it would have been impossible to complete the preparation of the material of the bulletin and turn it over to you in its present form, without the unselfish assistance of Mr. Richard W. Marshall of Shreveport, Louisiana, and Mrs. Benita Rayfield of Little Rock, Arkansas, and I am greatly indebted to them for their cooperation.

The great importance of the petroleum industry in Arkansas may be appreciated from the fact that, during the 13 years since the discovery of oil in Union County in 1921, the estimated production has been in excess of 408,000,000 barrels, valued at approximately $392,091,000. This is 53.7 per cent of the value of all minerals produced in Arkansas during the 55-year period from from 1880 to 1935. The tax income to state, county, and city governments, directly and indirectly due to the production of oil, is estimated to be at least $17,000,000 during the 10-year period from 1922 to 1931, inclusive.

It is hoped that the information contained in this report will encourage intelligent prospecting for oil and will prove to be a contributing factor toward the discovery of new producing areas within the Gulf Coastal Plain in Arkansas.

Yours very sincerely,

GEORGE C. BRANNER,
State Geologist.

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PART I.

STRATIGRAPHY AND STRUCTURE

The southwestern and eastern parts of Arkansas lie within the Gulf Coastal Plain physiographic and geologic province. That part of the Gulf Coastal Plain which lies in Arkansas embraces an area of 27,370 square miles, or about 52 per cent of the area of the state.

The Gulf Coastal Plain sediments consist of sands, clays, marls, shales, and limestones but include anhydrite and volcanic rocks ranging in age from Mesozoic to Recent. They rest on a pre-Cretaceous erosional surface of folded and faulted Paleozoic and older rocks.

The oldest Coastal Plain rocks belong to the Comanche series and include the Trinity, Fredericksburg, and Washita groups. They crop out in a narrow belt in Sevier, Howard, and Pike counties. The Gulf series (Upper Cretaceous) crops out in southwestern Arkansas in a parallel, but somewhat wider belt, which extends from the Texas and Oklahoma line eastward into Clark County. The Tertiary rocks are the most widely distributed, occupying, for the most part, the Coastal Plain to the south of the Cretaceous and extending eastward to a line drawn from Little Rock southward into Ashley County. The eastern part of the state, except for small outcrops of Tertiary rocks along the western margin of the Coastal Plain and narrow belts along the flanks of Crowley's Ridge, is mantled with sands, gravels, and loams of Pleistocene and Recent age.

The usual interpretation of the pre-Cretaceous history of this region requires the postulation of geolsyncline (the Ouachita geosyncline) which received sediments from land areas to the south. Folding and trusting of the geosynclinal sediments began in the Carboniferous period and culminated in the Permian time with the formation of the Ouachita Mountains. The final stage in the mountain building is believed to have been the vertical uplift of the frontal part of the mountains and subsidence of the hinterland, as well as the outer and central zones of the Ouachita Mountain system in its widest development. As a result of these movements, a basin was developed to the south which received sediments from the elevated Ouachita Mountains in later Permian time, and in which the salt, underlying a part of this region, is believed to have accumulated.

The Ouachita Mountains are strongly arcuate in form with only the northernmost part exposed in southwestern Arkansas and southeastern Oklahoma. Their continuation under the Coastal Plain has been traced from Oklahoma to the vicinity of

the central mineral region of Texas and thence westward to the Marathan region in southwestern Texas. From the easternmost exposure in the vicinity of Little Rock, the Ouachita Mountains are believed to continue under the Coastal Plain sediments in a general southeasterly direction through southeastern Arkansas, northeastern Louisiana, and Mississippi, into Alabama.

Cessation of the mountain building forces was followed by a period of denudation which, at the beginning of the Mesozoic, had reduced this region to a peneplain. The downwarping of this peneplain permitted the early Cretaceous sea to invade this region from the southwest. The strand lines of the Comanche sea were generally determined by the trend of the Ouachita Mountains as previously outlined. The earliest sediments are a series of impure limestones, shales, and fine-grained sands, provisionally assigned to the Neocomian, which have been penetrated to a depth of more than 1,500 feet. After the deposition of the Neocomian, the sea retreated, and a series of red clays and sands accumulated which, in Arkansas, reached a thickness of over 2,000 feet.

After an interval of emergence the sea again invaded Arkansas, and the Glen Rose sediments were deposited. The Glen Rose is divided into the Upper and the Lower Glen Rose with an intervening zone of interbedded anhydrite and limestone.

The Lower Glen Rose in its typical development in southwestern Arkansas is 900 to 1,000 feet thick, composed of generally impure, earthy limestone and shale but decreases in thickness and exhibits near-shore characteristics toward the north and east.

The anhydrite zone, 600 feet thick in southwestern Arkansas, consists of interbedded anhydrite, marine limestone, and shale.

Marine conditions of deposition continued for a brief period after the deposition of the anhydrite and associated limestone and shale. Regression and the deposition of red clays and sand, which interfinger basinward with marine limestone and shale, followed. This movement is the correlative of that in Texas, when the Paluxy sands were deposited. The Trinity sediments above the anhydrite represent in part the marine Glen Rose and in part the Paluxy sand of Texas.

The Fredericksburg and Washita groups are represented by marine limestone and shales, which have a maximum thickness of 400 feet in Miller County, Arkansas. Their total thickness and maximum eastward extent is not now determinable.

The deposition of the Comanche was followed by uplift and marked flexing of the strata along a northwest-southeast trend through southeast Arkansas and northeast Louisiana, which parallels the eastward extension of the Ouachita Mountains. In the subsequent interval of erosion, the Comanche strata were truncated and the region reduced to a peneplain.

Downwarping and Upper Cretaceous deposition began in east Texas after a brief interval of emergence, and the sea gradually expanded eastward, submerging Arkansas in Eagle Ford or early Austin time. The basal Upper Cretaceous formations rest unconformably on Comanche strata, ranging in age from Washita in the western part to early Trinity in the eastern part of the state. The basal beds are composed in large part of volcanic material, believed to have been derived from volcanic vents situated in southwestern Arkansas and northeastern Louisiana. The volcanic activity may have begun with the upwarp of the Comanche strata but was most active during the Upper Cretaceous and, in a milder form, extended into the Taylor.

The Upper Cretaceous was a period of relative crustal stability, during which marine conditions of deposition prevailed, but differential warping in a southeasterly trend through southeastern Arkansas and northeastern Louisiana operated to modify the lithology and thickness of the Upper Cretaceous sediments.

In the western part of the area the Upper Cretaceous formations are composed chiefly of clays, shales, marls, and chalk with sands in the basal and upper parts of the series, which total 2,200 feet in thickness. These strata diminish in thickness eastward and become increasingly sandy in southeastern Arkansas, where they are 200 to 800 feet thick. In eastern Arkansas to the north of Drew and Chicot counties, they again increase in thickness to more than 1,000 feet and lithologically are more nearly the counterpart of the Mississippi than of the southwestern Arkansas section.

At the close of the Cretaceous period the sea retreated from the region, and a long period of time elapsed before marine deposition was resumed. That the emergence of this region occurred with a minimum of differential warping is indicated by the lithologic similarity and by the uniform thickness of the Arkadelphia marl (uppermost Cretaceous) and the Midway formation (basal Tertiary).

The crustal stability, prevailing during Upper Cretaceous and Midway deposition, was succeeded by a period of crustal instability, which began in Wilcox time and continued into the Miocene epoch. The strand line, which had been more or less permanently fixed during the Cretaceous period, began to migrate back and forth over the region. Nonmarine sediments were deposited in the wake of the retreating sea alternately with marine sediments, deposited during a period of transgression. The maximum extent of marine deposition was reached with the deposition of the Jackson formation.

During Wilcox time differential warping of the sea floor exerted a marked influence on the sediments and on the structure of the region. Northern Louisiana and southern Arkansas began to rise as the embayments on either side were depressed; the structural salient, inclusive of northern Louisiana and southern Arkansas, began to take shape and attained its final form in a marked regional uplift which occurred late in Tertiary period.

The uplift was accompanied by erosion that reduced the terrain to the base level in early Pliocene time. Over this peneplain were spread the Lafayette sands and gravels, which are correlated with the Citronelle formation. The present topography was carved from the uplifted Pliocene and earlier formations during the Pleistocene and Recent epochs.

The regional monoclinal structure of the Gulf Coastal Plain, dipping gently towards the coast, is modified by transverse warping, resulting in broad gentle upwarp between shallow, broad depressions along the inner margin of the Coastal Plain. The structural salient, inclusive of southern Arkansas and northern Louisiana, and the east Texas and Mississippi embayments are typical examples of such structural features.

The Sabine uplift in northwestern Louisiana and the Monroe uplift in northeastern Louisiana are integral parts of the structural salient but have sufficient structural individuality to be broadly outlined in form. These uplifts, separated by a shallow syncline, are broad, dome-like folds 75 to 100 miles in diameter.

Numerous minor structural types which may be divided into normal structures, including normal faults and salt-dome structures are superimposed on the structural salient and the larger uplifts.

The normal structure include anticlines, domes, structural terraces, faults, and synclines. The dome-like structures are the dominant form, but the anticlinal form is present in southeastern Arkansas. The structural relief is generally less than 150 feet. The faults, which in Arkansas occur in a generally east-west trending zone, are normal with throws, some about 500 feet high. The known faults in Louisiana are associated with domes.

The salt-dome structures include the typical salt domes, generally 4 to 6 miles in diameter with a central salt core which has pierced and sharply tilted the inclosing strata. The salt-dome structures should, perhaps, include the Homer, Bellevue, and Pine Island domes, large domes with diameters of 10 to 15 miles and structural relief of over 1,000 feet. Salt has not been encountered in these domes, but gravimetric surveys indicate its presence at considerable depths.

The normal folds include the anticlines, domes, and structural terraces. The folds are generally dome-like in form but anticlinal folds are present in southeastern Arkansas. The structural relief is generally less than 150 feet.

PART II

OIL AND GAS FIELDS

The producing areas of the Gulf Coastal Plain in Arkansas, except for small areas in Lafayette and Miller counties, are situated within a southeast-trending belt 15 to 20 miles in width which extends from the Irma field in Nevada County through central Union County to the Louisiana line. Within this belt 14 distinct producing areas have been discovered since 1921, known as Smackover, El Dorado, Lisbon, Irma, Stephens, East El Dorado, Woodley, Rainbow City, Urbana, Mount Holly, Bradley, Garland City, Sec. 14, T. 18 S., R. 14 W., and Sec. 2, T. 18 S., R. 15 W. These fields have a total productive acreage of about 49,365 acres and vary in size from about 85 acres, the area of the Bradley or Mt. Holly fields to 29,505 acres, the area of the Smackover field.

Most of the oil-producing areas are anticlinal, domal, or structural terraces. In a few areas the oil is confined by virtue of the character of the reservoir rocks, either lensing of the sand or lateral decrease in porosity.

Except in the case of the Garland City, Mount Holly, and Urbana fields the production is obtained from the Upper Cretaceous (Gulf series) formations. The Nacatoch sand and the Ozan formation of the Gulf series have been the most prolific producers of petroleum. Production is obtained from depths ranging from about 1,500 feet to 3,500 feet. From 1921 to 1933 the different producing areas described in this report have produced a total of 388,392,586 barrels of oil.

PART III

SUMMARY DESCRIPTION BY COUNTIES

Changes in the character and thickness of the Coastal Plain sediments, in many instances of marked degree from one area to another, exercise definite influence on the oil and gas possibilities of the different parts of the Coastal Plain in Arkansas. For this reason, the structure and stratigraphy of the 46 separate counties in the Gulf Coastal Plain is summarized. County well lists give information as to the number and depth of the wells which have been drilled.

Several counties lie partly in the area of exposed Paleozoic rocks and partly in the Gulf Coastal Plain. Few deep wells have been drilled in these counties and, consequently, the data relating to the subsurface strata are meager. The Cretaceous sediments are generally thin and are not believed to be very favorable areas in which to explore for oil and gas deposits.

OIL AND GAS GEOLOGY
OF THE
GULF COASTAL PLAIN IN ARKANSAS

By W. C. Spooner

INTRODUCTION

From 1920 to the present time, more than 800 deep wells were drilled in the Gulf Coastal Plain of Arkansas in addition to the great number of wells drilled within the oil and gas-producing fields of the region. These wells have furnished a vast amount of geologic data and have revealed the fact that the geologic history is more complex than was indicated by the strata. For the reader's convenience, the report has been divided into three parts.

Part I. *Stratigraphy and Structure*: Deals with the general geology and regional structure.

Part II. *Oil and Gas Fields*: Describes the oil and gas-producing fields of the Coastal Plain of Arkansas.

Part III. *Summary Description by Counties*: In this part the geologic features of the individual counties have been summarized, and the deep wells, together with their correlation and other essential data, are listed.

ACKNOWLEDGMENTS

This work was done under the direction of Mr. George C. Branner, State Geologist of Arkansas, to whom the writer is greatly indebted for assistance rendered in the preparation of this report. To Mr. Garland O. Grigsby, my assistant in the early part of this work, I am indebted for the collection of much of the well data, for the careful tabulation of these data, and for the preparation of maps and sections.

To Mr. Roy T. Hazzard, Gulf Refining Company, Shreveport, Louisiana, I am indebted for assistance in the field work and for the many profitable discussions concerning the geologic problems of this area. To Mr. Merle C. Israelsky, paleontologist for the United Gas Company, Shreveport, Louisiana, for the examination of a vast amount of material, for the preparation of a chapter on the Cretaceous Ostracoda of Arkansas, and for much information concerning the correlation of deep well material. To Mr. L. P. Teas, Humble Oil and Refining Company, who accompanied the writer on a number of trips in the field and contributed much information from deep wells drilled in this region. To Mr. C. L.

Rankin, Humble Oil and Refining Company, who contributed the map of the Arkansas fault zone. To Mr. Stephen H. Rook, paleontologist, Gulf Refining Company, Shreveport, Louisiana, for the examination of materials from many deep wells and for other data.

Grateful acknowledgment is extended to many of the oil companies for their generous contribution of valuable information.

PREVIOUS WORK

The geologic literature published prior to 1858 contains brief references to the geology of the Gulf Coastal Plain of Arkansas, but the earliest systematic description of its geologic features was given by D. D. Owen,[1] State Geologist from 1857 to 1860, who published two volumes of reports.

During the administration of J. C. Branner, State Geologist from 1887 to 1893, the Arkansas Geological Survey published a number of notable contributions to the geology of Arkansas. Hill[2] mapped and described the geology of southwestern Arkansas; Call[3] described Crowley's Ridge, northeastern Arkansas; Williams[4] described the igneous rocks of Arkansas; and Harris[5] mapped and described the Tertiary formations of southern Arkansas.

A valuable report by Veatch[6] on the geology of Arkansas was published in 1906. This report described the physiography, stratigraphy, structure, and geologic history of southern Arkansas. The geology of northeastern Arkansas was described by Stephenson and Crider[7] in 1916.

The Lower Cretaceous system was described by Miser and Purdue[8], who also described the asphalt-bearing rocks of southwestern Arkansas.

The Upper Cretaceous formations of southwestern Arkansas have recently been mapped and described in admirable detail by

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[1] Owen, D. D., First report of a geological reconnaissance of the northern counties of Arkansas, pp. 1-256, Little Rock, 1858.

———, Second report of a geological reconnaissance of the middle and southern counties of Arkansas, pp. 1-153, Philadelphia, 1860.

[2] Hill, R. T., The Neozoic geology of southwestern Arkansas: Arkansas Geol. Survey Ann. Rept., vol 2, pt. 1, pp. 1-189, 1888.

[3] Call, R. E., The geology of Crowley's Ridge: Arkansas Geol. Survey Ann. Rept., for 1889, vol. 2, pp. 1-223, 1891.

[4] Williams, J. F., The igneous rocks of Arkansas: Arkansas Geol. Survey Ann. Rept. for 1890, vol. 2, pp. 1-391 and 429-457.

[5] Harris, G. D., The Tertiary geology of southern Arkansas: Arkansas Geol. Survey Ann. Rept. for 1892, vol 2, pp. 1-207, 1894.

[6] Veatch, A. C., Geology and underground water resources of northern Louisiana and southern Arkansas: U. S. Geol. Survey Prof. Paper 46, 422 pp., 196.

[7] Stephenson, L. W., and Crider, A. F., Geology and ground waters of northeastern Arkansas: U. S. Geol. Survey Water-Supply Paper 399, 1916.

[8] Miser, H. D., and Purdue, A. H., Gravel deposits of the Caddo Gap and DeQueen quadrangles, Arkansas: U. S. Geol. Survey Bull. 690, pp. 15-31, 1918.

———, Asphalt deposits and oil conditions in southwestern Arkansas: U. S. Geol. Survey Bull 691, pp. 271-292, 1918.

Dane[9]. This important work has served as a basis for correlating the subsurface rocks encountered in drilling wells in southern Arkansas.

The more important contributions to the geology of the Gulf Coastal Plain of Arkansas are here listed in the bibliography that follows.

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The following list of papers, relating to the geology of the Gulf Coastal Plain of Arkansas, contains most of the important contributions and some that are chiefly of historic interest.

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1817

Maclure, William, Observations on the geology of the United States of America with some remarks on the effect produced on the nature and fertility of soils by the decomposition of the different classes of rock: Am. Philos, Soc. Trans., new ser., vol. 1, pp. 1-127 and map.

1821

Nuttall, Thomas, Observations on the geologic structure of the valley of the Mississippi: Acad. Nat. Sci. Philadelphia, Jour., vol. 2, pt. 1, pp. 14-52 (esp. pp. 33-48).

1835

Featherstonhaugh, G. W., Geological report of an examination made in 1834 of the elevated country between the Missouri and Red rivers: U. S. 23d Cong., 2d Sess., House Doc. 151, pp. 39-86, Washington.

1853

Marcou, Jules, A geological map of the United States, and the British provinces of North America, Boston.

1854

Warder, J. A., A geological reconnaissance of the Arkansas River, pp. 1-27, Cleveland.

1858

Cox, E. T., Report of a geological reconnaissance a part of the State of Arkansas: First report of a geological reconnaissance of the northern counties of Arkansas, pp. 193-256, Little Rock.

[9] Dane, C. H., The Upper Cretaceous formations of southwestern Arkansas: Arkansas Geol. Survey Bull. 2, 1929.

Marcou, Jules, Geology of North America; with two reports on the prairies of Arkansas and Texas, the Rocky Mountains of New Mexico, and the Sierra Nevada of California, pp. 1-144, pls. 1-9, Zurich.

Owen, D. D., First report of a geological reconnaissance of the northern counties of Arkansas, 256 pp., 10 pls. (esp. pp. 19-41), Little Rock.

This report includes notes on the following counties: Greene (now in part Clay County), Poinsett (now in part Cross County), Jackson, Independence, and White (pp. 19-41). Owen correlates the unconsolidated deposits of Crowley's Ridge in northern Arkansas, including those of both Eocene and Pleistocene ages, with the Quaternary period. The hard Eocene quartzites he referred to erroneously as the Potsdam sandstone (Cambrian).

1860

Owen, D. D., Second report of a geological reconnaissance of the middle and southern counties of Arkansas, pp. 1-153, 7 pls. (esp. pp. 146-153), Philadelphia.

This report describes surface features, the soils, and certain geological features of many of the counties within the Gulf Coastal Plain area. Owen recognized the Eocene age of the fossiliferous marls exposed on Little Crow Creek east of Forrest City. This report contains many analyses of soils and waters.

1861

Humphreys, A. A., and Abbot, H. L., Report upon the physics and hydraulics of the Mississippi River: U. S. Army, Corps of Topographical Engineers, Prof. Papers, no. 4, pp. 1-456, Appendix pp. i-cxlvi, 20 pls., Philadelphia.

This work contains much information pertaining to the physiography of the valley of the Mississippi River and its main tributaries and considerable data on the composition of the immediate river banks.

1872

Hilgard, E. W., On the geological history of the Gulf of Mexico; Am. Assoc. Adv. Sci., Proc., vol. 20, pp. 222-236.

This history contains the first systematic account of the geology and geological history of the Gulf embayment region. The paper includes a black and white sketch map showing the distribution of the Cretaceous, Tertiary, and Quaternary formations.

Smith, E. A., Remarks on the geology of the Mississippi bottom; Am. Assoc. Adv. Sci., Proc., vol. 20, pp. 252-261.

1873

Britton, J. B., Lignite near Camden along Ouachita River; Am. Inst. Min. Eng., Trans., vol. 1, pp. 223-224.

1881

White, C. A., Descriptions of new invertebrate fossils from the Mesozoic and Cenozoic rocks of Arkansas, Wyoming, Colorado, and Utah; U. S. Nat. Mus., Proc., vol. 3, pp. 157-162 (esp. p. 161).

1882

White, C. A., On certain Cretaceous fossils from Arkansas and Colorado: U. S. Nat. Mus. Proc., vol. 4, pp. 136-139 (esp. p. 137).

Wilson, E. H., Report on the result of borings at Memphis, Tenn., Helena, Ark., Arkansas City, Ark., Greenville, Miss., and Lake Providence, La., with date pertaining to similar work previously executed: U. S. Mississippi River Comm. Progress Rept. 47th Cong., 1st Sess., S. Ex. Doc. 10, Appendix J and Ji, pp. 139-257.

This paper contains much information on the character of the alluvial deposits of Mississippi River (esp. pp. 139-239).

1884

Heilprin, Angelo, Contributions to the Tertiary geology and paleontology of the United States, p. 37, published by the author, Philadelphia.

Hilgard, E. W., and Hopkins, F. V., Report upon the examinations of specimens from borings on Mississippi River between Memphis and Vicksburg: U. S. (War Dept.) Chief Eng., Annual Rept., 48th Cong., 2d Sess., H. Ex. Doc. 1, pt. 2, vol. 2, pt. 4, App. TT, pp. 2885-2903.

White, C. A., On Mesozoic fossils: U. S. Geol. Survey, Bull. 4, pp. 16-17, pls. 7-9.

1886

Peale, A. C., Lists and analyses of the mineral springs of the United States: U. S. Geol. Survey Bull. 32, pp. 118-122.

1888

Hill, R. T., Neozoic geology of southwestern Arkansas: Arkansas Geol. Survey Ann. Rept., vol. 2, pt. 1, pp. 1-189, Little Rock.

Hill described the general physiographic, geologic, and structural features of this part of Arkansas. He showed that the presence of the major divisions of the Cretaceous system were more broadly developed in Texas.

1889-1891

Branner, J .C., Arkansas Geol. Survey Ann. Rept. for 1889, vol. 2, pp. xi-xvi.

Branner gives a brief account of the origin of Crowley's Ridge and describes the depression which brought into existence the conditions necessary to the deposition of the Tertiary (Eocene) formations of the embayment. He recognizes that, at a later time, Mississippi River followed a course west of Crowley's Ridge, and that through its agency, the great low-

lands area between the ridge and the Ozark province was eroded out and partially refilled. He states that Ohio River, following a course southward, was accomplishing similar results east of the ridge in the area now known as the Mississippi lowlands; the junction of the two streams was somewhere south of Helena. Crowley's Ridge is correctly interpreted to be an erosion remnant which separates these two great valleys.

Call, R. E., The geology of Crowley's Ridge: Arkansas Geol. Survey Ann. Rept. for 1889, vol. 2, pp. 1-223, 1891.

Call's geology includes a general description of the ridge and a detailed description of many geologic sections and other natural features. A map showing the geographic position of the ridge accompanies the report. St. Francis County is given special attention in a chapter entitled, "Report on St. Francis County," (pp. 143-183) accompanied by a topographic and geologic map of a part of the county on a scale of four miles to the inch, with contour interval of 10 feet. The supplement to the report gives descriptions of geologic sections on Arkansas River in White, Woodruff, Lonoke, and Prairie counties, particularly Pine, White, and Red Bluff. He lists nearly all the fossils figured by Owen at White Bluff and regards them as Claiborne age.

Chamberlin, T. C., and Salisbury, R. D., On the relationship of the Pleistocene to the pre-Pleistocene formations of the Mississippi basin, south of the limit of glaciation: Am. Jour. Sci., 3d ser., vol. 41, pp. 359-377, 1891.

This contains references to the gravel and loess deposits capping Crowley's Ridge. The gravels are probably of pre-Pleistocene age and separated from the overlying loess by an erosion unconformity. In terms of the accepted classification of that time, the loess is correlated with the first glacial epoch.

Clark, W. B., Correlation papers (Eocene): U. S. Geol. Survey Bull. 83, pp. 74-75, 1891.

Knowlton, F. H., Descriptions of fossil woods and lignites from Arkansas: Arkansas Geol. Survey Ann. Rept. for 1889, vol. 2, pp. 249-267, 1891.

Knowlton describes eight specimens of lignite of the Eocene strata of Crowley's Ridge and describes and figures four species of silicified wood from the Crowley's Ridge gravels, which the collector, Mr. Call, believes were originally mechanically derived from the underlying Eocene series.

McGee, W. J., The Lafayette formation: U. S. Geol. Survey Ann. Rept. for 1889, vol. 12, pt. 1, pp. 347-521, 1891.

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Harris, G. D., The Tertiary geology of southern Arkansas: Arkansas Geol. Survey Ann. Rept. for 1892, vol. 2, pp. 1-207, Morrilton.

This report describes the Tertiary system of Arkansas west of Arkansas River with briefer references to the outcrops of Cretaceous and Eocene strata along the margin of the Coastal Plain north of Little Rock. Many detailed sections are described, and fossil localities are listed. Many fossils are described and figured. The areal distribution of the lignitic Eocene (Wilcox formation), Claiborne, and the Jackson is shown on the accompanying geological map.

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1902

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The work briefly describes occurrences of asphalt in the area and gives a number of analyses.

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———— Asphalt deposits and oil conditions in southwestern Arkansas: U. S. Geol. Survey Bull. 691, pp. 291-292.

Miser discusses the general relationship of the area to the Ouachita Mountain region. The Trinity group is discussed in some detail, and a number of local sections are given. The character and thickness of the Trinity group, as shown by well records, are briefly reviewed. It also contains a number of well records and their correlations. The asphalt localities are listed, and the origin of the asphalt and possibilities of oil and gas are discussed.

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of faults follows the strike of the Wilcox-Claiborne contact along the northern part of the alignment, but along the southwestern part of the line of weakness advances down-dip until this faulted zone lies entirely within the area of the Claiborne outcrop.

The Falcon fault, outlined at the surface by the division of nonmarine beds of the Wilcox and Claiborne formations into lithologic units on the basis of their typical ferruginous concretions, was later verified by geological test wells. From the Lewisville fault in Lafayette County westward, the faulted zone is obscured by a mantle of alluvium and Quaternary sand and gravel and was outlined by shallow geological test wells.

Thirty-seven geological test wells were drilled along the faulted zone disclosures against the southern boundary of the "garbens." One deep test on the Falcon closure tested all the sands of the Upper Cretaceous and 1,300 feet of the Lower Cretaceous. This well yielded only showings of oil and gas. Although the most promising areas along this fault zone have been carefully tested, there still remains some possibility of opening deep commercial pools between the Irma field and the Texas state line.

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PART I.

STRATIGRAPHY AND STRUCTURE

STRATIGRAPHIC GEOLOGY

GENERAL STATEMENT

The sedimentary history of the Gulf Coastal Plain of Arkansas began in the Mesozoic era and, according to our present knowledge, with the deposition of the Comanche series. A nearly complete record of the geologic activities from the Lower Cretaceous to the present time is found in the sedimentary rocks of this region. Measurements of rocks exposed, records of deep wells, and estimates show that more than 10,000 feet of sediment consisting of sands, shales, marls, chalks, limestones, anhydrite, and volcanic materials was deposited in the Gulf Coastal Plain of Arkansas.

The geologic boundaries of the Gulf Coastal Plain changed from time to time, and the changes are recorded in the sediments. The sediments, originally deposited in nearly horizontal layers, have been warped and exposed to erosion so that a complete stratigraphic sequence is nowhere present within the state.

The Comanche series (Lower Cretaceous) crops out in a narrow band through Sevier, Howard and Pike counties. These strata attained their fullest development in the southwestern corner of the state, where the maximum thickness is now found.

The Gulf series (Upper Cretaceous) crops out in a narrow east-west trending band through Little River, Howard, Hempstead, Nevada, and Clark counties in southwestern Arkansas. Formations of this age exhibit considerable variation in character and thickness, attaining a maximum thickness of more than 2,000 feet in the southwestern part of the state. (See Pl. II and Fig. 7.)

The Tertiary sediments are most fully developed in the eastern part of the state (upper Mississippi embayment) where they attain a maximum thickness of more than 4,500 feet.

The Pleistocene and Recent sediments are present chiefly in the Mississippi Valley in the eastern part of the state, where they reach a maximum thickness of nearly 300 feet.

CORRELATION

The correlation of the Tertiary and Cretaceous formations of the Gulf Coastal Plain formations of Arkansas with those of the adjacent parts of Texas, Louisiana, and Mississippi is given in Table 1.

TABLE 1.—*Tentative correlation chart*

System	Series	Group	Formations: East and Northern Texas	Formations: Arkansas	Formations: Northern Mississippi	Formations: Northern Louisiana
Quaternary	Recent		Alluvium	Alluvium	Alluvium	Alluvium
	Pleistocene		Port Hudson, Beaumont clay	Port Hudson, Loess	Port Hudson, Loess	Port Hudson, Loess
Tertiary	Eocene		Jackson	Jackson	Jackson	Jackson
		Claiborne	Cockfield	Cockfield	Cockfield	Cockfield
			Cook Mountain	Cook Mountain	Wautubbee	Cook Mountain
			Sparta sand	Sparta sand	Kosciusko	Sparta sand
			Mount Selman: Weches, Queen City, Reklaw	Weches, Queen City, Reklaw / Cane River	Winona / Tallahatta	Cane River
			Wilcox (Including Carrizo sand)	Wilcox	Wilcox	Wilcox
			Midway	Midway	Tippah / Porters Creek	Midway
Cretaceous	Gulf (Upper Cretaceous)	Navarro	Navarro	Arkadelphia marl, Nacatoch sand	Ripley, Selma	Arkadelphia marl, Nacatoch sand
		Taylor	Upper Taylor	Saratoga chalk, Marlbrook marl, Annona chalk		Saratoga chalk, Marlbrook marl, Annona chalk
			Pecan Gap chalk			
			Wolfe City sand	Ozan	Eutaw: Coffee sand	Ozan
			Lower Taylor	Buckrange sand		Buckrange sand
		Austin	Austin: Brownstown marl, Blossom sand, Bonham	Brownstown marl, Tokio	Eutaw: Tombigbee	Brownstown marl, Tokio
			Eagle Ford	Woodbine	Tuscaloosa	Eagle Ford
			Woodbine			Largely absent
	Comanche (Lower Cretaceous)	Washita	Grayson	Undifferentiated (Present only in south-western part of state)	Not recognized	Undifferentiated (Present only in western part of state)
			Main Street			
			Pawpaw			
			Weno			
			Denton			
			Fort Worth			
			Duck Creek			
			Kiamitia			
		Fredericksburg	Goodland	Goodland	Not recognized	Undifferentiated
		Trinity	Paluxy	Paluxy	Not recognized	Paluxy
			Glen Rose	Upper Glen Rose, Anhydrite zone, Lower Glen Rose	Not recognized	Upper Glen Rose, Anhydrite zone, Lower Glen Rose
			Basement sands—Travis Peak	Travis Peak	Not recognized	Travis Peak
		Neocomain?	Overlapped	Marine limestone, shale, and sand	Not recognized	Marine limestone, shale, and sand

SUMMARY OF PRE-MESOZOIC HISTORY

The Paleozoic history of this region postulates a geosyncline (the Ouachita geosyncline) which occupied the site of the Ouachita Mountains now in part exposed at the surface in southeastern Oklahoma and in central Arkansas, but in part concealed beneath the Coastal Plain sediments. The sediments which accumulated in the Ouachita geosyncline were derived from Llanoria, a postulated Paleozoic land to the south.

During the Pennsylvanian epoch the sediments in the Ouachita geosyncline were highly folded and overthurst toward the north, followed in the early Permian epoch by vertical uplift to complete the orogeny of the Ouachita Mountains. The geologic events that transpired in the interval between the Permian uplift of the Ouachita Mountains and the beginning of Mesozoic deposition are not recorded in this region, but necessarily include Permian deposition, denudation of the Ouachita Mountains, and the completion of the Ouachita peneplain[1] in Jurassic time. In this connection the question of Permian sedimentation to the south of the Ouachita Mountains presents itself,. and, in the absence of definite proof to the contrary, it is reasonable to assume that such sediments are present. Elevation of the Ouachita Mountains concomitant with depression of Llanoria in early Permian (the first, an established fact, and the second, a reasonable assumption) presents conditions favorable to the development of a sedimentary basin to the south of the mountains. The alignment of the Ouachita Mountains strongly suggests that they extend southeastward from Arkansas and southwestward from Oklahoma under the Coastal Plain sediments—a condition that would determine broadly the outline of an assumed Permian sedimentary basin. The abruptness of the termination of the basin toward the mountain front would be contingent upon the relative magnitude of uplift and depression and upon the possibility that the southern mountain front may have terminated in a fault. If the assumption of a Permian sedimentary basin is admitted, the salt in northern Louisiana and eastern Texas is most logically correlated with the Permian series. The interval between the Permian and Cretaceous depositions represents a long period of time and, perhaps, a complex series of geologic events; but whatever the history may have been, the final result was the development of the Ouachita peneplain prior to the deposition of the earliest known Cretaceous sediments.

The Comanche sediments of this region were deposited on the tilted and submerged portions of the Ouachita peneplain.

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[1] Miser, H. D., and Purdue, A. H., The Hot Springs district: U. S. Geol. Survey, Geol. Atlas Hot Springs folio (No. 215) 1923.

Melton, F. A., and McGuigan, F. H., The depth to the base of the Trinity sandstone and the present attitude of the Jurassic peneplain in southeastern Oklahoma and southwestern Arkansas: Am. Assoc. Petrol. Geol., Bull., vol. 12, pp. 1005-1014, 1928.

The present attitude of the basement floor along the margin of the Coastal Plain is shown in Plate III and is briefly discussed in the following paragraphs.

PRESENT ATTITUDE OF THE BASEMENT FLOOR

The Gulf Coastal Plain sediments of this region were deposited on the tilted and submerged portion of the Ouachita peneplain[2], developed in highly folded and faulted Paleozoic and probably older rocks. The present attitude of a portion of this tilted peneplain, extending beneath the Coastal Plain sediments, is shown in Plate III, by means of contour lines at intervals of 500 feet. Increased depths to the basement floor and lack of deep wells has largely limited the area mapped to the inner margin of the Coastal Plain. The deep wells that have reached the basement floor are listed in Table 2.

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[2] Miser, H. D., and Purdue, A. H., op. cit.
Melton, F. A., and McGuigan, F. H., op. cit.

TABLE 2.—*List of wells that have penetrated the Paleozoic basement rocks in Arkansas.*

Index No.*	Company	Farm	Well No.	Location	Total depth feet	Elev. feet	Estimated depth below sea level to Paleozoic
SEVIER COUNTY							
1.	Sevier Co. O. & G. Co.	Coulter	1	30- 9S-29W	1283	500	650
HOWARD COUNTY							
2.	Perpetual O. & G. Co.	Schultz	1	31- 9S-27W	1280	358	902
3.	Thompson et al	Dorman	1	33- 9S-27W	1362	450	900
HEMPSTEAD COUNTY							
4.	Arkansas Nat. Gas Co.	Goodlett	1	34-10S-26W	1844	398.52	1421.48
PIKE COUNTY							
5.	Henderson Synd., E. R.	Tilyou	1	26- 8S-24W	1586	351	19
CLARK COUNTY							
6.	Arkansas Nat. Gas Co. (Gurdon)	McAlpine	1	32- 9S-20W	3008	225	1000
7.	Heath & Lovett	Arnold	1	12- 9S-20W	834	175	800
8.	Arkansas Oil Snyd.	Barringer	1	26-10S-20W	3191	247	1600
9.	Whelen Oil Co.	Burrows	2	35-10S-20W	2351	250	1600
10.	Casey (Anderson)	Sloan	1	18- 8S-19W	1096	200	400
11.	Littlejohn & Hall	Fee	1	21- 8S-18W	1321	200	600
12.	Dudley Arkansas Interests	Grayson-McLeod	1	35- 9S-18W	1402	287	1109
HOT SPRING COUNTY							
13.	Lesh & Eagre	Manning	1	9- 5S-17W	1106	350	50
14.	Malvern O. & G. Co.	Hall	1	34- 5S-17W	1000	400	450
15.	Cleary Bros.	Henson	1	19- 4S-16W	1608	320	15
16.	Marr Johnson (White)	Malvern Lbr. Co.	1	36- 4S-16W	1152	230	771
17.	Starr Oil Co.	Cunningham	1	11- 5S-16W	1100	200	875
OUACHITA COUNTY							
18.	Hall's Smackover Assignments	Goodgame	1	19-11S-16W	2273	151	2081
DALLAS COUNTY							
19.	Ohio Oil Co.	Jackson	1	19- 8S-16W	1885	330	1354

* Number refers to well numbers in Plate III.

Index No.	Company	Farm	Well No.	Location	Total depth feet	Elev. feet	Estimated depth below sea level to Paleozoic
20.	Hall's Camden Interests	Taylor, Horace	1	5-10S-16W	2179	240	1876
21.	Dudley's Arkansas Interests	Owen	1	27-10S-16W	2238.5	236	1994
22.	Eagle Lbr. Co.	West et al	1	12-10S-16W	2253	241.5	1987.5
23.	Ohio Oil Co.	Taylor	1	27- 9S-17W	1857	200	1498
24.	Heibron Oil Co.	Eagle Mills Lbr. Co.	1	30- 9S-14W	3210	365	1900
25.	Kemp et al (Bucksnort)	Green	1	18-10S-13W	3155	280	2605
GRANT COUNTY							
26.	Winters, Harry et al	Butler & Lamb	3	25- 6S-15W	2153	230	1923
27.	Texas O. & G. Co.	Chi. L. & T. Co.	3	18- 6S-13W	2521	243	2277
28.	Texas O. & G. Co.	Chi. L. & T. Co.	2	16- 6S-13W	2597	246	2341
29.	Texas O. & G. Co	Chi. L. & T. Co	1	14- 6S-13W	2786	226.91	2520.09
30.	Shaffer O. & R. Co.	Long-Bell	1	36- 5S-12W	3313	300	2960
31.	Shaffer O. & R. Co.	Youngblood	1	34- 4S-13W	2286	281.2	1814.8
32.	Calark Oil Co.	Haley	2	19- 4S-13W	1779	300	1478
33.	Sheriden Co. (Strange)	Gladys-Belle	1	16- 4S-13W	2102	318.5	1748.5
34.	Cambrian Trust Ltd.	Fee	4	22- 3S-12W	2064	342	1678
35.	Lewis, Ralph, Tr.	Boyle-Farrell	1	11- 3S-12W	2152	374	1401
SALINE COUNTY							
36.	Haley, W. W.	Arkansas Short Leaf Lbr Co.	1	6- 3S-14W	725	376	324
37.	Wayman O. & G. Co.	Little Rock O. & G. Co.	1	5- 2S-12W	3410	256	774
PULASKI COUNTY							
38.	Van Waggoner, Fred	Valentine	1	25- 2N-11W	2072	250	215
39.	Stiles Interests	Frazier Plantation	3	27- 1N-11W	660	225	427
40.	Stiles Interests	Vera Stiles	3	27- 1N-11W	1005	225	422
41.	Wonder State Dev. Co.	Wilson	1	21- 2S-11W	1547	259	1300
JEFFERSON COUNTY							
42.	Decem Oil Co.	Hensley	1	7- 3S-10W	2605	260	1800
43.	L. A. Schumacher	M. & P. Danaher	1	16- 5S- 9W	3826	216	3610
CLEVELAND COUNTY							
44.	Arkansas Nat. Gas Corp.	Tate	1	4- 9S-11W	3620	175	3186

Index No.	Company	Farm	Well No.	Location	Total depth feet	Elev. feet	Estimated depth below sea level to Paleozoic
LINCOLN COUNTY							
45.	John Watkins (L. B. Cook, Tr.)	McGehee Planting Co.	1	5- 8S- 7W	4970	185	4740
ASHLEY COUNTY							
46.	The Texas Co.	Gay	1	33-16S- 4W	3187	128	3050
CHICOT COUNTY							
47.	The Texas Co.	Hammond	1	23-17S- 2W	3496	125	3050
ARKANSAS COUNTY							
48.	Moberly D. & L. Co.	Weaver	1	17- 3S- 5W	3250	223	3650
49.	Arkansas O. L. & D. Co.	Pettit-Griffith	1	7- 2S- 5W	3360	210	3046
LONOKE COUNTY							
50.	Arkansas Oil Corp.	Scroggin	1	17- 2S- 9W	2166	228	1746
51.	Stiles Interests	Luella Stiles	4	18- 2S- 8W	100	210	2000
52.	Fletcher-Gates Dev. Co.	Fletcher	1	13- 1S- 8W	2265	217	1889
53.	Fletcher-Gates Dev. Co.	Fletcher	2	27- 1N- 7W	2040	220	1790
PRAIRIE COUNTY							
54.	Bowler Well & Con. Co.	Screeton-Hardke	1	20- 2N- 6W	2130	260	1650
55.	Transcontinental O. Co.	Novak	1	36- 2N- 6W	2954	223	2050
56.	Bowler Well & Con. Co.	John Sims	1	31- 2N- 5W	2348	225	2115
57.	Harvey Dev. Co.	Koucourek	1	5- 1N- 5W	2564	225	2205
58.	Arkansas Grand Prairie	McClintock	1	12- 2N- 5W	2770.7	193.58	2388.42
59.	DeValls Bluff No. 3	Gates	1	12- 3N- 5W	2510	190	1700
60.	Bellport & Hickman	Thomas	1	8- 4N- 6W	1508	240	920
WOODRUFF COUNTY							
61.	Gregory, W. N.	Gregory	1	6- 6N- 3W	1675	200	1035
62.	Knox & Adams	Howell	1	25- 6N- 3W	1785	220	1526
63.	Woodruff Co. Arkansas Synd.	Rosser	1	7- 5N- 2W	2111	250	1644
JACKSON COUNTY							
64.	Newport Water Well			14-11N- 3W	2800	215	400
65.	Jackson Co. Dev. Co.	Carroll	1	31-11N- 1W	670	220	900

Index No.	Company	Farm	Well No.	Location	Total depth feet	Elev. feet	Estimated depth below sea level to Paleozoic
66.	Sutton, A. N.	Johnson & Berger	1	31-10N- 1W	1269	215	1047
67.	Page	Greenhaw	1	3-12N- 1W	972	250	700
	St. Francis County						
68.	Brownlee Drilling Co.	Whitted	1	28- 4N- 1W	2810	224	2352
69.	Jennings O. Co. (Pace)	Whitted	1	28- 4N- 1W	2745	224	2306
70.	E. H. Henderson	Britton	1	1- 4N- 1W	3750	217	2343
71.	Walmar O. Co. (Field & Jones)	White	1	1- 4N- 2E	3411	215	3013
72.	Forrest Oil Co.	Shirley	1	15- 6N- 3E	3201	309	2963
	Crittenden County						
73.	Painter, J. Jr.	Patterson	1	35- 9N- 7E	3516	225	3051
74.	Painter, J. Jr.	Hunter	1	24- 9N- 7E	3614	225	3100
	Poinsett County						
75.	Aarnes et al	Lemmon & Kahn	1	23-10N- 6E	3005	215	2600
76.	Scott, J. F., Tr.	Nelson	2-A	12-11N- 3E	3723	275	1949
77.	Scott O & G. Co.	Cole	1	15-11N- 3E	3758	300	1650
	Craighead County						
78.	Daniel (Chal) Drl. Co.	Scott C. of C.	1	18-14N- 3E	2231	250	1100
	Lawrence County						
79.	Home Oil Co.	Long	1	11-16N- 1E	411	280	127.5
	Randolph County						
80.	Oil River O. & G. Co.	Holland	1	15-18N- 1E	500	300	50
	Greene County						
81.	Volcanic O. & G. Co.	McDaniel	1	16-16N- 5E	1694	350	1225
	Clay County						
82.	Clay Co. Oil Co.	Marshall	1	5-21N- 5E	1856	300	45
83.	Arkmo O. & G. Co.	Gossett	1	29-21N- 8E	907	300	422
84.	Jeffus, J. C., Tr.	Underwood	1	4-20N- 8E	1214	489	800
85.	Texas Piggott Oil Co.	Sallee	1	11-20N- 8E	1233	300	924

From the Oklahoma line eastward to Ouachita River, the strike is nearly east-west, and the slope is toward the south at the rate of 75 to 50 feet per mile. East of Ouachita River the strike changes to northeast and continues in that direction to the northeastern corner of the state. The slope in that area is toward the southeast at the rate of 50 to 100 feet per mile almost to Mississippi River, where the direction changes to southwest and where the floor rises towards the northwest to intersect the Coastal Plain in northeastern Mississippi. The change in dip from southeast to southwest coincides with the axis of the upper Mississippi embayment. The course of Mississippi River closely parallels the axis of the embayment.

The records of several deep wells drilled in Ashley, Chicot, and Drew counties, southeastern Arkansas, and of other wells drilled in the adjacent parts of Louisiana and Mississippi indicate that the basement floor in those areas lies relatively near the present surface of the ground. The Texas Company's Kieffer No. 1 well in sec. 11, T.18 S., R.4 W., and the March et al Williams No. 1 well in sec. 8, T.18 S., R.4 W., Ashley County, encountered quartzites and hard gray shales, with only a slight amount of red material, in contact with the base of the Monroe gas rock of Upper Cretaceous age. The rocks cored in these wells closely resemble the younger Paleozoic rocks of the Ouachita Mountains and are distinctly different from any known Trinity or other Cretaceous sediments which have been cored in numerous deep wells in Louisiana and Arkansas. Careful examination of the material found below the Monroe gas rock in these wells has failed to find organic remains, except small carbonized plant fragments, but doubtlessly these rocks are older than Cretaceous and are probably of Paleozoic age. In addition to the two above mentioned wells, the Ohio Oil Company's Jerome Lumber Company No. 1 well in sec. 13, T.15 S., R.4 W., Drew County; the Texas Company's Hammond No. 1 well in sec. 23, T.17 S., R.2 W., Chicot County; and the Texas Company's Gay No. 1 well in sec. 35, T.16 S., R.4 W., Ashley County, encountered igneous rock in contact with the basal Upper Cretaceous.

The age of the igneous rock is not definitely established but is generally considered to be of Cretaceous age; however, the fact remains that the top of the igneous rock, recorded in these wells, lies in the same plane of erosion as the wells which recorded sedimentary rocks older than the Trinity. This fact is not conclusive evidence for the pre-Cretaceous age of the igneous rocks, but, together with the evidence afforded by the deep wells in Louisiana and Mississippi, it indicates that the basement rocks normally should lie approximately at the depth at which the igneous rocks were encountered.

The basement floor, on that basis, lies from 3,000 to 3,500 feet below sea level in the southeastern corner of Arkansas. Towards the north the slope appears to be gentle with steep slope towards the west.

An abrupt change in the rate of inclination of the basement floor along a line drawn from southern Little River County, eastward into east-central Ouachita County, and continued from that point in a northeasterly direction into Cleveland County, is indicated by the records of deep wells. To the north of this line, the basement floor lies at depths ranging from sea level to 2,500 and 3,500 feet below sea level; to the south, wells hundreds of feet deeper failed to reach the base of the Lower Cretaceous. The abrupt change in the rate of inclination of the basement floor is again noted in Ashley County and is traceable in a general southeasterly direction along the east side of the Monroe and Richland fields in northeastern Louisiana.

The abrupt change in the slope of the basement floor may be due in part to the sharp flexing and in part to faulting, but on the whole the evidence is insufficient to determine definitely the causes. The flexure is in large part the result of movement at the end of the Comanche epoch, but the oldest known Cretaceous sediments (Neocomian ?) do not extend north of the flexure, and the Travis Peak formation decreases in thickness over the flexure, suggesting that the initial movement occurred in the earliest Cretaceous time. The flexure may represent an older line of weakness, developed incidental to the uplift of the Ouachita Mountains with recurrence of movement concomitant with the downwarping and submergence of the Ouachita peneplain, which initiated the Cretaceous sedimentary cycle of the region. In a general way the flexure coincides with the outlines of the Lower Cretaceous base of deposition.

The best evidence of faulting along the flexure is afforded by the records of the C. E. Murdock Eagle Mills No. 1 well in sec. 29, T.12 S., R.15 W., and the Barnsdall and Foster's Freeman-Smith No. 1 well in sec. 8, T.13 S., R.15 W. The distance between these wells in a north-south direction is less than 4 miles. The Murdock well found quartzitic sandstone, very hard carbonaceous brown shale, and very hard white nonfossiliferous limestone, which are considered to be of Paleozoic age, in contact with the basal Upper Cretaceous sediments. The Barnsdall and Foster wells, on the other hand, found typical Trinity red shale and sand in contact with the basal Upper Cretaceous, which continued to the bottom of the hole, a thickness of 500 feet. The relationship between these wells is shown in Figure 2. Other cross sections accompanying this paper indicate the position and the nature of the flexure. An index map showing areas covered by cross sections in this report is shown in Plate IV.

CRETACEOUS SYSTEM

COMANCHE SERIES (LOWER CRETACEOUS)

GENERAL STATEMENT

The oldest rocks recognized at the surface in the Gulf Coastal Plain of Arkansas, consist of gravels, sands, shales, and limestones of Trinity age, having a total thickness of less than 1,000 feet, which have been divided into several members and lentils designated by individual names but grouped under the general term, "Trinity formation." The Trinity formation is overlain by 10 to 50 feet of Goodland limestone of Fredericksburg age, on which is superimposed 20 feet of shale and limestone correlated with the Kiamichi clay of early Washita age or late Fredericksburg age.

The Comanche rocks exposed at the surface in southwestern Arkansas present distinct near-shore facies of deposition as contrasted with the more typical marine facies of deposition recorded in deep wells farther to the south, where more than 400 feet of Washita and Fredericksburg and more than 6,000 feet of Trinity sediments have been measured. Owing to the differences in the lithology of the Comanche sediments, the existing nomenclature cannot be properly applied to both the subsurface and surface strata.

The following table is intended to show the nomenclature of the Comanche series in common usage.

TABLE 3.—*Generalized section of the Comanche series (Lower Cretaceous) in Arkansas*

Group	Lower Cretaceous rocks in southwestern Arkansas after H. D. Miser, U. S. Geol. Survey Bull. 690.		Lower Cretaceous rocks described in this report	
	Formation or member	Thickness feet*	Formation or member	Thickness feet
Washita	Kiamichi clay	20	Undifferentiated	400†
Fredericksburg	Goodland limestone	10-50		
Trinity	**Trinity formation:**		Paluxy sand and Upper Glen Rose	1700
	Sand and clay member	200		
	DeQueen limestone	70		
	Sand and clay (mostly clay)	150	Anhydrite zone	600
	Dierks limestone lentil	40	Lower Glen Rose	950
	Sand and clay (mostly sand)	100		
	Pike gravel member	50		
Neocomian?			Travis Peak	2000
			Marine limestone, shale, and sand	800†

*—Figures give the maximum thickness.

ROCKS EXPOSED AT THE SURFACE

TRINITY GROUP

EXTENT AND RELATION

The Trinity formation, as mapped and defined by Miser and Purdue[3], includes all the Trinity group exposed at the surface. These writers have named several members of the Trinity formation and have pointed out their relationships to the Trinity group of Texas. (See Pl. II.)

The Trinity formation is exposed in Arkansas in a narrow east-west trending belt, extending from the Oklahoma line in Sevier County to near Antoine in eastern Pike County, which ranges in width from less than 5 miles in Pike County to about 15 miles in Sevier County. The following is a summary description of the several members comprising the Trinity formation.

PIKE GRAVEL MEMBER

The Pike gravel is the basal member of the Trinity formation. It is separated from the underlying basement rocks by a profound unconformity, whose plane truncates folded and faulted Paleozoic rocks. It consists of pebbles usually less than half an inch in diameter but contains many larger pebbles and many cobbles as much as 10 inches in diameter. The larger pebbles and the cobbles are in most places abundant in a thickness of several feet at the base of the Pike gravel member. The pebbles and cobbles are partly thoroughly rounded, and most of them are dense, white, gray, brown, black, or red novaculite, unquestionably derived from the Arkansas novaculite exposed in the Ouachita Mountain a short distance to the north of the outcrop of the Pike gravel member. A small number of pebbles, however, are composed of quartz, quartzite, and sandstone. Some of the gravel is conspicuously cross-bedded; most of it is loose and contains some sand and clay lenses in the upper part, filling in the interstices between the pebbles. Nearly horizontal beds of gravel are cemented in places by brown iron oxide and are thus converted into hard conglomerate.

The Pike gravel member is at most places 20 to 50 feet thick, but it apparently attains a thickness of 100 feet near Murfreesboro, Pike County.

LOWER SAND MEMBER

Above the Pike gravel member is 100 feet of fine-textured gray and yellow, generally cross-bedded, sand in massive beds and some thin beds of clay. This member contains the asphalt-

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[3] Miser, H. D., and Purdue, A. H., Gravel deposits of the Caddo Gap and DeQueen quadrangles: U. S. Geol. Survey Bull. 690, pp. 15-30, 1918.

———. Asphalt deposits and oil conditions in southwestern Arkansas: U. S. Geol. Survey, Bull. 691, pp. 271-292, 1918.

Miser, H. D., Lower Cretaceous (Comanche) rocks of southeastern Oklahoma and southwestern Arkansas: Assoc. Petrol. Geol. Bull., vol. 11, no. 5, pp. 443-453, 1927.

bearing beds of southwestern Arkansas, described by Miser and Purdue[4].

DIERKS LIMESTONE LENTIL

The Dierks limestone ranges in thickness from a feather edge, west of Dierks, to 40 feet in the vicinity of Delight, where it is overlapped by the Tokio formation of Upper Cretaceous age. According to Miser[5], it lies 200 feet above the base of the Trinity formation at its easternmost exposure near Murfreesboro, Pike County, but descends lower and lower in the section toward the west and is only 50 feet above the base along the western part of the outcrop, a short distance west of Dierks, Arkansas. In the vicinity of Dierks, the Dierks limestone lentil is made up of hard crystalline grayish limestone, interbedded with thin layers of green shale. The limestone is made up largely of small oysters (*Ostrea franklini*) and other shells, is sandy, and appears to grade into sands both above and below.

HOLLY CREEK MEMBER

The name, "Holly Creek member," was proposed by Vanderpool[6], to designate the beds of sand and clay that occupy the interval between the Dierks and DeQueen limestones. It is made up of a series of red and yellowish clays, thin beds of sand, and lentils of gravel. It is 150 feet thick in the vicinity of Dierks, Arkansas, but increases in thickness to 300 feet along the Arkansas-Oklahoma line. The Ultima Thule gravel lentil of the Holly Creek member is 40 feet thick near the Oklahoma line but decreases in thickness to a few feet on Cossatot River, where it lies just above the Dierks limestone. Towards the west it approaches nearer and nearer the base of the Trinity formation and finally merges into the Pike gravel member near the state line. In composition it is similar to the Pike gravel, but it contains a greater number of quartz pebbles.

DE QUEEN LIMESTONE MEMBER

The DeQueen limestone crops out in a sinuous band extending from the Arkansas-Oklahoma line eastward into T.9 S., R.25 W., where it is overlapped by the Tokio formation of the Upper Cretaceous epoch. It is 60 to 75 feet thick, made up of beds of tough green clay interbedded with thin limestone and a thin stratum of gypsum and celestite near the middle of the member. The limestones, generally less than 1 foot thick, are usually gray, hard, and compact; but many are earthy and contain small lenses of clay. Oysters and other pelecypods are numerous in many layers. The thickest exposure of gypsum is in Plaster Bluff,

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[4] Miser, H. D., and Purdue, A. H., op. cit.

[5] Miser, H. D., op. cit.

[6] Vanderpool, H. C., A preliminary study of the Trinity group in southwestern Arkansas, southeastern Oklahoma, and northern Texas: Am. Assoc. Petrol, Geol., Bull., vol. 12, no. 7, 1928.

where it is found in a single bed ranging from 10 to 14 feet in thickness. At Messers Creek, south of Dierks, Arkansas, the gypsum is less than 3 feet thick, and to the west of this locality, it is represented chiefly by thin lenses of celestite.

UPPER SAND MEMBER

The outcrop of this member is slightly more than 7 miles wide between DeQueen and Horatio but decreases to a fraction of a mile in the vicinity of Tokio. It is made up of fine-textured, generally cross-bedded sands with some interbedded clays. It is usually compact, but a small part of it is firmly cemented by iron oxide. When unweathered it is gray, but in most exposures it is red and yellow. This member is 160 feet thick on Messers Creek, south of Dierks, but increases in thickness toward the west. Toward the east it thins rapidly as the result of truncation.

AGE AND CORRELATION

The Dierks and DeQueen limestone contain invertebrate fossils, which, according to T. W. Stanton, show rather definite relations to the fauna of the Glen Rose limestone of the Trinity group of Texas. The following fossils from these limestones have been identified by Stanton[7].

Fossils from the DeQueen limestone member of the Trinity formation in southwestern Arkansas

Serpula paluxiensis Hill	Mytilus tenuitesta Roemer ?
Membranipora sp.	Cyprina ? sp.
Barbatia parva missouriensis Hill	Eriphyla pikensis (Hill)
Avicula sp.	Astarte ? sp.
Ostrea franklini Coquand	Glauconia branneri (Hill)
Ostrea franklini var. camelina Cragin	Glauconia ? sp.
Anomia texana Hill	

Fossils from the Dierks limestone lentil of the Trinity formation in southwestern Arkansas

Serpula peluxiensis Hill	Modiola branneri Hill
Nucula sp.	Astarte ? sp.
Cucullaea sp.	Eriphyla pikensis Hill
Barbatia parva missouriensis (Hill) ?	Corbicula arkansaensis Hill
Ostrea franklini Coquand	Cardium sevierense Hill
Exogyra sp.	Glauconia sp.
Anomia texana Hill	

The sands and gravels below the Dierks limestone are probably no older than the Lower Glen Rose limestone, penetrated in deep wells farther south in Arkansas.

The upper sand member of the Trinity formation has been correlated with the Paluxy sand, the uppermost formation of the Trinity group of Texas. In southern Arkansas it interfingers

[7] Miser, H. D., op. cit., p. 450.

with marine limestone and shales and is not separable from the Upper Glen Rose.

FREDERICKSBURG GROUP

GOODLAND LIMESTONE

The Fredericksburg group is represented by the Goodland limestone, which crops out north of Cerro Gordo and at a few places farther east along Little River. It is about 50 feet thick and consists chiefly of hard gray thick-bedded sandy limestone but includes some beds of hard yellowish-gray calcareous sandstone.

WASHITA GROUP

KIAMICHI CLAY

The Washita group is represented by about 25 feet of gray marl and hard fossiliferous limestone, containing an abundance of *Gryphaea navia* Hall, a characteristic Kiamichi fossil.

ROCKS NOT EXPOSED AT SURFACE OF

COMANCHE SERIES (LOWER CRETACEOUS)

GENERAL GEOLOGY

The highway emergent condition of the continent in the closing stages of the Paleozoic era was followed by a period of denudation in which the Ouachita Mountains and the adjacent area were reduced to a peneplain in early Mesozoic time, and the continent as a whole was reduced to relatively low levels. A sedimentary cycle was initiated in the early Cretaceous, during which the Gulf gradually expanded over the continental border, reaching the maximum landward extent in the late Cretaceous and the early Eocene.

The earlier known sediments, deposited during this cycle, were a series of marine strata, tentatively correlated with the Neocomian, which have been penetrated to a depth of 1,500 feet in northwestern Louisiana. The succeeding Trinity sediments begin with the Travis Peak formation, a regressional series composed of red shales and sands which attain a thickness of 2,000 feet or more in southwestern Arkansas. The normal deposition of the overlapping Glen Rose sediments was interrupted by the precipitation of the anhydrite and again towards the close of the Trinity epoch by a Gulfward retreat of the sea, during which red shales and sands again accumulated in Arkansas. The Trinity sediments decrease in thickness and at the same time exhibit increasingly near-shore characteristics from south to north and from west to east. (See Figs. 1 and 4.)

ATTITUDE OF THE BASEMENT FLOOR IN RELATION TO THE SEDIMENTATION

The change in the rate of inclination of the basement floor in southern Arkansas and northeastern Louisiana, whether marking a simple flexure or a fault, exerted a pronounced influence on the character and the thickness of the Trinity sediments and may in some degree have determined subsequent deformational trends. To the north and east of the line of flexing, the Trinity strata are of nominal thickness as contrasted with increased thickness to the south and west. The lithology of the sediments likewise was influenced; shoreward facies were developed to the north and east of the line of deformation; a transitional zone appeared in the vicinity of the flexure; and a more definitely marine facies predominated south and west of the line of flexure. The Neocomian sediments seem to have been limited landward by the flexure, and the Glen Rose, although transgressing it, loses its marine characteristics on the landward side of the flexure.

CONDITION OF DEPOSITION DURING THE COMANCHE EPOCH

The oldest Cretaceous sediments recognized in this region consist of a series of marine limestones, shales, and sands, tentatively correlated with the Neocomian of southwestern Texas and Mexico. These sediments have been penetrated to a maximum depth of 1,500 feet in northwestern Louisiana. These sediments were penetrated in Lion Oil and Refining Company's Hayes A-9 well, sec. 9, T.16 S.. R.15 W., Smackover field, Union County where, owing to the intrusion of salt, the complete section may not have been revealed. The base of these sediments has not been reached, and, consequently, their relationship to the basement floor is not known; but inasmuch as the early Cretaceous sediments were deposited in a marine transgression of the Gulf over a gently warped peneplain, they probably rest uncomfortably upon the basement floor. The line of flexure in the basement rocks, previously defined, marks the northern and eastern limits of the Neocomian marine transgression in Arkansas and northeastern Louisiana.

The predominatly marine environment that prevailed during the deposition of the Neocomian was terminated by elevation of the land areas bordering the Gulf. The rate of increase of both the supply of sediments and the Gulfward retreat of the sea is indicated in the succeeding Travis Peak formation of the Trinity group, which in Arkansas is composed of sands and some red clay in the lower part and of red clays and sands in the upper part. The Travis Peak formation is 2,000 feet thick in southern Arkansas. The red sediments decrease in thickness towards the south and in DeSoto and Sabine parishes, Louisiana, and the adjacent parts of Texas are represented by gray predominatly noncalcareous shales, indicating that the retreat of the sea may not have continued much to the south of that area.

Principally weeds entered the sea in early Glen Rose time, now represented by generally calcareous but in part noncalcareous clays and shales, interbedded with argillaceous limestones. The structure of these, their wide distribution, and uniform lithological character suggest that the site of deposition was a broad, shallow basin. While these sediments accumulated basinward, fine sands, clays in part red, and impure, earthy limestones were accumulating along the margin of the sea in Arkansas.

In the upper part of the Lower Glen Rose formation, the lithologic changes from shales and argillaceous limestones to relatively pure and in part crystalline and oolitic limestone indicate a marked change in sedimentary environmental condition involving decrease in the rate of supply of sediments and increase both in the amount of salts carried in solution and in conditions favorable to the precipitation of such salts. These conditions continued to the end of Lower Glen Rose time and to the top of the anhydrite zone. The anhydrite zone of the Glen Rose attains the fullest development in a zone that parallels the strand line and the flexure in the basement rocks, as previously outlined, and overlies the area of greatest thickness of the Travis Peak formation and the Lower Glen Rose. The anhydrite zone is 600 or more feet thick at its maximum development but decreases in thickness both basinward and landward. (See Pl. V and Fig. 4.)

The deposition of the anhydrite and associated limestones and shales was followed by a return to marine conditions of deposition during which 100 to 200 feet of shales and argillaceous limestones accumulated in the southwestern part of Arkansas. The Gulf began to retreat, and a series of sands and red shales accumulated in the wake of the retreating sea, representing in part the Upper Glen Rose and in part the correlative of the Paluxy sand of Texas. The maximum transgression of the Trinity sea is indicated in Figure 1.

CONDITIONS OF DEPOSITION IN FTEDERICKSBURG AND WASHITA TIME

After an interval of emergence at the close of the Trinity, the sea probably submerged southwestern Arkansas in Fredericksburg time. In this and the following Washita time, a series of limestones and shales accumulated. The extent of the Fredericksburg and Washita inundations are not determinable, but the meager evidence available suggests that they probably were no more widespread than in the preceding Glen Rose formation.

CLOSING EVENTS OF THE LOWER CRETACEOUS

The Lower Cretaceous epoch closed with a withdrawal of the sea from Arkansas and northern Louisiana. The retreat of the sea was accompanied by uplift in which the Comanche strata

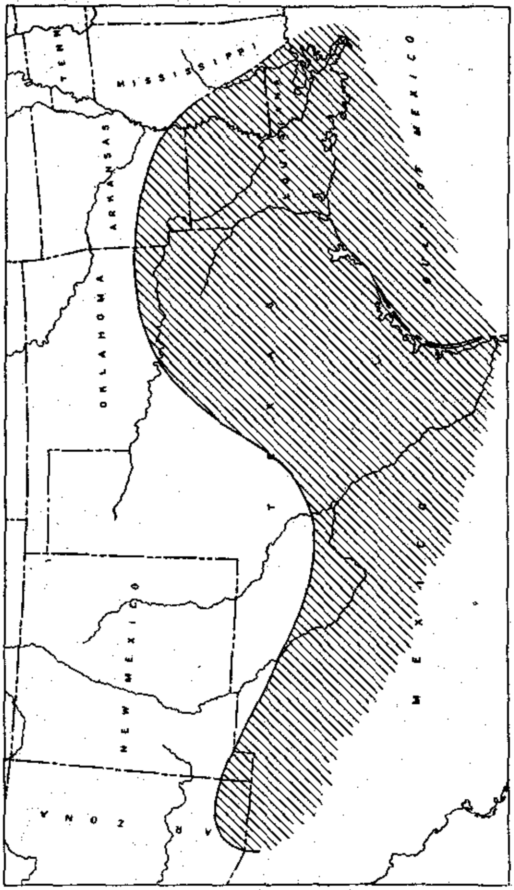

FIGURE 1.—Paleographic map showing limits of the Trinity sea. In part after T. W. Stanton.

were tilted to the south and west. The warping was most pronounced in southeastern Arkansas and northeastern Louisiana, along a line coinciding closely with the line of flexure in the basement floor, shown in Plate III. The uplift was followed by an interval of erosion, during which the Comanche strata were truncated and the terrain reduced to a peneplain.

NEOCOMIAN

The oldest sediments recognized in Arkansas and Louisiana are composed of marine limestone, shales, and sands, which have been penetrated to a depth of more than 1,500 feet in northwestern Louisiana. In Arkansas these sediments have been penetrated only in the Lion Oil and Refining Company's Hayes A-9 in sec. 9, T.16 S., R.15 W., Smackover field, Union County, where the base was found in contact with rock salt. The Cretaceous age of these sediments is definitely established, and the fauna studied indicates their close relationship to the Neocomian

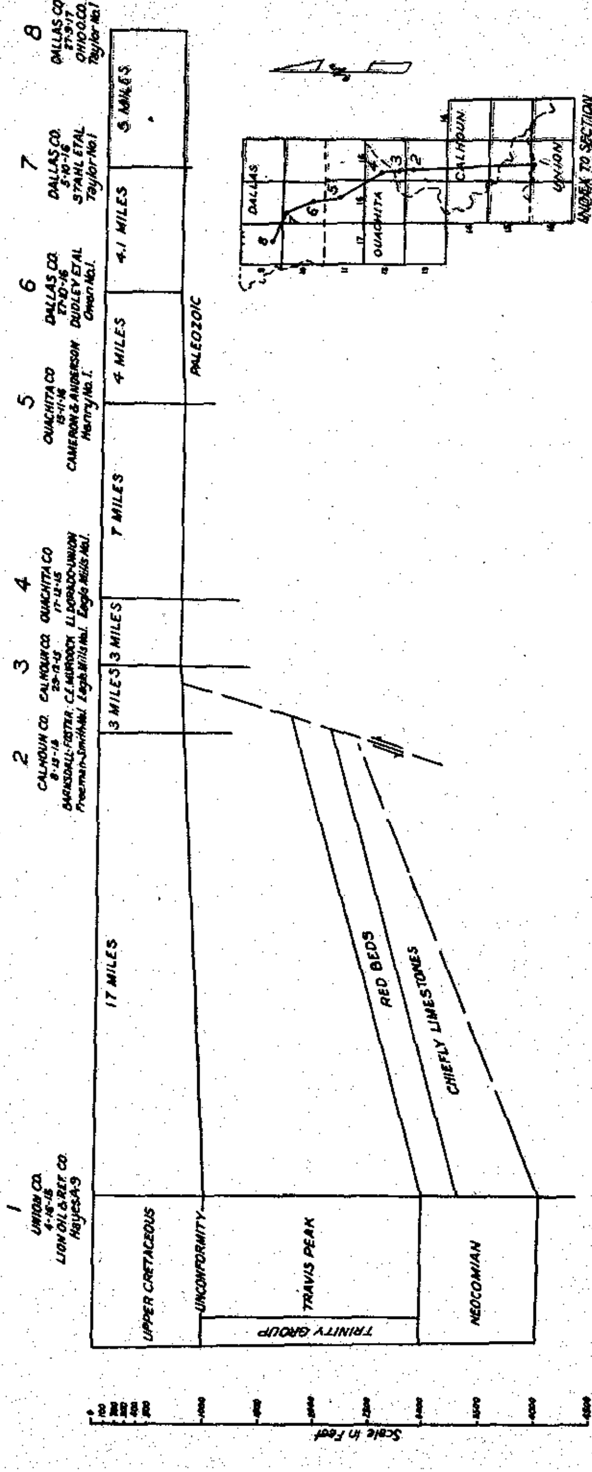

FIGURE 2.—Cross section from Dallas County southward into Smackover showing relationship of the basement rocks to the Cretaceous.

of Mexico and southwestern Texas, but until critically studied this correlation must be considered as tentative.

TRINITY GROUP

TRAVIS PEAK FORMATION

DISTRIBUTION AND CHARACTER

The Travis Peak formation occupies the interval between the Neocomian and the Lower Glen Rose.

It is the most widely distributed member of the Trinity group, underlying all of the state south of the outcrop and south of a line drawn from the easternmost exposure through southern Clark and Dallas counties into the southeastern corner of Drew County and thence south through Ashley County. Throughout most of Ouachita, Calhoun, Bradley, Ashley and the eastern half of Union counties, its upper surface is in contact with the basal beds of the Upper Cretaceous system. (Fig. 2.) Elsewhere the Travis Peak formation is overlain by the Glen Rose formation. (Fig. 3.) Its subsurface distribution is shown in Figure 2.

The series is made up principally of fine-grained sands and sandstones with interbedded clays, shales, and sandy clays. The clays and shale in the upper half are dominantly red, varying in hue from pink to dark-red, but they also contain thinner beds of gray, buff, green, and purple. The lower half of the series contains a greater proportion of sands and is generally lighter in shade with light-gray to pale-green and dark-brown colors prevailing.

The sands and some of the clays and shales are in places sparingly calcareous and lignitic; the lignitic materials consist either of finely divided particles or thin streaks along the bedding planes. Siderite is present locally at a few horizons. Beds of gravel, made up mainly of small chips of novaculite, are recorded in wells, but appear to be limited to the north side or the immediate vicinity of the line of sharp-flexing in the basement rocks.

THICKNESS

The Travis Peak formation and its relationship to the Neocomian (below) and to the Glen Rose formation (above) is shown in Figure 4, a diagrammatic cross section of the Trinity group. According to this interpretation, the series is lense-shaped with the greatest thickness near the line and to the south of sharp flexing, shown in Plate III. To the north of this line there is a marked decrease in thickness towards the shore line, which suggests regressive overlap. To the south there is a gradual thinning of the red facies of the Travis Peak formation, but its total thickness is not determinable.

The Travis Peak formation is from 1,800 to 2,100 feet thick in the Pine Island, Bellevue, and Cotton Valley fields, Louisiana.

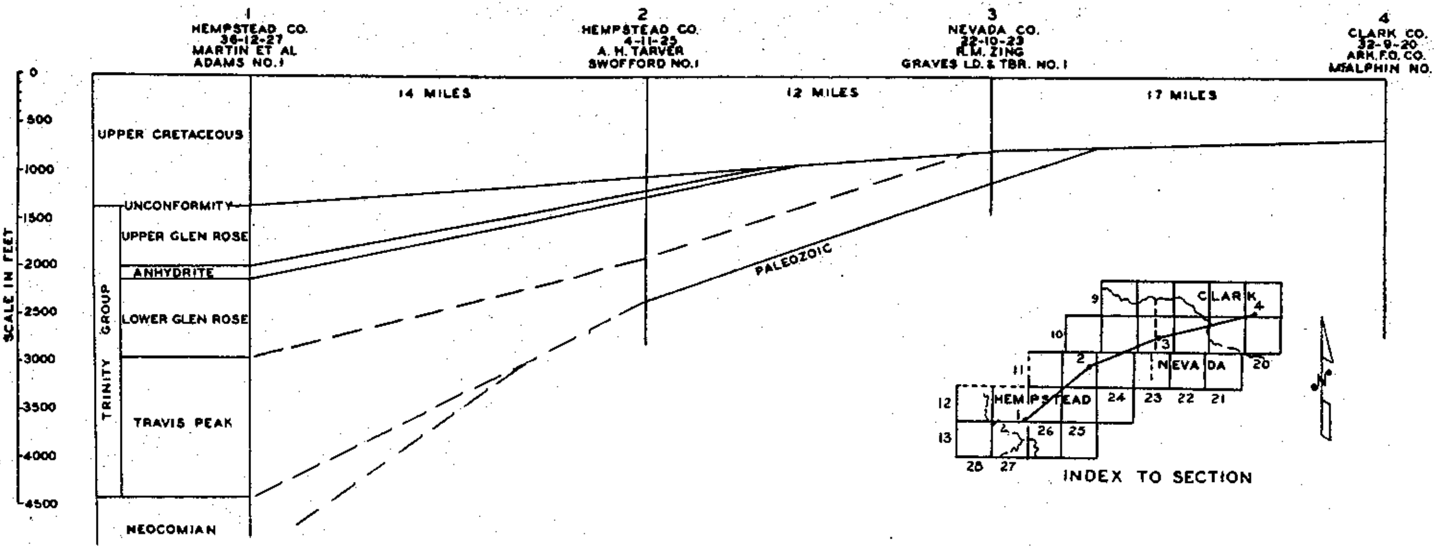

FIGURE 3.—Cross section from Clark County southwestward into Hempstead showing relationship of the basement floor to the Cretaceous.

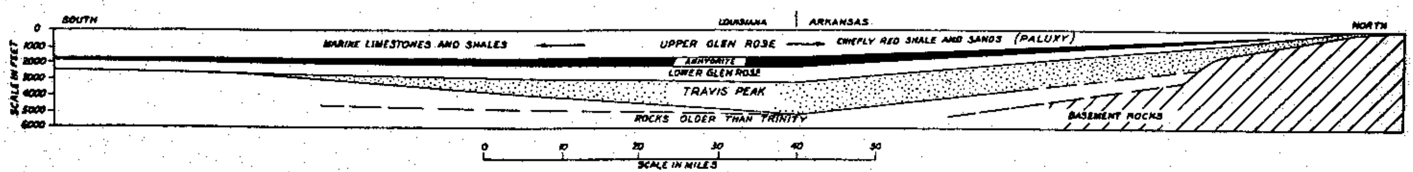

FIGURE 4.—Diagrammatic north-south section of the Trinity group through northwestern Louisiana and southwestern Arkansas.

In Arkansas deep wells in Ouachita and Union counties record more than 1,700 feet of beds without reaching the base of the series, which probably will maintain a thickness of about 2,000 feet northward of the line of flexing which extends from southern Little River County eastward almost to Hampton, Calhoun County, and thence southeastward into Louisiana.

AGE AND CORRELATION

Few fossils are present in the Travis Peak formation. Deep wells in the Pine Island field in Louisiana have recorded a few poorly preserved ostracods and shell fragments in the upper 200 feet of the formation, which appears to be transitional from the typical Travis Peak into the overlapping Glen Rose formation. Elsewhere, occasional fossils leave imprints, and wood fragments have been recorded at several horizons, notably in the lower part of the formation.

The records of deep wells drilled in northwestern Louisiana indicate that the base of the Travis Peak formation rests with apparent conformity on the Neocomian and at the top grades upward into the Glen Rose formation. The same relationship probably exists in the adjacent part of Arkansas; whereas farther to the north it overlaps the Neocomian to rest directly on the basement floor.

TYPICAL WELL SECTION

Typical well sections of the Travis Peak formation are given below. The section that follows, although from northwestern Louisiana, may be regarded as typical of this series in southwestern Arkansas.

Section of the Travis Peak formation in Dixie Oil Company's Dillon No. 92 well, sec. 13, T. 21 N., R. 15 W., Caddo Parish, Louisiana

Character	Depth in feet
Travis Peak formation:	
Red shale	3897–3900
Red shale, sandy shale, and fine-textured sandstone	3900–3937
Gray sandy shale	3937–3944
Hard, purplish-gray fine-grained sandstone and sandy shale	3944–3965
Gray, purplish-pink, and reddish-brown fine-grained sandstone; some siderite	3965–3999
Purplish sandy shale; siderite	3999–4002
Light-gray, fine-grained sandstone with thin laminae of shale, in part calcareous	4002–4004
Dark-gray lignitic sandy shale; fossil leaves	4004–4005
Medium-gray, fine-grained, hard sandstone	4005–4009
Gray calcareous sandy shale; few ostracods	4009–4011
Light-gray argillaceous limestone; fragments of shells	4011–4014
Mainly light-gray fine-grained sandstone, in part calcareous; streaks of pink and purple sandstone in lower part	4014–4035
Gray lignitic sandy shale with intercalated thin streaks of lignitic sandstone	4035–4038
Medium-gray lignitic sandstone; fossil leaves	4038–4042

Gray, purplish-brown fine-grained sandstone; some siderite; some thin beds of sandy shale, interbedded with the sandstone	4042–4114
Purple and gray mottled sandy clay	4114–4128
Brick-red clay	4128–4135
Purple clay	4135–4159
Pink, green, and brown fine-grained sandstone	4159–4181
Purple clays	4181–4201
Red and gray mottled fine-grained sandstone	4201–4206
Purple and sandy clays; fine-textured	4206–4225
Mottled green and red very fine-grained sandstone	4225–4227
Pale-green, purple, red and gray fine-grained sandstone; lignitic at the base	4227–4294
Hard dull purple clay	4294–4297
Mainly fine-grained gray, light-brown, and red sandstone, containing thin lenses of red clay; sandstone is in part lignitic	4297–4378
Gray conglomerate, consisting of fragments of calcareous shale in sandstone matrix	4378–4382
Gray, fine-grained sandstone; sparingly calcareous	4382–4410
Reddish-brown sandy shale	4410–4449
Light-brown sandstone	4449–4451
Hard sandstone	4451–4469
Lignitic sandstone	4469–4471
Red sandy shale	4471–4476
Maroon sandy shale	4476–4485
Pink, gray, and white sandstone with interbedded red and gray sandy shale	4485–4620
Purple fine-grained sandstone	4620–4646
Red and gray sandy shale and beds of fine-grained sandstone	4646–4748
Hard pink calcareous sandstone and argillaceous red sandstone	4748–4758
Maroon sandy shale and pink sandstone	4758–4770
Red and brown sandstone	4770–4772
Red sandy shale	4772–4782
Red shale	4782–4838
Red sandy shale	4838–4846
Red sandy shale	4846–4867
Gray cross-bedded sandstone	4867–4878
Maroon and light-gray fine-grained sandstone	4878–4893
Maroon sandy shale	4893–4912
Maroon and pale green mottled sandstone	4912–4937
Thinly laminated purplish sandstone and red sandy shale; in part micaceous	4937–4957
Brick-red sandy shale	4957–4976
Sandy shale	4976–4986
Pink coarse-grained sandstone	4986–5006
Purple sandy shale	5006–5016
Pink and purplish sandstone with some irregular streaks of shale; in part coarse-grained	5016–5170
Hard light-gray and white fine-grained sandstone	5170–5186
Dark-gray lignitic sandy shale	5186–5190
Pink coarse-grained sandstone	5190–5214
Purple shale	5214–5224
Light-pink sandstone	5224–5262
Hard sandy shale	5262–5276
Purple sandstone and shale	5276–5306

Yellow and gray mottled sandstone	5306–5318
Purplish sandy clay	5318–5336
Light-gray, pink, and purplish sandstone; small amount of shale, in part lignitic	5336–5425
Blue, gray, and red sand and sandy clay	5425–5598
Light-gray to white sand	5598–5634
Hard blue-gray and brown medium-textured sand, sandstone, and clayey sand; with thin beds of gray, blue, brown, and red sandy clay	5634–5960
Base of Travis Peak	5960

Section of Travis Peak formation in Grote et al, Arden No. 1 *well in sec.* 2, *T.* 13 *S., R.* 31 *W., Little River County, Arkansas*

Character	Depth in feet
Travis Peak formation:	
Sand (Cuttings from 2924-2928 feet consisted of light-brown medium-textured sand)	2928–2931
Sand (Cuttings of 2931-2948 feet consisted of light-brown fine to medium-textured sand)	2931–2942
Hard bluish-gray sand (Cuttings at 2954-2968 feet consisted of gray fine-textured sand)	2942–2964
Gray sand (Cuttings at 2968-2969 feet consisted of light-gray calcareous sand and gray lignitic sand and sandstone)	2964–2969
Hard lime (Core at 2969-2973 feet consisted of gray sand with small particles of red, brown, and gray shale)	2969–2973
Running sand	2973–2979
Hard lime (Core at 2979-2993 feet consisted of white fine-grained sand)	2979–2983
Hard sandy lime	2983–2993
Soft sand and lignite (Core at 3000 feet consisted of brown, red, and gray shale, particles of lignite, and cream-colored friable, fine-grained sandstone)	2993–3010
Hard sand	3010–3013
Soft gray sand (Core at 3018 feet consisted of light-gray sand)	3013–3035
Hard sandy lime	3035–3045
White sandy lime	3045–3060
Sand (Core at 3070 feet consisted of light-gray sand)	3060–3070
Hard sand	3070–3095
Light slate (Core at 3097 feet consisted of light-brown fine-grained sand and sandstone)	3095–3098
Sand, pyrite, and fossils (Core at 3123 feet consisted of fine-textured sand)	3098–3124
Hard sand	3124–3134
Red sandy shale (Core at 3134-3136 feet consisted of fine-textured sand)	3134–3136
Lime (Core at 3144 feet consisted of red and light-green shale; noncalcareous shale)	3136–3144
Sand (Core at 3160 feet consisted of light-brown, fine-grained sand)	3144–3166
Red shale (Core at 3172-3175 feet consisted of red, green, and light-gray shale and clay)	3166–3173
Hard lime	3173–3175
Red shale with streaks of hard lime	3175–3200
Hard sand	3200–3225
Very hard white sandy lime	3225–3240
Light sandy clay	3240–3242

Fine hard sand (Core at 3246 feet consisted of light-gray fine-grained sand)	3242–3272
Hard lime	3272–3273
Hard light-brown sand streaks and gravel (Core at 3280 feet consisted of brick-red sandy, slightly calcareous clay; core at 3300 feet consisted of red sand and clay; core at 3310 feet consisted of fragments of green and purplish claystone and brown fine-grained calcareous sandstone)	3273–3310
Light-brown sand (Core at 3310-3312 feet consisted of pink sand with particles of green and purplish clay; core at 3330-3345 feet consisted of light-tan fine-grained sand)	3310–3341
Very hard lime (Core at 3358 feet consisted of poorly sorted fine to coarse-textured sand and gravel, mainly quartz, but includes some fragments of black chert; core at 3359 feet consists of loose sand and broken fragments of light-gray chert)	3341–3363
Very hard sands and various colored gravels (Core at 3363 feet is light-brown fine-textured sand; core at 3368-3369 feet consists of fine-grained to coarse-grained sand and broken gravel, made up of light-gray chert and fine-grained black quartzite; core at 3379-3386 feet is same as above; core at 3400-3406 feet consists of fine, broken gravel and sand. Gravel consists of fragments of white, pink, and gray chert, some black quartzite and fragments of igneous rock)	3363–3406

Section of Travis Peak formation in Humble Oil and Refining Company's Hein No. 2 well, in sec. 1, T. 14 S., R. 21 W., Irma field, Nevada County, Arkansas

Character	Depth in feet
Travis Peak formation:	
Sandy shale and pyrite (Two cores from 3023-3031 feet consist of medium-gray hard lignitic shale and light-gray hard lignitic sandstone)	3023–3031
Sany limestone	3031–3040
Red shale (Two cores from 3044-3053 feet consist of dull-red, light-gray hard shale with spots of olive and dull, reddish-brown shale with spots of light-gray shale)	3040–3060
Gray sand and shale (Two cores from 3060-3064 feet consist of light-gray fine-textured shaly sandstone with irregular patches of slightly greenish shale)	3060–3065
Red shale (Core from 3064-3068 feet consists of dull reddish-brown slightly calcareous hard shale)	3065–3068
Sand and shale (Cores at 3084-3092 feet consist of light-gray slightly calcareous shale, dull reddish-brown, olive-brown hard noncalcareous shale, and olive-brown and light-gray mottled very slightly calcareous shale)	3068–3099
Sandy shale (Cores at 3111-3115 feet consist of dull, faint reddish-brown hard shale with streaks of grayish brown and spots of light-brown shale, bottom of core is light-gray sandy shale; core at 3121-3128 feet consist of light-gray sandy clay, spotted with fragments of lignite, hard medium-gray fine-grained slightly lignitic sandy clay, medium-gray and light-gray hard sandy clay, and friable sand with lignite and some pyrite)	3099–3128

Sand rock (Core at 3128-3129 feet consists of light greenish-gray calcareous fine-textured sandstone with inclusions of rounded fragments of limestone, green clay balls, rounded siderite, sandy clay balls, and some lignite)	3128–3129
Shale (Core at 3144-3148 feet consists of dark-maroon sandy clay with irregular partings of green sandy clay, hard green shale with thin seams of light-gray sand, and light-brown medium-textured, porous sandstone, with spots of pale-green clay)	3129–3147
Sand	3147–3148
Red sandy shale (Core at 3148-3150 feet consists of dark-maroon sandy clay, spotted with brown and green, sandy clay, round, indurated balls of sandy clay and sandstone)	3148–3150
Shale	3150–3154
Sandy shale, hard (Core at 3154-3156 feet consists of brownish-red, maroon, pink, and pale-green mottled cross-bedded fine-grained argillaceous sandstone and some fragments of chert)	3154–3155
Sandy shale	3155–3164
Red shale (Cores at 3164-3168 feet consist of hard dark-maroon, green, and brown clay with inclusions of ferruginous clay concretions and hard bluish-green fine-grained sandy clay, mottled maroon and red)	3164–3167
Gray sandy shale	3167–3183
Sand and lime	3183–3185
Sandy shale (Cores at 3185-3193 feet consist of black, red, maroon, and brownish-red mottled fine-grained slightly sandy clay; maroon, reddish-brown, and green mottled fine-grained, argillaceous sandstone; and light-greenish gray, fine-grained sandstone)	3185–3231
Gray sand and sandy shale (Cores at 3231-3237 feet consist of light greenish-gray fine-grained sandstone)	3231–3237
Sand and sandy shale	3237–3247
Sandy shale	3247–3267
Sandy limestone (Bit sample at 3273 feet consists of greenish-gray sandy clay with small, round rust spots)	3267–3273
Shale and lime (Cores at 3273-3277 feet consist of dark-red hard sandy shale with some purple spots and with some streaks of pale-green sandy shale)	3273–3330
Red sand	3330–3331
Red sandy shale	3331–3351
Sand, sandy shale, gray and red lime, and red shale (Core at 3351-3360 feet consists of pale red, faint purple and purplish-gray hard sandy shale; bottom of core is light-gray fine-textured sandstone)	3351–3360
Sticky red shale	3360–3393
Hard red shale	3393–3401
Hard red sandy shale (Core at 3408-3412 feet consists of dull reddish-brown calcareous hard shale, with streaks and spots of light-gray, clayey, very fine-grained sandstone	3401–3412
Red sandy shale	3412–3435
Red sandy shale and lime	3435–3470
Shale	3470–3522
Red shale (Core at 3523-3534 feet is same as above)	3522–3530
Sandy shale	3530–3545

Streaks of red shale and lime	3545–3573
Sandy shale	3573–3583
Hard red sand (Core at 3583-3584 feet is brown calcareous coarse-textured sandstone)	3583–3584
Hard sand	3584–3586
Hard red sand	3586–3609
Red sandy shale	3609–3619
Hard redsand	3619–3630
Hard sand	3630–3640
Shale	3640–3646
Sand and red shale	3646–3669
Red sandy shale	3669–3693
Hard red sand	3693–3711
Hard sand (Core at 3722-3723 feet is olive-brown hard shale; core at 3730 feet is light greenish-gray fine-textured sandstone)	3711–3736

Section of Travis Peak formation in Garrett-Modisette Drilling Company's Union Saw Mill Company No. 1 well, in sec. 7, T. 18 S., R. 13 W., Union County, Arkansas

Character	Depth in feet
Travis Peak formation:	
Chalky sand with brown streaks	3160–3163
Hard lime	3163–3190
Red and white gumbo	3190–3197
Red and white rock	3197–3200
Red gumbo	3200–3206
Hard lime	3206–3235
Hard, gummy lime	3235–3260
Gas sand	3260–3263
Sand	3263–3271
Gummy lime	3271–3283
Green lime	3283–3290
Sand	3290–3295
Gummy lime (Core from 3310-3312 feet is a pinkish, coarse-textured noncalcareous sandstone)	3295–3321
Green and red gummy lime	3321–3340
Hard lime	3340–3348
Gummy lime	3348–3354
Hard sand (salt water)	3354–3380
Red beds	3380–3420
Water sand	3420–3430
Red beds	3430–3450
Gray lime	3450–3460
Sand (salt water)	3460–3465
Gummy lime	3465–3470
Shale blue with red and white streaks	3470–3615
Sand with streaks of shale (salt water)	3615–3620
Conglomerate	3620–3630
Brown sand	3630–3642
Gummy lime	3642–3682
Brown and gray sand	3682–3689
Hard, gummy lime	3689–3694
Sand	3694–3706
Hard blue rock	3706–3710
White and red sand and shale	3710–3795

Hard sand	3795–3801
Gravel, sand, and lignite	3801–3806
Hard sand	3806–3858
Red beds	3858–3860
Sand (salt water)	3860–3904
Red sand and shale	3904–3915
Hard sand	3915–3955
Hard lime	3955–3965
Sand	3965–4070
Hard red and gray shale with streaks of sand	4070–4080
Hard sandy lime	4080–4160
Hard sandy shale	4160–4162
Hard blue shale with some streaks of sand	4162–4280
Sand with streaks of red shale	4280–4295
Red shale with streaks of blue shale	4295–4309
Total depth of well	4309

UPPER TRINITY SEDIMENTS

GENERAL STATEMENT

The Upper Trinity as herein defined includes the sediments which occupy the interval from the top of the Travis Peak formation to the base of the Fredericksburg group. These sediments are from 3,000 to 3,300 feet thick in the southwestern part of the state but decrease in thickness and change laterally in character to the north and east.

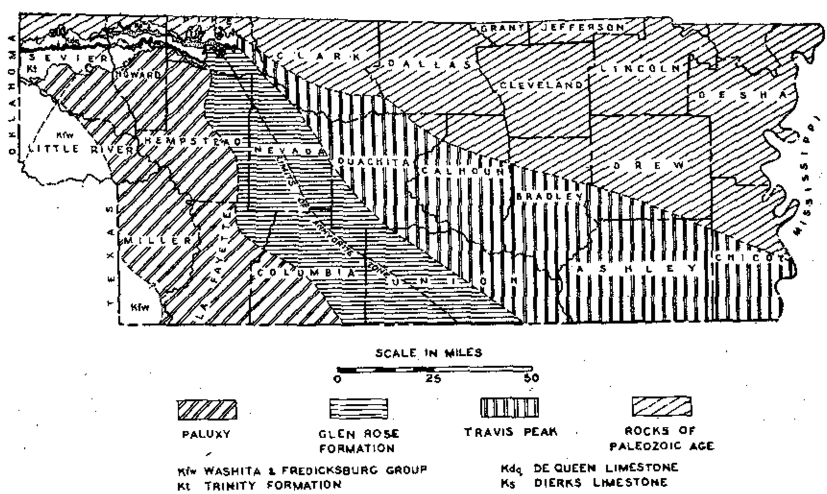

FIGURE 5.—Map of southern Arkansas showing approximate subsurface distribution of Comanche series (Lower Cretaceous).

Where typically developed in southwestern Arkansas and the adjacent parts of Louisiana and Texas, the Upper Trinity may be divided into four more or less well-defined members: Paluxy sand, dominantly sands and red shales; the Upper Glen Rose, dominantly marine limestone and shales; a zone of anhydrite with interbedded marine limestone and shales; and the lower Glen Rose, dominantly marine limestone and shales. On the whole the available records are inadequate for the purpose of sharply differentiating between the Upper Glen Rose and the overlapping Paluxy sands and clays.

CHARACTER AND DISTRIBUTION

The northern limit of the Glen Rose formation is defined by the outcrop of the DeQueen and Dierks limestone in Sevier, Howard, and Pike counties. The eastern limit is along a line drawn from the easternmost outcrop of the Dierks limestone in Pike County southeastward through the western part of the Smackover and East El Dorado fields and through central Union County into Louisiana. The subsurface distribution of the Trinity group is shown in Figure 5. The eastern limit of the Glen Rose formation was determined by a plane of erosion which truncated the Comanche strata from west to east. The original area of the Glen Rose deposition extended towards the east for some distance beyond its present limits.

LOWER GLEN ROSE

The Lower Glen Rose formation is most fully developed in the southwestern corner of the state, where it is 900 to 1,000 feet thick. The uppermost 100 to 150 feet of beds consist chiefly of light-colored, in part oolitic limestone, in which are included a few thin beds of gray shales. The remainder of the formation is made up of gray to green shales, and finely sandy shales, interbedded with gray argillaceous and earthy limestone. In general the shales and limestones alternate in thin beds, but more massive beds of shale and limestone from a few feet to 50 feet in thickness are present in the section. A considerable part of the shales and sandy shales are only sparingly calcareous or noncalcareous and in some places contain small amounts of lignitic material. The limestones at a few horizons are oolitic in structure.

The sharp contrast from dominantly silty material to the chemical precipitates which make up the greater part of the upper 100 to 125 feet of beds, indicates a distinct change in sedimentary environment, suggesting that these beds were formed in the cycle of precipitation in which the overlying anhydrite was formed. This belief is strengthened by the fact that they are best developed in the area wherein the anhydrite zone is from 400 to 600 feet thick.

Toward the north and east, the Glen Rose changes laterally in character, as indicated by the records of deep wells drilled in southern Little River, Howard, Nevada, and Union counties.

In southern Little River County, the Lower Glen Rose is 500 feet thick, made up principally of gray, blue, and green shales and finely sandy shales with some red shales in the middle and lower parts of the member. The shales, which are both calcareous and noncalcareous, are interbedded with generally fine-textured sandstone and subordinate thin beds of limestone.

In the Stephens and Irma fields the Lower Glen Rose formation is from 750 to 825 feet thick, composed chiefly of gray to green shales and finely sandy shales with some red shale in the upper and lower part, interbedded with calcareous, fine-textured sandstone, and arenaceous limestones. Limestone and fine lignitic material are present at a few horizons in the Irma field.

The Lower Glen Rose formation in western Union County contains a slightly greater amount of limestone than in the Stephens field, but is otherwise essentially similar in character. In northeastern Louisiana the Lower Glen Rose formation likewise changes in lithology, containing an increasingly greater amount of sands and red shales and less limestone and calcareous shales from west to east.

ANHYDRITE ZONE

The anhydrite zone of the Glen Rose formation is made up of thin-bedded and massive anhydrite, interbedded with marine limestones and shales, which attain a maximum thickness of somewhat more than 600 feet in southern Arkansas and the adjacent parts of Louisiana and Texas. The anhydrite zone diminishes both landward and basinward with the belt of maximum thickness parallel with the margin of the Trinity sedimentary basin as outlined in Figure 1. (See also Fig. 4.)

In Arkansas the anhydrite zone is represented in the outcrops of gypsum beds in Sevier, Howard, and Pike counties. In the eastern part of the state and in northeastern Louisiana, its eastern limits were determined by truncation. (See Pl. VI.)

The anhydrite members, white to dark-blue in color, occur in beds a few inches to 60 feet in thickness. They are interbedded with generally thin-bedded limestones, which are generally finely crystalline but in part earthy and oolitic, and thin-bedded, fairly massive shales. The limestones and shales are in part sparingly fossiliferous. Typical well sections of the anhydrite are given at the end of this section.

UPPER GLEN ROSE INCLUDING THE PALUXY SAND AT THE TOP

These members of the Trinity group include the strata above the top of the anhydrite zone and below the base of the Fredericksburg group. The Upper Glen Rose and the Paluxy sand doubtlessly present distinct formational units in Arkansas, but, owing to the paucity of accurate data from deep wells drilled through these sediments, it is impossible to separate accurately one from the other.

In Little River County the Grote et al Arden No. 1 well, sec. 2, T.13 S., R.31 W., records predominately red nonfossiliferous sediments from 1,360 to 2,180 feet below the surface, a thickness of 820 feet, which may be assigned to the Paluxy sand. In the same well, fossiliferous limestones and shales containing *Glauconia branneri* and *Orbitulina texana* were recorded from 2,180 to 2,410 feet below the surface. There, beds 230 feet thick are definitely of Glen Rose age.

South of Little River County the first records furnishing any considerable details of the Upper Trinity strata are in the Rodessa field, just south of the Arkansas line in Louisiana. In this area the upper 350 to 400 feet of sediments (see core record of Norton et al Hill No. 1 well in sec. 33, T.23 N., R.16 W., Caddo Parish, Louisiana, page 51) consists of predominantly red nonfossiliferous shales and sands, which may be assigned to the Paluxy sand. Between the Paluxy and the top of the anhydrite zone is 1,250 to 1,300 feet of sediment composed of gray shales and clays, fine-grained sandstones, and light-gray to buff sandy limestones and sandstones. In the upper part the clays and sandstones are in part lignitic, and maroon to brown shale and clays are interbedded with the non-red clays and sand throughout the section but are most prominent in the upper two-thirds. The contact between the Paluxy sand and the Upper Glen Rose is taken where the first fossils appear. The fauna in the upper part is represented by ostracods. *Orbitulina texana*, a characteristic Glen Rose fossil, first appears about 500 feet above the top of the anhydrite zone.

The subsurface distribution of the Upper Glen Rose, including the Paluxy sand, is shown in Figure 5.

In De Soto Parish, Louisiana, the Paluxy sand is absent and the entire section from the top of the anhydrite zone to the base of the Fredericksburg is represented by marine shales and limestones. To the east of the Sabine uplift in Bossier, Bienville, Webster, and Claiborne parishes, Louisiana, the Paluxy equivalent again appears in the section and continues eastward to the line where these sediments have been removed by truncation.

The Upper Glen Rose, including the Paluxy sand, is 1,000 to 1,100 feet thick in southern Little River County but diminishes rapidly in thickness northward to the outcrop in Sevier, Howard, and Pike counties. Along the Louisiana line in southwestern Arkansas and the adjacent part of Texas, these sediments are 1,700 to 1,800 feet thick and approximately 1,600 feet thick in DeSoto Parish, Louisiana.

THICKNESS OF THE GLEN ROSE

The maximum thickness of the Lower Glen Rose anhydrite zone and the Upper Glen Rose, including the Paluxy sand, is from 3,300 to 3,500 feet in the southwestern corner of the state;

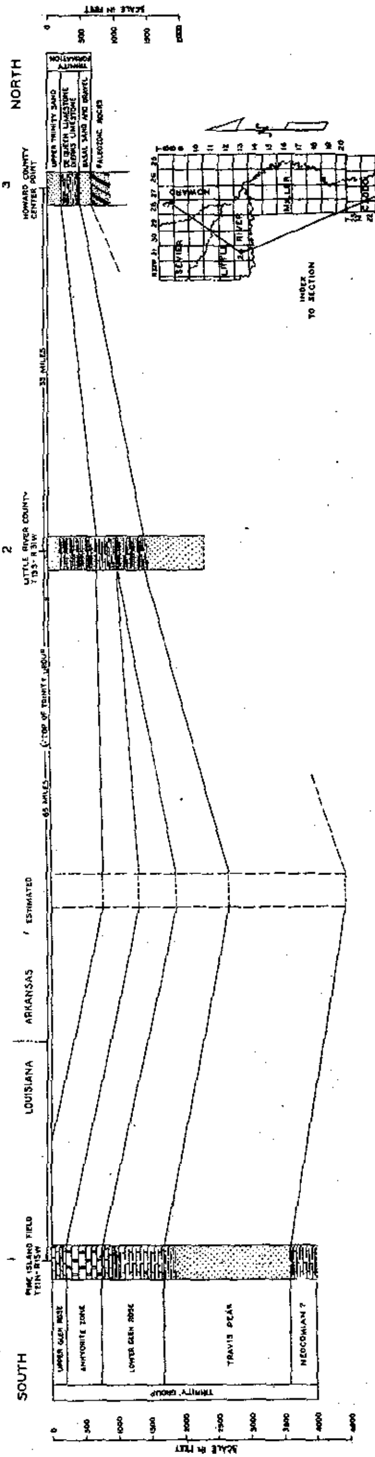

FIGURE 6.—Cross section from the Pine Island field, Louisiana, to Center Point, Arkansas, showing the Trinity group.

1,500 feet thick in Little River County; less than 600 feet thick at the outcrop in Howard County.

CORRELATION

The upper part of the Glen Rose formation contains *Glauconia branneri* and *Ostrea franklini* Coquand and other forms that are common in the DeQueen and Dierks limestones in southwestern Arkansas, which, according to Miser[8], are closely related to the fauna of the Glen Rose limestone of Texas. This relationship is further strengthened by the presence of *Orbitolina texana,* a large foraminifera characteristic of the Glen Rose in Texas.

TYPICAL WELL SECTIONS

Typical well sections of the Glen Rose formation are given in the following well records, and their stratigraphic relationship is also shown in Figures 4 and 6 and Plates V and VI.

Section Glen Rose formation Pine Island Field, Louisiana

Character	Thickness in feet
Upper Glen Rose:	
Gray calcareous shale	15
Gray argillaceous limestone	45
Gray calcareous shale and gray earthy limestone	45
Gray shale	30
Gray dominantly argillaceous limestone with thin streaks of gray shale	140
Gray shale	50
Gray limestone, in part argillaceous	80
Gray limestone with thin beds of shale	60
Anhydrite zone:	
Interbedded anhydrite and gray limestone	20
Massive white and bluish-gray anhydrite	40
Interbedded gray limestone and anhydrite	65
Massive white and bluish-gray anhydrite	45
Interbedded gray limestone and anhydrite	15
Massive white and blue anhydrite	55
Gray limestone and anhydrite	20
Massive anhydrite	50
Interbedded anhydrite and limestone	60
Massive white and bluish-gray anhydrite	100
Gray and dark-gray argillaceous limestone and shale	50
Anhydrite	10
Lower Glen Rose:	
Light-colored limestone, in part oolitic with a few thin beds of gray shale	145
Dark-gray noncalcareous shales and sandy shale	15
Gray and pale-green noncalcareous shale	50
Dark-gray, mainly noncalcareous shale with some thin beds of argillaceous limestone	120

[8] Miser, H. D., Lower Cretaceous (Comanche) rocks of southwestern Arkansas and southeastern Oklahoma: Petrol. Geol., Bull., vol. 11, no. 5, 1927.

Interbedded gray to dark-gray shale and limestone	30
Gray shale, sparingly calcareous	25
Gray limestone	5
Gray shale and thin-bedded limestone	25
Gray limestone	5
Dark-gray shale	10
Interbedded limestone and shale	20
Gray limestone	10
Interbedded gray dominantly noncalcareous shale and gray to dark-gray argillaceous limestone	115
Gray shale	25
Shale and limestone	10
Gray shale, in part calcareous, in part noncalcareous	20
Alternating thin beds of limestone and shale	80
Gray oolitic limestone	20
Alternating thin beds of gray shale and limestone	50
Gray and cream-colored limestone	50
Gray shale, in part noncalcareous, interbedded with gray argillaceous limestone	50
Gray oolitic limestone	10
Gray shale	10
Red and green shale	8
Sand	6
Gray calcareous, noncalcareous shale, and earthy limestone	50

Section of Glen Rose formation Norten et al Hill No. 1 well sec. 33, T. 23 N., R. 16 W., Caddo Parish, Louisiana

Character	Depth in feet
Paluxy and Upper Glen Rose:	
Red and yellow shale	3190–3197
Red shale	3197–3200
Red shale and boulders (Core 3200-3208 feet, red and gray mottled silty shale)	3200–3230
Red shale (Bit samples at 3250 feet show red and gray mottled shale)	3230–3253
Gumbo and shale	3253–3269
Red shale and gumbo	3269–3360
Hard shale	3360–3374
Hard sandstone	3374–3376
Black and red sandy shale with streaks of hard sandstone	3376–3381
Red sandy shale (Core 3376-3383 feet, rusty-red and gray mottled shale; thin red, brown, and gray sandstone lenses; medium-gray noncalcareous lignitic clay, and gray calcareous lignitics sandstone)	3381–3383
Hard shale, sandy shale with streaks of limestone	3383–3465
Broken lime with streaks of shale	3465–3490
Hard shale and lime rock	3490–3539
Hard lime rock	3539–3548
Lime and shale	3548–3550
Hard gray shale (Core 3550-3555 feet, medium-gray calcareous and noncalcareous shale. Ostracods)	3550–3558
Hard lime	3558–3577
Hard sand and lime	3577–3578
Lignite, shale with streaks of sand (Core 3577-3581 feet, gray noncalcareous laminated shale, fine gray lignitic micaceous shale, and gray sandstone)	3578–3582

Blue shale	3582–3587
Hard lime	3587–3609
Lime and shale	3609–3637
Hard lime	3637–3641
Sticky shale with streaks of lime	3641–3648
Shale	3648–3660
Hard lime	3660–3675
Sandy shale (Core 3683-3688 feet, brown gummy clay and medium to light-gray fine-grained micaceous lignitic sandstone)	3675–3688
Shale	3688–3690
Hard sand with streaks of shale	3690–3694
Sand (Core 3695-3701 feet, light-gray, calcareous sandstone)	3694–3701
Limestone and brown shale	3701–3702
Brown shale (Core 3701-3703 feet, gray finely crystalline limestone; core 3703-3711 feet, gray calcareous shale, red micaceous shale)	3702–3711
Gray shale and limestone (Core 3711-3716 feet, buff dense limestone and gray micaceous shale. Ostracods)	3711–3716
Brown mottled shale and sand (Core 3716-3722 feet, gray finely crystalline limestone with some brown shale. Ostracods)	3716–3722
Sandstone (Core 3722-3727 feet, medium-gray fine-grained thinly laminated cross-bedded sandstone and gray calcareous silty shale	3722–3727
Sandy shale	3727–3741
Blue and brown shale (Core 3741-3744 feet, dark brown and gray slightly calcareous, micaceous shale)	3741–3743
Streaks of sand and shale	3743–3783
No record	3783–3808
Streaks of sand, hard red shale and breaks of soft black shale (Core 3808-3812 feet, red and brown silty shale, with breaks of light-gray calcareous sandy limestone)	3808–3815
Sticky shale	3815–3820
Sandy lime and shale (Core 3820-3826 feet, light to medium-gray sandy limestone with small lenses of calcareous sandstone)	3820–3826
Sand (Core 3826-3827 feet, medium-gray calcareous thinly laminated fine-grained cross-bedded sandstone)	3826–3827
Blue sandy shale with streaks of hard sand	3827–3835
Sandy shales with streaks of lime (Core 3833-3838 feet, gray calcareous and noncalcareous silty shale with streaks of fine-grained calcareous sandstone)	3835–3840
Hard sandy lime shells and hard red sand (Core 3840-3842 feet, hard, light-gray limestone with shell fragments and purplish, sideritic sandstone)	3840–3842
Streaks of lime and red claystone (Core 3842-3854 feet, mottled gray and brown silty shale and argillaceous limestone)	3842–3854
Sandy limestone (Core 3854-3856 feet, alternating bands of medium-gray sandy limestone and light-gray to buff limestone)	3854–3856
Streaks shale, lime and red claystone	3856–3890
Red beds and sand	3890–3904
Sand streaks and sticky red clay (Core 3904-3916 feet, light-gray sandstone and maroon silty shale)	3904–3916

Red claystone streaks of sandy shale (Core 3916-3930 feet, red and brown mudstone with lenses of fine-grained sandstone and gray to buff arenaceous limestone)	3916–3930
Red sandy shale with streaks of blue shale (Core 3930-3945 feet, red and brown mudstone with lenses of fine-grained sandstone)	3930–3945
Hard fine sand rock	3945–3947
Hard gray shale (Core 3946-3949, medium-gray slightly calcareous mudstone with a few partings of fine-grained calcareous sandstone)	3947–3949
Red sandy shale (Core 3961-3974 feet, maroon silty shale and lenses of pink to brown calcareous, argillaceous sandstone)	3949–3975
Fine and coarse sand	3975–3977
Blue sandy lime and gumbo (Core 3973-3980 feet, same as core from 3961-3974 feet)	3977–3980
Gray shale and gumbo (Core 3980-3988 feet, gray mudstone with laminae of fine-grained calcareous sandstone)	3980–3998
Lime with streaks of sand (Core 3990-3998 feet, gray sandy limestone with some maroon shale)	3998–4008
Red gumbo	4008–4012
Sand	4012–4014
Blue shale	4014–4020
Red sandy shale streaks lime (Core 4022 feet gray, gritty sand; core 4022-4034 feet, red shale and sand)	4020–4065
Sticky shale with streaks of lime	4065–4105
Lime	4105–4107
Sandy lime with streaks of shale	4107–4122
Sandy shale with streaks of gumbo	4122–4142
Hard sand (Core 4141-4147 feet, red, angular sand; core 4151-4163 feet, medium-white, angular sand)	4142–4163
Sand	4163–4210
Gumbo	4210–4211
Red shale—streaks of gumbo (Core 4234-4242 feet, maroon calcareous claystone and red noncalcareous sandstone)	4211–4242
Gumbo	4242–4246
Hard sand	4246–4252
Red gumbo	4252–4254
Gumbo	4254–4260
Sand rock (Core 4260-4262 feet, medium-gray limestone)	4260–4262
Gumbo (Core 4265 feet, medium-brown, noncalcareous shale)	4262–4266
Hard and soft sand (Core 4265-4280 feet, light-gray calcareous sandstone with streaks of maroon claystone)	4266–4283
Shale and lime (Core 4283-4286 feet, medium-gray limestone, maroon clay and sand)	4283–4293
Sandy lime and shale (Core 4286-4295 feet, dark-gray noncalcareous silty shale with thin partings of calcareous and noncalcareous brown clay; core 4295-4307 feet, thinly laminated soft claystone and fine-grained sand)	4293–4309
Hard lime and sand	4309–4312
Red and blue sandy shale	4312–4314
Hard shale and gumbo	4314–4330
Hard sand (Core 4330-4332 feet, gray shale and fine-grained, angular sand)	4330–4332
Lime shells and shale (Core 4350-4352 feet, dark-gray noncalcareous, silty shale and light-gray to buff calcareous sandstone)	4332–4378

Shale (Core 4386-4392 feet, dark-gray calcareous mudstone, lenses of limestone, and light-gray limestone with irregular clayey veins; core 4392-4395 feet, medium-gray, marly limestone and dense light-gray limestone. *Orbitolina texana*	4378–4395
Hard lime	4395–4403
White fine-grained sandstone	4403–4405
Red gumbo	4405–4408
Gumbo	4408–4418
Sand and gumbo	4418–4423
Sand	4423–4438
Red shale	4438–4441
Lime and shale (Core 4468-4470 feet, gray, gritty sand)	4441–4490
Hard sandy lime (Core 4483-4494 feet, white medium-grained sandstone)	4490–4500
Lime and shale (Bit sample 45100 feet, dark-gray clay with fine sand)	4500–4537
Shale	4537–4538
Lime and shale (Core 4546-4555 feet, gray chalky limestone and gray shale)	4538–4557
Sandy shale	4557–4569
Pink lime with streaks of sand	4569–4571
Hard sandy lime	4571–4572
Pink lime streaks of sand	4572–4577
Gummy shale	4577–4578
Sand, lime, and red sandy shale	4578–4584
Lime and shale with streaks of sand (Core 4570-4588 feet, gray limestone with partings of dark-gray calcareous shale)	4584–4600
Lime and streaks of shale	4600–4608
Sandy shale, black and red shale (Core 4613-4620 feet, hard, white, sandstone and reddish-brown to maroon silty shale; core 4624-4626 feet, maroon sandy shale)	4608–4627
Sand and sandy shale	4627–4652
Sand	4652–4653
Lime and shale	4653–4661
Hard crystalline lime	4661–4672
Lime and shale (Core 4663-4682 feet, light-gray calcareous cross-bedded sandstone with laminae of light-gray limestone, reddish-brown mudstone; core 4682-4707 feet, light-gray, fine-grained sandstone with partings of dark-gray micaceous shale; core 4709-4723 feet, dark-gray noncalcareous brittle silty shale; reddish-brown clays and pale-brown sandy shale; core 4719 feet, medium-gray to buff limestone)	4672–4736
Brown shale and hard lime	4736–4739
Lime and shale (Core 4723-4731 feet, medium-gray calcareous shale with lenses of gray limestone; core 4741-4762 feet, gray limestone with thin partings of shale)	4739–4770
Lime and black shale	4770–4780
Lime and shale (Core 4762-4784 feet, medium-gray argillaceous limestone; core 4784-4794 feet, medium-gray noncalcareous, and red and brown calcareous grit; core 4819-4830 feet, gray noncalcareous shale, and light-gray cross-bedded sandstone)	4780–4820

Anhydrite zone:	
Anhydrite and shale	4820–4830
Anhydrite	4830–4837
Lime and anhydrite	4837–4846
Lime and black and gray shale	4846–4851
Black shale	4851–4853
Lime and shale	4853–4865
Lime and anhydrite	4865–4879
Lime and shale	4879–4881
Anhydrite and lime	4881–4883
Lime and hard shells	4883–4895
Anhydrite	4895–4909
Lime and anhydrite	4909–4933
Lime	4933–4939
Lime shells and shale (Core 4920-4938 feet, anhydrite, gray, finely crystalline limestone with black oolites; (core 4996-5017 feet, gray, finely crystalline limestone; core 5052-5062 feet, gray calcareous shale and gray limestone)	4939–5087
Anhydrite and lime	5087–5088
Lime, shale, and shells	5088–5091
Anhydrite	5091–5098
Anhydrite interbedded with limestone and shale (Core 5115 feet, gray finely crystalline limestone)	5098–5134
Anhydrite (Core 5120-5142 feet, gray, finely crystalline limestone)	5134–5152
Anhydrite, limestone, and shale (Core 5185-5207 feet, gray, finely crystalline limestone and anhydrite)	5152–5210
Shale and lime	5210–5220
Anhydrite (Core 5234-5237 feet, gray finely crystalline limestone with black oolites)	5220–5258
Anhydrite, lime, and shale	5258–5314
Lime and black shale (Core 5342-5357 feet, gray crystalline limestone with black oolites and anhydrite; core 5357-5371 feet, same as above)	5314–5404
Anhydrite limestone and shale	5404–5447
Lower Glen Rose:	
Lime rock	5447–5451
Lime and shale	5451–5480
Black shale and shells	5480–5485
Lime and shells	5485–5490
Limy shale, sandy shale, and sand	5490–5497
Sandy shale and sand	5497–5505
Sand (Core 5506, gray angular fine-textured lignitic sandstone)	5505–5506
Total depth of well	5506

Complete section of the Glen Rose made from deep wells in Webster and Claiborne parishes, Louisiana.

Character	Thickness in feet
Upper Glen Rose:	
Gray shale	60
Limestone	30
Gray argillaceous limestone and shale	280

Gray sandy shale	25
Gray shale	30
Gray limestone	70
Gray argillaceous limestone and shale	40
Gray limestone	50
Gray shale with thin streaks of limestone	30
Earthy limestone	60

Anhydrite zone:

Gray, white, and pink anhydrite	4
Dark-gray fissile fossiliferous shale	3
Gray calcareous shale	10
Gray limestone, containing shell fragments	2
Gray shale, slightly calcareous	12
White powdery calcium sulphate	2
Dark-gray shale	8
Dark-gray calcareous shale and gray earthy limestone	12
Light-gray fossiliferous limestone, interbedded with dark-gray shale	12
Dark-gray dense fossiliferous limestone	14
Dark-gray shale and gray limestone	25
Gray shale	23
Dark-gray shale and finely crystalline gray limestone; fossiliferous	18
Dark-gray earthy limestone	14
Black shale; slightly calcareous	10
Dark-gray argillaceous limestone	4
Black shale, interbedded with gray slightly sandy limestone	4
Dense white anhydrite, calcite filling along fracture planes	8
Interbedded anhydrite and fine-textured buff limestone	8
White and bluish-gray anhydrite	12
Limestone and anhydrite	6
Dark-gray earthy limestone	2
Light-blue and white anhydrite	4
Anhydrite with blobs and stringers of gray limestone	6
Anhydrite	5
Anhydrite, interbedded with black dense shaly limestone	5
White and bluish-gray anhydrite	18
Gray limestone with inclusions of anhydrite	6
Anhydrite	4
Dark bluish-gray, fine-textured limestone	4
Conglomerate of limestone and anhydrite	5
Anhydrite with thin stringers of gray limestone	24
White and blue anhydrite	53
Gray oolitic limestone	9
Anhydrite	3
Anhydrite with stringers of gray limestone ¼ to ¾ inches thick	4
Anhydrite	17
Gray to dark-gray limestone, in part oolitic with some thin stringers of dark-gray shale	42
Dark-gray shale	10
Gray oolitic limestone containing shell fragments	6
Interbedded gray shale and earthy limestone	16
White and blue anhydrite, interbedded with gray argillaceous limestone	11
Anhydrite	6
Interbedded anhydrite shale and limestone	12

Dark-gray finely crystalline limestone	6
Anhydrite	8
Lower Glen Rose:	
Gray finely crystalline limestone	12
Very fine-grained bluish-gray sand	16
Gray fossiliferous limestone	8
Gray very fine-grained sandstone	4
Brown and green mottled shale	3
Brown fine-grained sandstone	5
Brown, gray, and olive-green shale	35
Gray limestone; fossiliferous	11
Gray silty sandstone and shale	12
Gray fine-textured lignitic sandstone	10
Reddish-brown clay	5
Gray and light-gray fine-grained micaceous sandstone	6
Brown clay	8
Silty gray sandstone	6
Earthy and sandy gray limestone	8
Very fine-textured pale-green sandstone	2
Greenish-gray and green noncalcareous shale	9
Gray finely crystalline, and gray argillaceous limestone, in part oolitic	11
Gray, blue, and olive-green noncalcareous shale	21

Section Glen Rose formation, Humble Oil and Refining Company's Hein No. 2 well, in sec. 1, T. 14 S., R. 21 W., Nevada County, Arkansas

Character	Depth in feet
Lower Glen Rose:	
Sandy shale (Cores 2187-2194 feet, light greenish-gray calcareous fine-textured micaceous sandstone; green slightly pyritic shale with spots and lenses of light-brown sand; yellowish-brown and light-gray, calcareous sandy shale; and light brownish-gray medium to fine-grained friable sandstone with pockets of green shale)	2187–2230
Hard sandstone (Core 2230-2231 feet, hard light pinkish-gray calcareous medium-textured sandstone)	2230–2233
Sand and shale (Cores 2232-2236 feet, light-gray, calcareous, conglomerate, consisting of small gray shale and limestone pebbles; lumps of green shale and small patches of lignite; hard gray noncalcareous indurated pyritic shale with thin lenses of light-gray sand and hard medium-gray noncalcareous shale with thin lenses of lignite)	2233–2255
Sandstone	2255–2256
Broken sandy shale and limestone (Core 2256-2261 feet, hard green and rust-red noncalcareous very fine-textured sandstone with inclusions of sandy-limestone pebbles and small boulders)	2256–2279
Sand	2279–2280
Sand and shale (Cores 2280-2286 feet, light-brown noncalcareous medium-textured hard sandstone and light-green indurated arenaceous shale)	2280–2286
Sandy shale	2286–2304
Shale, sand, and limestone (Cores 2305-2308 feet, dull brown calcareous medium-textured friable sandstone and gray porous conglomerate, consisting of brown and gray	

limestone fragments; interbedded light-gray and light-brown sand, green shale balls, and lumps and veins of calcite and pyrite; all irregularly bedded in a gray shale matrix)	2304–2312
Sandy shale	2312–2321
Sand (Cores 2322-2325 feet, green, rusty-red and gray mottled sandy shale and brown medium-textured noncalcareous sandstone)	2321–2325
Sandy shale (Cores 2340-2346 feet, conglomerate made up of small dark-gray, light-brown and gray, well-rounded limestone boulders in a hard light-brown calcareous, sandstone matrix; greenish-gray noncalcareous very fine-grained clayey sandstone; hard light-green, purplish-red, and yellowish-brown mottled finely arenaceous, noncalcareous clay; and hard purplish-red finely arenaceous clay with mottlings of light-green and brown; cores 2346-2354 feet, light-brown medium-grained hard sandstone and light-tan noncalcareous sandstone)	2325–2376
Red shale (Cores 2370-2380 feet, clay conglomerate with lenses of light-green and rusty-brown clay; conglomerate, made up of lumps of indurated slightly siliceous red, green, and yellow clay, lumps of dolomite, and clay ironstone concretions in mottled clay matrix)	2376–2401
Sand (Cores 2402-2410 feet, light greenish-gray calcareous, sandy clay with small patches of light-brown fine-grained sandstone; and light-tan calcareous and noncalcareous fine-textured sandstone with thin lenses of green shale)	2401–2403
Sandy shale	2403–2427
Sand	2427–2428
Red shale and sand (Core 2428-2435 feet, rusty-brown and light-green noncalcareous, sandy clay)	2428–2435
Red shale	2435–2449
Red and gray shale and sand (Cores 2449-2450 feet, yellowish-brown, medium-brown, light-green, and rusty-red, mottled noncalcareous sandy shale; core 2451-2452 feet, like above; some fine sand present)	2449–2452
Red shale (Cores 2478-2482 feet. red, green, and light-brown mottled noncalcareous, slightly sandy clay; cores 2482-2486 feet, light-green noncalcareous, slightly sandy clay and variegated dark rusty-red and light-green shale; core 2498-2500 feet, reddish-brown shale with irregular patches of green shale)	2452–2500
Broken sand and shale (Cores 2500-2506 feet, green and rusty-red shale, containing small amount of fine sand and some siderite; core 2520-2522 feet, hard green noncalcareous shale which breaks with a conchoidal fracture; core 2522-2526 feet, rusty-red and green noncalcareous shale in which a small amount of fine sand is present)	2500–2552
Shale and shells (Core 2562-2568 feet, gray calcareous, arenaceous shale and oyster shells present; hard light-green noncalcareous shale and some fine sand present; core 2568-2570 feet, brownish-red arenaceous shale with blotches of green shale)	2552–2570

Red shale (Cores 2593-2599 feet, green and reddish-brown noncalcareous shale with some fine sand present; core 2599-2601 feet, hard light-green arenaceous shale; Ostracods)	2570–2643
Hard sand (Core 2643-2645 feet, gray, slightly calcareous sandy shale with small specks of lignite)	2643–2645
Sandy shale (Core 2645-2650 feet is like core from 2643-2645 feet; Chara seeds and Ostracods)	2645–2650
Shale	2650–2657
Sandy shale and shells (Cores 2657-2663 feet, gray, green, and brown shale and sandy shale; part calcareous and part noncalcareous, sparingly lignitic; contains Ostracods and limestone breccia in a light-gray calcareous sandstone matrix)	2657–2663
Shale	2663–2673
Sand and shale (Cores 2673-2677 feet, medium-gray calcareous fine-textured slightly argillaceous and fossiliferous sandstone; shell fragments and Ostracods; hard green and gray calcareous shale with Ostracods and shell fragments)	2673–2677
Sandy shale (Cores 2677-2683 feet, gray and green calcareous shale and fine-grained sandstone; Chara seeds, Ostracods, and oyster shell fragments)	2677–2683
Shale (Core 2695-2698 feet, medium-gray, slightly calcareous shale with pockets of sand; brown and gray shale and light bluish-gray fine-grained sandy shale)	2683–2698
Sandy shale	2698–2703
Shale and lime (Cores 2703-2707 feet, shell fragments in gray sandy limestone matrix [Ostracods]; and light-gray calcareous fine-grained sandy limestone with lenses of gray shale [Ostracods])	2703–2707
Limestone	2707–2727
Broken sand, sandy lime, and shale (Cores 2727-2735 feet, hard cross-bedded greenish-gray micaceous fine-grained standstone; hard bluish-gray noncalcareous slightly micaceous, sandy shale; hard medium-gray noncalcareous shale and hard brownish-gray fossiliferous limestone)	2727–2735
Shale and sandy lime (Core 2761-2769 feet, hard greenish-gray calcareous fine-grained argillaceous and sparingly fossiliferous sandstone; shell fragments and Ostracods)	2735–2798
Broken lime	2798–2818
Broken lime and sandy shale	2818–2839
Broken lime (Core 2926-2930 feet, light greenish-gray slightly calcareous very fine-textured sandstone; Ostracods)	2839–2944
Sandy shale	2944–2946
Red and blue shale (Core 2944-2948 feet, top—light-gray hard very fine-grained noncalcareous sandstone with thin streaks of gray shale; middle part of core—light-gray noncalcareous shale with streaks of very fine silty sand; bottom of core—same as upper part)	2946–2960
Lime	2960–2962
Hard sandy lime	2962–2974
Broken lime	2974–3023

Section of Glen Rose formation in Calgo Oil Company's Primm No. 1 well in sec. 9 T. 18 S., R. 17 W., Union County, Arkansas

Character	Depth in feet
Glen Rose formation:	
Hard lime (Core 3353-3356 feet, dark-gray to nearly black calcareous, fine silty clay, containing some fragments of megascopic fossils)	3353–3359
Black shale streaked with sand (salt water)	3359–3363
Hard sandy lime (Core 3363-3365 feet, hard fine-grained sandstone, containing shell fragments)	3363–3365
Hard sandy lime and black shale	3365–3369
Lime and gyp (Core 3369-3373 feet, reported to be brown shale)	3369–3373
Hard sandy lime	3373–3378
Hard red finely sandy shale	3378–3382
Sand	3382–3399
Soft sandy lime	3399–3408
Soft water sand	3408–3415
Red gumbo and shells	3415–3447
Sand and shale	3447–3458
Shale and gumbo	3458–3476
Shale and sand	3476–3479
Red shale and gumbo	3479–3496
Shale and gumbo	3496–3614
Hard sandy shale and shells (Core 3615-3617 feet, light greenish-gray and olive-green hard dense fossiliferous limestone, with abundant shell fragments; lower part of core is greenish-gray sandy shale. Ostracods)	3614–3617
Gumbo	3617–3634
Sandy shale and shells (Core 3634-3635 feet, dark-gray shaly and fine sandy, calcareous shale; and light-gray hard finely sandy limestone; some carbonaceous material and shell fragments)	3634–3636
Hard sandy lime	3636–3643
Hard and gummy shale (Core 3645-3646 feet, light greenish-gray hard fossiliferous shale; in part finely sandy, contains shell fragments, cast of small pelecypods and Ostracods)	3646–3650
Hard sand (Core 3650-3651 feet, light-gray and greenish-gray fine-textured sandstone)	3650–3651
Red shale (Core 3652-3653 feet, red conglomeratic clay, containing numerous pebbles of hard greenish calcareous shale up to an inch in length)	3651–3657
Hard sandy shale	3657–3661
Hard sandy lime (Core 3661-3662 feet, light-gray hard massive fine-textured sandy limestone with many minute cavities formed by removal of fine shell fragments)	3661–3664
Shale	3664–3672
Hard sand (Core 3675-3679 feet, top is light-gray hard fine-textured sandstone, slightly calcareous; bottom of core soft very finely laminated earthy chalk, alternating with white, nearly pure chalk and gray argillaceous fine sandy, chalky limestone; core 3679-3687 feet, white fine-textured slightly calcareous sandstone with a few fine streaks of lignite)	3672–3712
Hard gummy shale	3712–3726

Sandy lime and lime (Core 3726-3728 feet, dark-gray very fine sandy and argillaceous limestone)	3726–3731
Hard gummy shale	3731–3739
Lime	3739–3742
Hard black shale (Core 3740-3745 feet, top of core is light-gray, dense, finely crystalline limestone composed in large part of shell fragments. Bottom of core light-greenish-gray, calcareous clay)	3742–3747
Hard lime (Core 3760-3764 feet, greenish-gray hard silty calcareous shale, containing shell fragments; hard gray limestone, composed chiefly of shell fragments and dark-gray noncalcareous shale)	3747–3764
Shale (Core 3764-3766 feet, dark-gray hard slightly calcareous shale, containing numerous casts of small pelecypods)	3764–3768
Sandy lime and lime	3768–3779
Black shale (Core 3777-3782 feet, greenish-gray hard slightly calcareous shale, light-gray hard shell limestone, and dark-gray noncalcareous shale)	3779–3782
Shale (Core 3782-3786 feet, light greenish-gray fine-textured sandstone with thin lenses of greenish-gray clay)	3782–3788
Broken lime (Core 3788 feet, greenish-gray and black shale, containing a few casts of pelecypods)	3788–3795
Shale (Core 3802 feet, black very fossiliferous shale, containing abundant *Glauconia branneri* Hill)	3795–3818
Lime	3818–3821
Shale	3821–3826
Lime (Core 3843-3844 feet, light-gray and slightly greenish earthy limestone and some brown clay)	3826–3844
Shale (Core 3845-3846 feet, light-gray and greenish-gray slightly arenaceous limestone; contains a few shell fragments and some imperfect fossil casts)	3844–3847
Shale (Bit sample 3852 feet, brown clay)	3847–3873
Sand (Core 3875-3878 feet, light greenish-gray, in part laminated sandstone; the sand is in part argillaceous and slightly micaceous; core 3878-3879 feet, white fine-textured unconsolidated sand)	3873–3897
Hard shale	3897–3925
Sandy lime and lime (Core 3925 feet, light-brown calcareous clay; core 3928 sand as above, but harder and contains cast of pelecypods and small foraminifera; core 3932-3934 feet, at top is black argillaceous fossiliferous, shaly limestone; bottom of core is gray hard massive argillaceous limestone)	3925–3936
Shale and lime	3936–3967
Sandy shale	3967–3975
Gummy lime	3975–3985
Limy sand, thin streaks of red shale	3985–3989
Sand and shale (Core 3989-3990 feet, light-gray hard fine-textured sandstone, cemented with calcite and some dark gray, slightly calcareous shale)	3989–3995
Black shale (Core 3991-3998 feet, top of core gray massive fine-textured argillaceous sandstone which contains considerable carbonaceous materials, middle part of core same as top; bottom of core is brownish slightly mottled with green fine sandy, noncalcareous shale)	3995–4000
Lime and sandy lime	4000–4006

Black shale and lime (Core 4006-4011 feet, gray slightly calcareous, very fine sandy shale with some thin layers of sandstone)	4006–4024
Hard brown rock (Core 4024-4025 feet, dark-red massive fine-textured sandstone with irregular patches of white sand)	4024–4027
Shale and lime	4027–4033
Sandy chalk (Core 4033-4036 feet, light-green massive very fine-textured sandstone with irregular patches of red; lower three inches of core is red shale)	4033–4036
Shale and lime	4036–4048
Hard sandy lime (Core 4051-4057 feet, top part of core is brownish-gray coarse-textured shell limestone and hard gray calcareous shale; middle part of core gray fine-textured argillaceous sandstone; bottom of core is light-gray fine-textured calcareous sandstone, slightly carbonaceous)	4048–4058
Shale	4058–4065

WASHITA AND FREDERICKSBURG GROUPS

The Washita and Fredericksburg groups are represented at the outcrop in southwestern Arkansas by a few feet of the Kiamichi clay and the Goodland limestone. These groups have been recognized in only a few wells drilled along the western border of the state. The Grote et al Arden No. 1 well in sec. 2, T.13 S., R.31 W., Little River County, records limestones and shales from 1,256 to 1,358 feet, which have been assigned to the Washita and Fredericksburg groups. The Magnolia Petroleum Company's Westmoreland No. 1 well in sec. 9, T.19 S., R.27 W., Miller County, records limestone from 3,765 to 3,852 feet which belongs to the Washita or the Fredericksburg groups. The Norton et al Hill No. 1 well in sec. 33, T.23 N., R.16 W., Caddo Parish, Louisiana, about 5 miles south of the state line, penetrated 235 feet of limestone and shales of Washita and Fredericksburg age. The total thickness of the combined Washita and Fredericksburg sediments may total 500 feet or more in the southwestern corner of Arkansas. The probable subsurface distribution of the Washita and Fredericksburg groups in Arkansas is shown in Figure 5.

The following section gives the character of these rocks in southwestern Arkansas.

Section of Washita and Fredericksburg groups in Norton et al Hill No. 1 well, sec. 33, T. 23 N., R. 16 W., Caddo Parish, Louisiana

Character	Depth in feet
Washita and Fredericksburg undifferentiated:	
Hard lime	2954–2971
Shale and lime	2971–2977
Lime rock	2977–3018
Broken formation	3018–3028
Hard lime (Core 3028-3030 feet, gray chalky limestone)	3028–3030
Hard sandy shale	3030–3045
Shale and lime (Core 3045-3052 feet, gray marly limestone)	3045–3053

Limestone (Core 3097-3100 feet, drab coarsely crystalline arenaceous limestone)	3053–3120
Sandy lime	3120–3134
Lime	3134–3175
Soft formation	3175–3176
Sandy shale with streaks of lime and shale (Core 3174-3180 feet, buff coarse limestone)	3176–3190

GULF SERIES (UPPER CRETACEOUS)

GENERAL STATEMENT

The Gulf series (Upper Cretaceous) consists of a series of clays, marls, shales, chalks, limestones, and sands, with some volcanic materials, which are most abundant in the basal beds. These strata, which crop out in a narrow generally east-west belt through Little River, Sevier, Howard, Hempstead, Nevada, and Pike counties in southwestern Arkansas, have been mapped and described in detail by Dane[9] whose work forms the basis for the correlation of the subsurface extension of these strata described in this report. The series attains a thickness of more than 2,000 feet in southwestern Arkansas, but in the southeastern part of the state the thickness is less than 200 feet.

GENERAL GEOLOGY

The geologic events immediately preceding the Upper Cretaceous, which culminated in the uplift of the Comanche strata and peneplanation of this region have been described on page 20. The Upper Cretaceous, although a period of regional downwarping and deposition, was characterized by mild differential warping of the sea floor upon which the sediments accumulated; this resulted in a variety of sedimentary environmental conditions and consequent variations in the lithology and thickness of the several formations which make up the Gulf series (Upper Cretaceous). The warping was persistently upward in northern Louisiana and southern Arkansas as contrasted with east Texas, where it was persistently downward. The sedimentation, except for minor breaks, was continuous throughout the Upper Cretaceous epoch.

The differential warping was most pronounced in a generally northwest-southeast trending belt through southeastern Arkansas and continued in the same direction through northeastern Louisiana and the adjacent part of Mississippi. The western margin of this belt of differential warping coincides rather closely with a line drawn along the west side of the Richland and Monroe fields in Louisiana, thence northwestward through the western part of the El Dorado and Smackover field. To the east of this line is a marked thinning and lateral change in the

[9] Dane, C. H., Upper Cretaceous formations of southwestern Arkansas: Arkansas Geol. Survey, Bull., no. 2, 1929.

character of the sediments as contrasted with the sediments in the area to the west. The differential warping was of sufficient magnitude to prevent the accumulation of a considerable part of the Gulf series.

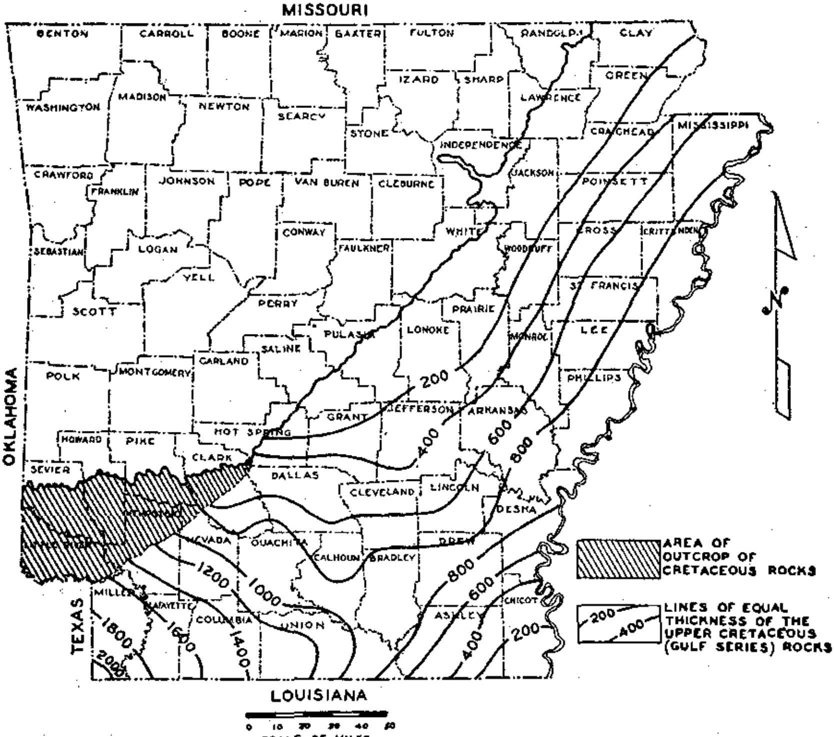

FIGURE 7.—Isopach map showing the thickness of the Upper Cretaceous sediments in Arkansas. Isopachs drawn at intervals of 200 feet.

THICKNESS OF THE GULF SERIES (UPPER CRETACEOUS)

The thickness of the Upper Cretaceous sediments in Arkansas is shown in Figure 7 by isopach (lines of equal thickness) drawn at intervals of 200 feet. These sediments attain their fullest development in southwestern Arkansas, where they are slightly more than 2,000 feet thick; they gradually diminish in thickness eastward to 1,000 feet along a line drawn from northern Nevada County and eastern Union County. In the northeastern part of the state they gradually increase in thickness from the Gulf Coastal Plain border towards Mississippi River attaining a thickness of somewhat more than 800 feet along the Arkansas-Mississippi line. In Bradley, Drew, Ashley, and Chicot counties their thickness ranges from less than 200 feet to about 800 feet with the least thickness in the southeastern corner of the state. The area of thin Upper Cretaceous sediments continues southward into Louisiana and Mississippi.

SEDIMENTARY PROVINCES

The Upper Cretaceous sediments of Arkansas were deposited in three sedimentary provinces, which, although they merge, may be broadly delineated in areal extent. The first embraces southwestern Arkansas, an area wherein the sediments have the same general characteristics as the equivalent sediments in east Texas. The second includes the marginal beds, characterized by progressive overlap and thinning of the strata towards the margin of the Coastal Plain. The third embraces southeastern Arkansas, an area that falls within the sphere of influence of the Monroe uplift, wherein the sediments depart widely in lithology, thickness, and stratigraphic relationship from those in southwestern Arkansas. This province presents many problems in correlation and sedimentation which will be discussed briefly in the following paragraphs.

CORRELATION AND STRATIGRAPHIC RELATIONSHIP OF THE UPPER CRETACEOUS IN SOUTHEATERN ARKANSAS

The stratigraphic relationship of the Upper Cretaceous formations in southeastern Arkansas is graphically shown in the several cross sections accompanying this report, especially Plates V, VII, VIII, IX, and X, and Figure 12.

The Tokio-Woodbine section diminishes in thickness from west to east; the Tokio formation, which in the western part is a fairly distinct lithological unit, becomes increasingly sandy and contains more volcanic material. The red beds at the base of the Upper Cretaceous attain their maximum thickness in Union and Ashley counties. The Tokio-Woodbine section is overlapped by the Marlbrook marl in the eastern parts of Drew and Ashley counties. The Brownstown marl also becomes increasingly sandy from west to east, lenses out, and is overlapped by the Ozan formation. The Ozan formation lenses out in southeastern Union, southeastern Bradley, northeastern Calhoun, and southwestern Dallas counties. To the south and east of these areas it is overlapped by the Marlbrook marl. The Marlbrook marl is present throughout most of southern Arkansas, except in parts of Chicot and Ashley counties, where it is overlapped by the Monroe gas rock of Navarro age. The Nacatoch sand changes laterally in character to the southeast; this change is evidenced by a decrease in the sand content and interfingering with limestones and chalk which, together with the Saratoga chalk, is included in the Monroe gas rock, typically developed in the Monroe gas field, Louisiana. The Arkadelphia marl, uppermost Cretaceous, is absent in the southeastern part of the state, where the Midway of Eocene age lies directly on the Monroe gas rock.

Objections to the interpretation given in the foregoing paragraphs may be made. For instance, it can be argued with considerable weight that the entire section which includes a part of the Marlbrook marl, the Ozan formation, Brownstown marl, and a part of the Tokio formation represents the attenuated equivalents of these formations farther to the west and that the changes in lithology and thickness are gradual, lateral changes, resulting from environmental conditions controlled by warping of the sea floor contemporaneous with sedimentation. It is difficult to marshal valid evidence contrary to such an interpretation of the sedimentary history of this region.

Another possible interpretation postulates alternations of sedimentation with emergence and erosion, but such an interpretation fails to explain satisfactorily the lateral changes in lithology and thickness of the sediments in southeastern Arkansas.

UPPER CRETACEOUS DEPOSITION

CORRELATION OF UPPER CRETACEOUS ROCKS BELOW THE BROWNSTOWN MARL IN SOUTHWESTERN ARKANSAS

The uplift at the close of the Comanche epoch was followed by an interval of erosion in which the uplifted and tilted Comanche strata were truncated, and the terrain was reduced to a peneplain over which the Upper Cretaceous sea transgressed Arkansas from the west and the south. The dating of the transgression hinges upon the age determination of the basal formations, inclusive of the Woodbine sand and the Tokio formation, as mapped and defined at their outcrops in southwestern Arkansas by Dane[10]. These formations were formerly included in the Bingen sand, as defined by Veatch[11]. The Woodbine sand, as redefined by Dane, is composed of tuffaceous sands, gravels, volcanic tuffs, and clays, which, at the outcrop in southwestern Arkansas, are separated by a bed of conglomerate made up principally of novaculite pebbles from the overlying Tokio formation, which also contains volcanic tuff in the lower part. Ross, Miser, and Stephenson[12] correlated the Woodbine in southwestern Arkansas, as defined by Dane, with the upper Woodbine sand of Texas. In the eastern part of the area of exposure, the overlying Tokio formation, formerly the upper part of the Bingen sand, is composed principally of sands which intertongue with marine clays toward the west. The Tokio formation is correlated with the Bonham clay (Upper Austin of Texas) by Steph-

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[10] Dane, C. H., op. cit.

[11] 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.

[12] Ross, C. S., Miser, H. D., and Stephenson, L. W. Water-laid volcanic rocks of early Upper Cretaceous age in southwestern Arkansas, southeastern Oklahoma, and northeastern Texas; U. S. Geol. Survey Prof. Paper 154-F, pp. 175-202, 1929.

enson[13]. According to the above interpretation of the stratigraphy, the Eagle Ford must be represented in Arkansas by an hiatus between the Woodbine, as defined by Dane, and the Tokio.

THE SUBSURFACE DEVELOPMENT OF THE UPPER CRETACEOUS ROCKS BELOW THE BROWNSTOWN MARL

The underground extension of Dane's Woodbine and Tokio section is known from a great number of deep wells drilled in southern Arkansas and northern Louisiana. These wells have furnished much data concerning the distribution, lithology, and geologic history of these sediments. The evidence available from this source does not permit a definite separation of these sediments in conformity with the usage of Dane, but strongly suggests a single stratigraphic unit in which the lateral changes in lithology were determined by the source of the sedimentary materials and by the environmental conditions under which they accumulated. The principal factors in determining the character of this single stratigraphic unit are thought to be the relationship of the sediments to the shore line, to areas of differential warping of the sea floor, and to the source of volcanic rocks.

The lithologic changes in the Upper Cretaceous sediments below the Brownstown marl from west to east naturally divide the area in which these sediments are present into southwestern and southeastern facies. The areas of the facies are here considered as depositional provinces. The southwestern province may be taken to include Little River, Hempstead, Lafayette, and Miller counties, Arkansas, and parts of the adjoining counties to the east. In these counties of Arkansas, Dane's Woodbine-Tokio section is divisible into three more or less distinct lithologic units which are gradational one into the other. The upper unit, which lies immediately below the Brownstown marl, is a sandy zone ranging from a few feet to nearly 100 feet in thickness, containing lignitic sands and clays and locally tuffaceous sands and gravels; the latter is lithologically similar to Dane's Woodbine in Howard and Pike counties. The upper unit is traceable in deep well records into the Blossom sand of northeastern Texas. The intermediate unit consists of gray clays and yellow to gray sands, which contain bentonite and bentonitic clays. The sand members decrease in thickness toward the west and southwest and intertongue with marine clays and shales which are in part fossiliferous and contain a marine invertebrate fauna assigned to the Austin of Texas. The lower unit is composed, for the most part, of mealy and ashy white sands and greenish-gray tuffaceous sands with some interbedded nonfossiliferous clays. Locally this unit contains thin beds and lenses of gravel; red clays are present in the basal part. This unit thins toward the

[13] Stephenson, L. W. Notes on the stratigraphy of the Upper Cretaceous formations of Texas and Arkansas: Am. Assoc. Petrol. Geol. Bull., vol. 11, 1927.

west and southwest from the outcrop in Sevier, Howard, and Pike counties with a marked decrease in the amount of volcanic material and gravel. It is apparently continuous with Dane's Woodbine sand in Howard and Pike counties, and in the subsurface extension bears the same unconformable relationship to the underlying Comanche rocks.

The Upper Cretaceous beds below the Brownstown marl in southeastern Arkansas are divisible on the basis of color changes in the sediments into upper non-red and lower red members.

The upper non-red member, composed of light-colored sands with subordinate beds of clays and shales and containing varying amounts of volcanic material, decreases in thickness from west to east. (See Fig. 8.) The lower red member, composed of

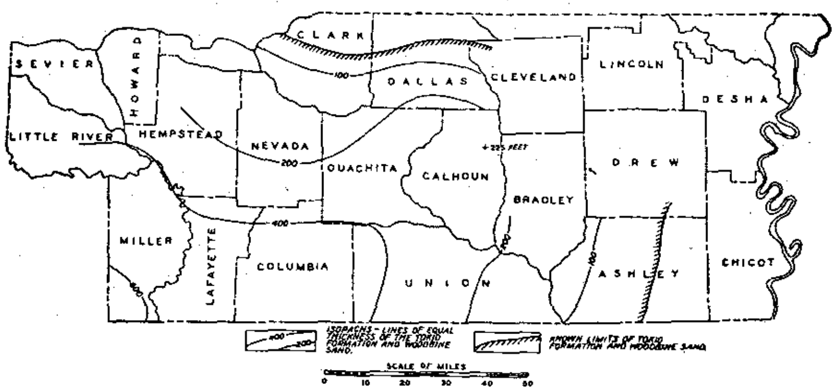

FIGURE 8.—Subsurface distribution of the Woodbine sand and Tokio formation. Contour lines show thickness of strata.

red clays interbedded with gray clays, sands, and bentomitic clays increase in thickness toward the east and southeast, attaining its fullest development on the flanks of the Monroe uplift in Ashley and Union counties where the maximum thickness is 300 feet. Over most of this area the upper and lower members merge laterally one into the other by interfingering of red and non-red sediments, but in parts of Union and Ashley counties they are separated by a disconformity. The disconformity is well illustrated in the deep wells in the Rainbow City district where the basal beds of the upper member, composed of sand containing lignite and gravel, lie on an irregular surface of the Upper Cretaceous red beds. This disconformable relationship is thought to be the result of differential warping in the area of the Monroe uplift.

UPPER CRETACEOUS ROCKS BELOW BROWNSTOWN MARL IN NORTHWESTERN LOUISIANA AND RELATIONSHIP TO THE EQUIVALENT SECTION IN ARKANSAS

The relationship of Dane's Woodbine-Tokio section of Arkansas to the equivalent section below the Brownstown marl in

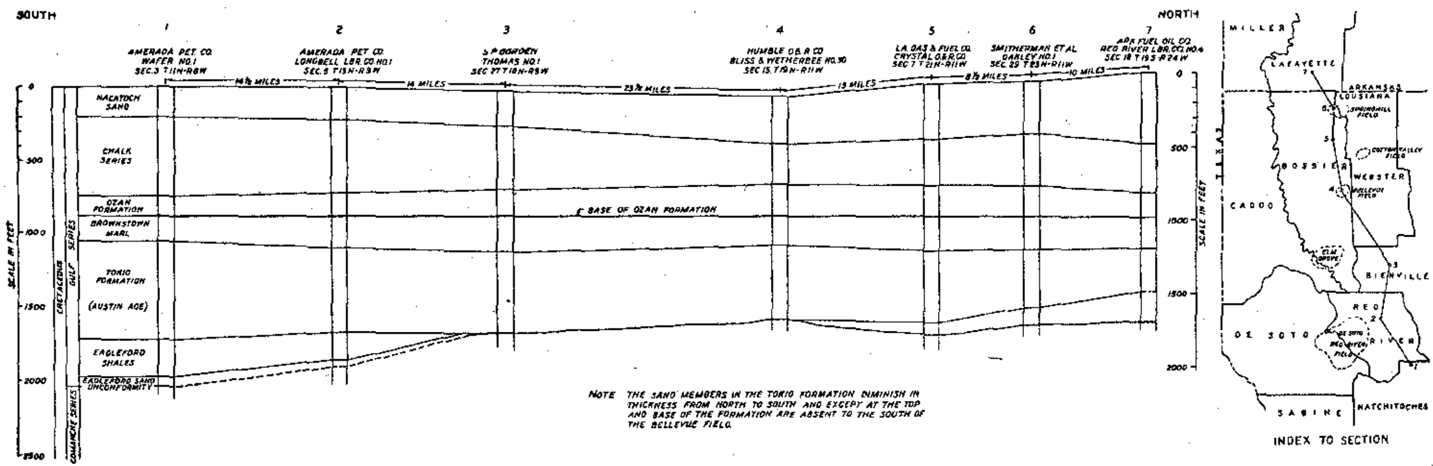

FIGURE 9.—Cross section from Lafayette County, Arkansas, southward into northern Natchitoches Parish, Louisiana, showing age and character of the basal Upper Cretaceous sediments.

northwestern Louisiana is shown graphically in Figure 9, a south to north diagrammatic well section from Natchitoches Parish, Louisiana, into Lafayette County, Arkansas. In this series of wells the lower unit of the southwestern Arkansas depositional province, as defined in previous paragraphs, is 100 feet thick in northern Bossier Parish, Louisiana, but the in Bellevue field is represented only by irregular thin beds and lenses of ashy sand and bentonite. The basal beds of this unit rest unconformably on an eroded surface of Trinity rocks. Within the intermediate unit the sand decreases progressively in thickness southward and in central Bienville Parish; the entire section from the base of the Brownstown marl to the Comanche erosion surface, except for a sandy zone at the top, consists of clay, shale and chalky shale. This chalky shale at the base contains a definite Austin microfauna. From the Bellevue field southward into central Bienville Parish, beds of Austin age rest unconformably on an eroded surface of Trinity rocks which, as a plane of erosion, is continuous northward into Arkansas. From central Bienville Parish southward into Natchitoches, Red River, and Sabine parishes, strata of Austin age lie with apparent conformity on strata of Upper Eagle Ford age. The Eagle Ford decreases in thickness northward, and younger beds are successively in contact with the underlying Trinity rocks, indicating a progressive northward overlap.

SUMMARY DISCUSSION OF CORRELATION OF THE UPPER CRETACEOUS ROCKS BELOW THE BROWNSTOWN MARL

The basal beds of the Upper Cretaceous, composed of sand, red clay and containing varying quantities of volcanic material, rest unconformably on an eroded and truncated surface of Comanche strata which range in age from Washita in the western part to early Trinity in the eastern part of Arkansas. These strata are continuous into northern Louisiana and are apparently continuous into the basal sands, gravels, and volcanic tuffs exposed at the surface in Sevier, Howard, and Pike counties, Arkansas, which have been correlated with the Upper Woodbine sand of Texas by Ross, Miser, and Stephenson[14]. It is certain that these sediments represent the basal beds deposited in a transgressing sea, but their relationships to strata of Austin age in northwestern Louisiana indicate that they are younger than the Texas Woodbine. The regional geologic history, which will be briefly mentioned, also points to the conclusion that the basal Upper Cretaceous beds of southern Arkansas are younger than the Woodbine of Texas.

The uplift at the close of Comanche deposition was pronounced in southern Arkansas and northern Louisiana, where the strata were tilted to the west, and in the following interval

[14] Ross, C. S., Miser, H. D., and Stephenson, L. W., op. cit.

of erosion were truncated, and the terrain was reduced to a peneplain over which the Upper Cretaceous sea transgressed. The truncation of the Comanche strata involved the removal of more than 3,000 feet of beds in southeastern Arkansas and northeastern Louisiana as compared with a relatively few feet of beds removed by erosion in east Texas. The removal of a part of these strata probably contributed sedimentary materials to the early Upper Cretaceous-Woodbine sea in the east Texas embayment. The stratigraphic evidence further indicates that the upwarp of southern Arkansas and northern Louisiana continued into the Upper Cretaceous epoch, expressed in differential upwarp which was more strongly emphasized in a southeasterly trend through southeastern Arkansas and northeastern Louisiana, where the minimum thickness of Upper Cretaceous sediments accumulated. (See Fig. 7.) Under conditions outlined above, it scarcely seems probable that the Woodbine sea, in which the Woodbine Ford of Texas accumulated, transgressed southern Arkansas and northern Louisiana.

On the other hand, the evidence submitted by Ross, Miser, and Stephenson[15] in support of the correlation of the basal Upper Cretaceous beds of southwestern Arkansas with the Woodbine sand of Texas is not easily refuted. Their correlation, however, is based on lithology, principally the presence of volcanic materials, and the apparent continuity of the basal Upper Cretaceous beds of southwestern Arkansas with the Woodbine sand of Texas. Volcanic material is also present in the Eagle Ford and the Austin formations of Texas and in the Tokio formation of Arkansas. The Upper Cretaceous formations below the Brownstown in northern Texas have not been critically studied. The areal geologic map[16] accompanying United States Geological Survey Professional Paper 154-F suggests the possibility that the Eagle Ford shale in Lamar and Red River counties, Texas, instead of being overlapped to the east by the Bonham clay may grade laterally into clays and sands now correlated with the Woodbine, a possibility not inconsistent with the available stratigraphic evidence which records persistent lateral changes in lithology and thicknesses of the Upper Cretaceous formation from Texas into Arkansas and northern Louisiana.

The interpretation most consistent with the geologic evidence indicates that the Upper Cretaceous sea first invaded Arkansas in Eagle Ford or early Austin time, submerging the southwestern part, probably as a narrow northeastward extension of the east Texas embayment, and gradually expanded, submerging southern Arkansas in Austin time, except the extreme southeastern part of the state which, together with the adjacent

[15] Ross, C. S., Miser, H. D., op. cit.

[16] Ross, C. S., Miser, H. D., and Stephenson, L. W., op. cit.

part of northeastern Louisiana and Mississippi, remained emergent until nearly the end of the Cretaceous period.

CONDITIONS OF DEPOSITION IN EARLY UPPER CRETACEOUS TO THE END OF THE TOKIO

Crustal movements initiated in late Comanche years continued into the Upper Cretaceous and although of relatively small magnitude, these movements exacted an important influence on the later Cretaceous history of Arkansas. The movements are differential with reference to the regional depression of the Gulf Coastal Plain province and are manifest in gentle differential upwarp of the region inclusive of southern Arkansas and northern Louisiana, as contrasted with the adjacent areas in east Texas, Louisiana, and Mississippi. The differential warping apparently was sufficient to prevent the submergence of most of southern Arkansas and part of northern Louisiana until Eagle Ford and Austin time, when the sea transgressed this area from the west and southwest. The differential warping was accentuated in a southeasterly trend through southeastern Arkansas and northeastern Louisiana which served, in effect, as a barrier between the areas of maximum depression to the west in Texas and to the east in Mississippi. The Upper Cretaceous sediments record prevailingly shallow waters and frequent oscillations of the strand line as the rate of differential warping varied with relation to the depression of the sea floor in the adjacent areas.

Volcanic activity may have accompanied the Comanche uplift, but whatever the date of the earliest activity may have been, it antedated the submergence of southeastern Arkansas and continued into Austin time. The basal Upper Cretaceous sediments of Arkansas are characterized by an abundance of volcanic materials which have been described from their surface exposures in southwestern Arkansas, southeastern Oklahoma, and northeastern Texas, in an excellent paper by Ross, Miser, and Stephenson[17]. These volcanic materials are water-laid and occur in strata ranging in age from early Upper Cretaceous to late Austin. The greatest abundance of volcanic materials is recorded in Sevier, Howard, and Pike counties, Arkansas, from which areas these materials diminish in thickness in all directions, a fact which led the authors to conclude that the volcanic material was ejected from vents situated in these counties.

The basal Upper Cretaceous sediments of southeastern Arkansas and northeastern Louisiana are represented by predominantly red beds, which are most fully developed on the north and west flanks of the Monroe uplift in Arkansas and Louisiana. The red beds may be generally divided into two parts: the basal

[17] Ross, C. S., Miser, H. D., and Stephenson, L. W., op. cit.

part consists of fine volcanic tuff, in part oxidized and altered to dark-red plastic clays, and in part nonoxidized gray, yellow, green, and grayish-purple bentonitic clays with some intercolated detrital material; the upper part is composed of red and gray mottled clays interbedded with sands. The red and gray mottled clays are believed to represent, in part at least, reworked red beds derived from the lower part of the red bed section. The red beds decrease in thickness westward on the flank of the Monroe uplift and appear to interfinger with marine Tokio. The relationship of the red beds to the underlying Comanche strata is shown in several cross sections.

In considering the origin of the basal Upper Cretaceous sediments of southeastern Arkansas and the environmental conditions under which they accumulated, it is necessary to again refer to the differential warping of this region during the Upper Cretaceous, which was expressed in a broad, generally southeast-trending arch through southeastern Arkansas and northeastern Louisiana. The maximum uplift occurred in northeastern Louisiana. The sea encroached upon this area of uplift from the west and southwest, submerging, in Tokio-Woodbine time, all unless the highest part of the uplift in northeastern Louisiana may have been represented by an island. The character of the basal Upper Cretaceous sediments indicates frequent oscillations of the sea, during which the flanks of the uplift were alternately submerged and raised above sea level, or at least to a plane where erosion was effective. The Monroe uplift was a center of volcanic activity which, in its earliest recognized stage of activity, is believed to be represented by the basal Upper Cretaceous red beds.

The data, although far from being conclusive, suggest that from this center of volcanic activity fine tuffs and ashes were spread over and beyond the uplift. The volcanic material was in part water-laid and preserved from oxidation; in part deposited on land, where it was oxidized and altered; and in the aggregate may have attained a considerable thickness over the uplift. As the complex differential warping of this region continued, most of this material was removed from over the uplift and redeposited in the Tokio-Woodbine sea, contributing a large part of the red material in the basal Upper Cretaceous.

The foregoing discussion, briefly summarized, indicates that the Upper Cretaceous sea first invaded southwestern Arkansas in Eagle Ford or early Austin time and gradually expanded to submerge most of the southern part of the state in Austin time. The basal beds contain abundant volcanic material deposited in shallow water and are thought to have been derived from volcanic vents situated in southwestern Arkansas and northeastern Louisiana. The basal beds are oldest in the western and youngest in the eastern part of the state. The sediments, inclusive of the Tokio formation, were evidently laid down in shallow waters and from their lateral gradation in lithology indicate varied and complex sedimentary environmental conditions which were determined primarily by the rate of differential warping in southeastern Arkansas and northeastern Louisiana. In general the waters increased in depth toward the west and southwest, where marine clays and shales intertongue with sands. The sandy and in part lignitic zone at the top of the Tokio formation, which is continuous into the Blossom sand of northeast Texas, reflects a change in sedimentary environmental conditions, probably brought about by a Gulfward shifting of the shore line.

UPPER CRETACEOUS DEPOSITION AFTER TOKIO TIME

GENERAL STATEMENT

After a brief interval of emergence at the close of the Tokio, the sea again invaded this region from the west in Brownstown time, submerging southern Arkansas to the west of a line drawn from northeastern Clark County into central Union County. A series of marine sediments accumulated in this sea which in southwestern Arkansas are composed of clays, marls, shales, and some thin beds of limestone, totaling 200 feet in thickness. To the east of central Clark, eastern Nevada, and western Union counties, there is a rather abrupt change in the lithology, and in a short distance a complete transition from marls to generally fine-grained in part glauconitic sands takes place, and at the same time the Brownstown sediments gradually decrease in thickness to a feather-edge along the line previously defined as the eastern limit of Brownstown deposition. The thinning and lateral changes from marls to sands towards the east indicate a shallowing of the waters in which these sediments accumulated and is interpreted to be the result of differential warping in a southeasterly trend through southeastern Arkansas and northeastern Louisiana. It is furthermore indicated that the sandy facies of the Brownstown accumulated near the shore, although characteristic shore deposits have not been recognized.

Sediments of Brownstown age have not been definitely recognized in eastern Arkansas, but it is probable that a part of the Arkansas syncline in Desha, Arkansas, and Phillip counties received sediments at that time.

Changes in sedimentary environmental conditions at the end of Brownstown deposition are evidenced in the Buckrange sand member at the base of the Ozan formation. Where typically exposed, the Buckrange sand is composed of quartz grains and in some places contains as much as 50 per cent of glauconite. In many places it also contains pebbles and grains of novaculite, phosphatic nodules, and shark teeth. The Buckrange sand exhibits considerable range in thickness and composition but is recognized as a distinct lithologic unit over most of southwestern Arkansas, the adjacent parts of Texas and northern Louisiana, as far south as Sabine Parish, more than 50 miles to the south of its outcrop in Arkansas. Wherever present, it is distinguished by abundant glauconite. The pebble-bearing sand is less widely distributed and in general is limited to a narrow belt, ranging from a few to about 30 miles in width, that parallels the outcrop and extends southeast through the Smackover and El Dorado fields in Arkansas. Pebble-bearing Buckrange sand is also present in the Haynesville[18] and Homer fields.

The Ozan formation decreases in thickness to the east of central Clark, Nevada, and Columbia counties and at the same time changes laterally from marls to sandy marls and sands, and as a whole is more sandy and micaceous than the underlying Brownstown marl. Sediments of Ozan age are present in eastern and northeastern Arkansas but their thickness, character, and distribution are not definitely known.

The prevailing marine conditions of sedimentation during Ozan time continued without interruption to the end of Taylor time with the deposition of a series of chalks and marls. The differential warping through southeastern Arkansas and northeastern Louisiana which assumed an important role in determining the lithology and distribution of the earlier Upper Cretaceous sediments, continued but with progressively diminishing effect. The sea expanded to submerge most of the Coastal Plain of Arkansas.

The decrease in thickness of the Annona chalk from more than 100 feet along the Texas line to its ultimate disappearance along a line from southwestern Hempstead County through northeastern Columbia County into southwestern Union County is not due to truncation by an unconformity at the base of the overlying Marlbrook marl but is explained in part as a mergence of the chalk eastward into the lower part of the Marlbrook and in part as an overlap of the Marlbrook eastward over the Annona.

The factors which determined the eastern limits of Annona chalk deposition likewise influenced Marlbrook sedimentation, evidenced in the thinning of the sediments and the appearance of sands in the lower part of the formation. The thinning and the changes in lithology are marked mostly in a generally southeast-trending belt which lies slightly east of the eastern limit of Annona chalk deposition. The Marlbrook sea submerged all of the Coastal Plain of Arkansas except a narrow belt along the

[18] Albertson, M., Possible explanation of large initial production of some wells in the Haynesville field, Louisiana; Amer. Assoc. Petrol. Geol., vol. 7, no. 37, pp. 295-296, 1923.

present margin of the Coastal Plain to the northeast of Clark County and the extreme southeastern part of the state. The Marlbrook sediments in their typical development in northeastern Arkansas are composed of chalks and marls which, eastward, merge into the Selma chalk of Mississippi. The position of the strand line in northeastern Arkansas is indicated in the thinning of the sediments and transition from marls and chalks to sands towards the northwest and their final disappearance in the section a short distance east of the present margin of the Coastal Plain.

Following the deposition of the Marlbrook, sedimentary environmental conditions again became favorable to the deposition of chalks, which continued to the end of the Saratoga. The Saratoga, although a chalk deposit, contains beds of sand, sandy marl and chalky sand where it crops out in southwestern Arkansas and the same is generally true of the marginal beds in northeastern Arkansas. The Saratoga, elsewhere, is generally less pure than the Annona chalk and contains only small amounts of sand. Dane[19] in describing the outcrop in southwestern Arkansas concludes that a considerable break in sedimentation occurs before the deposition of the Saratoga chalk but the evidence is not in harmony with underground conditions over most of Arkansas where there is a complete transition from the Marlbrook into the Saratoga. The Saratoga sea submerged all of the Coastal Plain of Arkansas except a narrow belt along the Ozark province to the north of Clark County.

The change from Saratoga to Nacatoch deposition is gradual and in general transitional. The marked increase in the sand content of the Nacatoch and the wide distribution of sands over southern Arkansas and northern Louisiana indicate crustal movement of a higher order than prevailed during the deposition of the underlying marls and chalks. The complex lithology of the sediments making up the Nacatoch appears to be the result of rapidly changing sedimentary environmental conditions which may result from variations in the rate of supply of sediments together with differential warping of the sea floor rather than widespread and frequent oscillations of the strand line. Differential warping of the sea floor is reflected in the variations in thickness and to some extent in the lithology of the sediments. (See Fig. 10.) Aside from the marginal sediments along the Ozark province to the northeast of Clark County, the thinnest Nacatoch deposits are in southeastern Arkansas overlying the persistent southeast-trending line of warping which extends into northeastern Louisiana.

Although the Nacatoch formation as a whole decreases in

[19] Dane, C. H., Upper Cretaceous formations of southwestern Arkansas: Arkansas Geol. Survey Bull., no. 2, pp. 111-114, 1929.

thickness and becomes increasingly calcareous to the south, it is much more sandy in the southwestern part of Arkansas than elsewhere in the state, excepting the marginal sediments in the northeastern part. The meager data at hand concerning the Nacatoch in northeastern Arkansas indicate a progressive east-

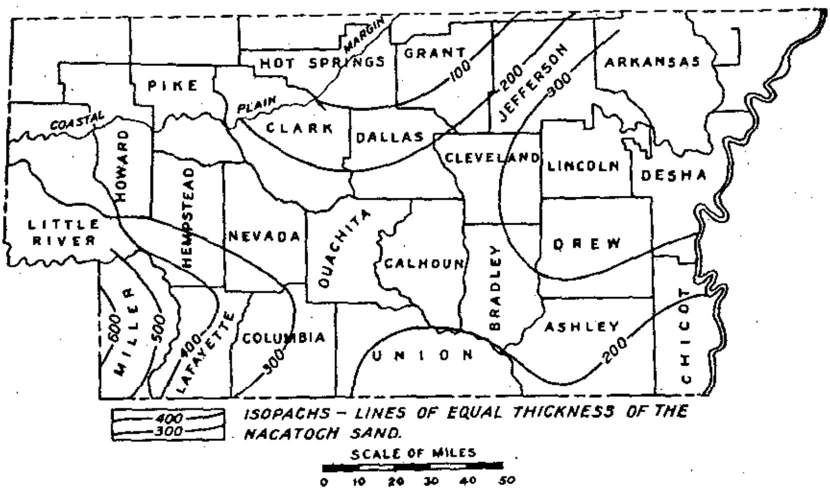

FIGURE 10.—Isopach map showing irregular thickness of the Nacatoch sediments.

ward increase in calcareous content and mergence with the Ripley formation of Mississippi. In the southeastern part of Arkansas and the adjacent parts of Louisiana and Mississippi, the Nacatoch is represented in part by the Monroe gas rock, consisting of generally porous crystalline limestones. Although deposition was apparently continuous, there is an abrupt change in lithology from sand and sandy clay in the Nacatoch to marls and shales in the overlying Arkadelphia marl. Arkadelphia deposition progressed uniformly while at least 160 feet of sediments accumulated. It is probable that the Arkadelphia may have been much thicker and may have included sediments deposited in the wake of the retreating Arkadelphia sea, which sediments later were removed by erosion during the long interval of emergence between Arkadelphia and Eocene-Midway time.

SUMMARY DESCRIPTION OF FORMATIONS

CHARACTER OF SURFACE FORMATIONS

WOODBINE SAND

The Woodbine sand in southwestern Arkansas, according to Dane[20], consists chiefly of sand and gravel, of which much is water-laid, volcanic material with minor quantities of red and dark-red clay intermingled. These beds are separated from the underlying Comanche series by a marked unconformity in con-

[20] Dane, C. H., op. cit.

sequence of which they rest upon Kiamichi clay along the Arkansas-Oklahoma line; whereas, further east across Little River, they rest upon successively lower members of the Trinity formation.

The Woodbine typically consists of olive-yellow cross-bedded sand in which grains of quartz, decomposed green volcanic rock, glassy kaolinized feldspar, and biotite are imbedded in a matrix of bentonitic clay. There are several layers of cross-bedded gravel with large, well-rounded cobbles of novaculite and igenous rock. In some beds these igneous cobbles are fresh; in others, they are completely altered to soft clay. The base of the Woodbine is marked by a particularly striking, but discontinuous, gravel bed which rests on a very irregular erosion surface.

The cobbles in this gravel consist dominantly of novaculite, but there are some quartzite, chert, and a considerable quantity of pebbles of soft, decomposed igneous rock. The pebbles range from a fraction of an inch to 4 inches in diameter and average about 2 inches. This and other gravel in the formation uniformly have the yellowish mealy clay matrix which is even more prominent in the sandy beds. Above the basal gravel and alternating with the soft, mealy yellowish sands, are soft greenish sands in which most of the grains are composed of what was once igneous material, now altered to an apparently structureless green clay. The soft yellow and green sands contain concretionary lenses and beds of hard greenish calcareous sandstone in which quartz grains and novaculite pebbles are cemented by white crystalline calcite. The Woodbine sand also contains minor pockets and beds of massive red clay and of very dark-gray plant-bearing clay.

The Woodbine sand is between 250 and 350 feet thick in southwestern Arkansas.

TOKIO FORMATION

Dane[21] described these beds as composed principally of intertonguing beds of dary-gray lignitic, fossiliferous clay, and cross-bedded gray coarse quartz pack sand, which weathers yellowish and reddish. East of Saline River the Tokio formation consists principally of quartz sand and novaculite gravel; west of the river it contains an increasing amount of clay. Much of the dark clay contains abundant shell prints, but some of it is only sparingly fossiliferous. The Tokio also contains minor beds composed of reddish ferruginous fossiliferous sand, glauconitic sand, pebbles, shark teeth, white clay, dark leaf-bearing clay, highly lignitic clay, carbonaceous sand, and coarse novaculite gravel. At the base of the Tokio there is a conspicuous and persistent gravel bed.

[21] Dane, C. H., op. cit.

Three prominent tongues of the fossil print-bearing clay extend eastward in addition to minor lenses and tongues of the clay, the relationships of which have not, as yet, been deciphered. These three major tongues are not sharply delineated and terminated but finger out eastward.

One tongue is near the base of the Tokio formation, just above the basal gravel. Another, which extends farther east, is near the middle of the formation. The third is at the top and carries large lenses of very hard calcareous fine-grained gray sandstone with numerous fossils, sandy clay, and some glauconitic sand. The two lower tongues are believed to coalesce toward the west. The lower half of the formation consists principally of clay.

Toward the east the Tokio truncates first the arkosic sands of Woodbine age and then successive members of the Trinity formation until finally it rests directly upon the Paleozoic basement rocks.

The Tokio is about 300 feet thick from the vicinity of the Nashville westward but thins eastward and is overlapped by the Brownstown marl.

CHARACTER OF SUBSURFACE BEDS

WOODBINE SAND AND TOKIO FORMATION

GENERAL STATEMENT

For the reasons given in the following paragraphs, it has seemed advisable to treat the subsurface equivalents of the Tokio formation and the Woodbine sand as a unit in this report, rather than to attempt to differentiate them into distinct formations which would entail many difficulties and, in the end, would prove to be an unsatisfactory treatment.

The Woodbine sand at the outcrop in Sevier, Howard, and Pike counties, consists chiefly of cross-bedded sand in which grains of quartz and decomposed volcanic rocks are imbedded in a bentonitic clay. There are several layers of cross-bedded gravels. The Woodbine sand is separated from the overlying Tokio formation by a distinct bed of conglomerate composed chiefly of novaculite. The Tokio formation consists principally of intertonguing dark-gary lignitic clays and cross-bedded sands west of Little River and of sands and novaculite gravel east of Little River. This formation thus exhibits a marked lateral change in lithology in the short distance represented in the outcrop, and correspondingly marked lateral changes are found in their subsurface extension.

The conglomerate bed separating the Woodbine sand and the Tokio formation is not recognizable a short distance south of the outcrop. In most of Miller and Lafayette counties and in parts of Columbia County, the upper part of the series of beds which comprises the Woodbine sand and the Tokio formation consists of gray to dark-gray clays and shales interbedded with generally cross-bedded and in part lignitic sands. The shales are in part fossiliferous and contain a fauna similar to that in the Tokio formation at the outcrop. The lower part in the same area is composed of sands, in part tuffaceous and containing thin layers of gravel, interbedded with clay and shale. In most of these areas the basal few feet of beds are made up largely of red clays. In Caddo Parish, Louisiana, shales and clays of Austin (Tokio) age rest directly on, or are separated by, thin beds of ashy sand from the underlying Comanche rocks.

Towards the east the lateral changes in character of the combined Woodbine-Tokio section are more pronounced than from the outcrop southward into Louisiana. The non-red section decreases in thickness and becomes increasingly sandy while the red beds at the base increase in thickness.

The character and thickness of the Woodbine-Tokio section along Mississippi River to the north of Drew and Chicot counties are not known, but regional studies indicate that strata of equivalent age are present in that area but may belong more properly with the Upper Cretaceous sedimentary basin of Mississippi. These strata, where present, may resemble the Tuscaloosa formation of Mississippi more than the Woodbine-Tokio section as developed to the west of these areas in Arkansas.

BASAL UPPER CRETACEOUS RED BEDS

CHARACTER AND DISTRIBUTION

The red beds at the base of the Upper Cretaceous, although present over most of southern Arkansas, are most fully developed in the southeastern part of the state, particularly in a crescent-shaped area flanking the Monroe uplift on the north and west. These beds lie unconformably upon eroded and truncated strata ranging in age from Washita and Fredericksburg in the western to early Trinity in the eastern part of the state and are overlain by strata ranging in age from Austin to Navarro. The lower limits of the Upper Cretaceous beds are usually difficult to determine in the driller's records as over a large area in southeastern Arkansas they are in contact with red beds of Trinity age. But where cored, the contact is in most places determinable on the basis of the presence of volcanic material.

The basal Upper Cretaceous red beds are most typically developed on the flank of the Monroe uplift and attain their maximum thickness in Ashley and Union counties, but extend with diminishing thickness into Calhoun, Bradley, and Drew counties. Thinner beds of red clays are present at the base of the Upper Cretaceous in Miller, Lafayette, Nevada, and Ouachita counties. The Gregory and Crain oil-producing sands in the Rainbow City field and the principal gas-producing sands of the Richland field, Louisiana, are included in this series of beds.

In southeastern Arkansas the red beds are divisible into two more or less distinct members. The basal member, present in southern Union and Ashley counties and extending south into Louisiana, is composed of red, brown, tan, and green to nearly white, generally structureless, waxy bentonitic clays, interbedded with white, green, and dark-brown sand and ashy sand. A definite sequence in the color schemes, repeated several times in the section, begins with deep red and by imperceptible gradation continues through various hues to green, gray, and white. The red and brown clays have the appearance of altered and oxidized bentonitic clays.

The upper member is composed of red, reddish-brown, and purplish-brown clays interbedded with gray clays, sandy clays, and in part, ashy sand and sandstones, with the non-red member showing up a considerable part of the total thickness. Bentonitic clays, although present, are thin, apparently lenticular and generally highly altered. The red beds in the lower part of the Upper Cretaceous in the Rainbow City field and the adjacent areas appear to be made up in part of reworked material from the lower member.

The presence of a stratigraphic break between the upper and the lower member is suggested but the data are not conclusive.

THICKNESS

The maximum thickness of the red beds in the basal part of the Upper Cretaceous is slightly more than 300 feet in Union County but decreases in thickness away from that area and is not more than 20 feet thick in the southwestern part of the state.

CORRELATION

A number of cores obtained from the red beds at the base of the Upper Cretaceous are reported to have contained Upper Cretaceous foraminifera, but it has been argued that the cores were contaminated with drilling mud and that the fossils were actually from strata above the red beds. Regardless of the merits of the argument the fact persists that fossil remains are very rare in, if not entirely absent from, the red beds at the base of the Upper Cretaceous.

The base of the red beds everywhere is in contact with eroded and truncated strata of Comanche age and, therefore, constitutes a part of the Woodbine sand as defined by Dane[22].

The available records show that the red beds lense out east-

[22] Dane, C. H., op. cit.

ward and are absent in southern Drew and Chicot counties and in eastern Morehouse and West and East Carroll parishes, Louisiana. To the north of Drew County deep well records show younger Upper Cretaceous strata in contact with the basement rocks, indicating a complete lack of connection with the Tuscaloosa formation of Mississippi which occupies the same stratigraphic position in the section.

Section of Upper Cretaceous red beds in Shell Petroleum Company's Carroll No. 1 well in sec. 19, T. 18 S., R. 16 W., Union County, Arkansas

Character	Depth in feet
Upper Cretaceous red beds:	
Upper part light-gray friable tuffaceous sandstone which grades downward into tan and brick-red clays in the lower part	3089–3096
Top of core is gray to green, coarse-grained tuffaceous sandstone, which towards the middle, is mottled with brown to black blotches; the bottom of the core is dark-gray to brown compact clay	3096–3103
Brick-red compact, massive clay with a distinct waxy luster	3103–3110
Top of core is grayish-green compact clay which changes downwards to brown and brownish-red clay at the bottom	3110–3114
Top of core is gray to pinkish-gray hard medium to coarse-grained sandstone with small inclusions of greenish-gray to green tuff; the middle of the core is a green and reddish-brown mottled tuffaceous sandstone which at the bottom has changed to deep-red	3114–3119
Gray and green coarse-grained tuffaceous sandstone with small patches of red; the lower part of the core is red fine sandy bentonitic clay	3119–3127
Top of core is green and red mottled clay, showing a gradation into brown and red in the lower part of the core	3127–3135
Dark-red to purplish clay which, towards the bottom of the core, changes to olive-green clay with a distinctly waxy appearance	3135–3140
White very fine-textured friable tuffaceous sandstone which, towards the middle of the core, is light-gray; bottom of core is red fine sandy clay	3140–3150
Upper part is light-green fine to medium-grained tuffaceous sandstone with blotches of red; middle and lower part is a brick-red slightly arenaceous clay	3150–3163
Dark reddish-brown fine-grained hard sandstone with inclusions of irregular lenses of gray sandstone becoming more clayey toward the middle. The lower part is brown hard clay with irregular patches of green sand	3163–3168
	3168–3279
Top is thin bed of green and light-red mottled fine-grained sandstone, traversed by fine veinlets of calcite; remainder of core is light-gray, friable tuffaceous sandstone	3279–3286
Light-green very fine-grained clayey sandstone containing patches of light-gray to white sand; middle part of core is a green waxy clay which grades downward into terra cotta and brown clay at the bottom of the core	3286–3293
No core record; logged by drillers as sticky red clay	3293–3343

Green compact, waxy clay at the top, grading downward into bluish-green fine pyretiferous clay; bottom of core is a gray very fine-grained argillaceous sand	3343–3349

Partial section of the Upper Cretaceous red beds in J. G. Marcum's McGarry No. 1 well, in sec. 10, T. 19 S., R. 4 W., Ashley County, Arkansas

Character	Depth in feet
Upper Cretaceous red beds:	
Red shale and gumbo	3018–3034
Hard red shale	3034–3051
Red sandy shale	3051–3070
Red bed	3070–3072
Rock	3072–3073
Sand and shale (Core 3096-3099 feet, green sandstone with blotches of black sand)	3073–3100
Red shale and sandy shale (Core 3099-3103 feet, dark-brown clays; core 3103-3110 feet, red and brownish clay; core 3110-3114 feet, grayish-green massive clay at the top and reddish-brown in middle and bottom of core; core 3114-3115 feet, gray to pink quartzitic sandstone; core 3115-3119 feet, green and reddish-brown mottled tuffaceous sandstone; core 3119-3124 feet, tuffaceous sandstone, gray and green in upper part, grading downward into reddish-brown at the base; core 3124-3127 feet, brown tuffaceous sandstone with irregular lenses of green sand; core 3127-3135 feet red and green mottled clay at the top, grading into green clay at the base; core 3135-3140 feet, dark-red to purple clays at the top, grading into olive-green clay at the bottom of core)	3100–3148
Hard sand (Core 3140-3150 feet, white friable tuffaceous sandstone, grading into gray sandy clay with blotches of red in the lower part of the core, fragments of fossil shells; core 3150-3154 feet, green tuffaceous sandstone; core 3154-3164 feet, deep-red massive clay; core 3164-3168 feet, brown sandstone at the top, and interbedded brown and green clay and sand in lower half of core	3148–3175
Red beds, hard and sandy	3175–3184
Hard sand (Core 3179-3186 feet, gray tuffaceous sandstone; core 3186-3194 feet, light-green fine-grained clayey sandstone in upper two feet, followed by green clays which grade into brown clay at the base)	3184–3194

NON-RED WOODBINE AND TOKIO

The series of non-red sediments comprising these formations overlies the red beds at the base of the Upper Cretaceous where these beds are present; elsewhere, they rest directly either on a surface of eroded and truncated Comanche rocks, or on the basement floor. The upper contact is with the Brownstown marl in the western and central part, but in the eastern part the contact is successively with the Ozan formation and the Marlbrook marl, the result of progressive eastward overlap.

DISTRIBUTION AND CHARACTER

The subsurface distribution of this series of beds, as determined from deep wells, is shown in Figure 8. The northern limit is along a line drawn through central Clark and Dallas counties into Cleveland County. In southeastern Arkansas these beds extend eastward to a line drawn through west-central Ashley County into southeastern Drew County. No deep wells have penetrated these strata in the intervening area, but the strata may possibly continue into Mississippi and merge by gradual transition with the Tuscaloosa formation of that state. This stratigraphic relationship is illustrated in Figure 11, a diagrammatic cross section from southeastern Arkansas into north-central Mississippi.

In Miller and Lafayette counties and parts of Columbia County, where this series attains its fullest development, the upper 100 to 150 feet of beds is composed of gray to dark-gray shales and sandy shales interbedded with light-colored generally fine-grained in part glauconitic and in part lignitic sands and sandstones. The contact with the overlying Brownstown marl is in most places marked by lignite, which is generally recognized by the driller, making the contact readily determinable in most of the well logs of this area.

The lower 150 to 400 feet of beds is composed of generally thin beds of gray

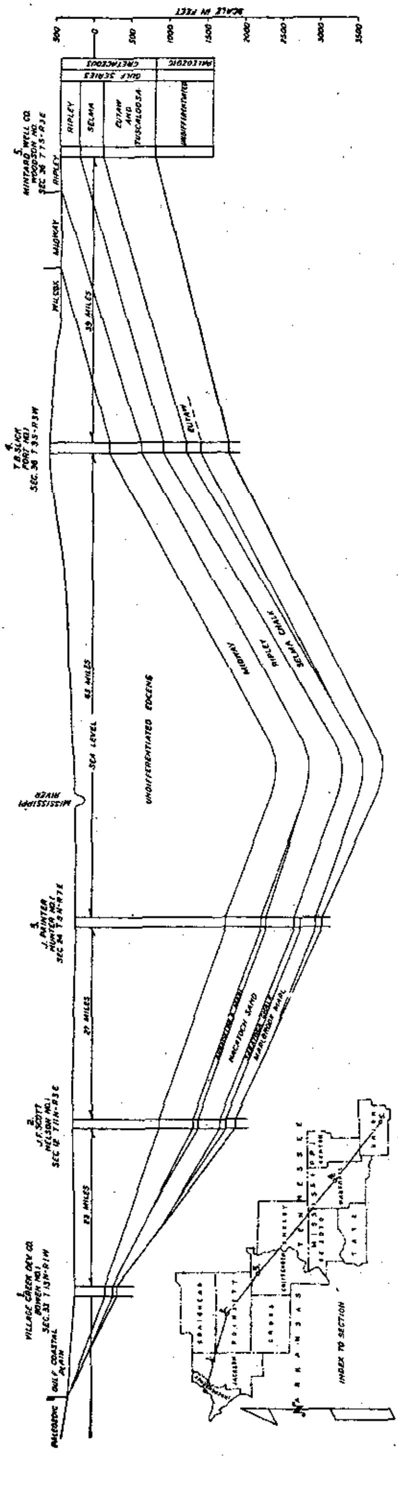

FIGURE 11.—Cross section from Independence County, Arkansas, southeastward into Union County, Mississippi, showing stratigraphic relationship between northeastern Arkansas and northern Mississippi.

to green shales and sandy shales interbedde with white to green sands and sandstones. The shale members are in part calcareous and in part noncalcareous and contain foraminifera at several horizons in the upper half of the member. In places the contact with the upper member is marked by a layer of gravel composed of chert pebbles but also contains fragments of igenous rocks and novaculite imbedded in a bentonitic clay. Irregular thin lenses of gravel are found at other horizons in this area. The sands are made up chiefly of fine to medium textured, at some horizons coarse-textured, quartz grains but also include grains of igenous rocks and chert fragments. These sands are generally tuffaceous and are in part glauconitic.

The basal beds of the series have been cored at only a few horizons in this area; most of the cores have been cut from the sandstone members and have furnished little information concerning the organic content of the shale and clay members.

North and east of Columbia County these sediments decrease in thickness, become increasingly sandy, and contain more volcanic materials, especially in the southeastern part of the state.

THICKNESS

The Tokio formation and the Woodbine sand, as herein defined, have a combined thickness of 600 feet in the southwest corner of Arkansas; they thin gradually to the east and northeast to 400 feet in western Union and northern Columbia counties, and to less than 100 feet thick in western Ashley County, central Clark County, and central Dallas County. The thickness of these strata in Cleveland County, parts of Bradley County and Drew County, and in the area to the east and northeast, is not known. The thickness of the non-red Woodbine and Tokio strata is shown in Figure 8, by means of isopach lines (lines of equal thickness).

RELATIONSHIP OF SURFACE TO SUBSURFACE BEDS

The Tokio formation and the Woodbine sand, as developed at the surface in southwestern Arkansas, represent in part sediments deposited near the margin of the sea and in part sediments deposited farther seaward. Owing to the complex warping, the equivalent sediments, concealed elsewhere in southern Arkansas by younger strata, vary in lithology and thickness according to the relationship to the margin of the sea and to the structure of the sea floor upon which they accumulated.

The Woodbine sand, a lithologic unit, interfingers with marine shales of Austin age to the south of the outcrop and in northwestern Louisiana is represented almost enitrely by marine shales and clays. The Tokio formation grades laterally into sands and contains volcanic material to the southeast of the outcrop where it is not separable from the Woodbine sand. The combined Tokio-Woodbine section becomes sandy and interfingers with red beds.

CORRELATION

The Woodbine sand, as exposed at the surface in southwestern Arkansas, is correlated with the Woodbine sand of Texas by Miser[23], Dane[24], and Stephenson[25]. The basis for the correlation was the recognition of similar deposits of volcanic material in the Woodbine sand of northeastern Texas and southeastern Oklahoma which apparently are continuous with the Arkansas outcrops. The Tokio formation, as mapped and defined by Dane[26] in southwestern Arkansas, is correlated with the Austin of the Texas section.

The typical Woodbine sand exposed at the surface in Arkansas interfingers southward with marine shale of Austin age, indicating that the Woodbine sand is in part younger than the Woodbine sand of Texas and in part at least, may be as young as early Austin.

Typical sections of the Woodbine and Tokio, as recorded in deep wells, are given in the following tables.

Section of Tokio formation and Woodbine sand in Arkansas Natural Gas Company's Red River Lbr. Co. No. 4 well, sec. 18, T. 19 S., R. 24 W., Lafayette County, Arkansas

Character	Depth in feet
Tokio formation and Woodbine sand:	
Shale and sandy lime	3043–3046
Sandy lime	3046–3051
Shale and sand	3051–3053
Sandy lime; salt water	3053–3057
Sand and shale	3057–3060
Sandy shale	3060–3069
Shale	3069–3084
Sand	3084–3085
Shale	3085–3129
Sandy shale	3129–3145
Sand	3145–3146
Sandy shale	3146–3153
Sand; salt water	3153–3160
Sandy shale	3160–3167
Sand	3167–3175
Shale	3175–3177
Sand	3177–3180
Sandy shale	3180–3184
Gravel and shale	3184–3186

[23] Miser, H. D., and Ross, C. S., Volcanic rocks in the Upper Cretaceous of southwestern Arkansas and southeastern Oklahoma; Am. Jour. Sci. 5th ser. vol. 9, no. 2, pp. 113-126, 1925.

[24] Dane, C. H., Oil-bearing formations of southwestern Arkansas: U. S. Geol. Survey, Press Notice 8823, Sept. 10, 1926.

———. Upper Cretaceous formations of southwestern Arkansas: Arkansas Geol. Survey, Bull. 2, 1929.

[25] Stephenson, L. W., Notes on the stratigraphy of the Upper Cretaceous formations of Texas and Arkansas: Am. Assoc. Petrol. Geo., Bull., vol. 11, no. 1, pp. 1-17, 1927.

[26] Dane, C. H., Upper Cretaceous formation of southwestern Arkansas: Arkansas Geol. Survey, Bull., no. 2, 1929.

Sand	3186–3188
Shale and gravel	3188–3199
Sand and gravel	3199–3207
Sandy shale	3207–3211
Sand	3211–3230
Shale	3230–3207
Sand and shale	3207–3260
Shale	3260–3265
Gummy lime	3265–3268
Sand	3268–3272
Shale	3272–3280
Sand; salt water	3280–3282
Sandy shale	3282–3292
Shale	3292–3300
Sand and shale	3300–3311
Sand	3311–3322
Sandy shale	3322–3335
Gummy lime	3335–3342
Sandy shale	3342–3364
Shale	3364–3367
Sand	3367–3385
Sandy shale	3385–3394
Sandy shale with streaks of sand	3394–3408
Shale	3408–3416
Sandy shale	3416–3418
Sandy lime	3418–3420
Shale	3420–3425
Sandy shale	3425–3457
Shale and sand	3457–3520
Upper Cretaceous red beds:	
Red shale	3520–3546

Section of Tokio formation and Woodbine sand in Brown et al Spencer No. 1 well in sec. 18, *T.* 18 *S., R.* 22 *W., Columbia County, Arkansas*

Character	Depth in feet
Tokio formation and Woodbine sand:	
Sand and lignite (Core 2994-3000 feet, top of core is slightly glauconitic sandstone; bottom of core is gray micaceous lignitic sandy shale)	2993–3000
Shale, sand, and lignite	3000–3013
Hard sandy lime	3013–3019
Shale	3019–3024
Sand with streaks of shale (Core 3024-3028 feet, greenish-gray glauconitic, lignitic sandstone)	3024–3029
Sand and shale	3029–3039
Gummy shale	3039–3046
Rock, sand and shale (Core 3047-3051 feet; top of core light-gray, calcareous, slightly glauconitic sandstone; middle and bottom of core medium-gray, slightly greenish, glauconitic sandy shale)	3046–3052
Sandy shale	3052–3063
Soft shale	3063–3079
Broken sand and shale	3079–3096
Shale, sandy shale, and streaks of sand	3096–3140
Hard sandy shale	3140–3160
Hard shale	3160–3177

Sandy shale, streaks of sandy lime	3177–3211
Gummy shale	3211–3221
Sandy shale	3221–3234
Hard shale, streaks of sand	3234–3250
Gummy shale	3250–3261
Gummy shale with streaks of lime	3261–3298
Shale with streaks of lime bowlders	3298–3323
Shale	3323–3335
Upper Cretaceous red beds:	
Red gumbo and shale	3335–3358
Sand	3358–3367
Red shale and gumbo	3367–3401
Hard shale and gummy shale	3401–3408
Red shale	3408–3413

Section of Tokio formation and Woodbine sand in Shell Petroleum Company's No. 1 *well, in sec.* 19, *T.* 18 *S., R.* 16 *W., Union County, Arkansas*

Character	Depth in feet
Tokio formation and Woodbine sand:	
Sandy shale (Core 2759-2766 feet, dark-gray, slightly glauconitic and arenaceous, calcareous shale; core 2766-2773 feet, dark-gray sandy shale)	2759–2773
Sandy shale with streaks of sand (Core 2773-2781 feet, gray thinly laminated shale and sand; core 2781-2788 feet, grayish-green indurated glauconitic fine and medium-textured sand and gray arenaceous shale; core 2788-2795 feet, gray sandy shale and fine-grained, green sand)	2773–2795
Sandy shale (Core 2795-2802 feet, gray sandy slightly calcareous shale; core 2802-2817 feet, dark-gray sandy shale	2795–2817
Shale (Core 2817-2824 feet, dark-gray compact shale and arenaceous shale; core 2824-2832 feet, dark-gray slightly sandy clay)	2817–2836
Sandy shale (Core 2832-2840 feet, dark-gray sandy clay at the top; bottom of core green glauconitic sand and sandy clay)	2836–2840
Sandy shale (Core 2840-2848 feet, dark-gray sandy clay and fine-grained glauconitic sand)	2840–2852
Hard sand	2852–2854
Sandy shale (Core 2848-2855 feet, greenish-gray fine-grained slightly glauconitic sand and sandy clay)	2854–2858
Shale and gumbo	2858–2888
Rock	2888–2889
Shale and shells (Core 2890-2895 feet, dark-gray shale	2889–2918
Sand (Core 2925-2932 feet, gray medium to coarse-grained sand and sandy clay, slightly lignitic and tuffaceous)	2918–2935
Gummy shale	2935–2965
Sandy shale with streaks of sand	2965–2982
Hard lime	2982–2985
Broken lime and sandy shale	2985–3020
Gummy shale	3020–3065
Sand and sandstone	3065–3075
Sand and lignite (Core 3068-3075 feet, gray and yellowish lignite, friable sandstone; core 3070-3084 feet, argillaceous coarse-grained lignitic sand, brownish-gray lignitic thinly laminated sandy shale, and dark-gray lignitic clay)	3075–3085

Gummy lime (Core 3084-3089 feet, tan plastic arenaceous clay)	3085–3089
Hard sand	3089–3093
Gummy lime (Core 3089-3096 feet, gray, medium-grained, brittle sandstone with red and tan clays in the bottom of core; core 3096-3103 feet, top is light tuff medium-grained sandstone and dark-gray compact, noncalcareous clay)	3093–3100[27]

Section of Tokio formation and Woodbine sand in Grote et al, Arden No. 1 well, sec. 2, T. 13 S., R. 31 W., Little River County, Arkansas

Character	Depth in feet
Tokio formation and Woodbine sand:	
Soft greenish sandstone	812– 815
Dark shale, sand rock	815– 844
Dark clay and glauconitic sand	844– 850
Dark shale	850– 880
Gray sand; salt water	880– 896
Dark shale; fossil shells (Cuttings, sandy fossiliferous clay containing sand-grains and some small bits of carbonaceous material)	896–1074
Coarse gravel (Well-rounded and subangular pebbles of novaculite, the largest ¾ inches in diameter)	1074–1076
Gray sand rock	1076–1081
Fine to coarse gravels, made up of quartz and novaculite pebbles	1081–1114
Upper Cretaceous red beds:	
Red and gray clays	1114–1194
Gravels—chiefly novaculite pebbles	1194–1199
Chocolate shale	1199–1219
Bluish-gray shale with streaks of red shale	1219–1247

Section of Tokio formation and Woodbine sand in Tarver et al Swofford No. 1 well in sec. 14, T. 11 S., R. 25 W., Hempstead County, Arkansas

Character	Depth in feet
Tokio formation and Woodbine sand:	
Pack sand (Core 847 feet, very fine gray—clayey sand; lignitic)	846– 849
Lignite (Core 849 feet, impure shaly lignite, slightly sandy)	849– 855
Blue shale	855– 879
Pack sand; water	879– 880
Hard packed sand	880– 930
Hard sandy shale (Core 935 feet, fine-grained light-gray sand slightly darker gray clay with lignitic plant fragments, distinctly laminated by variation in percentage of carbonaceous material)	930– 965
Gummy shale and pyrites	965– 981
Hard pyrite	981– 983
Gummy shale and pyrite	983–1013
Gumbo	1013–1019
Shale and bowlders	1019–1029
Gumbo	1029–1034
Blue shale	1034–1050
Gumbo	1050–1053
Hard sandy lime	1053–1065

[27] For section of Upper Cretaceous red series in this well see paragraph describing these rocks.

Upper Cretaceous red beds:	
Red shale and gumbo	1065–1118
Red rock	1118–1120
Broken red rock	1120–1130
Gumbo	1130–1135
Sandy shale and boulders	1135–1163
Red gumbo	1163–1170
Base of Upper Cretaceous beds	1170

Section of Tokio formation and Woodbine sand in Louisiana Refining Corporation's Manley No. 1 well in sec. 15, T. 15 S., R. 19 W., Ouachita County, Arkansas

Character	Depth in feet
Tokio formation and Woodbine sand:	
Rock	2272–2275
Sandy shale	2275–2281
Sand	2281–2285
Sandy lime	2285–2291
Gummy shale	2291–2325
Sandy lime	2325–2339
Gummy shale	2339–2344
Sandy lime	2344–2354
Shale and shells	2354–2389
Sand; oil show	2389–2403
Shale and sand	2403–2433
Lignite	2433–2436
Sand	2436–2486
Sand and shale	2486–2496
Gravel	2496–2502
Shale with streaks of gravel	2502–2533
Hard sand	2533–2535
Upper Cretaceous red beds:	
Red shale	2535–2548
Sand	2548–2554
Red shale	2554–2557
Red and gray shale	2557–2592
Chalky shale	2592–2597
Sand	2597–2630
Red and green shale	2630–2635
Base of Upper Cretaceous beds	2635

Section of Tokio formation and Woodbine sand in Amerada Petroleum Corporation's Matlock No. 1 well in sec. 10, T. 12 S., R. 13 W., Calhoun County, Arkansas

Character	Depth in feet
Tokio formation and Woodbine sand:	
Sandy shale	2886–2915
Salt water sand (Core 2917-2922 feet, light-gray medium-grained tuffaceous sandstone)	2915–2922
Sand and shale (Core 2927-2932 feet, light-gray, fine-grained, tuffaceous sandstone)	2922–2982
Sand and shale with streaks of lignite (Core 2982-2987 feet, greenish-gray, noncalcareous shale, with patches of fine-textured tuffaceous sand)	2982–3080
Gummy chalk	3080–3082

Gummy shale	3082-3097
Hard sandy lime	3097-3107
Base of Upper Cretaceous	3107

BROWNSTOWN MARL (RESTRICTED)

CHARACTER OF SURFACE BEDS

According to Dane[28], where typically exposed, the Browntown marl consists of dark-gray calcareous clay or marl, which weathers very deeply and becomes light greenish-gray and brownish-gray. The unweathered marl may be nearly massive. The weathered marl usually shows distinct bedding. In many outcrops the marl contains a small percentage of very fine sand, but characteristically it is free from palpable sand. The contact between the Brownstown and the Tokio formations is a slightly irregular surface, and borings filled with sandy clay extend from the Brownstown into the Tokio. Locally, within a few feet of the base, there are layers of hard, dense gray limestone that carry numerous poorly preserved fossils. The Brownstown marl completely overlaps the Tokio formation a few miles east of Antoine Creek.

Eastward, the formation becomes increasingly sandy. In the lower part there are beds that weather reddish, composed of fine-grained quartz sand, mixed with considerable quantities of marly material. Massive, blue-gray argillaceous sand, which contains hard calcareous sandstone lenses and sandy marl is also present. In the western part of its exposure the base of the Brownstown is marked by pure, fine-grained, cross-bedded quartz sand.

The Brownstown marl is from 200 to 250 feet thick in Hempstead County and farther west but thins east of Hempstead County.

CHARACTER OF THE SUBSURFACE BEDS

Distribution and character.—The Brownstown marl is present everywhere in southeastern Arkansas to a line drawn from near Arkadelphia in Clark County southward through central Union County into Louisiana. To the east it is overlapped by younger sediments but may reappear in the section in Lincoln and Desha counties and in parts of Arkansas and Phillips counties.

In Miller and Lafayette counties and parts of Columbia and Nevada counties, where it is typically developed, the Brownstown marl consists of dark-gray calcraeous clays, marls, and shales, generally in massive beds and free of sand, with some thin strata of impure limestone.

Eastward in Ouachita and Union counties, the formation

[28] Dane, C. H., Upper Cretaceous formations of southwestern Arkansas: Arkansas Geol. Survey, Bull. no 2, 1929.

becomes increasingly sandy and is composed chiefly of fine-grained in part glauconitic quartz sand and gray finely sandy marls and clays. In its easternmost extension the Brownstown marl is composed chiefly of fine-grained and argillaceous sands.

Thickness.—The Brownstown marl is silghtly more than 200 feet thick in Miller County and farther east but thins east of western Union and western Ouachita counties.

Correlation.—The Brownstown marl is correlated with the basal Taylor of Texas by Stephenson[29]; but Israelsky[30], who has made a critical study of the Upper Cretaceous ostracods, correlates this formation with the Bonham clay of the Austin group of Texas on the basis of their content of microfossils. Well sections drawn from Arkansas into Texas suggest that the Brownstown marl of Arkansas is the equivalent of the Bonham clay of Texas.

A typical well section of the Brownstown marl is given below:

Section of Brownstown marl in Arkansas Natural Gas Company's Red River Lumber Company No. 4 well in sec. 18, T. 19 S., R. 24 W., Lafayette County, Arkansas

Character	Depth in feet
Brownstown marl:	
Shale	2832–2878
Shale with streaks of lime	2878–2910
Sticky lime	2910–2915
Shale	2915–2950
Sticky shale	2950–2959
Lime	2959–2960
Hard lime	2960–2961
Gummy lime	2961–2969
Shale	2969–3003
Sandy shale	3003–3006
Hard shale	3006–3026
Lime	3026–3027
Shale	3027–3043
Base of Brownstown marl	3043

OZAN FORMATION

CHARACTER OF THE SURFACE BEDS

According to Dane[31], the Ozan formation consists of sandy, micaceous marl, typically exposed at the town of Ozan, Hempstead County.

At the base of the formation in Sevier, Howard, and Hempstead counties, there is a sandy marl or marly sand, 3 to 8 feet thick, containing as much as 50 per cent of coarse glauconitic

[29] Stephenson, L. W., Notes on the stratigraphy of the Upper Cretaceous formations of Texas and Arkansas: Am. Assoc. Petrol. Geol., vol. 11, no. 1, 1927.

[30] Israelsky, M. C., Notes on the correlation of the Brownstown (restricted) formation of Arkansas: Am. Assoc. Petrol. Geol., vol. 13, no. 6, pp. 683-684, 1929.

[31] Dane, C. H., op. cit.

grains. In many outcrops it also contains thin, highly polished pebbles and grains of black chert, phosphatic nodules, locally numerous shells, phosphatic casts, and shark teeth. The coarse sand lies on an irregular surface of the calcerous clay of the Brownstown marl.

The basal glauconitic sand of the Ozan formation crops out a short distance north of the village of Buckrange, also 1 mile northeast of the village on the road to Nashville, Howard County; it is, therefore, named the "Buckrange sand."

The Buckrange sand merges gradually upward into micaceous, very sandy, massive marl with extremely abundant small oyster shells, frequently in coquina-like layers. There is a second glauconitic sandy marl, 50 feet higher stratigraphically, which is well exposed in Howard County. It seems to be represented in Sevier County by a glauconitic, chalky marl. Both glauconitic beds are represented in Little River County.

The upper part of the Ozan formation is almost uniformly massive dark sandy, micaceous marl. Toward the top there are some beds of poorly stratified and cross-bedded marly sand, in which the quartz grains are very fine; a few beds of hard limestone are also present.

The Ozan formation is between 150 and 250 feet thick in Hempstead County and farther west but gradually thins toward the east.

The Buckrange sand lentil of the Ozan formation thins towards the east; and inasmuch as the percentage of sand in the Brownstown marl increases in that direction, the differentiation of the Ozan and Brownstown becomes increasingly difficult and has only been tentatively accomplished in Clark County and thence eastward.

CHARACTER OF THE SUBSURFACE BEDS

Distribution and character.—The Ozan formation is present throughout southwestern Arkansas and eastward into southeastern Union County, central Bradley County, northeastern Calhoun County, southwestern Dallas County, and northeastern Clark County. To the east of these areas it is overlapped by the Marlbrook marl but may reapper in the section in Lincoln, Desha, Arkansas, and Phillips counties.

In the southwestern part of this area and extending eastward to near the Smackover and El Dorado fields, the Ozan formation is composed of gray and greenish-gray micaceous marls and sandy marls, with some thin lenses or beds of argillaceous limestone and chalky marls in the southwestern part of the area. At the base of the formation is a persistent, generally glauconitic sand member or a series of interbedded sands and sandy marls to which Dane[32] has given the name, "Buckrange sand." In its subsurface extension this sand member, which is an important oil and gas-producing horizon in southern Arkansas and northern Louisiana, exhibits considerable variations in character and thickness. In the Bradley district in southern Lafayette County, it is about 40 feet thick, consisting of fine-grained glauconitic, micaceous sand at the top; interbedded thin sands and sandy shales in the middle part; and glauconitic sand, containing fine grains of chert. In parts of Columbia and Nevada counties this member is absent. Where present, the Buckrange sand merges gradually upward into sandy marls, which in most places contain abundant small oyster shells, frequently in coquina-like layers which are finely developed in the Haynesville, Louisiana field, immediately south of Columbia County. In places the upper part of the Ozan formation contains beds of fine-grained generally glauconitic and marly sands and thin beds of limestone.

The Ozan formation thins and becomes increasingly sandy to the east of a line drawn from the outcrop through southwestern Ouachita and western Union counties into Louisiana, and, as the sand content of the formations above and below increase in that direction, the differentiation of the Ozan becomes increasingly difficult.

In the Smackover field and in the area to the south, the Ozan formation is made up of sands at the top and bottom with intermediate beds of marl and sandy marls. The upper sand is commonly called the "Meakin sand" or the "Louann sand"; the lower sand, the correlative of the Buckrange sand, is called the "Graves sand"; both are important oil and gas-producing sands in the Smackover field. The Meakin sand is white to gray micaceous and generally fine-textured quartz sand. The Graves sand is gray to greenish-gray fine to coarse-textured quartz sand, in part glauconitic, and locally contains small phosphate and chert pebbles and some volcanic material.

Farther to the east the Ozan formation is composed chiefly of sand and sandy marl.

Thickness.—The Ozan formation, including the Buckrange sand at the base, is slightly more than 100 feet thick in Miller, Lafayette, and parts of Columbia counties but gradually thins toward the east.

Correlation.—The Ozan formation has been tentatively correlated with the lower part of the Annona chalk, as exposed in the vicinity of Clarksville, Texas[33], partly on paleontologic grounds and partly by other evidence. According to Israelsky[34]

[32] Dane, C. H., op. cit.
[33] Stephenson, L. W., op. cit.
[34] Israelsky, M. C., op. cit.

the Ozan formation is the basal formation of the Taylor group of Texas.

A typical well section of the Ozan formation is given below, and detailed sections of the Buckrange sand are given in the description of the oil fields.

Section of Ozan formation in Arkansas Natural Gas Company's Red River Lumber Company No. 4 well in sec. 18, T. 19 S., R. 24 W., Lafayette County, Arkansas

Character	Depth in feet
Ozan formation:	
Gumbo	2667–2682
Gypsum and broken lime	2682–2694
Chalk	2694–2696
Gummy lime	2696–2720
Gummy shale and lime	2720–2783
Sandy shale and sandy lime	2783–2789
Buckrange sand:	
Cap rock	2789–2792
Hard sand	2792–2793
Sand	2793–2795
Sandy shale	2795–2798
Sand	2798–2802
Sandy shale	2802–2808
Sand	2808–2811
Sand and shale	2811–2813
Hard sand	2813–2815
Hard sandy shale	2815–2832

ANNONA CHALK

CHARACTER OF THE SURFACE BEDS

According to Dane[35], the Annona chalk in its surface expression is a massive, heavy-bedded hard white chalk which is sparingly fossiliferous. At the westernmost exposure in Arkansas in the Rocky Comfort area, it is apparently transitional at the base into the Ozan formation, but east of this locality, where the bed is exposed, there is a sharp break in lithology, and borings filled with chalk extend from the base of the Annona into the underlying sandy marl. The Annona chalk of southwestern Arkansas is of Taylor age and is the equivalent of the upper part of the Annona chalk as exposed at the type locality around Clarksville, Texas.

The Annona is approximately 100 feet thick in Little River and Sevier counties but thins eastward through Howard County. In westernmost Hempstead County, in the vicinity of Yancy, it is only 2 or 3 feet thick. East of this locality it is not present in the section.

CHARACTER OF SUBSURFACE BEDS

Distribution and character.—The Annona chalk underlies

[35] Dane, C. H., op. cit.

southwestern Louisiana eastward to a line drawn through central Hempstead and southwestern Nevada counties into the southeastern corner of Columbia County. To the east of this area, it is overlapped by the Marlbrook marl.

The Annona chalk is recorded in deep wells as hard chalk with soft chalk and chalky marl at the top and bottom. Cores of the Annona chalk show it to consist principally of white, gray, and bluish-gray generally massive chalk with some chalky marl, which locally is sparingly glauconitic.

Thickness.—The Annona chalk is 10 feet thick in Miller County, and 100 feet thick in central Columbia County, but thins rapidly to the east of that area.

MARLBROOK MARL (RESTRICTED)

CHARACTER OF THE SURFACE BEDS

Dane[36] has redefined the Marlbrook marl, restricting it to the beds beneath the Saratoga chalk, which in previous reports, had been treated as a member of the Marlbrook marl by Veatch[37] who also included the clayed beds in the lower part of the Nacatoch sand as here differentiated.

The Marlbrook marl is a strikingly uniform chalky marl, which is dark-blue when fresh and weathers deeply to a nearly white color. It is free from palpable sand and is, therefore, highly plastic when wet. The marl commonly occurs in thick beds but locally is massive and devoid of bedding. Toward the top it is fossiliferous and contains some coquina-like shell beds. The lower part of the Marlbrook marl contains some very chalky layers a few feet thick and is only sparingly fossiliferous. At the base the Marlbrook is transitional into the Annona chalk in which are shaly layers in the upper part. Nevertheless, the change from chalk is usually rather abrupt. When the Annona is absent and when the Marlbrook rests directly on the Ozan formation, there is a sharp contact and evidence of a break in sedimentation.

The Marlbrook marl is about 200 feet thick north of Saratoga, Howard County, but gradually thins eastward to only 50 feet in eastern Clark County.

CHARACTER OF THE SUBSURFACE BEDS

Distribution and character.—The Marlbrook marl probably underlies all of the Coastal Plain of Arkansas except a small area in the southeastern corner and in a narrow belt along the margin of the Coastal Plain north of Clark County, where it is overlapped by younger sediments.

In the southwestern part of the state the Marlbrook marl

[36] Dane, C. H., op. cit.

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

closely resembles the strata exposed at the surface north of Saratoga, Howard County, and is composed of gray to dark-blue marls with some chalky marl in the upper part and thin beds of chalk in the lower part. It appears to be transitional into the Saratoga chalk (above) and into the Annona chalk (beneath).

The Marlbrook marl maintains its general characteristics in eastern Nevada, western Ouachita, and western Union counties, where it begins to change laterally in character and becomes increasingly sandy towards the east and the southeast. Throughout most of southeastern Arkansas, the Marlbrook is composed of marl, in part chalky, interbedded with fine sandy marl and generally fine-grained glauconitic sands; but locally in this area it is composed principally of sands and marly sands.

The Marlbrook marl is overlapped by the Nacatoch sand along the margin of this Coastal Plain to the north of Clark County but reappears in deep wells located from 20 to 25 miles basinward. The marginal beds are predominantly sandy but in a short distance grade laterally into marls and chalks, which attain a considerable thickness in the central part of the Arkansas syncline north of Drew and Chicot counties.

In that area the Annona chalk of southwestern Arkansas may be present and together with the Marlbrook marl and Saratoga chalk form a lithologic unit which to the east merges with the Selma chalk of Mississippi. (See Fig. 12.)

Thickness.—The Marlbrook marl is 200 feet thick north of Saratoga in Howard County and 150 feet thick in southwestern Miller county. It is 150 to 175 feet thick in Lafayette and Columbia counties and in parts of Nevada, Ouachita, and Union counties but decreases in thickness in southeastern Arkansas. The Marlbrook is estimated to range in thickness from a few feet in the western part to 200 feet or more in the southeastern part of the Arkansas syncline.

Correlation.—The Marlbrook marl is correlated by Stephenson[38], with the upper part of the Taylor marl of Texas.

From the outcrop southward into northwestern Louisiana it grades laterally into chalks and is then not separable either from the underlying Annona or the overlying Saratoga chalks. In the area of the Arkansas syncline the evidence suggests an eastward gradation from marl into chalks identified with the Selma chalk of Mississippi.

SARATOGA CHALK

CHARACTER OF SURFACE BEDS

The Saratoga chalk which rests unconformably on the Marlbrook marl, according to Dane[39], is a comparatively thin forma-

[38] Stephenson, L. W., op. cit.
[39] Dane, C. H., op. cit.

tion, ranging from 20 to 60 feet in thickness. It was previously included as a member of the Marlbrook marl but is now treated as a separate formation because it is separated from the underlying barl by a well-exposed and persistent lithologic and faunal break. The chalk rests on an irregular surface, and its basal few inches locally contain glauconitic sand. Almost everywhere borings filled with glauconitic chalk extend down into the underlying marl. The lower few feet of the Saratoga chalk consists of hard sandy or marly chalk with disseminated glauconite and contains abundant large shells. The uppermost Marlbrook is usually a pure dark-gray marl without sand, which weathers light-gray, but in its upper few feet there are many small isolated pockets or lenses of glauconitic chalk of the same character as the borings that extend from the base of the Saratoga into the marl. The upper part of the Saratoga contains marl and clay and in eastern Clark County includes beds of chalky sand, containing abundant small black macerated plant fragments.

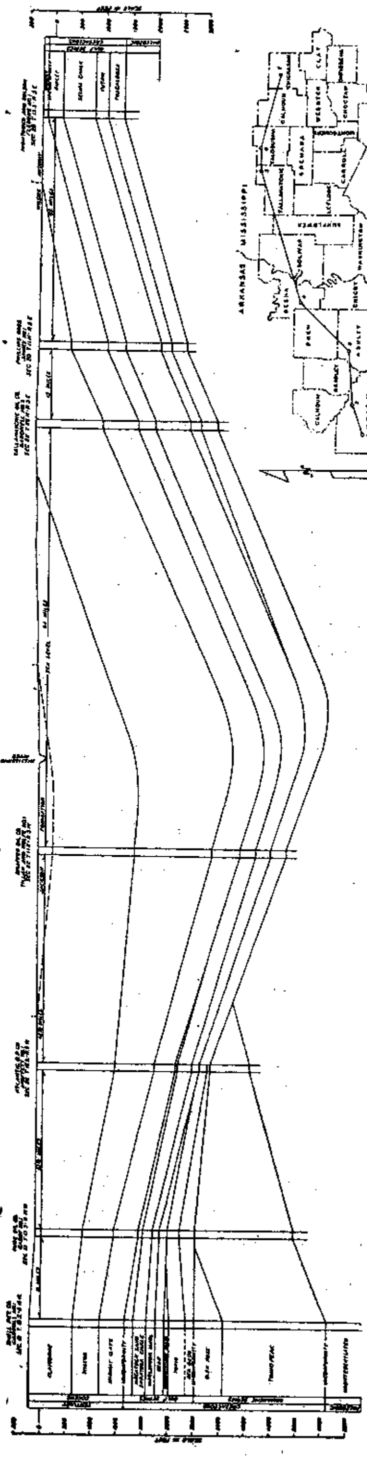

FIGURE 12.—Cross section from Union County, Arkansas, eastward into Chickasaw County, Mississippi, showing stratigraphic relationship between eastern Arkansas and northern Mississippi.

CHARACTER OF THE SUBSURFACE BEDS

Distribution and character—The Saratoga chalk underlies all of the Coastal Plain of Arkansas except a narrow belt adjacent to the Ozark province to the north of Clark County, where it is overlapped by the Nacatoch sand, and possibly a small area in the southeastern corner of the state, where the uppermost Cretaceous is represented by the Monroe gas rock which has not been definitely correlated but may be in part of Saratoga age.

In southwestern Arkansas, where it attains its fullest development, the Saratoga consists of white and gray generally massive chalk with some interbedded marly chalk. The same general characteristics are maintained throughout southern Arkansas.

Thickness.—The Saratoga chalk is 150 feet thick in southwestern Miller County and 100 feet thick in most of Lafayette and Columbia counties. This formation decreases in thickness toward the northeast and east of this area, ranging from a few feet to 75 feet in thickness.

Correlation.—The base of the Saratoga, according to Dane[40], clearly marks the base of the beds of Navarro age in Arkansas. This correlation is predicated on the existence of an unconformity at the base of the Saratoga chalk which also marks the base of the *Exogyra costata* zone. Other workers in this region are inclined to include the Saratoga in the Taylor group, thus placing it at the top of the beds of Taylor age in Arkansas. To the south and southwest in Louisiana and Texas the Saratoga chalk increases as the Marlbrook marl decreases in thickness and becomes increasingly chalky, finally these formations together with the Annona chalk at the base merge into an essentially continuous chalk formation. Eastward into Mississippi the Saratoga, Marlbrook, and Annona chalks are represented in the Selma chalk.

NACATOCH SAND

CHARACTER OF SURFACE BEDS

As described by Dane[41], the Nacatoch sand, which unconformably overlies the Saratoga chalk, is a complex unit, composed of cross-bedded yellowish and gray fine-grained quartz sand, hard crystalline fossiliferous sandy limestone, coarse, richly glauconitic sand, fine argillaceous dark blue-black sand and pure light-gray clay and marl. For some distance east of Little Deciper Creek, the Nacatoch completely overlaps the Saratoga chalk and rests directly on the Marlbrook marl. The Saratoga, however, reappears from under the Nacatoch in the immediate vicinity of Arkadelphia.

The Nacatoch sand is divisible into three lithologic units, which are continuously traceable from a point west of Washington, Hempstead County, eastward to Dobyville, Clark County. These three units are completely gradational one into the other. The lowest consists of bedded gray clay, sandy clay, and marl;

[40] Dane, C. H., op. cit.
[41] Dane, C. H., op. cit.

dark clayey, very fine-grained sand and harder irregular concretionary beds which contain lenses of calcareous fossiliferous slightly glauconitic sand. Both eastward and westward, this lowest part of the Nacatoch changes laterally to fine-grained gray cross-bedded quartz sand, which weathers yellowish and contains partings and pockets of clay. The lowest unit is estimated to be 100 feet thick north of Washington and is about 60 feet thick near Okolona, where it is almost pure clay. The middle unit consists of dark-greenish sand, which contains from 20 to 80 per cent of coarse glauconite grains and which weathers lighter shades of green. The middle unit also contains hard, irregular concretionary beds, cemented with calcite, and subordinate beds of dark blue-gray argillaceous, massive, fine-grained sand. The greensand member is about 50 feet thick near Washington and 40 feet thick near Okolona. East of Terre Noir Creek, Clark County, it grades into gray quartz sand, which weathers yellow, and contains small poorly preserved fossil prints and casts.

The upper part of the Nacatoch sand is composed of unconsolidated gray fine-grained quartz sand, which weathers yellowish and reddish. Cross-bedding is commonly present in this sand but is obscure unless revealed by differential weathering of thin clay partings. Locally the sand is massive and structureless and contains a few hard lenses and beds of fossiliferous sandstone, cemented by crystalline calcite; beds of gray and white clay as much as 2 feet thick, are also present.

West of Washington and east of Dobyville, the Nacatoch sand cannot be divided into the three units just described; instead it consists chiefly of sand which is characteristic of the upper of the three units. Between Saratoga and Fulton the whole thickness of the Nacatoch apparently consists of sandy beds of uniform composition, but, near Arkadelphia and for some distance west, the lower part of the Nacatoch consists of dark-gray or greenish-gray massive argillaceous fine-grained sand, which contains scattered grains of glauconite. Distributed through this massive sand are small lenses and beds of hard dark-gray sandstone cemented by calcite. Some of the lenses contain numerous fossils; others are nonfossiliferous. This lithologic unit is at least 100 feet thick as exposed at High Bluff on Ouachita River, but westward it grades rapidly to yellowish sand, which is only slightly argillaceous and contains only small poorly preserved fossil prints.

The Nacatoch sand is about 400 feet thick in western Hempstead County but thins gradually eastward to about 150 feet near Arkadelphia.

CHARACTER OF THE SUBSURFACE BEDS

Distribution and character.—The Nacatoch sand underlies all of the Gulf Coastal Plain of Arkansas except in a very narrow belt adjacent to the Ozark province to the north of Clark County, wherein it is overlapped by Tertiary sediments. In the southern part of the state, including the southeastern part of Union County, the southern and eastern parts of Ashley County, and most of Chicot County, the uppermost Cretaceous consists of limestone, called the "Monroe gas rock," which is believed to include the equivalent of the Nacatoch sand as developed elsewhere in the state.

The Nacatoch formation, in general, is divisible into two lithologic units which are gradational one into the other but recognizable through most of the Coastal Plain of Arkansas. The lower unit is composed of gray clays and shales, finely sandy clays, and, in some areas, contains thin beds or lenses of concretionary limestone and sandy limestone. In the marginal beds to the north of Clark County, this unit consists principally of fine-grained, in part glauconitic sand with thin concretionary beds. In parts of southeastern Arkansas, including parts of Union, Ouachita, Calhoun, Bradley, Dallas, and Cleveland counties, it is composed primarily of finely sandy clay and sandy marl with thin lenses of limestone.

The upper unit is composed chiefly of gray fine-grained sands interbedded with clayey sands, sandy clays, and calcareous sandstones. The greensands, prominently developed in the vicinity of Washington, Hempstead County, appear to be represented in this unit, locally at least, by beds of glauconitic sand and sandstone. In general, there is an increase in the calcareous and argillaceous content of this unit towards the south and southwest from Hempstead and Clark counties and the area of the Arkansas syncline towards the axis of the syncline. Lenticular structure of the individual members composing this part of the Nacatoch is strongly suggested by the available records.

The responsiveness of the Nacatoch to environmental conditions is indicated by the marked lateral changes in lithology and thickness, recognizable locally in many places, but prominently exhibited in the area of the Smackover field where the formation is composed principally of sand over the Norphlet dome area but grades laterally into sandy clays and clays, interbedded with thin and generally lenticular sands on the flanks of the dome.

The Nacatoch sand is an important oil and gas-producing horizon in the El Dorado, East El Dorado, Lisbon, Smackover, and Irma fields.

Thickness.—The maximum thickness of the Nacatoch sand recorded is in southwestern Miller County where it is 575 feet thick. It decreases in thickness towards the east of Miller County and is 250 to 300 feet thick in Columbia and Nevada counties but is only 125 to 250 feet thick in Union, Ouachita, Cleveland, and southern Dallas counties. In the area adjacent to Mississippi River north of Chicot County, the Nacatoch is probably not less than 300 feet thick.

MONROE GAS ROCK

The "Monroe gas rock" is applied to a series of crystalline limestones forming the principal gas-producing horizon in the Monroe gas field in Louisiana. Inasmuch as this name is in common usage, and the correlation of these strata with the standard Arkansas section is not definitely determined, it seems advisable to retain the name for the present.

The Monroe gas rock is extensively developed in northeastern Louisiana but continues into southern Union County, southern and eastern Ashley County, and northern Chicot County, Arkansas. In these areas it rests on strata ranging in age from Marlbrook to Lower Trinity and is overlain by strata of Midway formation (basal Eocene age). The areal distribution of the Monroe gas rock coincides closely with the extent of the Monroe uplift.

The Monroe gas rock is composed of white and light gray hard generally porous crystalline limestone, which in some places contains small amounts of fine quartz sands. To the north of the area of its typical development in southeastern Arkansas, the Monroe gas rock interfingers with the Nacatoch sand; this condition is well illustrated in the record of the Arkansas Fuel Oil Company's Crossett Lumber Company No. 1 well in sec. 1, T. 19 S., R. 7 W., Ashley County.

THICKNESS

The Monroe gas rock is from 200 to 300 feet thick in southern Ashley and Chicot counties but decreases in thickness towards the north and northwest.

CORRELATION OF THE NACATOCH SAND AND THE MONROE GAS ROCK

The Nacatoch sand is correlated with the Navarro formation of Texas, which has not yet been subdivided. It may be the equivalent to a zone of somewhat glauconitic gray sands and sandy clays, containing calcareous and fossiliferous lenses, which is extensively developed in northeastern Texas. To the east it is in part the equivalent to the Ripley formation of Tennessee and Mississippi.

The correlation of the Monroe gas rock, in part at least with the Nacatoch sand, is indicated by the fact that beds of typical

Monroe gas rock lithology interfinger with Nacatoch sand in Union and Ashley counties, but in part it may be the correlative of the Saratoga chalk. The Arkadelphia marl has not been recognized as a distinct lithologic unit in the area wherein the Monroe gas rock is typically developed; whether or not this formation is also represented in the Monroe gas rock is at present unknown.

ARKADELPHIA MARL

CHARACTER OF SURFACE BEDS

The Arkadelphia marl is the uppermost formation of the Gulf series and overlies the Nacatoch sand unconformably, resting upon an irregular surface of slight relief which probably represents only a brief time break. The basal few feet of the Arkadelphia marl contains hard gray sandstone, lenses of fossiliferous gray limestone, and gray calcareous sandstone, lenses of fossiliferous sandy gray limestone, and gray calcareous sandy clay. The remainder of the formation consists almost exclusively of dark marly clay and marl, which weathers light-gray. The marl and clay are poorly bedded or massive and in most places have a markedly conchoidal or lump fracture. The marl is prevailingly free from sand and contains locally a few layers of dense gray concretionary limestone or white impure chalk. The Arkadelphia marl characteristically contains shell fragments and foraminifera and in some outcrops yields an abundant fauna, although locally it contains no fossils.

The Arkadelphia marl along its outcrop has a thickness of about 150 feet which decreases eastward to about 120 feet in eastern Clark County.

CHARACTER OF THE SUBSURFACE BEDS

Distribution and character.—The Arkadelphia marl is present throughout the Coastal Plain of Arkansas, except in a small area which includes parts of Ashley County and most of Chicot County, where the Midway formation rests directly on the Monroe gas rock. It has not been determined whether the Arkadelphia marl has been removed by erosion or changes laterally in character in this area.

The Arkadelphia marl is remarkably uniform in character throughout southern Arkansas and northern Louisiana and is recognized in Mississippi where it is included in the Ripley formation. It is composed chiefly of dark-gray to nearly black marly clay and marl but contains beds of chalky marl and thin beds and lenses of chalk, and locally, thin beds or lenses of sandstone and sandy shale in the basal part of the formation.

Thickness.—The top of the Arkadelphia marl is an erosion surface developed during a long period of emergence. The thickness of the formation, nevertheless, is remarkably uniform, ranging from about 50 to 150 feet, with the greater thickness in the southwestern part of the state.

Correlation.—The Arkadelphia marl is the upper part of the *Exogyra costata* zone and is represented in northeast Texas by the upper part of the Navarro formation. The Arkadelphia marl is recognizable as a distinct lithologic unit in Mississippi where it is included in, and forms the upper part of, the Ripley formation.

Typical well sections of the Nacatoch sand and Monroe gas rocks are given in the following tables.

Section of Nacatoch sand in Magnolia Petroleum Company's Westmoreland No. 1 well in sec. 9, T. 19 S., R. 27 W., Miller County, Arkansas

Character	Depth in feet
Nacatoch sand:	
Hard sand	1831–1842
Hard lime rock	1842–1854
Hard sand	1854–1876
Broken ilme	1876–1880
Sand	1880–1896
Hard lime	1896–1910
Sand	1910–1922
Broken lime	1922–1932
Sand	1932–1995
Lime rock	1995–2000
Broken lime and shale	2000–2007
Shale	2007–2012
Sand	2012–2038
Sand and shale	2038–2057
Rock	2057–2070
Shale	2070–2115
Sand	2115–2132
Hard rock	2132–2135
Sand	2135–2234
Sand and shale	2234–2254
Shale	2254–2265
Sand and shale	2265–2305
Hard shale	2305–2337
Hard sand and shale	2337–2368
Shale and rock	2368–2391

Section of Nacatoch sand in Arkansas Fuel Oil Company's Longino and Goode No. 1 well in sec. 14, T. 18 S., R. 20 W., Columbia County, Arkansas

Character	Depth in feet
Nacatoch sand:	
Sand	1966–1967
Lime	1967–1969
Sand	1969–1971
Sand and shale	1971–1973
Sand	1973–1980
Sandy limestone	1980–1984
Sand	1984–1991

Broken sandy lime	1991–1993
Sand	1993–1999
Broken lime	1999–2003
Sand	2003–2005
Sandy limestone	2005–2007
Sand	2007–2009
Sand and shale	2009–2014
Broken sand	2014–2016
Sandy lime	2016–2020
Limestone	2020–2023
Sand and shale	2023–2024
Sand and sandy limestone	2024–2052
Sand and shale	2052–2060
Shale	2060–2063
Sand and sandy lime	2063–2087
Sand and shale	2087–2093
Sand and sandy limestone	2093–2130
Limestone and shale	2130–2138
Sand, sandy limestone, and limestone	2138–2163
Shale	2163–2174
Sandy limestone	2174–2177
Gummy lime	2177–2210
Gummy lime and shale	2210–2266

Section of Nacatoch sand in Talbot and Markle's Copeland No. 1 *well in sec.* 31, *T.* 19 *S., R.* 19 *W., Columbia County, Arkansas*

Character	Depth in feet
Nacatoch sand:	
Sand with shale breaks; oil show	2287–2295
Sand	2295–2305
Sand and shale	2305–2313
Sand	2313–2332
Hard sandy lime	2332–2346
Shale and boulders	2346–2425
Shale	2425–2465
Hard sand	2465–2469
Gumbo and lime	2469–2545

Section of Nacatoch sand in Shell Petroleum Company's Carroll No. 1 *well in sec.* 19, *T.* 18 *S., R.* 16 *W., Union County, Arkansas*

Character	Depth in feet
Nacatoch sand:	
Sandy shale (Core 2039-2046 feet, gray sandy shale, dark-gray compact clay, and fine-grained glauconitic sand; core 2048-2050 feet, gray fine sandy clay with irregular patches of gray fine-grained sand)	2037–2050
Hard sand, cap rock (Core 2053 feet, gray medium-grained hard slightly glauconitic sandstone)	2050–2054
Soft gray sand (Core 2056 feet, gray medium-grained slightly clayey sand)	2054–2066
Gray sand and shale (Core 2063-2073 feet, gray clay, fine-grained argillaceous sand, and sandy clay)	2066–2073
Gray sand (Core 2073-2080 feet, gray fine to medium-grained in part clayey sand, and thin lenses of gray compact clay)	2073–2087
Shaley sand	2087–2091

Sandy shale (Core 2087-2095 feet, gray compact shale and sandy shale)	2091–2095
Sticky shale (Core 2105-2115 feet, gray, medium-grained argillaceous sand)	2095–2121
Hard sandy lime	2121–2130
Soft sand (Core 2128-2135 feet, gray sandy shale, sand, and clay)	2130–2137
Broken sandy lime (Core 2135-2145 feet, gray silty sand and sandy shale; core 2145-2155 feet, gray sandy shale)	2137–2170
Stick shale (Core 2155-2175 feet, gray silty sand and sandy shale)	2170–2228
Sandy shale (Core 2230-2237 feet, dark-gray marl)	2228–2245

Section of Nacatoch sand in Natural Gas and Fuel Corporation's Cordell No. 1 well in sec. 9, T. 18 S., R. 13 W., Union County, Arkansas

Character	Depth in feet
Nacatoch sand:	
Limestone and streaks of hard shale	2192–2212
Gray limestone	2212–2215
Hard sandy shale; show of oil	2215–2228
Sand (Core 2234-2240 feet, light-gray fine-grained calcareous sandstone; core 2240-2247 feet, light-gray, fine-grained calcareous sandstone; core 2247-2254 feet, medium-gray calcareous sandstone)	2228–2254
Hard sandy shale and streaks of oil sand (Core 2254-2270 feet, medium-gray fine to medium-grained calcareous sandstone)	2254–2270
Lime and shale	2270–2318

Section of Nacatoch sand in Pure Oil Corporation's Gregory No. 1 well in sec. 10, T. 17 S., R. 14 W., Union County, Arkansas

Character	Depth in feet
Nacatoch sand:	
Sand with streaks of shale	2135–2150
Limestone	2150–2161
Sandy shale	2161–2175
Rock	2175–2176
Shale	2176–2197
Broken rock and sand	2197–2200
Shale and sand rock	2200–2220
Sand with hard streaks	2220–2240
Limestone with streaks of sand	2240–2258
Chalk and sand with streaks of shale	2258–2286

Section of Nacatoch sand in Louisiana Oil Refining Corporation's Manley No. 1 well in sec. 15, T. 15 S., R. 19 W., Ouachita County, Arkansas

Character	Depth in feet
Nacatoch sand:	
Sand; show of oil	1484–1492
Hard gray lime	1492–1500
Sandy lime	1500–1550
Hard lime	1550–1588
Broken lime and shale	1588–1643
Lime	1643–1653
Shale	1653–1693
Gumbo and shale	1693–1738

Section of Nacatoch sand in Arkansas Natural Gas Corporation's Tate No. 1 well in sec. 4, T. 9 S., R. 11 W., Cleveland County, Arkansas

Character	Depth in feet
Nacatoch sand:	
Sand	2930–2955
Sand and shale	2951–2961
Sand and limestone	2961–2992
Hard shale and limestone	2992–3030
Hard sandy shale	3030–3048
Shale and streaks of limestone	3048–3080

Section of Nacatoch sand in Ohio Oil Company's Taylor No. 1 well in sec. 27, T. 9 S., R. 17 W., Dallas County, Arkansas

Character	Depth in feet
Nacatoch sand:	
Sand	1051–1220
Sandy shale	1220–1234
Shale and chalk	1234–1252

Section of Nacatoch sand in Atlantic Oil Producing Company's Moffat No. 1 well in sec. 28, T. 16 S., R. 8 W., Ashley County, Arkansas

Character	Depth in feet
Nacatoch sand:	
Hard sand and chalky sand (Core 2778-2784 feet, white calcareous sandstone)	2776–2789
Sandy chalk	2789–2790
Sand (Core 2790-2792 feet, light-gray calcareous sandstone)	2790–2795
Broken lime rock	2795–2806
Sand	2806–2810
Soft sand with thin streaks of lime (Core 2811-2816 feet, medium-gray friable calcareous sandstone)	2810–2816
Hard broken lime	2816–2830
Chalky shale (Core 2839-2845 feet, gray, friable, calcareous sandstone)	2830–2845
Sandy chalk and streaks of shale	2845–2879
Chalk (Core 3009-3016 feet, medium-gray calcareous sandstone)	2879–3034

Section of Nacatoch sand in Arkansas Fuel Oil Company's Crossett Lumber Company No. 1 well in sec. 1, T. 19 S., R. 7 W., Ashley County, Arkansas

Character	Depth in feet
Nacatoch sand:	
Hard sand and lime (Core 2714-2718 feet, white sandy limestone)	2714–2718
Hard sandy lime (Core 2719-2721 feet, light-gray sandy limestone)	2718–2721
Sand (Core 2721-2727 feet, light-gray sandy limestone)	2721–2727
Sand (fresh water) (Core 2727-2733 feet, light gray soft, fine-grained sandstone)	2727–2733
Lime (Core 2733-2740 feet, medium-gray, soft calcareous sandstone)	2733–2745
Hard lime and streaks of sand	2745–2757
Sand and streaks of lime (Core 2757-2762 feet, medium-gray, soft calcareous sandstone)	2757–2762

Sandy shale and lime (Core 2762-2768 feet, light-gray, calcareous sandstone)	2762–2783
Hard sandy shale	2783–2788
Hard sand and lime (Core 2790-2793 feet, white fine sandy, crystalline limestone (Monroe gas rock); core 2793-2798 feet, light-gray porous, sandy, crystalline limestone; core 2798-2802 feet, medium-gray hard calcareous sandstone and shell fragments; core 2802-2803 feet, light-gray hard calcareous sandstone and soft medium-gray calcareous sandstone)	2788–2803
Sand	2803–2805
Sand and lime (Core 2805-2807 feet, white very slightly sandy, porous, crystalline limestone with fossils (Monroe gas rock)	2805–2807
Lime and sandy shale (Core 2807-2812 feet, gray calcareous sandstone)	2807–2812
Lime and shale	2812–2833
Hard lime	2833–2840
Lime and shale	2840–2862
Hard lime and shale	2862–2873
Hard lime and shale (Core 2873-2879 feet, light-gray sandy limestone)	2873–2913
Sandy shale and lime (Core 2913-2920 feet, gray calcareous sand)	2913–2932

Section of Monroe gas rock in the Texas Company's Gay No. 1 *well in sec.* 33, *T.* 16 *S., R.* 4 *W., Ashley County, Arkansas*

Character	Depth in feet
Monroe gas rock:	
Gas rock (Cuttings 2866-2867 feet, white hard, porous, sandy limestone, containing a considerable amount of crystalline calcite; core 2867-2867½ feet, white hard, porous, crystalline limestone, containing many medium-sized quartz grains)	2866–2889
Broken gas rock (Core 2867½-2899 feet, white hard, porous, crystalline limestone)	2889–2899
Gas rock	2899–2924
Broken gas rock (Core 2924-2929 feet, white hard fine-grained sandy limestone)	2924–2954
Sandy chalk (Core 2954-2959 feet, white, medium-hard, limestone, in part crystalline with a small amount of fine quartz grains)	2954–2959
Broken gas rock	2959–2984
Chalk rock (Cores 2984-2986 feet, white hard crystalline limestone)	2984–3003
Gas rock	3003–3048
Broken chalk and gumbo	3048–3088
Gas rock (Cores 2986-3105 feet, white hard and medium-hard limestone, in part crystalline, containing a few quartz grains)	3088–3114

TERTIARY SYSTEM

GENERAL STATEMENT

The Tertiary system in Arkansas is represented chiefly by the Eocene series, which is divisible into four formational units and which has a maximum thickness of nearly 5,000 feet. The Pliocene is thought to be represented by the Lafayette sands and gravels exposed in Crowley's Ridge in northeastern Arkansas and tentatively correlated with the Citronelle formation of Louisiana and Mississippi. The Oligocene and Miocene series are not represented in Arkansas (See Table 1.)

EOCENE SERIES

GENERAL STATEMENT

The Eocene series of Arkansas consists of sands, sandy clays, and clays in part lignitic and carbonaceous and of marine clays, sandy clays, clays and marls, in part glauconitic and containing thin beds and lenses of limestone and chalk. The series contains an abundance of siderite and ferruginous concretions, irregular thin lenses of bentonitic clay, and locally irregular lenses and boulders of quartzite.

The Eocene sediments are from 1,500 to 2,000 feet thick in the southwestern part but increase in thickness to more than 4,000 feet in the eastern part of the state.

The Eocene formations have not been mapped in detail, and, in general, their characteristics are indifferently recorded in deep wells. Because of these facts, the Eocene sediments are described under the broader formational units, as follows:

- Tertiary system
  - Eocene series
    - Jackson formation
    - Claiborne formation
    - Wilcox formation
    - Midway formation

MIDWAY FORMATION

DISTRIBUTION

The Midway formation crops out in a narrow, more or less continuous, belt 1 to 5 miles in width, extending from the Texas line in northern Miller County to Little Rock, Pulaski County. Northeast of Little Rock, the formation has been recognized in a small area near Cabot, Lonoke County, and in a narrow outcrop, not more than half a mile in width, extending from the vicinity of Bradford, White County, to Depart Creek, southern Independence County. Elsewhere in this area the Midway is overlapped by younger Eocene strata or concealed beneath Quaternary alluvial deposits.

CONTACT OF MIDWAY FORMATION WITH UNDERLYING ROCKS

From the Texas line northeastward to Ouachita River in the vicinity of Arkadelphia, the basal Midway lies directly on the Arkadelphia marl of Cretaceous age. Where the Midway again

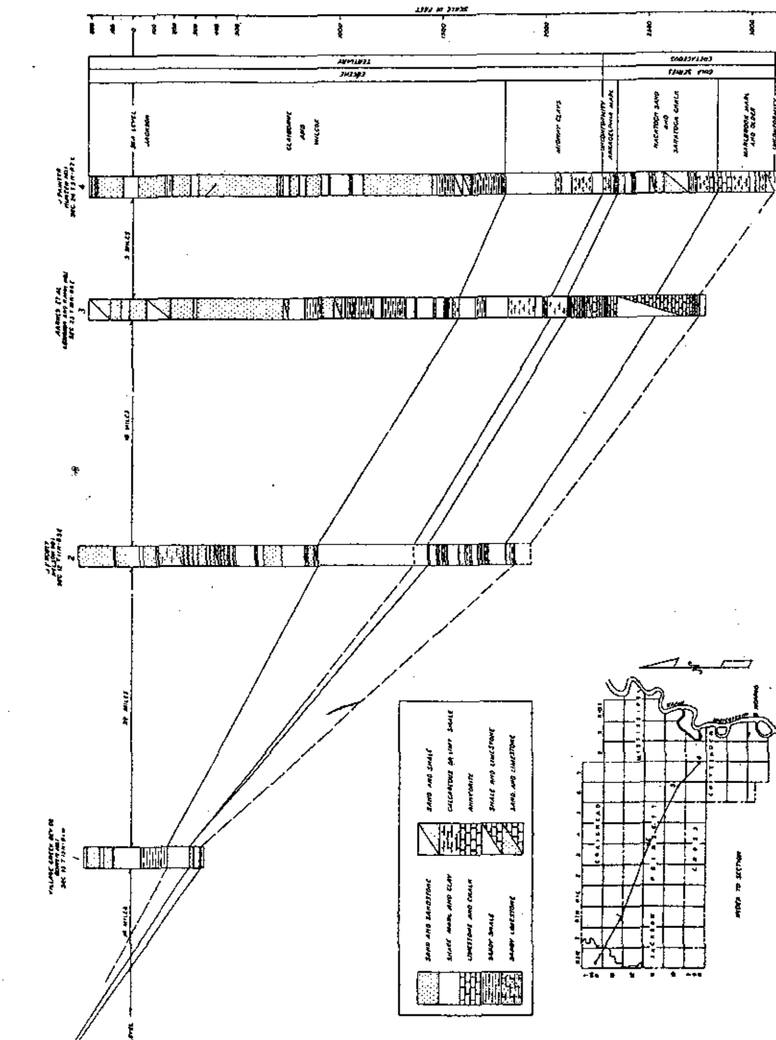

FIGURE 13.—Cross section through Jackson, Poinsett, and Crittenden counties.

appears at the surface between Arkadelphia and Malvern, it lies directly on strongly folded and truncated strata of Paleozoic age, which form the basement floor upon which the Coastal Plain sediments were deposited. This relationship of the basal Midway to the basement rocks appears to continue northeastward to the border of the state. (See Fig. 13.) The rocks in contact with the base of the Midway formation range widely in lithology, consisting of marls in the western part, principally of slates and novaculites between Arkadelphia and Little Rock,

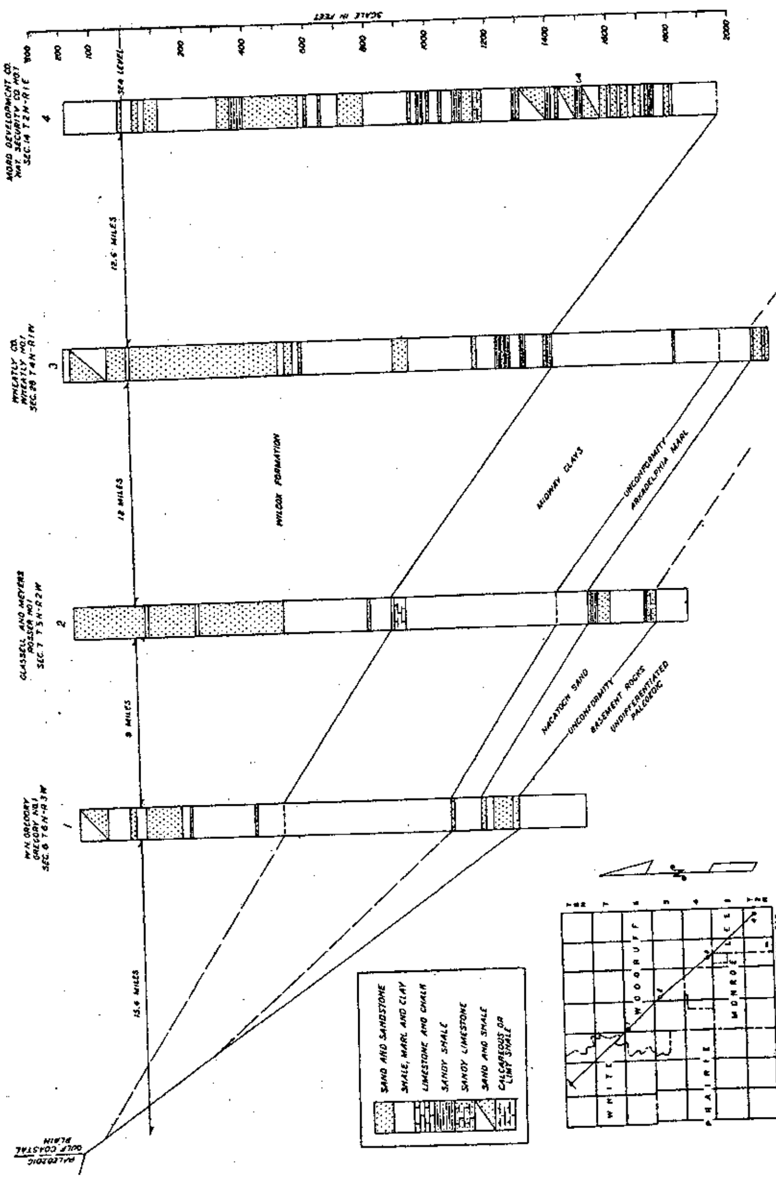

FIGURE 14.—Cross section through White, Woodruff, and Lee counties.

and principally of sandstones and shales to the northeast of Little Rock; the sediments at the base of the Midway exhibit correspondingly wide ranges in lithology. (Fig. 14.)

The Cretaceous-Eocene contact exposed in the NW¼ sec. 26, T. 11 S., R. 23 W., 2.9 miles east of Emmett on the old highway from Emmett to Prescott, has been described by Dane[42]:

"At this place a ditch north of the road exposes a ledge of hard, yellow-weathering, gray earthy limestone about a foot thick. This ledge is concealed above by soil. The limestone is sandy and contains abundant fossil shells, very few of which are well preserved, and, dark, long rhombs of calcite. It grades downward into calcareous, slightly sandy clay and then into a calcareous waxy clay containing some poor shells, including probably *Ostrea pulaskensis*, an Eocene form.

"About three feet below the hard limestone is a bed of marl, a foot thick, containing phosphatic nodules and some phosphatic fossil casts, as well as numerous foraminifera, and small shells. In this zone there are yellowish lenses of sand, six inches long and one inch thick, containing abundant rotten shells of foraminifera. The marl below them is thickly studded with small phosphatic nodules..... There is little doubt that the zone of phosphatic nodules marks the base of the Midway."

Other localities in which the base of the Midway is exposed are found between Emmet and Hope. Dane[43] described another outcrop located 4.4 miles north of Hope, along the road to DeAnn, about a mile south of the bottom of Flat Branch of Terre Range Creek. At this locality the top of the Arkadelphia marl is a massive, dirty chalk with a slightly irregular upper surface, on which rests a bed that ranges in thickness from half an inch to 10 inches. Where thin, this bed is sandy marl, in which most of the grains are rounded particles of black and gray phosphate, nodules of calcite, and grains of glauconite. The bed contains irregular nodules of light-gray phosphate, the largest half an inch in diameter, small fragments of *Ostrea*, fish teeth, and numerous foraminifera; where thicker, it is a gray, calcareous sandy clay in which are embedded masses of dirty chalk like that exposed below, 6 to 9 inches in diameter. In the sandy clay are embedded specimens of *Exogyra costata* of the Arkadelphia type. The relations here indicate that this sandy layer is the basal Midway formation, and that the *Exogyra* in it are reworked from the underlying Cretaceous, together with the lumps of white marl.

The base of the Midway formation has not been recognized west of Hope in Hempstead County.

In the vicinity of Malvern, where the Midway rests directly on Paleozoic slate and novaculite, the basal bed consists of

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[42] Dane, C. H., Upper Cretaceous formations of southwestern Arkansas: Arkansas Geol. Survey Bull. 2, 1929, p. 154.

[43] Dane, C. H., op. cit.

gravel, made up chiefly of fragments of novaculite embedded in clay. At Bradford, White County, the basal bed of the Midway is composed of thin layers of gravel, consisting of pebbles and cobbles of soft brown sandstone, which range in size up to 6 and 8 inches in diameter, with average diameters of one-half to one inch. The gravels are derived from the Paleozoic rocks underlying this area.

The lower 25 to 50 feet of beds in the Midway formation are made up of calcareous clays, marls, limestones, and sands which, in Arkansas, are recognizable as a distinct zone in the Midway, extending from Hope, Hempstead County, northeastward into Independence County. The zone has been recognized to the west in Texas[44] and to the east in Mississippi, where it is correlated with the Clayton limestone of Midway age.

In Hempstead and Nevada counties, where this zone has been examined and described by Dane[45], the zone consists chiefly of gray calcareous clays with thin lenses of yellowish earthy limestone and contains locally small lenses of fine sand at the base. East of Ouachita River, where the Midway again appears at the surface, the sand at the base and the overlying limestone have increased in thickness. In sec. 8, T. 1 S., R. 13 W., the sand at the base of the Midway is 5 feet thick, and the overlying limestone is 12 feet thick. A section exposed on Fourche Creek in Pulaski County exhibits the same thickness of sand with 14 feet of limestone above it. To the northeast of Little Rock the limestone becomes increasingly sandy, and in Independence County consists of limestone beds 1 to 1½ feet thick, interbedded with thin beds of gray and yellowish-gray sands. The basal beds of the Midway are abundantly fossiliferous.

The remainder of the Midway formation consists of dark-gray noncalcareous clays, which, on the outcrop, appear light brownish-gray and bedded and show an irregular, conchoidal fracture. Fresher exposures are darker gray and nearly massive but show obscure laminations. The upper, generally noncalcareous Midway is nearly free from sand but contains at some places a few small flakes of Muscovite. In some places this clay contains beds of concretionary sand, a fraction of an inch to an inch thick, streaks of limonite, hard black broken nodular and siderite concretions. Fossils are very rare in the upper Midway.

The contact of the Midway with the overlying Wilcox formation is observable at only a few localities but is well exposed in the vicinity of Lanesburg, Nevada County, where the characteristic dark-gray noncalcareous Midway clay exposes a slightly

[44] Plummer, H. J., Foraminifera of the Midway formation in Texas: Texas Univ., Bull. 2644, pp. 206, 1926.

[45] Dane, C. H., op. cit.

irregular surface, in contact with irregular thin beds and lenses of lignite and lignitic clays which, in turn, are overlain by light-colored sands belonging to the Wilcox formation.

LOCAL DETAILS

An outcrop of the basal Midway in a gully along the Okalona road 1.3 miles northwest of Beirne in Clark County, is described by Dane[46].

"Here, there are 20 feet of very slightly calcareous light-gray clay, with poor bedding. At the base of this, there is about a foot of massive sandy marl containing numerous small, irregular, brown and black phosphatic nodules and oolites, shark and fish teeth, echinoid spines, foraminifera and a few glauconite grains."

A number of outcrops of the Midway are described by Harris[47] and by Stephenson and Crider[48] of which the following are representative of this formation.

Section of Lower Midway in sec. 8, T. 1 S., R. 13 W., Pulaski County
(G. D. Harris)

Character	Thickness in feet
Soil	1
Enclimatoceras limestone; yellowish and gray, more or less friable, exterior of fossils often stained brownish by iron oxide; replete with *Enclimatoceras ulrichi*, 1 to 12 inches in diameter	1⅝
Ostrea limestone; compact, light-gray limestone, containing numerous specimens of *Ostrea pulaskensis*	3
Turritella limestone; light yellowish and gray, somewhat sandy, often honeycombed and cavernous, weathering irregularly; at base, especially replete with *Turritella mortoni*	8¼
Sandstone, light yellowish	2¾
White compact sand, tinged yellow on exterior and containing scattered blue nodules; exposed thickness	2

Generalized Section at Bradford, White County, Arkansas
(Stephenson and Crider)

Character	Thickness in feet
Top of terrace capped with gravel (Lafayette formation?)	
Red calcareous clay	5–10
Gray calcareous clay	5–10
Layers of limestone interbedded with unconsolidated sand	20
Thin layer of gravel, consisting of pebbles and cobbles of soft brown sandstone which range in size up to 6 or 8 inches in diameter, with an average diameter of one-half to one inch. These are derived from rocks of Paleozoic age	½– 1
Unconformity	
Paleozoic sandstone and shale	

[46] Dane, C. H., op. cit., p. 158.

[47] Harris, G. D., The Tertiary geology of southern Arkansas: Ark. Geol. Survey Ann. Rep. for 1892, vol. 2, 1894.

[48] Stephenson, L. W., and Crider, A. F., Geology and ground waters of northeastern Arkansas: U. S. Geol. Survey Water-Supply Paper 399, 1916.

Section in a cut of the St. Louis Iron Mountain and Southern Railway one-quarter of a mile south of Grandglaise, Jackson County

(Stephenson and Crider)

Character	Thickness in feet
Top of hill and slope covered with brownish sandy loam and overgrown with vegetation	25
Midway formation:	
Limestone in layers 1 to 1½ feet thick, interbedded with thinner layers of soft gray calcareous sand; the limestone contains small greenish pebbles of sandstone which are particularly abundant in layers 5 to 8 feet above base; the upper and lower surfaces of the limestone layers present numerous rounded and irregular concretionary projections which extend upward and downward into the intervening layers of sand; the limestone contains an abundance of imperfectly preserved fossil remains, among which T. W. Vaughan has identified the following: *Balanophyllia sp.*, *Tornatella bella* Conrad, *Furritella mortoni* Conrad, and *Mesalia pumila* (Gabb)	22

THICKNESS

The maximum thickness of the Midway formation along the outcrop in Arkansas is present in the southwestern part of the state, where it is not less than 400 feet thick; northeast of Ouachita River the thickness decreases. (Fig. 15.)

FAUNA AND CORRELATION

The fossils of the Midway formation of Arkansas have been studied by Harris[49] and others who have identified the following species listed by Stephenson and Crider[50]:

Fossils from the Midway formation of Arkansas

Belanophyllia sp.
Cucullaea macrodonta Whitfield
Ostrea crenulimarginata Gabb
Ostrea pulaskensis Harris
Pecten alabamiensis Aldrich
Venericardia planicosta Lamarck
Calyptraphorus velatus Conrad
Tournatella bella Conrad
Natica alabamiensis Whitfield
Turritella alabamiensis Whitfield
Turritella mortoni Conrad
Turritella multilira Whitfield
Mesalia pumila Gabb
Potamides alabamiensis Whitfield
Tubulostium dickhauti White
Volutilithes limopsis Conrad ?
Volutilithes petrosa (Conrad) ?
Enclimatoceras ulrichi White
Calianassa ulrichi White

49 Harris, G. D., op. cit.
50 Stephenson, L. W., and Crider, A. F., op. cit.

On the evidence of the contained fauna, these beds are correlated with the Midway group of Alabama, the lower calcareous

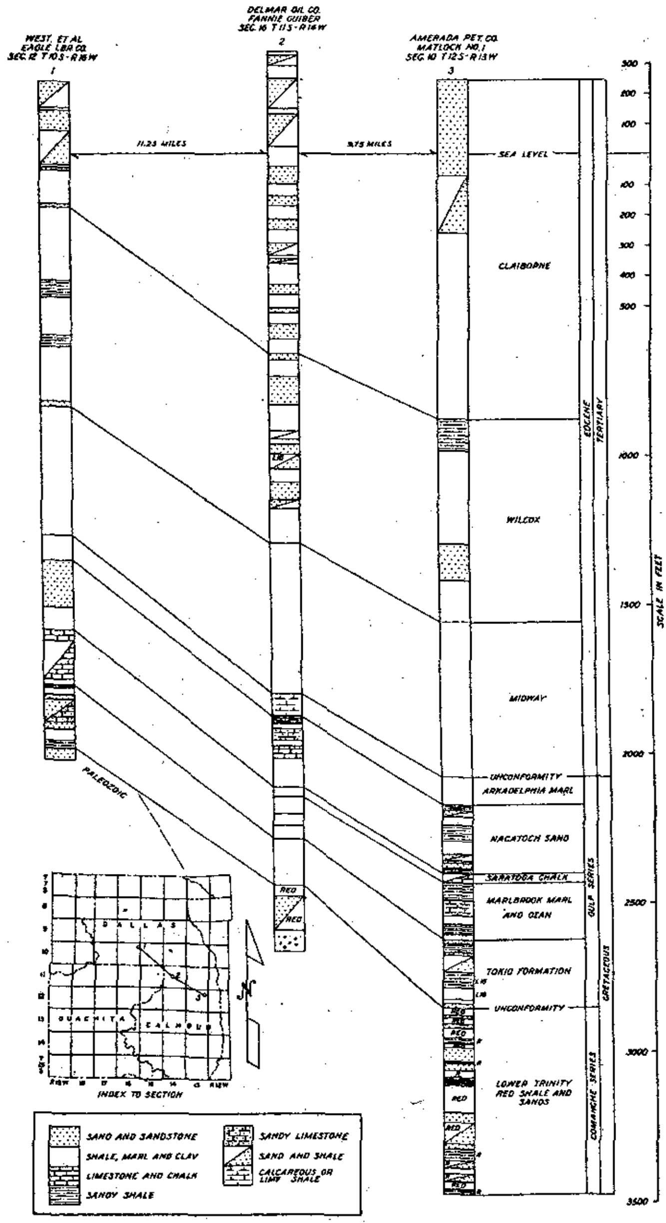

FIGURE 15.—Cross section through Dallas and Calhoun counties.

and fossiliferous zone being regarded as the equivalent of the Clayton limestone of Mississippi.

CHARACTER OF THE SUBSURFACE BEDS

DISTRIBUTION AND CHARACTER

The Midway formation which underlies all of the Gulf Coastal Plain of Arkansas, maintains the same general lithologic characteristics throughout this region.

Through most of southern Arkansas the contact between the Midway and the underlying Cretaceous is marked by a bed of white to gray ash, having a maximum observed thickness of approximately 6 feet. Above the ash bed, there are 50 to 100 feet of gray calcareous clay and shale with interbedded thin lenses and layers of chalk and limestone. In some places, especially in the northeastern part of the state, thin sands are locally recorded in deep wells. This part of the Midway contains a distinct marine invertebrate fauna.

The remainder of the Midway formation consists principally of gray, noncalcareous clays and shaly clays, containing an abundance of siderite concretions. The upper few feet to 50 feet or more in most places are sandy and not easily distinguished from the overlying Wilcox formation into which it is transitional, but, in general, it is somewhat finer in texture and lacks the brownish tinge which is characteristic of the Wilcox formation.

A few arenaceous foraminifera are present in the Midway above the basal calcareous zone, but they are rarely found in the upper 300 feet of the formation.

THICKNESS

The Midway formation ranges in thickness from 450 to 600 feet, with the greater thickness in the Arkansas syncline in the eastern part of the state.

A typical deep well record of the Midway is given below:

Section of Midway formation in Shaffer Oil and Refining Company's Long-Bell No. 1 well in sec. 36, T. 5 S., R. 12 W., Grant County, Arkansas

Character	Depth in feet
Midway formation:	
Gray sandy shale (Core 2181-2196 feet, dark-gray, interlaminated silt and micaceous clay; core 2196-2236 feet, same as above; core 2236-2256 feet, same as above; core 2256-2264 feet, medium gray noncalcareous silty shale; siderite concretions)	2170–2264
Medium sandy shale (Core 2265-2280 feet, medium gray, noncalcareous silty shale; siderite concretions)	2264–2300
Gummy shale (Core 2305-2317 feet, medium-gray noncalcareous, silty clay; few grains glauconite)	2300–2345
Sandy shale (Core 2345-2360 feet, medium-gray, noncalcareous silty clay; few grains glauconite and fish remains)	2345–2360
Gummy shale (Core 2384-2403 feet, medium-gray noncalcareous clay)	2360–2402

Lime	2402–2403
Gummy shale (Core 2403-2423 feet, medium-gray to dark-gray, noncalcareous shaly clay)	2403–2511
Gumbo	2511–2543
Limy shale (Core 2546-2550 feet, light-gray calcareous shaly clay; abundant Midway foraminifera; core 2564-2575 feet, same as above; core 2575-2590 feet, same as above; core 2590-2610 feet, light-gray calcareous clay with conchoidal fracture; Midway foraminifera; core 2610-2620 feet, same as above; core 2620-2756 feet, medium-gray calcareous shaly clays; Midway foraminifera)	2543–2935

WILCOX FORMATION

HISTORICAL SUMMARY

The name "Wilcox" was proposed by Crider[51] in 1906 for a series of sands, clays and lignite interposed between the Midway group below and the Claiborne group above, which are typically exposed in Wilcox County, Alabama.

Other terms have been applied to this formation. Harris[52], in describing the Tertiary of Arkansas used the term "lignitic stage." Veatch[53] in 1905, applied the name "Sabine formation" to these strata in Louisiana and Arkansas, taking the name from Sabine River in Sabine Parish, Louisiana, and Sabine County, Texas, where they are typically exposed. In the United States Geological Survey publications, subsequent to 1906, the name "Wilcox" has been applied to this formation.

DISTRIBUTION

The Wilcox formation crops out in almost continuous belt 6 to 20 miles in width, which extends from the Texas line in northern Miller County to Little Rock. Northeast of Little Rock it is generally concealed beneath Quaternary alluvial deposits but appears at the surface in local areas in Lonoke and White counties, and on the flanks of Crowley's Ridge in Poinsett, Craighead, Greene, and Clay counties.

The Wilcox formation is composed principally of sands and sandy clays but contains beds of carbonaceous clays and lignite, siderite concretions, and locally, thin beds and lenses of bentonitic clay and lenses and boulders of quartzite. The formation, although exhibiting marked lateral variations in lithology is, through most of its outcrops in southwestern Arkansas, divisible into four more or less distinct lithologic units which are gradational one into the other. A fairly complete section of the Wilcox formation is exposed between Lanesburg and Rosston, Nevada County, where the section is as follows:

[51] Crider, A. F., Geology and mineral resources of Mississippi: U. S. Geol. Survey, Bull. 283, pp. 25-28, 1906.

[52] Harris, G. D., The Tertiary geology of southern Arkansas: Arkansas Geol. Survey, Ann. Rept. 1892, vol. 2, 1894.

[53] Veatch, A. C., Geology and underground water resources of northern Louisiana with notes on adjoining districts: Louisiana Geol. Survey Rept. of 1905, 1907.

———Geology and underground water resources of northern Louisiana and southern Arkansas: U. S. Geol. Survey, Prof. Paper 46, 1906.

Section Wilcox formation between Lanesburg and Rosston

Character	Thickness in feet
Generally fine-grained, in part argillaceous and carbonaceous gray and yellowish-gray, irregularly bedded sands. Contains ferruginous concretions ½ to 1½ inches in diameter, and some thin beds of gray clay	150–200
Brown, dark-gray to black, slightly sandy carbonaceous and lignitic clay, containing thin beds of gray sands, abundant concretions of limonite and weathered siderite, 12 to 18 inches in diameter, with a rather definite horizon of much weathered siderite concretions about one foot thick near the top of the zone	50
White to gray and yellow, generally, massive, cross-bedded, medium to coarse-grained sand which weathers yellow to red, contains thin partings of white to gray clay and locally, thin lenses of bentonitic clay; grades upward into clayey sands and in the upper 50 feet or more, contains gray and brown lignitics, very sandy clay; lenses and boulders of quartzite are present in the lithologic unit	250
Generally sandy clays and clayey sands, lignitic at the contact and for some distance above the contact. Contains siderite concretions	50

In general the carbonaceous content of the Wilcox formation increases to the west and east of Nevada County. The lignite beds are especially well developed to the north of Camden in northern Ouachita County, where a workable bed of lignite 6 feet thick has been mined. The horizon in which this bed occurs is correlated with the carbonaceous clay member in the upper part of the Wilcox formation. Beds of lignite occur at many other localities.

THICKNESS OF WILCOX FORMATION

The Wilcox formation along its outcrop in Arkansas ranges in thickness from 500 to 600 feet.

CORRELATION

The Wilcox formation as developed in Arkansas is the equivalent of at least a part of the Wilcox group of Alabama.

SUBSURFACE BEDS

DISTRIBUTION AND CHARACTER

The Wilcox formation underlies all of Arkansas to the south and east of the outcrop. In general it maintains the same characteristics as along the outcrop but contains more clays and carbonaceous material, especially in the southeastern part of the state.

THICKNESS

The Wilcox formation is from 500 to 600 feet thick in the south central part of the state but increases in thickness towards the east and west. In southern Miller and Lafayette counties it is from 800 to 1,000 feet thick and is probably more than 1,500 feet thick in Desha, Lincoln and Arkansas counties in the southeastern part of the state.

Core record of Wilcox formation in Cambrian Trust Company's Fee No. 1 well in sec. 3, T. 9 S., R. 8 W., Lincoln County, Arkansas

Character	Depth in feet
Top of Wilcox formation:	
Dark-brown shale with light-gray silt partings small patches of lignite present	1911–2133
Light-brown waxy clay with leaf impressions	2133–2212
Light-brown lignitic clay	2212–2242
Light-gray, fine-grained sandstone and black lignitic shale	2242–2247
Light-gray clay	2272–2297
Gray and light brown lignitic clay with siderite and calcareous lignitic sandstone boulders	2322–2382
Brown sandy lignitic clay	2382–2412
Light-gray calcareous, lignitic sandstone (boulders)	2412–2415
Light-gray, very fine-grained sandstone	2424–2443
Medium-gray noncalcareous sandstone	2443–2458
Medium-gray noncalcareous clay and lignite	2458–2469
Brown lignitic clay	2482–2502
Light-gray lignitic clay	2502–2508
Light-brown lignitic clay	2508–2532
Medium-gray shaly clay	2532–2547
Light-gray silt stone	2547–2557
Light-brown lignitic clay	2557–2574
Medium-gray lignitic, noncalcareous sandstone	2547–2589
Interlaminated light-gray fine sand and dark-gray clay	2589–2613
Lignite and brown lignitic clay	2613–2622
Light-gray clay	2625–2643
Light-brown lignitic clay	2654–2671
Lignite	2671–2683
Light-brown lignitic clay	2683–2699
Light-gray, fine-grained sandstone	2699–2706
Light-brown lignitic clay	2712–2745
Light-gray noncalcareous, fine-grained sandstone	2745–2763
Light-gray friable sandstone	2763–2767
Dark-gray calcareous sandstone (boulders)	2767–2776
Medium-gray clay	2776–2793
Light-brown lignitic clay and lignite	2793–2815
Light-brown lignitic clay	2815–2834
Light-brown clay	2834–2847
Light-gray, ashy-appearing sandstone	2847–2896
Total depth of well	2896

CLAIBORNE GROUP

The Claiborne formation, as shown on the geologic map of Arkansas (See Pl. II) is inclusive of the Claiborne group which in the adjoining states has been divided into several formational units. The Claiborne sediments exposed at the surface in Arkansas consist chiefly of sand and ferruginous clays in the southwestern part, and of sands and carbonaceous clays in the southeastern part of the state and contain only slight amounts of glauconite which characterizes the Claiborne sediments in Texas, Louisiana, and Mississippi. These sediments contain poorly preserved fossil remains, chiefly in the form of casts.

The Claiborne nomenclature has been the subject of much discussion and some controversy during the past year, the result of detailed field studies in different parts of the Gulf Coastal Plain. The more recent papers dealing with this subject are:

Ellisor, A. C., Correlation of the Claiborne of east Texas with the Claiborne of Louisiana: Am. Assoc. Petrol. Geol. Bull., vol. 13, pp. 1333-1350, 1929.

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Renick, B. C., Recently discovered salt domes in east Texas: Am. Assoc. Petrol. Geol. Bull., vol. 12, 1928.

Moody, C. L., Tertiary history of region of Sabine uplift: Am. Assoc. Petrol. Geol. Bull., vol. 15, pp. 531, 552, 1931.

The last mentioned paper contains a very excellent discussion of the regional Claiborne stratigraphy in which the correlation and nomenclature is most logically presented. Moody's correlation is given in the following table:

TABLE 4.—*Correlation of the Claiborne group**

<table>
<tr><th colspan="2">Age</th><th colspan="2">East Texas</th><th colspan="2">Louisiana and Arkansas</th><th>Mississippi</th></tr>
<tr><td rowspan="9">Tertiary Eocene</td><td rowspan="9">Claiborne Group</td><td colspan="2">Cockfield</td><td colspan="2">Cockfield</td><td>Cockfield</td></tr>
<tr><td colspan="2">Cook Mountain</td><td colspan="2">Cook Mountain</td><td>Wautubbee marl</td></tr>
<tr><td colspan="2">Sparta sand</td><td colspan="2">Sparta sand</td><td>Kosciusko sand</td></tr>
<tr><td rowspan="6">Mount Selman</td><td rowspan="2">Weches</td><td rowspan="2">Weches</td><td rowspan="6">Cane River</td><td rowspan="3">Winona sand</td></tr>
<tr></tr>
<tr><td rowspan="2">Queen City</td><td rowspan="2">Queen City</td></tr>
<tr><td rowspan="3">Tallahatta</td></tr>
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		Sparta sand		Sparta sand		Kosciusko sand
		Mount Selman	Weches	Weches	Cane River	Winona sand
			Queen City	Queen City		Tallahatta
			Reklaw	Reklaw		

* Moody, C. L., Tertiary history of region of Sabine uplift: Am. Assoc. Petrol. Geol. Bull., vol. 15, p. 536 1931.

The basal Claiborne beds, the equivalent of the Reklaw of Texas, crops out in a narrow belt from Texas to Ouachita River. To the northeast of Ouachita River these beds have not been recognized definitely, and it seems probable that they are overlapped by younger Claiborne strata. The basal Claiborne strata are composed of clays and ferruginous sandy clays with platy concretions and irregular beds of limonite. They contain small amounts of glauconite which has been generally altered by weathering, giving the sediments their characteristic red and brown coloring. The basal Claiborne is 25 to 50 feet thick.

The overlying Queen City sand is represented in Arkansas by a series of light-colored sands interbedded with clays and sandy clays, generally gray, but, where weathered, also red and brown. This part of the Claiborne contains some lignitic material and thin lenses of ferruginous sand.

The equivalent of the Mount Selman of Texas is represented in the central part of the state by ferruginous sands and clays which are in part glauconitic. The glauconitic beds increase in thickness both towards the west and east.

The Sparta sand is represented by generally massive white and grayish-white sand with partings of white and reddish clay.

The Upper Marine member, the equivalent of the Cook Mountain of Texas, as developed in Arkansas, is composed of sands and clays in part glauconitic and ferruginous.

The Cockfield formation crops out principally in southeastern Arkansas. West of Ouachita River it occupies an area which includes the southeastern part of Columbia County, all of Union County, and that part of Ouachita County lying south of the Smackover fault. To the east and northeast the continuity of the Cockfield outcrop is interrupted by the wide flood plain of Ouachita River, but again appears at the surface in northeastern Calhoun County and extends northeastward through Grant County and southeastward through Bradley County with diminishing width. The Cockfield consists of generally light-colored sand, in part lignitic, ferruginous sands and gray to dark-gray lignitic clays.

SUBSURFACE BEDS

The Claiborne group is at the surface or underlies a large part of the Coastal Plain of Arkansas. It consists of nonmarine sands and clays and marine glauconitic sands, clays, and marls which in the adjoining states have been divided into several formations that are generally recognizable in Arkansas. These formational units are not recognizable in the driller's logs but are known from a few widely spaced wells which have carefully sampled these sediments. These records, although incomplete, suffice to determine in a general way the distribution, character, and thickness of the formational units of the Claiborne group in southern Arkansas.

The Claiborne group increases in thickness from west to east; it is from 900 to 1,000 feet thick in the western and central parts of the state and not less than 1,500 feet in the Arkansas syncline in Arkansas County.

The Mount Selman, which in Texas is divided into Weches at the top, Queen City sand, and Reklaw at the base, is present throughout southern Arkansas. The members vary, some in character and thickness, and the formation as a whole increases in thickness to the east. The Weches and Reklaw members of the Mount Selman consist principally of glauconitic sands and clays but contain lignitic clays in the eastern part of the state. The Queen City member consists principally of sands with subordinate beds of lignitic clays and some thin beds of lignite. The Mount Selman is about 250 feet thick in the southwestern and central parts but increases to more than 500 feet in the eastern part of the state.

The Sparta sand consists of generally massive light-colored sands with subordinate beds of clays. It is 325 to 400 feet thick in the western and central parts but decreases to 200 feet or less in the eastern part of the state.

The Cook Mountain formation consists chiefly of glauconitic sands, clays, and marls. It is 100 to 150 feet thick in the southwestern and central parts of the state and slightly more than 200 feet thick in southern Bradley County. It increases in thickness to the east and northeast of Bradley County where its maximum thickness probably is not less than 400 feet.

The Cockfield formation increases in thickness to the east and is more than 200 feet thick in central Bradley County. It is probably 300 to 400 feet thick in Arkansas County.

JACKSON FORMATION

The Jackson formation crops out at the base of Crowley's Ridge in northeastern Arkansas and south of Arkansas River in Jefferson, Lincoln, Drew, and Bradley counties. It consists of sands, clays, and fossiliferous marls. The sands are white to gray, massive and thin-bedded; vary in texture from fine to coarse, and in places contain glauconite and lignite. The clays are gray, dark-gray, blue, and green, massive and laminated and in part lignitic and glauconitic. The marls consist of calcareous and glauconitic clays and thin calcareous and glauconitic sands.

The Jackson formation increases in thickness to the east but its maximum thickness is not determinable in any of the well records.

Partial section of Reklaw (Cane River) in Ohio Oil Company's Jerome Lumber Company's No. 1 well in sec. 13, T. 15 S., R. 4 W., Drew County, Arkansas

Character	Depth in feet
Shale and gumbo	1386–1388
Gumbo	1388–1398
Shale and boulders	1398–1401

Broken sandy gumbo (Core 1386-1388 feet, chocolate-colored mudstone; core 1399-1404 feet, same as above; core 1410-1412 feet, chocolate-brown sandy, calcareous shale; core 1412-1419 feet, chocolate-brown, calcareous, glauconite shale)	1401–1419
Gumbo	1419–1451
Hard formation	1451–1452
Gummy chalk	1452–1470
Gumbo and sandy shale (Core 1473-1480 feet, light-gray, glauconitic marl; core 1480-1487 feet, chocolate-brown, calcareous glauconitic marl)	1470–1499
Gumbo	1499–1500
Sand	1500–1507
Sandy shale (Core 1494-1504 feet, light-gray glauconitic marl)	1507–1516
Greensand (Core 1507-1521 feet, interfingering chocolate-brown calcareous mudstone and light-gray glauconitic marl)	1516–1548
Brown sand and shale (Cores 1521-1543 feet, light-green, glauconitic sandstone; core 1543-1550 feet, light-brown, calcareous, glauconitic, sideritic, micaceous, fine-grained sandstone)	1548–1573

STRUCTURAL GEOLOGY

GENERAL STATEMENT

The Gulf Coastal Plain strata of this region are composed chiefly of sands, shales, and limestones deposited near or at moderate distances from the margin of the sea in which they accumulated. They rest on a peneplained surface developed in highly folded and presumably faulted rocks which range in age from late Paleozoic to pre-Cambrian. The strata are gently warped, the dips are generally less than 75 feet and rarely more than 150 feet per mile in the Upper Cretaceous and Tertiary strata, and seldom more than 150 feet per mile in the Comanche strata. The local structural features consisting of domes, anticlines, structural terraces, and normal faults are of small magnitude.

The known deformation history of the Gulf Coastal Plain sediments began with the downwarping and generally south and southwest tilting of the Ouachita peneplain[54] and submergence by the early Cretaceous sea. The downwarping continued, with minor interruptions, to the end of the Comanche epoch when the strata were uplifted, tilted to the south and west, and local structural features of small magnitude were developed. The uplift was followed by an interval of erosion during which the newly uplifted strata were truncated and the terrain was reduced to a peneplain. This plane of truncation marks the most conspicuous unconformity in the Coastal Plain sediments of this region.

The Upper Cretaceous was essentially a period of downwarping and marine sedimentation, but differential warping of the sea floor is reflected in a general upward movement of southern Arkansas and northern Louisiana, as contrasted with the adjacent areas of depression. The differential warping was most pronounced in a southeasterly trend through southeastern Arkansas and northeastern Louisiana, evidenced in the marked thinning of the Upper Cretaceous sediments over these areas. At the close of the Cretaceous period the waters retreated from the Continental borders; southern Arkansas and northern Louisiana emerged and for a considerable period of time remained above water. The uniform thickness of the Arkadelphia marl (uppermost Cretaceous) and the Midway formation (basal Eocene) and the similarity in lithology suggest that the retreat of the Cretaceous sea was accomplished without marked warping of the strata. The pronounced hiatus in northeastern

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[54] Miser, H. D., and Purdue, A. H., Geol. Atlas Hot Springs folio.
Melton, F. A., and McGuigan, F. D., The depths to the base of the Trinity sandstone and the present attitude of the Jurassic peneplain in southeastern Oklahoma and southwestern Arkansas: Am. Assoc. Petrol. Geologist Bull., vol. 2, no. 10, pp. 1005-1014, 1928.

Louisiana, where basal Midway sediments are in contact with strata and range in age from late Cretaceous to early Trinity, is considered to be the result of sedimentary environmental conditions during Upper Cretaceous time, rather than of uplift at the end of the Cretaceous period and subsequent erosion in the interval of emergence prior to Midway deposition.

The relative crustal stability characterizing the Upper Cretaceous ended with the Midway, and a period of crustal instability was initiated, which continued with variable intensity to the end of the Tertiary period. Southern Arkansas and northern Louisiana, relative to the surrounding areas, were markedly elevated by differential warping, a movement that culminated in uplift and the permanent withdrawals of the Gulf waters from these regions in the Miocene epoch. The regional as well as the local structural features recognizable in the strata assumed their final form in this episode of uplift.

Subsequent erosion developed a penneplain in the uplifted Cretaceous and Tertiary strata which, in the Pliocene or early Pleistocene epoch, was covered with sands and gravels of the Lafayette formation which was correlated with the Citronelle formation of Louisiana and Mississippi. The Pliocene or early Pleistocene peneplain was uplifted and tilted towards the south, and the present topography was sculptured by erosion .

STRUCTURAL FEATURES

The regional monoclinal structure of the Gulf Coastal Plain, dipping gently towards the coast, is modified by transverse warping, resulting in broad gentle upwarp between shallow, broad depressions along the inner margin of the Coastal Plain. The structural salient, inclusive of southern Arkansas and northern Louisiana, and the East Texas and Mississippi embayments (Pl. XI) are typical examples of such structural features.

The Sabine uplift in northwestern Louisiana and the Monroe uplift in northeastern Louisiana are integral parts of the structural salient but have sufficient structural individuality to be broadly outlined in form. These uplifts, separated by a shallow syncline, are broad, dome-like folds 75 to 100 miles in diameter. (Figs. 16 and 17.)

Numerous minor structural types which may be divided into normal structures, including normal faults, and salt-dome structures are superimposed on the structural salient and the larger uplifts.

The normal structures include anticlines, domes, structural terraces, faults, and synclines. The dome-like structures are the dominant form, but the anticlinal form is present in southeastern Arkansas. The structural relief is generally less than 150 feet. The faults, which in Arkansas occur in a generally east-west trending zone, are normal with throws, some about 500 feet high. The known faults in Louisiana are associated with domes.

The salt-dome structures include the typical salt domes, generally 4 to 6 miles in diameter with a central salt core which has pierced and sharply tilted the inclosing strata. The salt-dome structures should, perhaps, include the Homer, Bellevue, and Pine Island domes[55], large domes with diameters of 10 to 15 miles and structural relief of over 1,000 feet. Salt has not been encountered in these domes, but gravimetric surveys indicate its presence at considerable depths.

The normal folds include the anticlines, domes, and structural terraces shown, by contour lines in Plates XI and XII. These folds are generally dome-like in form but anticlinal folds are present in southeastern Arkansas. (Pl. XI.) The structural relief is generally less than 150 feet.

The faults, which in Arkansas occur in a generally east-west trending zone, are normal faults with displacements up to slightly more than 400 feet. The known faults in Louisiana are associated with local domes.

DEVELOPMENT OF THE MAJOR STRUCTURAL FEATURES

The dominant movements recorded in the Coastal Plain sediments are negative movements reflected in the downwarping of the sedimentary areas, and resulting in a general Gulfward inclination of the strata. The downwarping was not continuous but was interrupted by briefer periods of uplift and emergence and was varied by differential warping transverse to the Coastal Plain margin. The final result of the complex warping, which began in the Cretaceous and continued to the end of the Tertiary, was the development of the structural features now recognizable in the strata of this region.

The warping reflected in the Coastal Plain strata is thought to be genetically related to the development of the Gulf of Mexico, and seemingly involves horizontal migration of subcrustal material at considerable depth. In a sense, the warping is independent of preexisting lines of weakness in the basement complex. On the other hand, the stratigraphic evidence clearly indicates that preexisting lines of weakness were important factors

[55] Spooner, W. C., Homer Oil Field, Claiborne Parish, Louisiana: Structure of Typical American Oil Fields, Am. Assoc. Petrol. Geol., pp. 196-228, 1929.

Teas, L. P., Bellevue Oil Field, Bossier Parish, Louisiana: Structure of Typical American Oil Fields, Am. Assoc. Petrol. Geol., pp. 229-253, 1929.

Crider, A. F., *Pine Island deep sands*, Caddo Parish, Louisiana: Structure of Typical American Oil Fields, Am. Assoc. Petrol. Geol., pp. 168-195, 1929.

in the determination of deformational trends in the Coastal Plain strata. In this connection it seems advisable to consider briefly the broader structural features of the basement floor on which the Coastal Plain sediments accumulated.

The dominant structural features of the basement rocks are the Ouachita Mountains of Arkansas and southeastern Oklahoma and their continuation under the Coastal Plain sediments.

Deep well records[56] have rather definitely established the fact that the Ouachita Mountains continue under the Coastal Plain from southeastern Oklahoma in a general south-southwest trend to the vicinity of the central mineral region and thence in a general westerly trend to the Marathon region in southwestern Texas. Their continuation from the vicinity of Little Rock, Arkansas, into northeastern Louisiana and Mississippi is indicated by the available data, though not definitely proved at this time. (See Pl. III.)

The Ouachita Mountains[57] were developed in a normal though complex orogenic cycle which began with lateral thrusting in the Carboniferous and culminated in vertical uplift in the Permian.

The structure of the basement rocks to the south of the known limits of the Ouachita Mountains is not determinable, but certain conditions may be inferred from the stratigraphy and structure of the Coastal Plain strata.

The salt in northern Louisiana and northeastern Texas, probably of Permian age, indicates that the central zone of the Ouachita Mountain system in its widest development had broken down and subsided, resulting in the development of the sedimentary basin to the south of the present Ouachita Mountains in Permian time. The relationship of the salt basin to the present Ouachita Mountain front further suggests that in its final development the mountains may have terminated in a normal fault with the downthrow towards the basin. The present Ouachita Mountains may then be considered as the frontal part of a longer Ouachita Mountain system.

Whatever the history of this region may be, it includes an interval of erosion, during which the Ouachita Mountains were reduced to a peneplain.

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[56] Miser, H. D., and Sellards, E. H., Pre-Cretaceous rocks found in wells in Gulf Coastal Plain south of Ouachita Mountains: Am. Assoc. Petrol. Geol. Bull., vol. 15, pp. 801-818, 1931.

Sellards, E. H., Rocks underlying Cretaceous in Balcones fault zone of central Texas: Am. Assoc. Petrol. Geol. Bull., vol. 15, pp. 819-827, 1931.

[57] Powers, Sidney, Age of the folding of the Oklahoma Mountains—the Ouachita, Arbuckle, and Wichita Mountains of Oklahoma and Llano-Burnet and Marathon uplifts of Texas: Geol. Society of America, Bull., vol. 39, pp. 1031-1072, 1928.

Van der Gracht, W. A. J. M., van Waterschoot, The permo-Carboniferous orogency in the south-central United States: erhandelinger der Koninklyke Akademie Von Wetenschappen te Amsterdam (Tweede sectie) Deel 27, No. 3, 1931.

The early Cretaceous sea transgressed this peneplain from the south and southwest, submerging eastern and southern Texas, western Louisiana, and southwestern Arkansas. The sea was limited in its landward extent to a line which coincides closely with the Ouachita Mountains as projected under the Coastal Plain. The parallelism between the strand line and the Ouachita Mountains (Pl. III) precludes the possibility that this relationship is fortuitous. The limitation of the strand line obviously was not due to the existence of topographic relief but to differential movement along a preexisting line of weakness in the basement rocks. The movement was differential and the result was depression on the side towards the Gulf. The strand line remained constant throughout the Comanche in Arkansas and northeastern Louisiana and in Texas to the end of the Trinity. The persistency of the differential movement along this line is evidenced not only in the permanency of the strand line but also in the marked increase in the thickness of the Comanche sediments on the basinward side of this line of weakness, a condition that is finely illustrated in Arkansas.

Marked rejuvenation of movement along this line in southeastern Arkansas and northeastern Louisiana at the end of the Comanche is evidenced in the pronounced tilting of these strata.

Continued differential warping along the projected Ouachita Mountain trend through southeastern Arkansas and northeastern Louisiana is evidenced in the marked thinning of the Upper Cretaceous strata. Its influence in later geologic time is evidenced by the persistent zone of faulting which extends from southwestern Texas into southeastern Arkansas. From the foregone brief discussion it is obvious that the structure of the Ouachita Mountains asserted a marked influence on the structure of the Coastal Plain strata.

The intense crustal activities during the Tertiary are reflected in the Gulf Coastal Plain strata. The Gulf migrated back and forth over this region, and differential warping, both transverse to and parallel with the continental border, was pronounced. The influence of the Ouachita Mountain trend was less marked, but it nevertheless asserted a pronounced influence on the structural features of this region in their ultimate development. The structural salient, inclusive of northern Louisiana and southern Arkansas, began to take shape in the early Tertiary and reached its final form in the Miocene.

The two outstanding individual features of this salient are the Sabine uplift in northwestern and the Monroe uplift in northeastern Louisiana. The Monroe uplift is situated on a pronounced deformational trend through southeastern Arkansas, northeastern Louisiana, which extends into Mississippi, and which coincides with the projected trend of the Ouachita Mountains. Comanche sediments of moderate thickness, which were sharply flexed at the end of Comanche deposition, were deposited over the Monroe uplift. The Monroe uplift began to rise relative to the surrounding areas in early Upper Cretaceous time, as evidenced by the thinning of the sediments and overlap over the flank. The upward movement continued in the Tertiary and its final form was attained in the Miocene. The Sabine uplift was the site of thick deposits of Comanche sediments, and shows only slight tendencies to rise at the end of the Comanche and during the deposition of the Upper Cretaceous. In fact, its real development began with Wilcox deposition and its final form, as that of the Monroe uplift, was reached in the Miocene. In the amount of relative uplift, they are comparable, but the Sabine uplift stands higher with reference to sea level.

From the foregone brief statements it is obvious that the Sabine and Monroe uplifts are of similar type, differing only in the time factor involved in their development. They are certainly the result of vertical movements originating at depth and transmitted upward to the incompetent Coastal Plain strata. Their possible origin will be briefly considered.

If the development of deeps, such as the Gulf of Mexico, involves horizontal migration of subcrustal material at depth, it offers a plausible explanation for the origin of the differential warping to which this region was subjected and for the development of such structural features as the Sabine and Monroe uplifts.

The differential warping incidental to the lateral displacement of subcrustal material at depth was influenced by preexisting lines of weakness in the basement rocks, clearly evidenced by the parallelism of such lines of weakness to the deformational trends in the Coastal Plain strata. This relationship is especially pronounced in the Cretaceous, a period of relative crustal stability. The intense crustal activities during the Tertiary necessarily implies that greater volumes of subcrustal material were displaced, and the resultant forces thus brought into existence were perhaps adequate to overcome, in part at least, the influence of preexisting lines of weakness and to establish new deformational trends, normal to the areas of subsidence.

The structural features such as the Sabine and Monroe uplifts are clearly the result of vertical upthrust, and their development seemingly requires irruption of subcrustal material into that part of the earth's crust underlying the area of disturbance. The localization of the areas of disturbance may have been selective rather than fortuitous, selective because of the irregularity of the surface in contact with the subcrustal material or because of existing weakness in the overlying crustal rocks. Volumetric changes incidental to crystallization probably were factors in determining the ultimate height to which the area was elevated with reference to the surrounding areas.

As an alternative hypothesis it may be argued that differential movements along a preexisting fault in the basement rocks may have accomplished the same results and that the origin of these uplifts would then be analogous to the larger structural features of Oklahoma and Kansas.

DEVELOPMENT OF MINOR STRUCTURAL FEATURES

The minor structural features are believed to be the indirect result of regional warping, and their origin postulates differential movements in the basement rocks and salt movements.

In the first case, the movement in the basement rocks may be either failure incidental to warping or rejuvenation of movement along preexisting faults; the resultant differential movement propogated upward to the incompetent Coastal Plain strata is reflected in folding, either domal or anticlinal in form, depending upon the length of the fault along which the movement originated. Where the differential movement is of sufficient magnitude, failure occurs in the Coastal Plain strata and normal faults are developed. The folds in Oklahoma and Kansas which have originated in this manner are generally assymetric with a steeper limb on the downthrown side of the fault in the basement rocks. In those areas, however, the sediments involved in the folding are relatively thinner and of a higher degree of competency than the Coastal Plain strata of this region.

In the second case, the flexing of the strata is the result of salt movements in which salt may have been concentrated along salt anticlines or in salt plugs. The extreme case is illustrated in the typical interior salt domes where a salt core half a mile to a mile in diameter has pierced the surrounding Cretaceous and Tertiary strata and, in some instances, reaches nearly to the surface. These domes are characterized by steeply dipping flanks but of small areal extent. The Homer, Bellevue, and Pine Island domes on the basis of gravimetric data must be considered as salt domes of large dimensions which have no penetration of the salt into the oldest recognized Trinity strata. Intermediate between these extremes are folds of small dimensions which may have originated either from salt movements or from differenital movement in the basement rocks.

Both types of folds may show contemporaneous folding, slight upward movement during the deposition of the sediments, as reflected in the thinning of the sediments, and, in some places, in modification of the lithology of the overlying sediments. The fact that such movement occurred during deposition is no criterion of their origin as contemporaneous folding is common to both types of folds. It is a fact that most of the oil and gas-producing folds in this region give evidence of contemporaneous folding in some degree, but their final development occurred during episodes of regional upwarp. The first episode in the Gulf Coastal Plain history dates from the end of the Comanche, and the second, during which the structural features now recognized in this region attained their final form, dates from the early Miocene.

The Arkansas fault zone, a persistent zone of faulting which extends in a general east-west trend across southern Arkansas, consists of a series of grabens 1 to 3 miles in width, with maximum displacements of slightly more than 400 feet. This zone of faulting is probably continuous westward into the Balcones or Mexia fault zones in Texas. These faults are not obviously related to the development of local folds, such as the faults in the Homer, Bellevue, and De Soto-Red River fields in Louisiana, but are thought to be related to the flexure on the basement rocks. It is of interest to note that the maximum displacement along these faults, as well as most faults in the Mexia and Balcones fault zones, is less than 500 feet.

STRUCTURE OF THE COMANCHE (LOWER CRETACEOUS)

The tilting and truncation of the Comanche strata immediately following their deposition resulted in a pronounced angular unconformity between these and the overlying Upper Cretaceous strata; in wide differences in the strike, direction, and rate of dip; and in the structural features in general.

Comparatively few wells have penetrated the Comanche strata to any considerable depths. Factors that have combined to increase the difficulty of determining accurately the structural features of these strata are: Truncation, which brought progressively older beds in contact with overlying Upper Cretaceous towards the north and east; and the physical character of the sediments which, except for the anhydrite zone, of limited areal extent, lack beds possessing sufficiently well-developed individual characteristics to be recognized from one area into another.

The choice of datum planes is, therefore, limited to either the top or the base of the anhydrite zone of the Glen Rose formation. The data available is insufficient for detailed mapping and barely adequate to indicate the major structural features of this region.

A generalized picture of the structural features of the Comanche strata in southwestern Arkansas and northern Louisiana is given in Plate XII, a structure contour map drawn on the base of the anhydrite zone of the Glen Rose formation.

The principal structural features of the Comanche strata shown in Plate XII are: (1) a south and southeast-dipping monocline along the outer margin of the area mapped; (2) a syncline which separates the area of monoclinal structure from the Sabine uplift, (3) the Sabine uplift in northwestern Louisiana, and (4) the Bellevue and Homer domes.

STRUCTURE OF THE COMANCHE (LOWER CRETACEOUS) IN SOUTHWESTERN ARKANSAS

The structure of the Comanche strata in southwestern Arkansas on the basis of available data is monoclinal with an east-west strike through Little River County and parts of Hempstead County and beyond that area generally southeast. The dip is to the south and southwest at the rate of 50 to 100 feet per mile. A pronounced syncline, wherein the base of the anhydrite zone lies about 6,000 feet below sea level, enters the southwestern corner of the state; it continues into Lafayette County and then turns south into Louisiana where it is a part of a regional syncline that parallels the Sabine uplift. The depths to the base of the anhydrite zone in the area mapped ranges from less than 1,000 feet below sea level in Little River and Hempstead counties to 3,000 feet below sea level in southwestern Union County, and more than 6,000 feet below sea level in southern Miller County.

That the structure of the Comanche strata in southern Arkansas is far less simple than is pictured on the basis of the meager available data is an obvious conclusion, as evidenced by the changes in direction of strike and rate of dip. It is scarcely probable that structural features comparable to those in northern Louisiana are present in this area, but there are no data to preclude the existence of local folds such as are generally associated with oil and gas accumulations.

The structure of the Comanche strata that lie east of the anhydrite zone is not determinable but their subsurface distribution indicates that in general they maintain approximately the same southeast strike although the rate of dip may vary. It is an area of active warping, and it seems probable that local fields of considerable magnitude may be present.

STRUCTURE OF THE COMANCHE (LOWER CRETACEOUS) IN NORTHERN LOUISIANA

The most conspicuous structural feature of the Comanche strata in northern Louisiana is the Sabine uplift in northwestern

Louisiana but includes the adjacent parts of Texas. It is a large dome-like fold more than 80 miles in length from north to south. The structural relief is more than 1,000 feet above the normal altitude of the Comanche strata. It is defined on the east by a syncline which enters Lafayette County, Arkansas, from the south and thence continues westward through Miller County into Texas. Superimposed on the Sabine uplift are two conspicuous domes: Pine Island dome in northern Caddo Parish and Bellevue dome in central Bossier Parish, which show structural reliefs of more than 1,500 feet above the normal altitude of the Comanche strata on the uplift. The development of these domes was in part contemporaneous with the deposition of the Glen Rose formation, indicated by the gradual thinning of this formation over the domes, especially pronounced over the Bellevue dome.

The Homer dome in Claiborne Parish is a pronounced structural feature in the Comanche strata, indicated by the record of the Louisiana Oil and Refining Company's Langston No. 10 well in sec. 19, T. 21 N., R. 7 W., which passed from the basal Upper Cretaceous into the lower half of the Neocomian, a hiatus representing nearly 3,000 feet of Comanche strata, which probably is represented in part by nondeposition and in part by truncation.

The pronounced increase in the rate of dip of the Comanche strata and the truncation of the Glen Rose formation in the Richland field and the adjacent areas indicate a departure from the normal monoclinal structure in that area and, perhaps, over a considerable part of the Monroe uplift. The available data are, however, inadequate to determine either the form or extent of any existent structural features.

STRUCTURE OF THE UPPER CRETACEOUS ROCKS

GENERAL FEATURES

Southern Arkansas, northern Louisiana, and the adjacent parts of Texas and Mississippi constitute a distinct structural unit of the Gulf Coastal Plain geologic province which may be broadly defined as a structural salient extending from the Ouachita Mountains Gulfward into central Louisiana. It is defined to the south by the Angelina-Caldwell flexure[58], to the west by the East Texas embayment, and to the east by the Mississippi embayment. It is shown in Plate XI, a structure contour map drawn on top of the Nacatoch sand.

The structural salient, as broadly defined above, includes a number of more or less well-defined structural unities, each exhibiting individuality in some degree. The more important of

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

these are: (1) A marginal monocline, a south and southeastward dipping monocline between the outer margin of the Coastal Plain and the Arkansas fault zone in southwestern Arkansas; (2) the Arkansas fault zone, a series of grabens extending from Miller County eastward into Bradley County; (3) the Arkansas syncline, a broad synclinal basin in northern and eastern Arkansas and the adjacent parts of Mississippi; (4) the Sabine uplift, a large dome-like uplift in northwestern Louisiana; (5) the Monroe uplift, a large fold in northeastern Louisiana and extending into southeastern Arkansas; (6) the Angelina-Caldwell flexure, a well-defined southward dipping monoclinal flexure crossing Louisiana from Sabine Parish into Madison Parish and into Mississippi; (7) the Bellevue and Homer domes in Louisiana, large quaquaversal folds of high structural relief; and, (8) the interior salt domes of Louisiana, small quaquaversal folds with a central core of rock salt. The above enumerated structural features are described in more detail in the following paragraphs.

STRUCTURAL FEATURES IN ARKANSAS

THE MARGINAL MONOCLINE

The strata lying between the Texas line and Ouachita River and between the margin of the Coastal Plain and the Arkansas fault zone, an area of 40 to 60 miles wide from south to north and 60 to 70 miles long from west to east, show prevailing southeast dips at the rate of 35 to 75 feet per mile. To the northeast this marginal monocline merges into the western limb of the Arkansas syncline.

Superimposed upon the monocline are a number of structural terraces which have modified the strike and rate of dip locally, but pronounced anticlinal folds are not known to exist within this area.

THE ARKANSAS FAULT ZONE

A series of grabens extending from Miller County eastward into Bradley County is herein designated as the Arkansas fault zone (See Pl. XIII). The western part of this zone has been described in detail by Rankin[59] and more detailed descriptions of the individual grabens will be found in the descriptions of the Irma, Stephens, and Smackover fields, and in the county reports.

In order from west to east, these grabens are designated as the Fouke, Lewisville, Falcon, Irma, Buena Vista, Stephens, and Smackover grabens. They are of similar type, differing chiefly in length and only slightly in width and in the amount of throw. The average width is from 1½ to 4 miles and the throw from 200 to 500 feet. The faults are characterized by low-angle fault

[59] Rankin, C. L., Faulting in southwestern Arkansas: Am. Assoc. Petrol. Geol. Bull., vol. 14, 1930.

planes, dipping into the graben at an angle which in most places approaches 45 degrees.

RELATIONSHIP OF FAULTS TO STRUCTURE

The trend of the faults appears to be independent of the strike of the strata which they cut. The Lewisville and Irma grabens trend roughly parallel with the Stephens graben at an angle of approximately 45 degrees, and the Fouke, Falcon, Buena Vista, and Smackover grabens trend at right angles to the strike. The grabens occur in a zone intermediate between an area to the north, where the structure is monoclinal, and the dip is to the south and east; an area of more diversified structure to the south which is related to, or influenced by, the Monroe and Sabine uplifts.

Along the south sides of the grabens are local areas of closure ranging from a few to more than 100 feet, which are best developed along the Lewisville graben at Stamps, and along the Falcon, Irma, and Smackover grabens, and which in the Irma and Smackover areas are more or less closely related to oil and gas-producing areas. The relation of the closure to the grabens is not determinable, but the faulting was incidental to the uplift of the region which must have progressed to a considerable elevation before faulting occurred, at least, sufficient to cause the development of the local structural features such as characterizes the Smackover and Stephens fields which do not appear to be related to the faulting. The closures along the Lewisville, Falcon, and Irma grabens, however, may be directly related to the faulting with which they are associated.

AGE OF FAULTING

The faulting was coincidental with the regional uplift early in Miocene time.

RELATION TO THE BALCONES FAULT ZONE

The Arkansas fault zone has been considered as the eastward continuation of the Balcones fault zone of Texas to which it is genetically related if not an actual continuation. This zone of faulting closely parallels the Cretaceous-Tertiary contact from eastern Arkansas into southwestern Texas.

THE ARKANSAS SYNCLINE

The Arkansas syncline, a restricted part of the upper Mississippi embayment, includes most of eastern Arkansas north of Bradley, Drew, and Chicot counties. It is a broad synclinal trough, plunging gently southward along its axis which closely follows the course of Mississippi River into northern Desha County where it is deflected by the Monroe uplift and trends slightly east of south into Mississippi.

The generalized structure of the Arkansas syncline is shown in Plate XIV, by contour lines drawn on top of the Upper Cretaceous at intervals of 500 feet and in more detail in Plate XV. The Cretaceous rocks reached in comparatively few wells widely scattered through this area suffice to determine its general features but are entirely inadequate to determine the detailed structural features.

In the area to the north of Dallas, Cleveland, and Lincoln counties, the strata dip from the Coastal Plain margin towards Mississippi River at the rate of 25 to 75 feet or more per mile. In the area to the south, the strike is irregular, conforming to the configuration of the Monroe uplift and the dip in consequence ranges in direction from east to north. The rate of dip in this area is from 20 to 75 feet per mile.

The deepest part of the syncline is estimated to be in Desha, Phillips, and Arkansas counties, where the top of the Cretaceous is estimated to be more than 4,500 feet below sea level.

The Arkansas syncline began to form during the Upper Cretaceous, but its principal development took place during the deposition of the Wilcox and Claiborne formations of Eocene age.

MONROE UPLIFT

The Monroe uplift is a pronounced structural feature of northeastern Louisiana, southeastern Arkansas, and the adjacent part of Mississippi and in a sense is the eastern counterpart of the Sabine uplift in northwestern Louisiana. This structural feature was developed through a complex series of geologic events but was primarily the result of differential warping of the sea floor with reference to the surrounding area.

The Monroe uplift is situated in a generally northwest-southeast trending line of weakness which coincides with the projected trend of the Ouachita Mountains under the Coastal Plain sediments. Movements along this line of weakness determined the eastern limits of the Comanche seas, as well as the pronounced flexing of the Comanche strata. The upward movement along this line continued through the Upper Cretaceous indicated by the thinning of the sediments and overlap over the area of upwarp. The result of these movements was the development of a generally northwest-southeast trending arch, extending from the Ouachita Mountains, southeastward into Mississippi for an indeterminate distance. The stratigraphic evidence indicates that the Monroe uplift (Fig. 17) as a localized structural feature began to take form in the Upper Cretaceous but although the upwarp was accentuated in this area, it, nevertheless, maintained its anticlinal form to the end of the Cretaceous.

The upwarp continued in the Tertiary, evidenced by thinning of the Wilcox formation (Fig. 18) over the uplift, but th intense crustal activities of this period established new deformational trends which modified the original structural form. The Angelina-Caldwell monoclinal flexure, formed in the Tertiary,

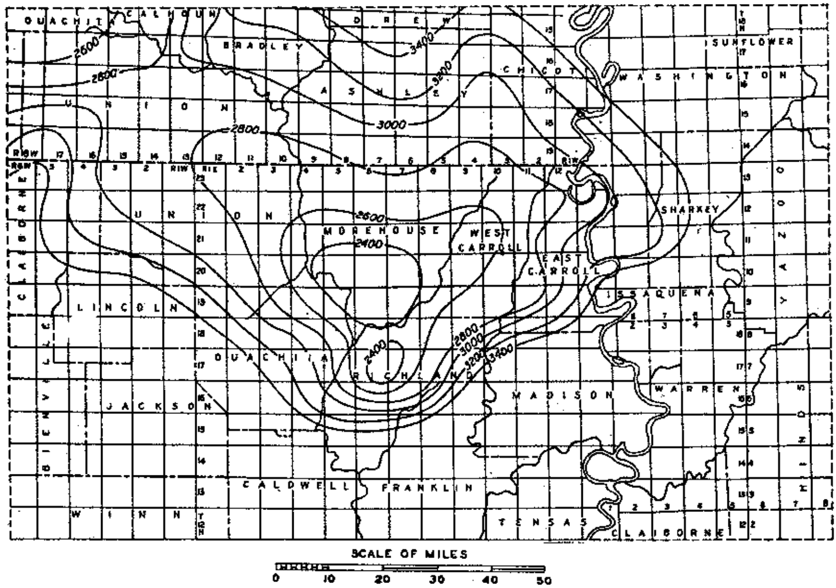

FIGURE 16.—Structure of Monroe area drawn on the base of the Upper Cretaceous. Contour interval 200 feet. Figures give depth below sea level.

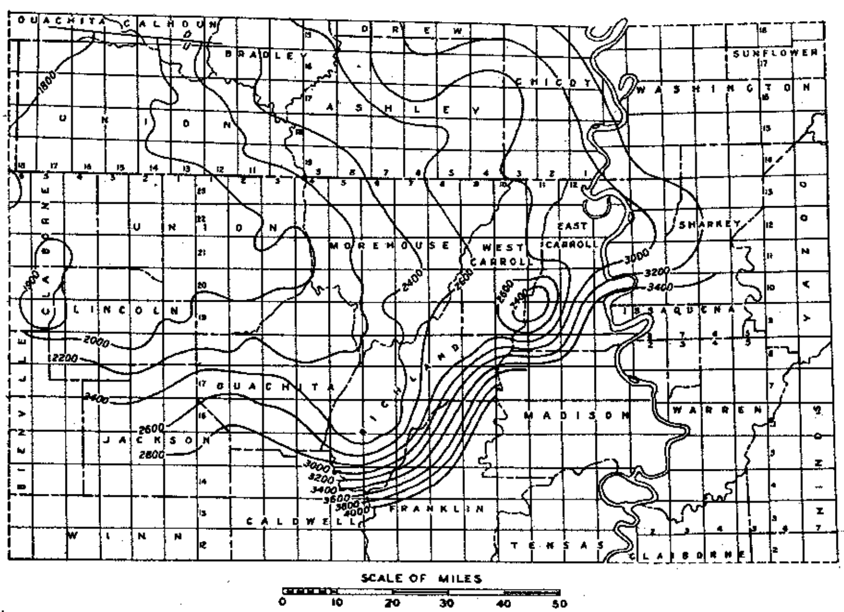

FIGURE 17.—Structure of Monroe area drawn on top of the Upper Cretaceous. Contour interval 200 feet. Figures give depth below sea level.

trends northeast-southwest across Louisiana into Mississippi and now constitutes the southern flank of the Monroe uplift, giving it a dome-like form.

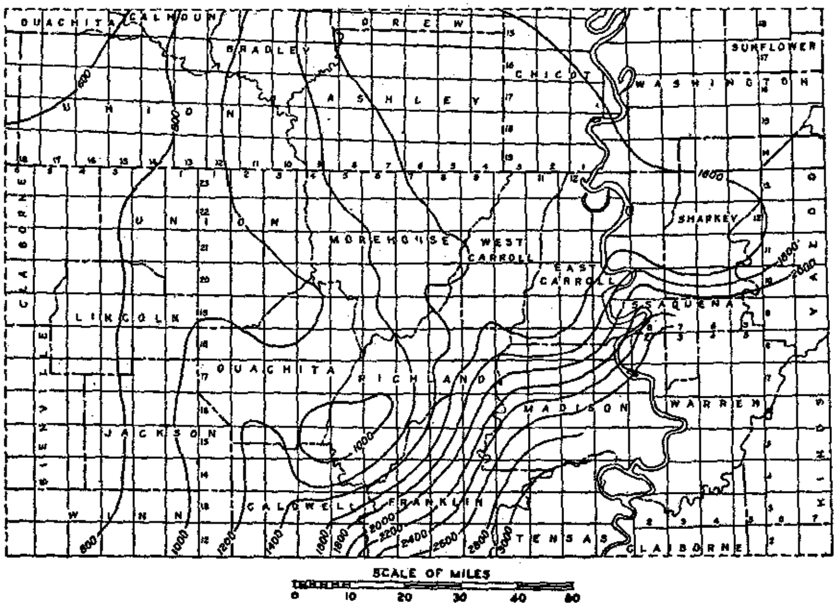

FIGURE 18.—Structure of Monroe area drawn on top of the Wilcox formation of Eocene age. Figures give depth below sea level.

The generalized structure of the Monroe uplift is shown in Figures 16, 17 and 18, by contour lines drawn respectively on the base of the Upper Cretaceous, the top of the Upper Cretaceous, and the top of the Wilcox formation of Eocene age. The structure on the base of the Upper Cretaceous is that of an assymetric dome whereas the structure on the top of the Upper Cretaceous and the top of the Wilcox formation is that of a broad structural terrace.

PART II

OIL AND GAS FIELDS

INTRODUCTION

THE PRODUCING FIELDS

The producing areas of the Gulf Coastal Plain of Arkansas, except for the small areas of Lafayette and Miller counties, are situated within a generally southeast-trending belt 15 to 20 miles wide, which extends from the Irma field in Nevada County through central Union County to the Louisiana line. This belt continues in the same direction into Louisiana to include the Monroe and Richland gas field. (See Pl. XI.) The producing areas described are listed below and shown in Plate XVI.

Producing areas in southern Arkansas

Principal oil-producing fields	
Smackover field	Union and Ouachita counties
El Dorado field	Union County
Lisbon field	Union County
Irma field	Nevada County
Stephens field	Columbia and Ouachita counties
Champagnolle district	
East El Dorado field	Union County
Woodley pool	Union County
Rainbow City field	Union County
Other producing areas	
Urbana	Union County
Sec. 14, T. 18 S., R. 14 W.	Union County
Sec. 2, T. 18 S., R. 15 W.	Union County
Mount Holly	Ouachita County
Bradley	Lafayette County
Garland City	Miller County

HISTORICAL SUMMARY OF PRODUCTION

The first well drilled in the Coastal Plain of southern Arkansas that yielded oil in sufficient quantity to suggest the presence of commercial production was the S. S. Hunter's, Lester and Holton No. 1 well, in sec. 13, T. 15 S., R. 19 W. This well was completed April 16, 1920, at a depth of 2,131 feet. A small quantity of oil was bailed from this well, which, as proved by later development work, was drilled in the Stephens graben, 2 miles east of the Stephens field. A few days after the Hunter well was completed, (April 22, 1920), gas was discovered by the Constantin Refining Company in the El Dorado field on the Hill lease in sec. 1, T. 18 S., R. 16 W., at a depth of 2,226 feet.

The initial daily production of gas in this well was 40,000,000 cubic feet. On January 10, 1921, nearly a year after the discovery of gas, the first oil well was completed by Busey and Mitchell on the Armstrong lease in sec. 31, T. 17 S., R. 15 W., with an initial daily oil production ranging from 3,000 to 10,000 barrels in the Nacatoch sand. The completion of this well marked the beginning of an intensive search for oil and led to the discovery of the following fields: Irma, October 1921; East El Dorado, January 10, 1922; Woodley, April 12, 1922; Smackover, April 10, 1922; Stephens, June 8, 1922; Lisbon, December 31, 1925; Rainbow City, January 22, 1927; and Garland City, October 10, 1932.

From 1921 to January 1, 1934, the south Arkansas fields have produced 388,392,586 barrels of pipe-line oil. Pipe-line run figures for all oil-producing fields in south Arkansas with the exception of the small Bradley pool in Lafayette County, were compiled by the Geological Dept. of the Gulf Refining Co. o Louisiana from this company's records. It should be noted tha the pipe-line production figures used do not take into considera tion either the oil used as fuel in the field or the oil wasted. No accurate figures are obtainable of these amounts. The accumula tive Arkansas gross production figures which include oil used in the field for fuel and oil wasted in addition to pipe-line runs, are estimated to be from about 2 to 8 per cent higher than the ac cumulative pipe-line figures to January 1, 1934. The productio of pipe-line oil for each field is shown in Table 7. As a matter o interest the following figures show the difference between th total pipe-line runs, the Am. Pet. Inst. actual production figure and the U. S. Bureau of Mines production figures. Comparativ figures of the pipe-line runs and the A. P. I. actual productio estimates for separate fields are given in Table 7A.

Comparison of pipe-line runs, A. P. I., and U. S. Bur. of Mines for Arkansas, 1921 *to* 1923, *inclusive*

Year	Pipe-line runs barrels	A. P. I. barrels	U. S. Bur. Mine barrels
1921	10,630,228	10,742,610	10,473,00
1922	15,549,319	16,462,950	12,712,00
1923	38,214,499	44,102,050	36,610,00
1924	43,391,994	48,068,300	46,028,00
1925	72,868,293	80,823,000	77,398,00
1926	57,388,754	58,704,000	58,332,00
1927	39,036,823	40,483,600	40,005,00
1928	30,707,283	32,091,600	32,096,00
1929	24,364,415	25,372,700	24,917,00
1930	19,256,797	20,179,550	19,663,00
1931	14,736,605	15,626,750	14,791,00
1932	11,550,605	12,464,500	12,051,00
1933	10,697,146	11,474,400	11,608,00
	388,392,586	416,596,010	396,684,00

Future production estimates, given in Table 5 and with fiel discussions, are made on the assumption that the rate of declin will continue in accordance with the trend of the field declin curve. The use of new production methods, however, may in crease the production rate and the total amount recovered.

TABLE 5.—*Summary of pipe-line production of southern Arkansas fields*

	Est. producing acreage	Pipe-line runs in bbls. to Jan. 1, 1934	Est. production per acre to Jan. 1, 1934	Est. production 1934-1940 incl.	Est. total production to Jan. 1, 1941	Est. production per acre to Jan. 1, 1941
Bradley	85	84,223	990			
El Dorado	7,740	40,934,110	5,289	3,072,000	44,006,110	5,684
East El Dorado	1,330	6,795,872	5,110	683,000	7,478,872	5,623
Garland City	220	87,265	397			
Irma	640	3,291,093	5,142			
Lisbon	2,640	5,669,089	2,148	451,000	6,120,089	2,318
Mount Holly	85	112,509	1,323			
Rainbow City	3,200	9,581,974	2,994	1,443,000	11,024,974	3,445
Sec. 14, T. 18 S., R. 14 W.		61,425				
Sec. 2, T. 18 S, R. 15 W.		3,438				
Smackover light	9,600	45,389,875	4,740	3,968,000	49,357,875	5,141
Smackover heavy	16,240	270,011,533	17,549	33,160,000	303,171,553	18,659
Stephens	2,850	4,816,057	1,690	1,194,000	6,010,057	2,112
Urbana	750	1,118,221	1,490			
Woodley	240	435,882	1,816			

AGE AND CHARACTER OF THE RESERVOIR ROCKS

STRATIGRAPHY

The reservoir rocks in this region are in the Cretaceous system. The principal producing sands are in the Gulf series of that system, except in the Mount Holly, Urbana, and Garland City districts, where some oil is produced from the Comanche series. The ages and names of the producing sands and areas are shown in Table 6.

TABLE 6.—*Producing sands in the oil fields of southern Arkansas*

<table>
<tr><th>Series</th><th>Group</th><th>Formation</th><th>Producing Sand</th><th>Field or district</th></tr>
<tr><td rowspan="4">Gulf
(Upper Cretaceous)</td><td>Navarro</td><td>Nacatoch</td><td>Nacatoch</td><td>Smackover, El Dorado, East El Dorado, Lisbon, Woodley, Stephens, and Irma fields</td></tr>
<tr><td rowspan="2">Taylor</td><td rowspan="2">Ozan</td><td>Meakin</td><td>Smackover; a little production in the El Dorado field</td></tr>
<tr><td>Buckrange (Graves of Smackover)</td><td>Smackover, Stephens, and Bradley fields</td></tr>
<tr><td>Austin</td><td>Tokio-Woodbine</td><td>2600-foot to 2900-foot</td><td>Smackover, El Dorado and Rainbow City fields</td></tr>
<tr><td rowspan="4">Comanche
(Lower Cretaceous)</td><td>Tokio Woodbine</td><td>Upper Cretaceous red beds</td><td>Crain and Gregory</td><td>Rainbow City field</td></tr>
<tr><td rowspan="3">Trinity</td><td>Upper Trinity (Paluxy)</td><td></td><td>Garland City</td></tr>
<tr><td>Glen Rose</td><td></td><td>Mount Holly district</td></tr>
<tr><td>Travis Peak</td><td></td><td>Urbana district</td></tr>
</table>

NACATOCH FORMATION

The Nacatoch formation is the most widely distributed producing formation of the Upper Cretaceous series in Arkansas and Louisiana. This formation consists predominantly of sand but contains subordinate beds of shale, clay, and arenaceous limestone, with a persistent bed of shale at its base. It is more than 400 feet thick in the western part of the state and diminishes in thickness toward the east. The thickness of the Nacatoch sand in the producing areas ranges from 150 feet in the El Dorado and Rainbow City fields to 300 feet in the Irma and Stephens fields. In the extreme southeast corner of Arkansas and in parts of southeastern Union and Ashley counties adjacent to the Louisiana line, the Nacatoch loses its lithologic identity but is probably represented in these areas by the Monroe gas rock, a limestone formation that is the principal producing bed in the Monroe gas field in Louisiana.

The oil and gas in the Nacatoch formation are found generally in the first 10 to 50 feet of its beds, which consists of fine to medium-textured sand and sandstone, in part argillaceous and in part calcareous, and of interbedded lenses of clay. In the El Dorado, Lisbon, East El Dorado, and Stephens fields the lenticular structure of the producing sands was an important factor that influenced to a large extent the accumulation of the oil and gas in the reservoir rocks.

The large initial daily production of the wells on the Norphlet dome and the exceptional recovery per acre were reflected in the favorable sand conditions in this area where the Nacatoch sand was 150 feet thick and consisted of fine to coarse-grained sand and sandstone which became more and more argillaceous and consequently less porous on the flanks of the anticline.

OZAN FORMATION

The Ozan formation contains two oil and gas-producing sands, the Meakin and the Buckrange sands. The Buckrange sand at the base of the Ozan formation is widely distributed in both Louisiana and Arkansas, but the Meakin sand is restricted in areal extent.

MEAKIN SAND

The oil and gas production from the Meakin sand is limited chiefly to the Smackover field where it yields light oil of 26° to 28° A. P. I. gravity in the Louann district. In the Norphlet district this sand, generally called the "Primm sand," yields gas. The Meakin sand is composed of white to gray, micaceous, generally fine-grained and well-sorted quartz grains with intercalated thin lenses of calcareous sandstone.

Year	El Dorado		Smackover		
			Light oil		
	Yearly	Accumulative	Yearly	Accumulative	
1921	10,630,228	10,630,228			
1922	10,560,841	21,191,069			
1923	4,640,075	25,831,144	5,308,450	5,308,450	2
1924	2,871,310	28,702,454	11,715,061	17,023,511	2
1925	2,220,713	30,923,167	9,482,993	26,506,504	5
1926	1,894,382	32,817,549	5,524,808	32,031,312	4
1927	1,662,445	34,479,994	3,738,527	35,769,839	3
1928	1,464,261	35,944,255	2,662,480	38,432,319	21
1929	1,305,267	37,249,522	2,075,745	40,508,064	1
1930	1,192,640	38,442,162	1,738,153	42,246,217	1
1931	976,263	39,418,425	1,284,510	43,530,727	1
1932	815,040	40,233,465	995,588	44,526,315	8
1933	700,645	40,934,110	863,560	45,389,875	7
	40,934,110		45,389,875		27

TABLE 6A.—*Producing horizons in the south Arkansas fields*

Series	Formation	Name of sand	Depth below surface to sand by fields											
			Smackover field	El Dorado field	Lisbon field	East El Dorado field	Woodley pool	Rainbow City field	Stephens field	Irma field	Mount Holly field	Urbana field	Bradley field	Garland City field
Upper Cretaceous (Gulf series)	Arkadelphia marl	No production												
	Nacatoch sand	Nacatoch	2000-2100	2150	2175	2150	2200		1500	1150				
	Saratoga chalk Marlbrook marl Annona chalk	No production												
	Ozan	Meakin sand	2050-2200	2500										
		Buckrange-Graves sand	2300						2100				2800	
	Brownstown marl and Tokio-Woodbine	2600-foot sand	2600											
		2700-2900-foot sand	2700	2900		2875		2700-2800						
		Deep sand	2800											
	Upper Cretaceous red beds	Crain sand						3000						
		Gregory sand						3200						
Lower Cretaceous (Comanche series)	Upper Trinity red beds													2950
	Upper Glen Rose													
	Anhydrite zone													
	Lower Glen Rose										2800			
	Travis Peak											3500		

BUCKRANGE SAND

The Buckrange sand is the principal oil-producing sand in the Stephens field and in the Bradley district in Lafayette County. The Graves sand, the stratigraphic equivalent of the Buckrange sand, is a prolific oil-producing sand of the Norphlet district of the Smackover field.

The Buckrange sand increases in thickness from west to east and reaches its maximum thickness along a belt extending from the Smackover field southward into Louisiana. In the area east of the Smackover field, where the Ozan formation consists principally of sand, the Buckrange is not recognizable as a distinct lithologic unit. In the Smackover field the Buckrange sand or its equivalent, the Graves sand, consists of gray to greenish-gray, fine to coarse-textured quartz sand. This sand is in part glauconitic and in some localities contains pebbles of chert. The Buckrange sand is 15 to 20 feet thick in the Norphlet district of the Smackover field. In the Stephens field the Buckrange sand is 30 to 50 feet thick, made up of alternating thin beds of sandstone and shale with 5 to 10 feet of sand at the top. In the Bradley district the Buckrange sand ranges in thickness from a few inches to 5 feet. To the south and west of the Stephens and El Dorado fields the Buckrange sand is generally thin and in local areas is absent.

TOKIO-WOODBINE

The Tokio-Woodbine section, divided into an upper non-red member and a lower red member, contains several oil and gas-producing sands. In the upper member are several sands in the Smackover field but the most important is the 2,600-foot, or "Third sand." In the Rainbow City field oil and gas are produced from a sand 2,750 to 2,850 feet in depth. In the northern part of the El Dorado field oil production was obtained from a sand at a depth of 2,900 feet. The 2,600-foot at Smackover field, the 2,900-foot sand at El Dorado field, and the 2,750-foot sand in the Rainbow City field occur at about the same position in the stratigraphic column.

The lower member of the Tokio-Woodbine section contains two oil and gas-producing sands, the Crain and Gregory sands, both of which are productive in the Rainbow City field. The Crain sand lies from 75 to 125 feet below the top of the red beds at a depth of 3,000 feet below the surface. This sand produces oil in the eastern part of the Rainbow City field. The Gregory sand lies from 150 to 200 feet below the Crain sand at an average depth of 3,200 feet below the surface. This sand is the principal producing horizon in the western part of the Rainbow City field.

The Crain and Gregory sands are made up of several more or less continuous lenses of sand.

TRINITY GROUP

The production in the Urbana district in Union County is obtained from a sand in the Travis Peak formation which lies about 350 feet below the base of the Upper Cretaceous.

The Mount Holly district produces a small amount of oil from a sand zone in the Lower Glen Rose near the contact with the base of the Upper Cretaceous.

The oil production in the Garland City district in Miller County is obtained from one or more sands in the upper part of the Trinity group.

STRUCTURE

GENERAL FEATURES

The structure of this region is the result of a series of movements that included regional downwarping and sedimentation, differential warping of the sea floor during sedimentation (contemporaneous folding), and regional upwarp. Two principal episodes of upwarp, one occurring at the end of the Comanche epoch and the other in the Miocene epoch, are clearly recognizable; disconformities are present in the intervening sediments which, although not of regional extent, may be significant in their relation to the origin and accumulation of oil and gas.

The regional structure of southern Arkansas, as determined on the top of the Nacatoch sand, is shown in Plates I and XI. The strike ranges from east and west to north and south and the dip from south to east. The dips are uniformly low, generally less than 25 feet and rarely more than 75 feet to the mile. The most conspicuous structural features are the grabens, which traverse the region from west to east and, in a general way, separate the marginal monocline to the north from the more complexly deformed area to the south. The producing fields are in the area south of the zone of faults.

The principal structural features in the area producing the oil and gas consist of a series of gentle folds generally trending in a southeasterly direction that extend from the fault zone nearly to the Louisiana line. The extreme western fold extends from the Stephens field into the northwest corner of T. 19 S., R. 16 W. Adjacent to this on the east is a similar parallel fold upon which are situated the Louann district of the Smackover field, and the El Dorado and Lisbon fields. The easternmost fold begins with the Norphlet dome of the Smackover field and extends southeastward through the Rainbow City field into the the northwest corner of T. 18 S., R. 13 W., where its axis swings sharply to the east through the Urbana district. A syncline

TABLE 9.—*Discovery wells in the oil and gas-producing areas of southern Arkansas*

Name of field	Discovery well	Location	Date	Horizon	Initial Production	Total depth sand record
Bradley	Ark. Nat. Gas Co.'s P. M. Allen No. 1	18-19-24	Dec. 1, 1925	Blossom	20 bbls.	2786-2789
El Dorado	Constantin Refg. Co.'s Hill No. 1	1-18-16	May 22, 1920	Nacatoch	7,000 M. cu. ft. gas	No record, T. D. 2243
	El Dorado Nat. Gas Co.'s Frazier No. 1	1-18-16	May 8, 1922	Meakin	40,000 M. cu. ft. gas	No record, T. D. 2470
	El Dorado Nat. Gas Co.'s Mellor No. 1	1-18-16	Sept. 6, 1922	2900-foot sand	400 bbls.	2933-2941
East field	Terry Summerfield O. Co.'s Smith No. 1	30-17-14	Jan. 10, 1922	Nacatoch	10,000 M. cu. ft. gas	2200-2207
	Gulf Refining Co. of La. Polk Ezell 4	13-17-15	June 14, 1923	Woodbine	10 bbls.	2870-2888
Garland City	Fitzwater et al E. L. Beck No. 1	33-15-26	Oct. 10, 1932	Paluxy ?*	25 bbls.	2954
Irma	L. Watkins et al Waters No. 1	11-14-21	Jan. 10, 1923	Nacatoch	4 bbls.	1184-1192
Lisbon	Raines et al Dumas No. 1	9-17-16	Dec. 31, 1925	Nacatoch	35 bbls.	2060-2070
Mount Holly	McDonald Bros. Wilson No. 1	25-15-18	Mar. 9, 1929	Mount Holly sand	225 bbls.	2863-2866
Rainbow City	Ohio Oil Company's Crain No. 1	1-17-14	June 22, 1927	Crain sand	50 bbls.	3009-3014
	Pure Oil Company's Gregory No. 1	10-17-14	Apr. 4, 1928	Gregory sand Base Tokio	2,037 bbls.	3141-3153
Smackover	Anderson Drlg. Co.'s Murphy No. 1	8-16-15	May 14, 1922	Nacatoch	50,000 M. cu. ft. gas	No record, T. D. 2025
	Roxana Petrol. Co.'s Primm No. 1	1-16-16	July 8, 1923	Meakin	33,000 M. cu. ft. gas	2320-2322
Norphlet district (Heavy oil)	Lion O. & Refg. Co.'s Graves No. 6	3-16-15	July 5, 1925	Graves	175 bbls.	2352-2375
	T. & P. Coal & O. Co.'s Layney No. 5	31-15-15	June 6, 1925	Third sand	800 bbls.	2576-2583
	D. N. Stewart et al Murphy No. 1	9-16-15	Nov. 24, 1926	Deep sand	20,000 M. cu. ft. gas	2726-2738
Louann district (Light oil)	Marr et al Saxon No. 1	4-16-16	Oct. 23, 1922	Nacatoch	150 bbls.	2009-2010
	Federal Petrol. Co.'s Childs No. 1	8-16-16	Dec. 15, 1923	Meakin	25 bbls.	2241-2265
	Danciger et al Saxon No. 2	4-16-16	Mar. 2, 1923	Third sand	50 bbls.	2610-2620
	Gulf Refining Co. of La. Saxon No. 1	5-16-16	Apr. 20, 1923	Deep sand	62 bbls.	2619-2624
Stephens	Buffalo Oil Co.'s Culp No. 1	22-15-19	Nov. 2, 1925	Nacatoch	15,000 M. cu. ft. gas	1538-1541
	Hudes & Aarnes's Brown No. 1	13-15-20	June 2, 1922	Stephens sand	30 bbls.	2077-2082
Urbana	Marine Oil Co.'s Winn Est. No. 1	11-18-13	Feb. 13, 1927	Tokio	60,000-70,000 M.cu.ft.gas†	2705-2711
	Marine Oil Co.'s Thompson A-3	10-18-13	Jan. 19, 1930	Trinity	500 bbls.	3526-3532
Woodley pool	T. J. Woodley et al Lovett No. 1	5-18-14	Apr. 12, 1922	Nacatoch	40,000 M. cu. ft. gas	2148-2163
	T. J. Woodley et al Van Hook No. 1	8-18-14	June 26 1922	Nacatoch	75 bbls.	2214-2223

* Note: Upper Trinity—Miller Co. Garland City—correlated with Paluxy sand of Texas.

that trends in general from east to west separates these two folds from the Monroe uplift whose northern extension into Arkansas is marked by the northern dip of the beds along the Louisiana-Arkansas line.

The regional structure inferred from a horizon in the lower part of the Tokio formation would no doubt be appreciably different in detail from that of the Nacatoch and Meakin sands, owing to the considerable range in thickness of that formation in the oil and gas-producing region, but the data available are not sufficient to show the structural details of that formation.

STRUCTURE OF THE COMANCHE SERIES

The Comanche series was uplifted and tilted to the west and southwest at the end of the Comanche epoch. The uplift was followed by an interval of erosion, during which the Comanche strata were truncated from west to east and the region reduced to a peneplain upon which the beds of the Gulf series were deposited. The subsurface distribution of the Comanche series is shown in Figure 5.

The structure of the Comanche series, as it can now be determined, is shown in Plate XII, contours drawn on top of the anhydrite zone of the Glen Rose formation. The eastern limits of this zone lie a short distance southwest of the El Dorado and Smackover fields. In the area farther east, the Comanche series contains no individual members or beds that can be traced from well to well.

The Comanche beds strike northwest and dip in an easterly to southeasterly direction at the rate of 75 to 100 feet to the mile. This same dip probably prevails eastward beyond the area shown in Plate XII.

GENERAL RELATION OF STRUCTURE TO THE ACCUMULATION OF OIL AND GAS

The oil and gas deposits in the Coastal Plain of Arkansas occur under a variety of structural types ranging from lenticular sands to well-defined anticlinal and domal structures. In the areas where well-defined anticlinal or domal structure is associated with the oil and gas accumulations there is a definite tendency to accumulate in the highest accessible part of the reservoir; that is, at the crest of the structures. The structural types and their relation to the oil and gas accumulation are classified in Table 10.

The Norphlet dome in the Smackover field and the Irma faulted anticline are the most pronounced local structural features of the oil and gas-producing areas of southern Arkansas. The Norphlet dome, which is roughly circular, has a diameter of 4 miles and a closure of 70 feet. The principal feature in the

TABLE 10.—*Structural types and their relations to accumulation of oil and gas*

Field	Type of structure	Relations of structure to accumulation
Smackover	Dome	Oil and gas accumulated over highest part of a dome
Norphlet district Louann district	Terrace limited on north by fault	Oil and gas accumulated over a terrace, but distribution determined by lensing of reservoir sand
El Dorado	Anticline	Nacatoch oil and gas accumulated on east flank; localization determined by structure of reservoir sand Oil and gas in 2900-foot sand accumulated on local dome, superimposed on anticline
East El Dorado	Terrace	Oil and gas accumulation determined by lenticular structure of reservoir sand
Woodley pool	Dome	Oil and gas accumulated over highest part of dome
Rainbow City	Terrace	Accumulation determined by lenticular structure of reservoir sand
Stephens	Terrace	Accumulation determined chiefly by structure of reservoir sand
Lisbon	In part anticline and in part syncline	Accumulation determined by structure of reservoir sand
Irma	Faulted anticline	Accumulation on highest part of fold
Bradley district	Probably terrace	Accumulation in lenticular sand
Urbana district	Not determinable	
Garland City	Not determinable	Probably lenticular sands

Irma field is a fault that trends generally from east to west and that has a displacement of 400 feet to the north. On the south side of the field the Nacatoch sand has a closure of 50 feet against the fault. The producing area lies within the closure on the Nacatoch sand.

ORIGIN AND ACCUMULATION OF OIL AND GAS

Oil and gas accumulations occur under a variety of conditions as related to depth, age of the inclosing beds, character of the reservoir rocks, and structural types. They appear to be the combined results of a number of factors which are either unknown or imperfectly understood. There is almost universal agreement that oil and gas originated from organic material buried in the sediments, but there are wide differences of opinion concerning the processes of alteration of the organic material and concerning the mode of accumulation. In geologic literature the view is generally held that the source beds are massive organic shales and limestones deposited under conditions favorable to the growth of organisms. Generally the shales and limestones in contact with or near the reservoir beds are favorable as the source for the oil and gas. The above stated viewpoint necessarily implies migration of the oil and gas from the source beds to the reservoir beds, and migration of the oil and gas through the reservoir beds, to their ultimate site of accumulation. A less commonly held viewpoint is that the oil and gas originated at, or near, the site of accumulation. For the oil accumulation of southern Arkansas and northern Louisiana, the writer favors the viewpoint that the oil originated at, or near, the site of accumulation. The reasons for holding this viewpoint will be briefly discussed.

The principal oil-producing fields of southern Arkansas occur in a generally northwest-southeast trending belt 10 to 15 miles wide and 50 miles long. This belt continues into Louisiana where it includes the Monroe and Richland fields, giving it a total length of 110 miles. The oil and gas-producing belt coincides with an area of marked changes in the character of the Upper Cretaceous sediments as contrasted with the area immediately to the west and the southwest.

The sediments decrease in thickness, become increasingly sandy, and generally depart widely in character from the more typical marine sediments in the adjacent area to the west. These changes are not closely related to the strand line of the Cretaceous sea. The changes in the character of the Upper Cretaceous sediments may be considered of regional extent in that they effect the oil and gas-producing belt and the adjacent areas to the east, but locally the sediments vary widely from place to place within this area. It is a well known fact that sediments are sensitive to environmental factors. This fact has been aptly summarized by Twenhoefel[1] in the following statement: "The sediments are responses to environmental conditions operating on the character inherited from the parent rocks and previous processes, and deposition of all varieties is due to environmental factors operating at the places of deposition. Inorganic sediments have high degrees of sensibility to environmental factors." The above statement is equally applicable to regional and local variations in the sediments.

It is the writer's opinion that the principal factor which determined the variation in the character of the sediments in this area was differential warping of the sea floor during deposition. The Cretaceous sediments accumulated on a peneplained surface of highly folded and faulted rocks which may range in age from late Paleozoic to pre-Cambrian. The lowering of the peneplain to accommodate the accumulating sediments was accompanied by differential movements in the basement rocks, probably along existing lines of weakness. These movements were propagated upward into the overlying sediments producing a

[1] Twenhoefel, W. H., Environment in sedimentation and stratigraphy: Geol. Soc. America, Bull., vol. 42, 1931, p. 423.

gentle arching of the sea floor. The regional feature on which the oil and gas-producing belt is situated appears to have been an active line of weakness, possibly related to the Ouachita Mountain system in its underground extension to the southeast. The differential warping of the sea floor in this area appears to have been more or less continuous, although of varying intensity, to the end of the Cretaceous. The local changes, most pronounced in the oil-producing areas, are expressed by the thinning of all, or a part of the sediments and in lateral changes in the character of the sediments, or both. Such changes are interpreted to be the result of slight differential movements of the basement rocks which, owing to the complex stresses involved in their movements may have been either intermittent or continuous for long periods of time. The principal effect of the differential warping of the sea floor was the modification of the current action by which the sediments were distributed over the sea floor. In the areas which rose even slightly above the normal level of the sea floor, the current action was more active, and the sediments were agitated and sorted. The resulting tendency was for the heavier material to accumulate over the higher areas and the finer material and the muds to accumulate over their flanks and in adjacent depressed areas. It is not unreasonable to assume that where evironmental factors locally modified the character of the sediments, organic life may have been more abundant, and conditions for the preservation and burial of the organic material may have been more favorable. Accepting this explanation it is then possible to postulate the existence of localized concentrations of organic material as the source of the oil and to obviate the necessity of assuming the long distance migration of the oil to its site of accumulation. This viewpoint emphasizes the importance of contemporaneous folding and sedimentation in relation to oil accumulation.

Local changes in the character and thickness of the sediments are strikingly illustrated in the Smackover field. Over the Norphlet dome the Nacatoch formation consists chiefly of sands with subordinate beds of shale. The formation increases in thickness down the flank and changes laterally to shale with subordinate beds of sand. In many, if not all, of the producing areas, the reservoir rock is most porous over the producing area decreasing in porosity towards the margins of, or beyond the producing area, apparently as the result of the presence of increasing amounts of argillaceous material.

The oil produced from the Nacatoch sand in the El Dorado district ranges from 19° to 36° A. P. I. gravity. In the El Dorado field proper the gravity is from 33° to 36° and the East El Dorado field the gravity is 19° to 20°. These two last producing areas are separated by a barren zone about 4 miles wide, but the sand in this zone as evidenced by several wells is continuous from one area into the other. In the other producing fields there are marked differences in the gravities of the oils produced, which fact suggests a local source for the oil and, furthermore, suggests that the gravity and composition of the oils depend upon the composition of the organic material from which they were derived.

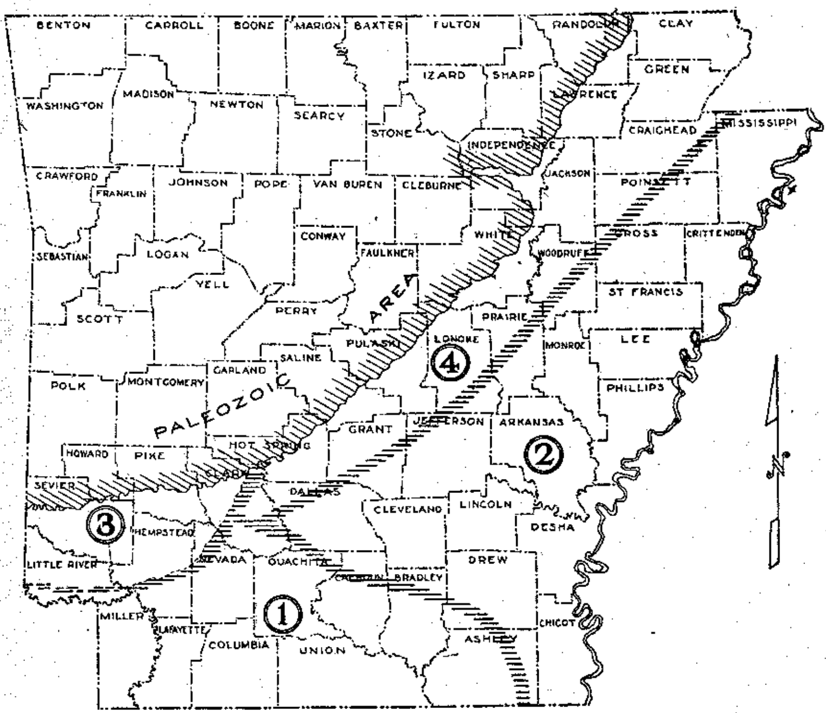

FIGURE 19.—Map showing oil and gas possibilities in the Gulf Coastal Plain in Arkansas.

Most oil-producing areas are of anticlinal structure in some form, whether anticlinal and domal structures, or structural terraces. In other areas the oil is confined by virtue of the structure of the reservoir rock, either lensing of the sand, or lateral decrease in porosity. Furthermore, many anticlinal structures are barren of oil and gas; a fact that gives additional weight to the viewpoint that the oil and gas originated near the site of its accumulation.

In considering the possibilities of oil production in the areas which are untested, or are inadequately tested in the Gulf Coastal Plain it is necessary to primarily consider their stratigraphy. For convenience, the Coastal Plain is divided into four areas (See Fig. 19), each one possessing general characteristics which may have a bearing upon its oil possibilities. These are discussed in the decending order of what is believed to be their importance. In area 1 the Upper Cretaceous strata, including most of the known oil and gas-producing horizons of this region, are present beneath the Tertiary strata. It also is underlain by strata of Comanche age which have not been adequately tested to determine their oil and gas-producing possibilities. From present evidence this area is believed to be the most favorable for commercial oil and gas accumulation in the Gulf Coastal Plain in Arkansas. In Area 2 the Comanche strata are absent. The Upper Cretaceous sediments are from 200 to 800 feet thick and include some of the known oil and gas-producing horizons. It is also an area of thick Tertiary sediments. This area, although not thoroughly tested, has yielded few shows of oil and gas. It is, therefore, considered to be less favorable for oil and gas accumulations than Area 1. In Area 3 most of the Upper Cretaceous strata are exposed at the surface. Comanche strata underlie the Upper Cretaceous through most of the area, but they are relatively thin as compared with the area to the south, and, this area seems less favorable for oil or gas accumulations than Areas 1 or 2. Area 4 represents the area wherein the Comanche strata are absent and the Upper Cretaceous is thin and represented by marginal deposits. This area cannot be considered as favorable for future exploration for oil and gas.

THE SMACKOVER FIELD

LOCATION AND DIVISIONS

The Smackover field includes more than 40 square miles in Tps. 15 and 16 S., Rs. 15, 16, and 17 W., on the line between Ouachita and Union counties. The town of Smackover, for which the field was named, stands near the center of the producing area. The field is divided into the Louann or light-oil district on the west, and the Norphlet or heavy-oil district on the east.

HISTORY OF DEVELOPMENT

The discovery well in the Smackover field, the Oil Operator's Trust Murphy No. 1 well in sec. 8, T. 16 S., R. 15 W., blew out April 14, 1922, forming a crater 450 feet in diameter and 50 feet deep. The well had an initial open-flow production of 30,000,000 cubic feet of gas and a rock pressure of 950 pounds in the Nacatoch sand at a depth of approximately 2,024 feet below the surface. This well was drilled near the apex of the Norphlet dome.

The first oil-producing well in this field was the V. K. F. Oil Company's Richardson No. 1 well in sec. 29, T. 15 S., R. 15 W., which was completed in the Nacatoch sand July 1, 1922, at approximately 2,000 feet. In October 1922, the production was extended westward into sec. 4, T. 16 S., R. 16 W., opening up the Louann district. The production in the Nacatoch sand was below expectation and resulted in exploitation to possible deeper oil zones and in the discovery of the Meakin sand which yields the light oil produced at Smackover at depths varying from 2,230 to 2,350 feet below the surface. The Graves sand was discovered by the Lion Oil and Refining Company in their Graves No. 6 well in sec. 3, T. 16 S., R. 15 W., which was completed January 28, 1925, at a depth of 2,501 feet. Later development work revealed the occurrence of oil and gas deposits in the Tokio-Woodbine section which underlies the Graves sand.

The peak of the production in this field from all sands was reached in 1925, when the yearly output was 69,000,000 barrels, of which 9,500,000 barrels was light oil (23° to 28° Baume) and 59,500,000 barrels was heavy oil (18° to 23° Baume). The highest monthly output was 1,182,900 barrels of light oil during June 1924, and 8,201,500 barrels of heavy oil during May 1925. Up to January 1, 1934, the Smackover field had produced 315,401,428 barrels of oil, of which 45,389,875 barrels was light oil and 270,011,553 barrels was heavy oil. On January 1, 1930, 962 wells produced 5,290 barrels of light oil, an average production of 5½ barrels per well; and 2,036 wells produced 41,837 barrels of heavy oil, an average of 20½ barrels per well on that day.

The eastern part, or the Norphlet dome, of the Smackover field has been described by Bell, Haury, and Kelly[1] in a paper dealing chiefly with the engineering problems of the field. The geology of the Smackover field has been described by H. G. Schneider[2], to whom the writer is indebted for the geologic structure map of the Graves sand and for much other valuable information that is incorporated in this paper. The same writer[3] has described and named the producing sands of the field. The names thus given, except that of the Blossom sand, are used in this paper.

STRATIGRAPHY

GENERALIZED SECTION

The Claiborne formation is at the surface in the Smackover field, but deep wells have penetrated all of the beds of the Eocene and Gulf series and more than 1,300 feet of the Comanche series. The stratigraphic section for the field is shown in Table 11.

CRETACEOUS SYSTEM

COMANCHE SERIES

The Comanche series is represented in the Smackover field by a part of the Lower Glen Rose, the Travis Peak, and by a series of chalky limestones which are provisionally assigned to the Neocomian. The Glen Rose strata are present only on the west side of the Louann district and perhaps in the graben to the north of the producing area; in the remainder of the field the basal Upper Cretaceous lies in contact with the Travis Peak formation.

NEOCOMIAN ?

In the Neocomian is included more than 600 feet of chalky limestone penetrated in the Lion Oil and Refining Company's Hayes A-9 well in sec. 4, T. 16 S., R. 15 W., Norphlet district. The limestone series lies with apparent unconformity on a salt mass and is overlain by the Travis Peak formation.

TRAVIS PEAK FORMATION

The Travis Peak formation consists of red, brown, purplish-brown, greenish-gray to dark-gray clays, shale and sandy shale interbedded with light-colored to brown sands and sandstones. The clay and shale members are most prominent in the upper part and the sand members predominate in the lower part of the formation. The sand is fine to medium-grained in the upper

[1] Bell, H. W., Haury, P. S., and Kelly, R. B., Preliminary report on the eastern part of the Smackover, Arkansas, oil and gas field: Arkansas State Bur. of Mines, 1923.

[2] Schneider, H. G., Smackover oil field, Ouachita and Union counties, Arkansas: Am. Inst. Min. and Met. Eng., Trans., vol. 70, pp. 1076-1099, 1924.

[3] Schneider, H. G., Names of producing sands in the Smackover, Arkansas, field: Am. Assoc. Petrol. Geol. Bull., vol. 9, no. 7, pp. 1116-1117, 1925.

TABLE 11.—*Generalized section of the formations in the Smackover field*

System	Series	Formation	Thickness in feet	Character of the beds
Quaternary	Recent		0-50	Surface alluvium
		Unconformity		
Tertiary	Eocene	Claiborne	500±	Sand, gravel, and clay, lignitic sand and clay, ferruginous sand and glauconitic sand and clay.
		Wilcox	700-750	Lignitic sand and clay
		Midway	550	Bluish-gray to dark-gray clay, with siderite concretions. Lower 50 feet dark-gray calcareous and fossiliferous clay.
		Unconformity		
Cretaceous	Gulf	Arkadelphia marl	90-100	Gray and dark-gray marl and shale and some chalky marl
		Nacatoch sand	150-200	Sand and calcareous sand, with some interbedded shale and sandy shale, Gray shale at the base. Oil and gas-producing sand.
		Saratoga chalk and Marlbrook marl	175-200	Marly, chalk and marl with interbedded sandy marl and chalk
		Ozan	170-180	Micaceous sand, shale, and sandy shale. Meakin sand at top and Graves sand at base. Oil and gas-producing sands
		Tokio-Woodbine	225-500	Chiefly tuffaceous sand and sandstone with some interbedded tuff, clay, and sandy clay. In part lignitic. Oil and gas-producing beds
		Red beds	0-150±	Red, gray and white clay interbedded with sand. Section consists largely of tuff
		Unconformity		
	Comanche (Trinity group)	Glen Rose	0-200±	Gray to green clay and impure limestone. Sandstone only in the extreme western part of Smackover field.
		Travis Peak	2000+	Interbedded red, brown, purple, and gray clay and light-colored sand and sandstone
		Neocomian	600+	Chiefly chalky limestone

part but is somewhat coarser grained in the basal part of the formation.

The Travis Peak formation is 2,000 to 2,100 feet thick in the Smackover field.

GLEN ROSE FORMATION

No data are available to show definitely the character of the Glen Rose formation in the Smackover field; however, a few miles to the west it consists of gray to green and red clay and shale interbedded with impure limestone and fine-grained sand and sandstone. Its maximum thickness in the western part of the Louann district is not more than 200 feet.

GULF SERIES

A generalized section of the Upper Cretaceous formations in the Smackover field is shown in Figure 20.

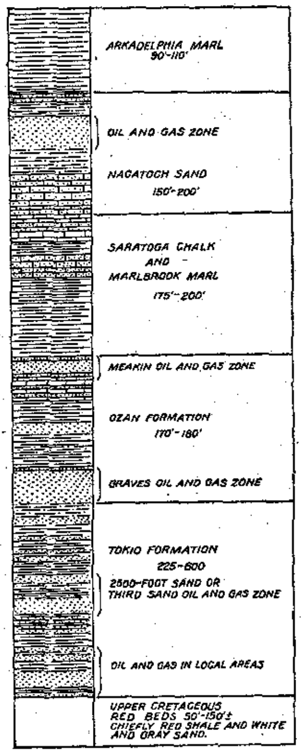

FIGURE 20. — Generalized section of Upper Cretaceous formation in the Smackover field.

TOKIO-WOODBINE

The basal Upper Cretaceous red beds are either absent or thin over the highest part of the Norphlet dome (See Pl. VI) but are present on the flanks where they are from 50 to 150 feet thick.

The non-red Tokio-Woodbine sediments consist chiefly of white to pale-green sands and sandstones interbedded with gray and green clays, sandy clays, and some thin beds of bentonite and subangular quartz grains generally in a matrix of volcanic tuff. The formation contains some carbonaceous material which occurs as finely comminuted particles and as fine streaks along the bedding planes.

The non-red Tokio-Woodbine section is from 225 to 275 feet thick over the top of the Norphlet dome, but its thickness increases to 300 to 375 feet on the south and east flanks of this dome and is 500 feet thick in the western part of the Louann district.

OZAN FORMATION

The Ozan formation in the Smackover field is represented by an upper and lower sand member and an intermediate shale member. Its basal member is the Buckrange sand, or the "Graves sand" as it is known in this field. It consists of gray to greenish-gray micaceous and in part glauconitic, fine to coarse-grained sand and sandy clays. It is from 30 to 40 feet thick. Over the Norphlet dome where it is a prolific oil-producing horizon the sand is generally coarse and contains pebbles of chert. The thickness of the productive sand is from 12 to 20 feet. The intermediate member consists of finely micaceous and glauconitic gray and green clayey marls and sandy clays and lenses of glauconitic sand. The Buckrange sand is 90 to 125 feet thick.

In the Smackover and Union County fields the upper member of the Ozan formation is known as the "Meakin sand." It consists of sands and sandy clays which in lithology closely resemble the Graves sand except that the grains are somewhat finer. The Meakin sand is 35 to 45 feet thick in the eastern part of the field but decreases towards the west and is not found west of the Louann district. The oil and gas-saturated portion is variable in thickness over the field.

MARLBROOK AND SARATOGA CHALKS

The Marlbrook and Saratoga chalks consist mainly of gray shale, marl, and chalky marl, but include some beds of sandy clay and calcareous sand. They are 175 to 200 feet thick in the Smackover field.

NACATOCH FORMATION

The Nacatoch formation contains beds of sand, shale, clay and chalky sandstone, but the different beds constituting the formation vary widely in thickness with the producing area of the field. Over the Norphlet dome it consists of sand and subordinate beds of shale and clay; the shale and clay members increase in thickness down the flanks of the dome until they constitute the greater part of the total thickness of the formation in the Louann district.

The sand consists of fine to medium-grained quartz and ranges in color from gray to green, its shade depending upon the quantity of glauconite it contains. Its porosity ranges widely and is determined by the quantity of argillaceous material that it includes and by the degree of its secondary calcification.

The Nacatoch formation is 150 feet thick on the Norphlet dome and more than 200 feet thick in the western part of the Louann district.

ARKADELPHIA MARL

The Arkadelphia marl consists of dark-gray calcareous shale and marl, which in this area have a thickness of 90 to 110 feet.

TERTIARY SYSTEM

EOCENE SERIES

MIDWAY FORMATION

The Midway formation consists mainly of gray and blue noncalcareous clay, containing many siderite concretions. At some places its basal 25 to 50 feet consist of calcareous clay. The formation is 500 to 550 feet thick.

WILCOX FORMATION

The Wilcox formation contains chiefly lignitic sand, sandy clay, and clay but includes thin beds of lignite. It contains an abundance of calcareous and siderite concretions. In the Smackover field this formation includes two sands, known as the "500-

foot water sand" and the "900-foot water sand," which have caused considerable difficulty in drilling. The Wilcox formation is 700 to 750 feet thick in the Smackover field.

CLAIBORNE GROUP

Over most of southern Arkansas, the Claiborne group consists of several formations which are continuous westward into Texas. The same formational units no doubt are present in the Smackover field but owing to lack of detailed data they cannot be recognized in the well records. The Claiborne consists chiefly of sands and subordinate beds of glauconitic sand and clay in the upper part. The basal 75 to 100 feet of beds consists of glauconitic sand and marl, and chocolate clays. The Claiborne group is 450 to 600 feet thick in the Smackover field.

STRUCTURE

The rocks at the surface in the Smackover field consist in part of Recent sand and alluvium and in part of massive sands of Claiborne age, which, owing to their charatcer, are not adapted to detailed mapping. The structure maps of the field are determined from studies of well records.

SUBSURFACE STRUCTURE

The most detailed structural map must be made up from well records. While any of the producing sands furnish a satisfactory datum plane, the Meakin and Graves sands are the most satisfactory because of their uniform thickness and distribution in the Smackover field. The interpretation of the structure, using the top of the Meakin sand as a datum plane, is shown in Plate XVII. The structure of the Norphlet dome by H. G. Schneider, contoured on the top of the Graves sand, is given in Plate XVIII.

The most prominent structural features in the Smackover field are the Norphlet dome on the east, the Louann terrace on the west, and the east-west trending down-faulted block on the north.

The Norphlet dome, named by Schneider[4], is of roughly circular form, and its beds dip 25 to 75 feet to the mile away from its apex which is in sec. 4, T. 16 S., R. 15 W. The lower rate of dip is to the west, the higher rate is to the east and northeast. The highest part of the dome, measured at the top of the Meakin sand, is between 2,100 and 2,125 feet below sea level. It is represented in Plate XVII by an area of 2,000 acres inclosed by the 2,125-foot contour line. The lowest closing contour line of the producing area is 2,175 feet below sea level, the amount of

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[4] Schneider, H. C., Smackover oil field, Ouachita and Union counties, Arkansas: Am. Inst. Min. and Met. Eng., Trans., vol. 70, pp. 1076-1099, March 1924.

closure on the dome varying from 50 to 70 feet. The productive portion of the dome is, therefore, 8 square miles.

The Norphlet dome is separated from the Louann district by a narrow saddle in the northeast corner of T. 16 S., R. 16 W., which merges into well-defined northward and southward plunging synclines.

The Louann terrace, named by Schneider[5] to designate the structural feature of the Smackover field east of the Norphlet dome, is a broad, relatively flat area of about 20 square miles, bounded on the north by the Smackover graben; on the east by a syncline having a general northerly trend, which separates this area from the Norphlet dome; and on the southwest by a syncline plunging to the southwest that extends into the southeast corner of T. 15 S., R. 17 W. On the northwest the Louann terrace merges into the regional monocline structure of this region, which dips to the south. Near the Smackover graben the Meakin sand is 2,100 to 2,125 feet below sea level, and there is a small closure of the 2,125-foot contour line in sec. 6, T. 16 S., R. 16 W., but in general the terrace is defined on the east, south, and southwest by the 2,150-foot contour line.

The Smackover field is bounded on the north by a fault which has a general east to west strike and traverses the central part of T. 15 S., Rs. 15, 16, and 17 W. The downthrow is to the north; where it can be accurately determined, the amount of displacement is 450 to 475 feet. The most accurate data at hand is obtained from the Atlantic Oil Production Company's Rowland wells in sec. 29, T. 15 S., R. 16 W., drilled just south of the fault, and from the Transcontinental Oil Company's Minor No. 1 well in sec. 20, T. 15 S., R. 16 W., drilled on the downthrown side of the fault. The producing wells on the south, or upthrown side, of the fault encounter the top of the Nacatoch sand at depths of 1,850 to 1,855 feet below sea level and have a normal stratigraphic section to the bottom of the hole.

The Transcontinental Oil Company's Minor No. 1 well encountered the top of the Nacatoch sand at a depth of 2,330 feet below sea level, the top of the Meakin sand at 2,685 feet below sea level, and the top of the Tokio-Woodbine section at a depth of 2,743 feet below sea level. The interval from the top of the Nacatoch sand to the top of the Meakin sand is normal, but the interval from the top of the Meakin sand to the top of the Tokio is only 60 feet, instead of the normal interval of 180 to 190 feet. The Graves sand and a part of the Ozan clay are absent, and it is, therefore, inferred that the fault plane passes through the Ozan formation about 60 feet below the top of the Meakin sand. By projecting this point to the Nacatoch fault trace, which is ap-

[5] Schneider, H. G., op. cit.

proximately located by the wells drilled in this area, it is found that the fault plane has a northward inclination of 45° to 55°. A cross section of the fault is shown in Figure 21.

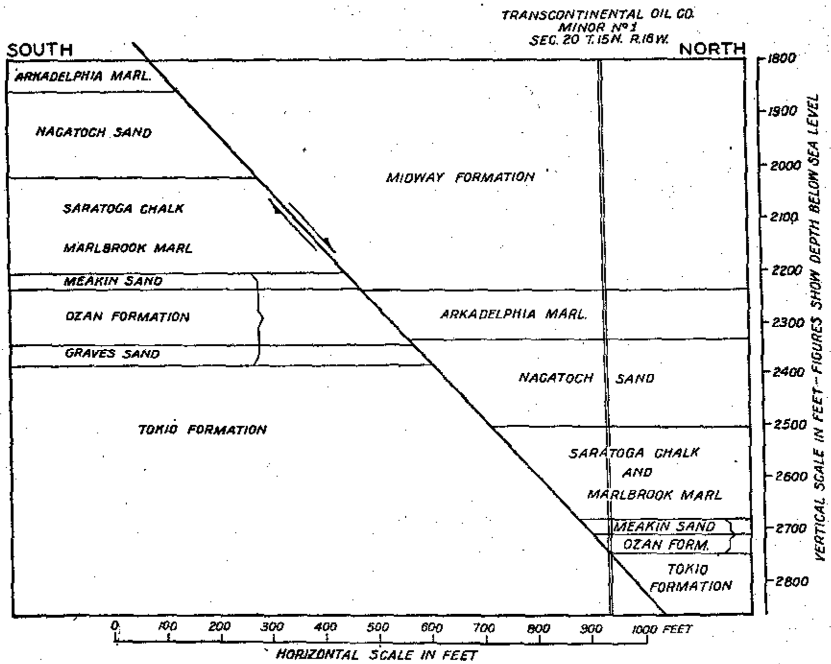

FIGURE 21.—South to north cross section of Smackover fault in sec. 20, T. 15 S., R. 16 W., Louann district.

STRUCTURE OF THE COMANCHE SERIES

The Comanche series is separated from the overlying Gulf series by a pronounced erosional unconformity which has truncated the beds of the Comanche series. The regional strike of this series is to the northwest and the regional dip is southwest (See Pl. XII and Fig. 3) Deep wells drilled a few miles to the west of the Louann district encounter beds of Glen Rose age in contact with the base of the Gulf series, but deep wells drilled in the Smackover field encounter red shales and sand of Travis Peak age at the same stratigraphic position.

The structure in the Comanche beds is not determinable owing to the absence of beds having sufficiently marked individual features to be correlated from well to well. The normal regional dip of the Comanche beds is 75 to 100 feet per mile to the west, and that of the Gulf series is 25 to 30 feet to the east. This difference in dip would indicate that unless the Comanche strata in the Smackover field depart from the normal regional dip the post-Comanche deformation was not sufficient to overcome the initial dip of these beds. The structure of the

Comanche beds may, therefore, be less pronounced than that of the overlying Gulf series.

RELATION OF STRUCTURE TO THE ACCUMULATION OF OIL AND GAS

The deposits of oil and gas in the Smackover field may be said to be normal to the structure in that they show a tendency to occupy the highest part of the fold or the reservoir rock in which they are inclosed. The relation observed suggests that the structure is the dominant feature that has determined the accumulation of oil and gas, although the localization of oil and gas in different parts of the field has been determined to some extent by the character of the reservoir beds, chiefly their lenticular structure and their porosity. Well sections through the Smackover field, showing correlation of the oil and gas-producing sands are shown in Plate XIX.

PRODUCTION

DISTRIBUTION AND CHARACTER OF PRODUCING SANDS

The limits of production of the four principal producing sands in the Smackover field are shown in Figure 22.

The uppermost or Nacatoch sand is productive over an area of 29,500 acres which includes both the Norphlet and Louann districts. It is the most widely distributed oil and gas-producing sand in the Smackover field. This sand is most productive in the Norphlet district where the structure is well-defined and the sand is most uniform in character and thickness. The productive area, nevertheless, extends far down the south and southwest flank of the Norphlet dome (See Pl. XVII) where the distribution of the oil and gas is obviously independent of the deformation of the inclosing beds and probably related to the character of the sand. In the Louann district the sand members of the Nacatoch progressively decreases in thickness toward the west. The distribution of the oil and gas is erratic and was apparently determined by the character and structure of the sand lenses rather than by the deformation of beds.

The Meakin sand, which is productive over an area of about 9,600 acres, yields the light oil of the Smackover field. This sand underlies both the Norphlet and the Louann districts. In the Norphlet district the Meakin sand produces gas and some oil; whereas, in the Louann district, it produces oil and some gas. The productive area is not continuous from one district to the other but is separated by a barren area 3 to 4 miles wide. In the Norphlet district the oil and gas accumulated over the highest part of the structure, but in the Louann district the accumulation has been modified by the westward lensing of the sand,

and this, rather than the structural deformation, has determined the western limit of the productive area.

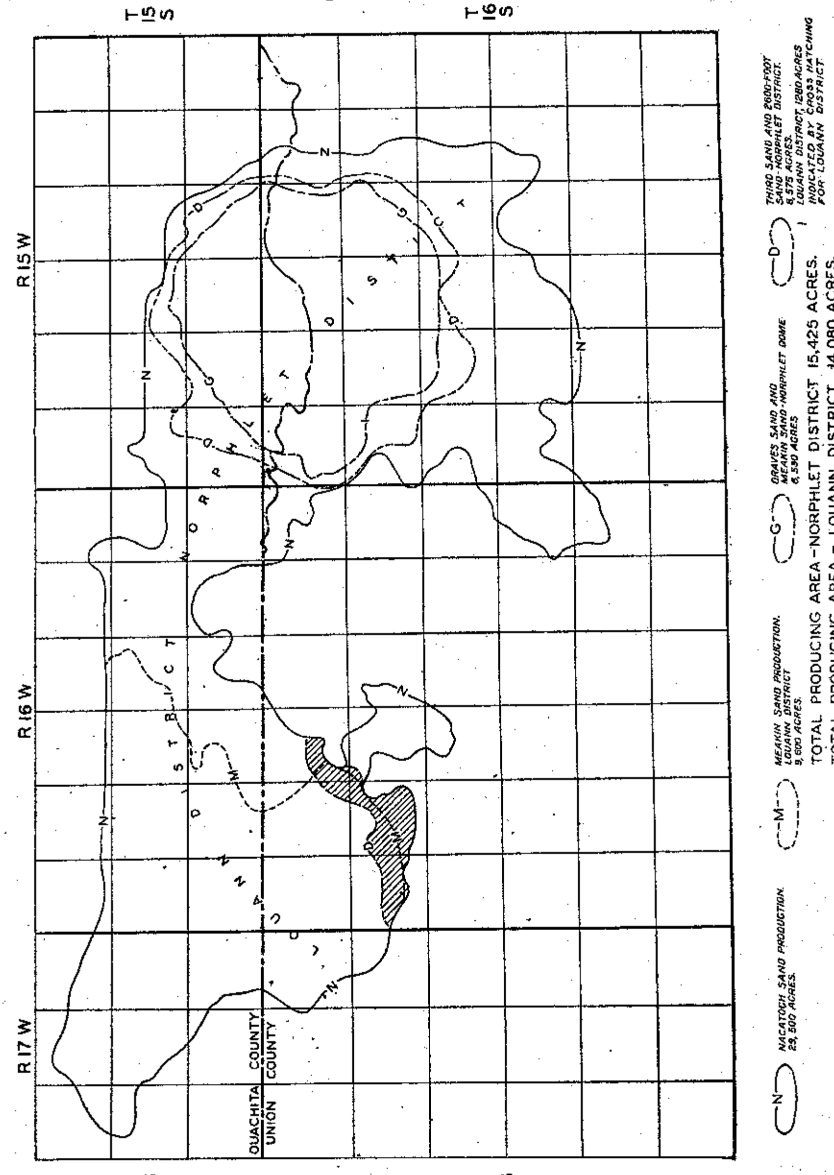

FIGURE 22.—Outline map of Smackover field showing areal distribution of different producing sands.

The relation of gas to oil in the Meakin sand of the Smackover field is interesting, for there is no obvious reason why this sand should yield chiefly gas in the Norphlet district and chiefly oil in the Louann district.

The Graves sand is productive only in the Norphlet district, where it covers about 6,500 acres. The producing area coincides closely with the outline of the Norphlet dome.

The Third sand has a total producing area of 9,125 acres, covering 555 acres in the Louann district and 8,575 acres in the Norphlet district.

In the Norphlet district the productive area of the Third sand coincides closely with the outline of the dome. In the Louann district the Third sand and deeper sands are productive in a crescent-shaped area on the southeast side of the district. The accumulation in this area is due to the lensing of the sands toward the northeast.

In the Smackover field there are four principal oil and gas-producing sands, all in the Gulf series of the Cretaceous system, as shown below:

Producing sands in the Smackover field

Name	Depth in feet below surface	Depth in feet below sea level	Average gravity of oil Degree A. P. I.
Nacatoch	1925-2150	1800-1890	20
Meakin	2230-2360	2100-2175	25
Graves	2340-2500	2240-2300	21
Third or 2600-foot	2550-2660	2420-2500	19-24

In addition to the producing sands listed above, there are several sands in the Tokio-Woodbine section that have yielded some oil and gas (See Fig. 23).

TABLE 12.—*Sand discovery wells in the Norphlet district, Smackover field*

Discovery well	Location	Completion Date	Initial Production	Depth below surface of prod. sand	Name of prod. sand
Oil Operators' Trust Murphy No. 1	8-16-15	Apr. 14 1922	50,000 M. cu. ft. gas*	2025 T. D	Nacatoch
V. K. F. Oil Co. Richardson No. 1	29-15-15	July 31 1922	300 bbls.	2048-2066	Nacatoch
Roxana Petrol. Corp. Primm No. 1	1-16-16	July 8 1922	33,000 M. cu. ft. gas	2320-2322	(Primm gas sand) Meakin sand
Lion Oil & Refg. Co. Graves No. 6	3-16-15	Jan. 28 1925	1000 bbls.	2490-2501	Graves
T. & P. Coal & O. Co. Laney No. 5	3-15-15	June 6 1925	800 bbls.	2576-2583	Third sand
D. N. Stewart et al, Murphy No. 1	9-16-15	Nov. 24 1926	20,000 M. cu. ft. gas	2726-2738	Deep sand

TABLE 13.—*Sand discovery wells in the Louann district, Smackover field*

Discovery well	Location	Completion date	Initial production	Depth below surface of prod. sand	Name of prod. sand
Marr et al, Saxon No. 1	4-16-16	Oct. 23 1922	150 bbls.	2009-2010	Nacatoch
Federal Petrol. Co. Childs No. 1	8-16-16	Dec. 15 1923	25 bbls.	2244-2265	Meakin
Danciger et al, Saxon No. 2	4-16-16	Mar. 2 1923	50 bbls.	2610-2620	Third sand
Gulf Refg. Co. Saxon No. 1	5-16-16	Apr. 20 1923	62 bbls.	2619-2624	Deep sand

NACATOCH SAND

The Nacatoch sand, known also as the "Shallow sand" and "First sand," is productive over an area of more than 45 square miles. (See Fig. 22.) It is found at depths of 1,925 to 2,150 feet below the surface or 1,800 to 1,890 feet below sea level.

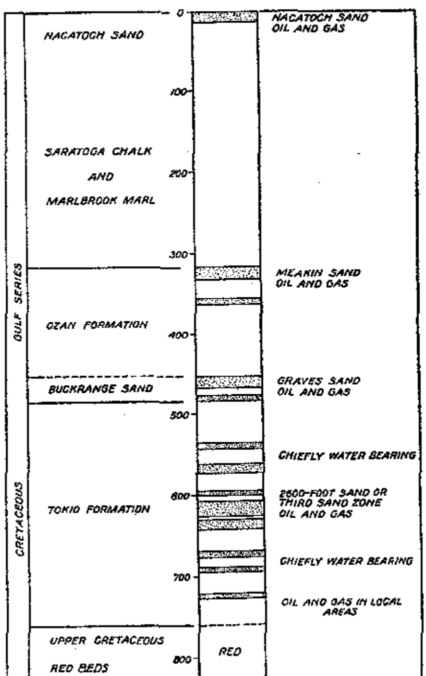

FIGURE 23.—Section showing oil and gas-producing horizons in Smackover field. Cored in Ramage et al, Ezzell No. 1 well, sec. 24, T. 16 S., R. 15 W. Figures give depth below the Nacatoch sand.

The Nacatoch sand exhibits marked lateral changes in character. Over the Norphlet dome it is made up chiefly of sand and subordinate beds of clay and shale, but to the east, south, and west it consists chiefly of clay and shale and subordinate beds of sand and limestone. In the area west of the Norphlet dome, the sand appears to grade laterally into sandy clay and from sandy clay into clay and shale until, in the western part of the Louann district, the formation is made up mainly of clay and shale and subordinate lenses of sand.

The sand members are generally gray but are greenish-gray to green where they contain glauconite and consist of fine to medium quartz grains generally subangular in shape. The poroisty of the sand varies widely, depending upon the amount of argillaceous material it includes and upon the degree of cementation.

The Nacatoch is 150 feet thick in the Norphlet district and consists principally of sand. The oil and gas are confined to the upper 100 feet of its beds, which may be called the Nacatoch oil and gas zone. The sand over the highest part of the dome contained gas and in slightly lower portions structurally, oil, but the zone was saturated at few places throughout with oil and gas.

In the eastern part of the Louann district, where the sand members were thinner than those in the Norphlet district, there were several beds of oil-saturated sand and intervening beds of dry or water-bearing sand. In the western part of the Louann district, the saturated sand is in the upper part of the formation.

The average gravity of the Nacatoch oil is 20° A. P. I. The largest recorded initial daily production from the Nacatoch sand was 25,000 barrels of oil and 50,000,000 cubic feet of gas.

MEAKIN SAND

The Meakin sand was named by Schneider[6] from the farm on which the discovery well was drilled. The Meakin sand is known also as the "Louann sand," the "2,200-foot sand," and the "2,300-foot sand." It is the light-oil sand of the Smackover field, yielding oil of 26° to 28° A. P. I. gravity. This sand is the principal oil sand in the Louann district, where it is productive over an area of 9,600 acres. The Meakin sand is not a large producer in the Norphlet district, although some gas has been obtained from its upper part, in what is commonly called the "Primm gas zone," and some oil from its lower part.

The Meakin sand is found at depths of 2,230 to 2,360 feet below the surface or 2,100 to 2,175 feet below sea level.

The Meakin sand marks a period in the depositional history when the strand of the sea, in which the Ozan sediments were laid down, migrated basinward, and coarse materials were deposited along the margin of the sea. The Meakin sand, therefore, represents a marginal unconformity at the top of the Ozan formation. The western limit of the Meakin sand coincides with the western limit of the productive area in the Louann district, and the lensing of the sand, rather than the structure, has determined the limits of oil production in that part of the field.

The Meakin sand is a white to gray micaceous generally fine-grained and well-sorted quartz sand, containing thin lenses of indurated sand (the cap rocks of the driller's records). The following is a typical core record of the Meakin sand:

[6] Schneider, H. G., op. cit.

Section of Meakin sand in the Texas Company's McAdoo No. 1 well in sec. 15, T. 16 S., R. 16 W.

	Depth in feet
Oil sand	2302 –2305
Sand	2305 –2316
Shell	2316 –2316½
Sand	2316½–2318⅜
Rock	2318⅜–2320
Sand; salt water	2320 –2325
Sand	2325 –2330½
Cap rock	2330½–2331½
Hard sand	2331½–2340
Soft sand	2340 –2342
Shale with streaks of sand	2342 –2347
Rock	2347 –2348
Sandy shale	2348 –2355

According to Schneider[7] the top of the Meakin sand produced oil in the area adjacent to the fault in the Louann district, but in T. 16 S., R. 16 W., the oil-saturated sand was 20 to 25 feet below the top of the Meakin sand.

The average initial daily production in the Meakin sand was 200 barrels of oil and 30,000,000 cubic feet of gas.

GRAVES SAND

The Graves sand, named for the farm on which the discovery well, the Lion Oil and Refining Company's Graves No. 8 well, was drilled in the SW¼ of SW¼ sec. 3, T. 16 S., R. 15 W., is the most productive bed in the Norphlet district. The Graves sand is the stratigraphic equivalent of the Buckrange sand which lies at the base of the Ozan formation. The Graves sand is found at depths of 2,340 to 2,500 feet below the surface, or 2,240 to 2,300 feet below sea level. The production from this sand is limited to the Norphlet district where it covers an area of 6,530 acres.

The Graves sand consists of gray to greenish-gray and fine to coarse quartz grains, varying in shape from angular to round. This sand is glauconitic in part and in places contains small pebbles of phosphate and chert. Intercalated with these beds of sand are thin lenses of indurated sand and lenses of thin beds of argillaceous sand, which have modified the porosity of the Graves sand, as shown by the wide range in the initial production of the wells. The Graves sand is 35 to 45 feet thick in the Norphlet district, and the oil-producing part of the sand is 15 to 20 feet thick.

The oil in the Graves sand has an average gravity of 21° A. P. I. The average initial daily production per well was about 2,000 barrels, but several wells had an initial daily production of 15,000 to 70,000 barrels.

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[7] Schneider, H. G., Personal communication.

THIRD OR 2,600-FOOT SAND

The discovery of the "Third" or "2,600-foot sand" antedates that of the Graves sand. It was the third producing sand found in the field. Schneider[8] correlated this sand with the Blossom sand, but there appears to be no adequate reason for the correlation.

The Third sand is found at depths of 2,550 to 2,650 feet below the surface. It is a series of sand beds and of intercalated thin beds of clay, of which the upper member, sometimes called the "Reynolds gas sand," produces chiefly gas, and the lower member, sometimes called the "Lawton sand," produces oil. The Third sand is gray, dark-gray, and green, and consists of fine to coarse quartz grains, varying in shape from angular to round, which is generally embedded in a matrix of volcanic tuff. At some places the sand is arkosic and contains small pebbles of chert and igenous rock. The thickness of the sand ranged from 40 to 50 feet. Its productive area covered 8,575 acres in the Norphlet district and 2,600 acres in the southeastern part of the Louann district. The oil ranges in gravity from 17° to 24° A. P. I.

The largest wells had an initial daily production of 3,000 barrels of oil and 40,000,000 cubic feet of gas, but the average daily initial production was small.

DEEP SAND

Below the Third sand, near the base of the Tokio-Woodbine section, there is a persistent bed 10 to 40 feet thick, known as "Deep sand," consisting of white coarse tuffaceous sand. This sand has yielded gas from the upper part and in places some oil from the lower part but is not a highly productive sand in the Smackover field.

POSSIBILITY OF PRODUCTION FROM DEEPER SANDS

A few wells drilled into the Comanche series have obtained showings of oil and gas in the red shale and sand of the Trinity group but have made no commercial production. These wells, which were favorably located with respect to the structure of the beds that are now producing, may be considered adequate tests of the immediate areas in which they were drilled and have made the prospect of obtaining oil or gas from deeper sands in the Smackover field seem less favorable.

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[8] Schneider, H. G., Smackover oil field, Ouachita and Union counties, Arkansas: Am. Inst. Min. and Met. Eng., Trans., vol. 70, pp. 1076-1099, March 1924.

———, Names of producing sands in the Smackover, Arkansas, field: Am. Assoc. Petrol. Geol. Bull., vol. 9, no 7, pp. 1116-1117, 1925.

PRODUCTION 1922 TO 1933 INCLUSIVE

The largest oil well completed in the Smackover field had an initial daily production of 25,000 barrels in the Nacatoch sand. Several wells produced at the rate of 5,000 to 10,000 barrels daily. The largest gas wells had initial daily volumes of 30,000,000 to 50,000,000 cubic feet.

Wells completed in the Meakin sand had average initial daily productions of 200 barrels of oil and 30,000,000 cubic feet of gas.

The average initial daily production of oil from the wells in the Graves sand was approximately 2,000 barrels, but a number of wells produced 15,000 to 70,000 barrels a day.

Wells drilled to the deeper sands had small average initial daily productions, but some of the larger wells produced 3,000 barrels of oil and 50,000,000 cubic feet of gas.

On January 1, 1930, there were 2,998 producing wells in the Smackover field, of which 962 produced 5,290 barrels of light oil, an average of 5½ barrels per well on that day, and 2,036 wells produced 41,837 barrels of heavy oil, an average of 20½ barrels per well on that day.

The oil production from the Smackover field is separated into light oil and heavy oil. The light oil is obtained chiefly from the Meakin sand in the Louann district, and the heavy oil from the Nacatoch, Graves, Third, and Deep sands. The Smackover field to January 1, 1934, had produced a total of 315,401,428 brarels of oil; 270,011,553 barrels of heavy oil and 45,389,875 barrels of light oil. The yearly production is shown in Table 14.

TABLE 14.—*Oil produced in the Smackover field from 1922 to 1933, inclusive*

Year	Light oil	Heavy oil	Total
1922		4,596 745	4,596,745
1923	5,308,450	25,503,985	30,812,435
1924	11,715,061	26,512 501	38,227,562
1925	9,482,993	59,553,435	69,036,428
1926	5,524 808	45,884,972	51,409,780
1927	3,738,527	30,717,116	34,455,643
1928	2,662,480	21,203 759	23,866,239
1929	2,075,745	16 793,254	18,868,999
1930	1,738,153	13,339,815	15,077,968
1931	1,284,510	10,164,077	11,448,587
1932	995,588	8,292,549	9 288,137
1933	863,560	7,449,345	8,312,905
Totals	45,389,875	270,011,553	315,401,428*

* It is estimated that between 5,000,000 and 10,000,000 barrels of oil produced in the Smackover field have been lost due to fires, floods, seepage

TABLE 15.—*Estimated production by sands in the Norphlet district*

Heavy-oil district

Year	Nacatcoh	Graves	Meakin, Third and Deep sand	Totals
1922	4,596,745			4,596,745
1923	25,503,985			25,503,985
1924	26,512,501			26,512,501
1925	16,545,900	40,856,635	2,150,900	59,553,435
1926	11,125,700	30,743,272	4,016,000	45,884,972
1927	8,312,800	19,279,000	3,125,316	30,717,116
1928	6,750,600	12,236,659	2,216,500	21,203,759
1929	6,404,600	8,784,900	1,603,754	16,793,254
1930	5,731,500	6.339,015	1,269,300	13,339,815
1931	5,158,400	3,993,130	1,012,547	10,164,077
1932	4,580,000	2,850,000	862,549	*8,292,549
1933	4,170,000	2,580,000	699,345	7,449,345
Totals	125,392,731	127,662,611	16,956,211*	270,011,553

* The small production from the Meakin sand and the Deep sand is included in the production of the Third sand.

ESTIMATED FUTURE PRODUCTION

The future production of the Smackover field, as estimated from the production decline curves and rate cumulative curves, is shown in Figures 24 and 25, prepared by Roy T. Hazzard. Future estimates are made assuming present production methods are unchanged. The estimated yearly production is given as follows:

Estimated future production in the Smackover field for 1934 to 1938 inclusive

Year	Light il	Heavy oil	Total
1934	792,000	6,510,000	7,302,000
1935	690,000	5,700,000	6,390,000
1936	612,000	5,075,000	5,687,000
1937	540,000	4,560,000	5,100,000
1938	492,000	4,115,000	4,607,000
1939	444,000	3,755,000	4,199,000
1940	398,000	3,445,000	3,843,000
Total	3,968,000	33,160,000	32,127,000

The oil reserves of the Smackover field are listed below:

Oil reserves of the Smackover field

	Barrels	Total
Light oil recovered to end of 1933	45,389,875	
Estimated future production of light oil to end of 1940	3,968,000	49,357,875
Heavy oil recovered to end of 1933	270,011,553	
Estimated future production of light oil to end of 1940	33,160,000	303,171,553
Total estimated recovery of oil to the end of 1940		352,529,428

The area producing light oil includes 9,600 acres. This had given an acre yield of 4,740 barrels to January 1, 1934, and an estimated total recovery per acre of 5,141 barrels to the end of 1940. The heavy oil is produced from the Nacatoch and Graves

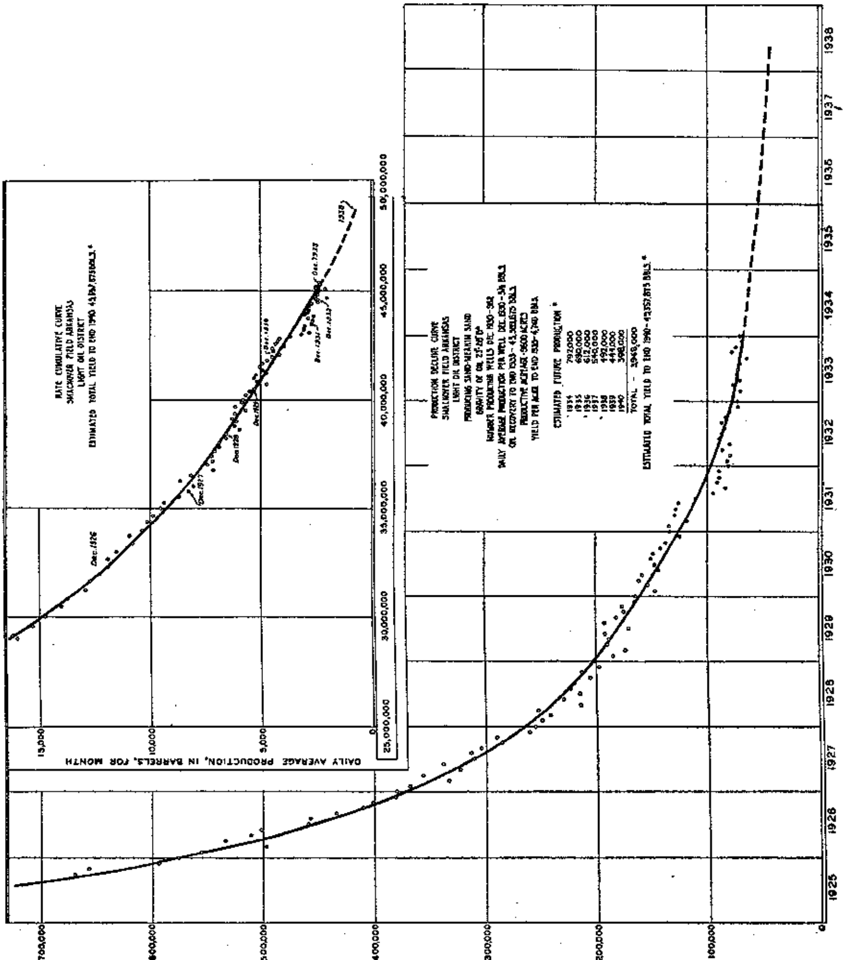


FIGURE 24.—Rate-cumulative curve, and production-decline curve, Smackover field, Arkansas, light-oil district. *Future estimates made assuming present production methods unchanged.

sands and from several sands in the Tokio formation, but as the production from each sand is not known, the acre yield cannot be accurately determined.

METHOD OF DRILLING

The rotary method of drilling was used in the Smackover field, but a number of wells that were drilled to the Nacatoch sand were deepened later with cable tools. In the early stages of the development of the Norphlet dome, large volumes of artesian water were encountered under high pressure, due to gas that had entered this sand from the cratered gas wells drilled on top of the dome. This water caused drilling to be difficult and made it necessary to set an additional string of 8-inch cas-

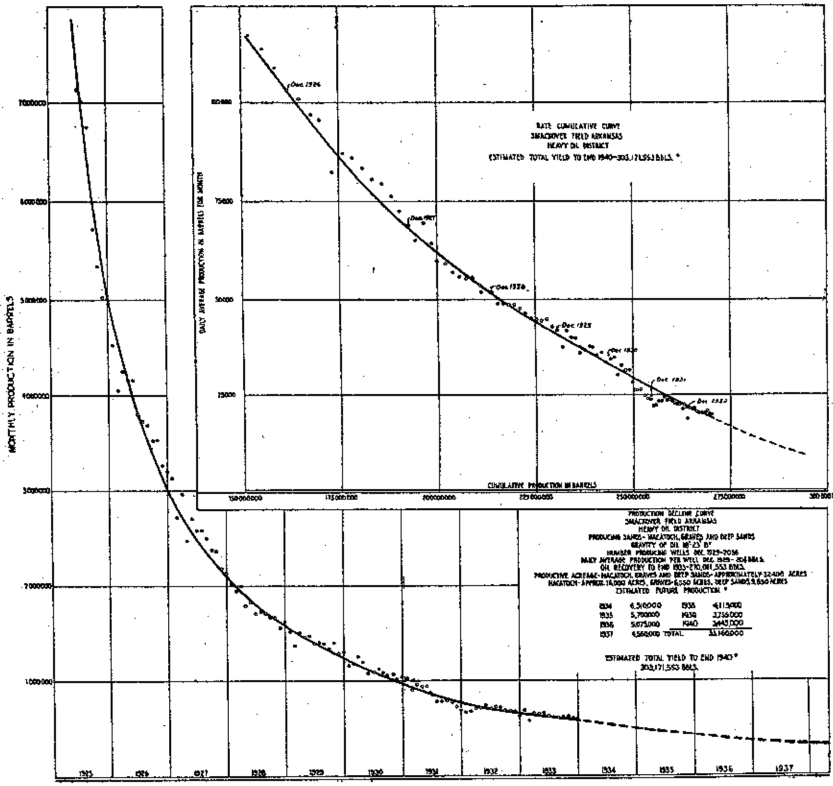


FIGURE 25.—Rate-cumulative curve, and production-decline curve, Smackover field, Arkansas, heavy-oil district. *Future estimates made assuming present production methods unchanged.

ing in some wells to exclude the water. In wells drilled under normal conditions, 200 to 350 feet of 10-inch surface casing was set to exclude the surface water, but the wells drilled to the Nacatoch sand were cased with 6-inch casing, cemented on top of the sand, and completed with from 50 to 150 feet of 4½-inch blank and perforated liner.

The wells drilled to the Meakin sand, except those that were deepened after testing the Nacatoch sand, set 10-inch surface casing and 6-inch casing on top of the sand and were completed with 4½-inch perforated liner.

Most of the wells drilled to the Meakin and Graves sands in the Norphlet district set 8-inch casing through the Nacatoch sand and 6-inch casing on top of the producing bed and were completed with 4½-inch perforated liner. The deeper wells that did not test the upper sands set 10-inch surface casing and 6-inch casing on top of the producing sand.

CHARACTER OF THE OIL

The Smackover crude oil is brownish-black and, according to the United States Bureau of Mines' standard, has an intermediate and naphthene base. Its gravity ranges from 19° to 28°. A. P. I.

The oil from the same sand in different parts of the field, especially that from the Tokio-Woodbine sands, shows considerable range in gravity which is due in part to the methods of treating the oil before it is turned over to the pipe-line companies and in part to the inherent properties of the oil. The available data, however, are unfortunately not complete enough to permit an elaboration of this statement. Summary analyses of Smackover crude oil follows:

Analyses of Smackover crude oil

(U. S. Bureau of Mines Bull. 291. Analysts: No. 6 and 7, B. A. Landry; No. 8, L P. Calkin)

Sample No.	6	7	8
Producing sand	Nacatoch	Nacatoch	Third
Depth (feet)	2,045-2,096	1,940-2,020	2,630-2,636
Color	brownish-black	brownish-black	brownish-black
Specific gravity	.935	.916	.899
A. P. I. gravity	19.8	23.0	25.9
Viscosity at 70°F. (Saybolt seconds)	870	910	310
Viscosity at 100° F. (Saybolt seconds)	340	200	150
Pour Point (°F)	below 5	below 5	below 5
Sulphur (per cent)	2.40	2.10	2.00
First drop (°C)	88	53	68
First drop (°F)	190	127	154

SUMMARY
Sample No. 6

	Per cent	Specific gravity	A. P. I. gravity
Gasoline light ends	-----	-----	-----
Total gasoline naphtha	7.3	.778	50.4
Kerosene distillate	-----	-----	-----
Gas oil	17.8	.864	32.3
Nonviscous lubricating distillate	10.6	.898–.921	26.1–22.1
Medium lubricating distillate	6.9	.921–.933	22.1–20.2
Viscous lubricating distillate	5.6	.933–.943	20.2–18.6

Total distillate (per cent) 48.2
Residuum (per cent) 48.8
Carbon residue of residuum 13.4
Carbon residue of crude 6.5
Base of crude oil Naphthene

SUMMARY
Sample No. 7

	Per cent	Specific gravity	A. P. I. gravity
Gasoline light ends	2.0	.720	65.0
Total gasoline and naphtha	13.9	.765	53.5
Kerosene distillate	3.5	.824	40.2
Gas oil	17.0	.859	33.2
Nonviscous lubricating distillate	10.2	.877–.912	29.9–23.7
Medium lubricating distillate	9.5	.912–.924	23.7–21.6
Viscous lubricating distillate	—	—	—

Total distillate 54.1
Residuum (per cent) 42.9
Carbon residue of residuum 14.6
Carbon residue of crude 6.3
Base of crude oil Intermediate

SUMMARY
Sample No. 8

	Per cent	Specific gravity	A. P. I. gravity
Gasoline light ends	2.0	.703	69.8
Total gasoline and naphtha	13.4	.751	56.9
Kerosene distillate	8.6	.816	41.9
Gas oil	13.7	.856	33.8
Nonviscous lubricating distillate	12.2	.875–.903	30.2–25.2
Medium lubricating distillate	8.1	.903–.9	25.2–23.8
Viscous lubricating distillate	—	—	—

Total distillate 56.0
Residuum (per cent) 41.0
Carbon residue of residuum 12.9
Carbon residue in crude 5.3
Base of crude oil Intermediate

Summary analyses of Smackover crude oil
(Gulf Refining Company Laboratory)

Company, well and sand	Location	A. P. I. gravity (°)	Flash point °F. (O. C.)	Sulphur (per cent S. D.)	Pour point	Gasoline (per cent)	Naphtha (per cent)
Gulf Refg. Co. T. C. Murphy No. 3 Nacatoch sand	sec. 9, T.16, R.13	20.7	90	2.17	Below 0	0	9.0
Reserve Petrol. Co. Fee No. 1 Meakin sand	sec. 30, T.15, R.16	26.2	70	1.80	Below 0	0	18.0
Standard Oil Co. Murphy & Hardy No. 7 Graves sand	sec. 4, T.16, R.15	21.3	70	2.08	Below 0	0	14.5
Federal Petrol. Co. Flenniken No. 6 2600-foot (Third sand)	sec. 6, T.16, R.15	21.8	115	2.01	Below 0	0	11.6

B. T. U. content of Smackover crude
(Lion Oil Rfg. Co. letter, 9-27-32. Chief Chemist)

Stock	B. T. U. per lb.	B. T. U. per gal.
Smackover crude	19,020	148,925
Pressure tar	18,715	154,230
Smackover residuum	18,710	157,450
Railroad fuel (150 vis.)	18,820	157,345
32/36 furnace oil	19,580	140,155

WATER CONDITIONS

Accurate data of water production in the Smackover field are not available but it is estimated that not less than 75 per cent of the fluid produced is water.

The following are analyses of water from the Graves sand and Meakin sand respectively:

Analysis of water from the Graves sand in the Smackover field
(Analyst, Fort Worth Laboratories)

Water sample 2631 from Marked Murphy A-8, sec. 8, T. 16 W., R. 15 S., Union County, Arkansas, received from Lion Oil Refining Company El Dorado.

Properties of reaction	Per cent
Primary salinity	78.06
Secondary salinity	21.74
Primary alkalinity	None
Secondary alkalinity	0.20
Per cent SO_4 in SO_4 plus Cl	0.02
Ratio CO_3 to SO_4	0.10

Constituents	Parts per million
Sodium (Na)	21,851.8
Calcium (Ca)	3,802.0
Magnesium (Mg)	943.5
Iron and aluminum oxides (Fe_2O_3, Al_2O_3)	12.0
Sulphate (SO_4)	11.1
Chlirode (Cl)	42,800.0
Carbonate (CO_3)	69.6
Silica (SiO_2)	20.0

	Reacting value	Per cent
Alkalies		
Sodium (Na)	948.56	39.03
Alkaline earths		
Calcium (Ca)	189.72	7.80
Magnesium (Mg)	77.55	3.17
Strong acids		
Sulphate (SO_4)	0.23	0.01
Chloride (Cl)	1,206.96	49.89
Weak acids		
Carbonate (CO_3)	2.32	0.10

Hypothetically combined as	Parts per million	Grains per U. S. gallon
Calcium carbonate ($CaCO_3$)	116.0	6.72
Calcium sulphate ($CaSO_4$)	15.7	0.91
Calcium chloride ($CaCl_2$)	10,366.5	602.42
Magnesium chloride ($MgCl_2$)	3,694.7	214.00
Sodium chloride (NaCl)	55,265.1	3,205.67
	69,458.0	4,029.72

Analysis of water from the Meakin sand in the Smackover field

(Analyst, Fort Worth Laboratories)

Marked wells A-2 salt water sample from northwest corner SW¼ SE¼ sec. 25, T. 15 W., R. 17 S., Union County, Arkansas, received from Atlantic Oil Producing Company, Dallas, Texas.

Properties of reaction	Per cent
Primary salinity	78.22
Secondary salinity	21.68
Primary alkalinity	None
Secondary alkalinity	0.10
Per cent SO_4 in SO_4 plus Cl	0.18
Ratio CO_3 to SO_4	0.55

Constituents	Parts per million
Sodium (Na)	19,388.7
Calcium (Ca)	3,280.0
Magnesium (Mg)	850.0
Iron and aluminum oxides (Fe_2O_3, Al_2O_3)	50.0
Sulphate (SO_4)	94.6
Chloride (Cl)	38,000.0
Carbonate (CO_3)	33.6
Silica (SiO_2)	35.0

	Reacting value	Per cent
Alkalies		
Sodium (Na)	853.40	39.11
Alkaline earths		
Calcium (Ca)	163.67	7.64
Magnesium (Mg)	69.87	3.25
Strong acids		
Sulphate (SO_4)	19.67	0.09
Chloride (Cl)	1,071.60	49.86
Weak acids		
Carbonate (CO_3)	1.12	0.05

Hypothetically combined as	Parts per million	Grains per U. S. gallon
Calcium carbonate ($CaCO_3$)	56.0	3.25
Calcium sulphate ($CaSO_4$)	134.0	7.77
Calcium chloride (CaCl)	8,914.4	517.20
Magnesium chloride ($MgCl_2$)	3,325.0	192.95
Sodium chloride (NaCl)	49,217.5	2,855.00
	61,646.9	3,576.17

THE EL DORADO FIELD

LOCATION AND EXTENT

The El Dorado field is in western Union County. It extends from the northern part of T. 19 S., R. 15 W., into the southeast corner of T. 17 S., R. 16 W., a distance of 10 miles, has a maximum width of 2 miles, and embraces an area of 7,740 acres. The town of El Dorado, for which it was named, is on the northeast side of the field.

HISTORY OF DEVELOPMENT

The discovery well of the El Dorado field, the Constantin Refining Company's Hill No. 1, in sec. 1, T. 18 S., R. 16 W., was completed April 22, 1920, with an initial production of 40,000,000 cubic feet of gas and a spray of oil produced from the Nacatoch sand at depths of 2,226 to 2,242 feet. On January 10, 1921, nearly a year later, Mitchell and Busey completed their Armstrong No. 1 well, in sec. 31, T. 17 S., R. 15 W., which yielded from 15,000,000 to 35,000,000 cubic feet of gas and 3,000 to 10,000 barrels of fluid, which included much water. By February this well was producing 1,000 to 1,500 barrels of clean oil daily.

Quoting from Bell and Kerr[9], "after about fifteen days blowing wild water began to appear and the fluid turned to a brownish color. Efforts to control the well were unsuccessful. The water increased rapidly until the oil and gas were completely choked off, limiting the well's productive life to about forty-five days. The well had either been drilled too deep or 'drilled itself' into bottom water by the unrestrained flow of gas. The well was abandoned during the latter part of April 1921."

A deeper sand was discovered May 7, 1922, by the El Dorado Natural Gas Company's Frazier No. 1 well in sec. 6, T. 18 S., R. 16 W., which produced 10,000,000 cubic feet of gas and 2,000 barrels of salt water from a depth of 2,529 feet. The productive bed was the Meakin sand, which lies at the top of the Ozan formation. This sand was tested in many wells, but in none was it a large producer of oil and gas.

A third sand was discovered by the Natural Gas and Petroleum Company's Mellor No. 1 well in sec. 1, T. 18 S., R. 16 W., completed September 4, 1922, with an initial daily production of 600 barrels of oil from depths of 2,948 to 2,952 feet. This sand is in the Tokio-Woodbine section and occupies the same stratigraphic position as the Third sand in the Smackover field.

[9] Bell, H. W., and Kerr, J. B., The El Dorado, Arkansas, oil and gas field: State Bur. of Min., Manuf. and Agri., Little Rock, Ark., 1922.

The production from this sand is not large and is limited to a small area in sec. 1, T. 18 S., R. 16 W.

A peak production of 1,746,294 barrels was reached in the El Dorado field in August 1921.

To January 1, 1934, the El Dorado field had produced 40,934,110 barrels of oil, and it is estimated that an additional 2,670,000 barrels will be produced during the next five years. On January 1, 1934, there were 257 producing wells that had an average daily production of 9 barrels.

TOPOGRAPHY

The topography of the El Dorado field is shown on the El Dorado quadrangle of the topographic atlas of the United States. The field extends along the divide between Cornie Bayou on the west and Bayou de Loutre on the east. Both streams flow, in general, southeastward. The stream bottoms are from 180 to 200 feet above sea level and the crest of the divide at a few places reaches an altitude of 300 feet, but the general altitude of the field is between 220 and 260 feet.

STRATIGRAPHY

GENERALIZED SECTION

The rocks at the surface in the El Dorado field consist of sand and sandy clay belonging to the upper part of the Claiborne formation (the Cockfield formation of Louisiana and Texas). Deep wells have penetrated all the beds of the Gulf series and several hundred feet of the Comanche series. A generalized section of formations in the field is shown in Table 16.

CRETACEOUS SYSTEM

COMANCHE SERIES

The Comanche series is represented in the El Dorado field by a part of the Lower Glen Rose formation and the Travis Peak formation of the Trinity group. The Travis Peak formation is probably underlain by sediments of Neocomian age but none of the deep wells drilled in the field have penetrated all of the Trinity group.

TRAVIS PEAK FORMATION

The upper 500 feet of the Travis Peak formation was cored in the Gulf Refining Company's Rosa L. Cook No. 1 well in sec. 1, T. 18 S., R. 15 W., on the east side of the El Dorado field. The core record is shown graphically in Figure 26. It consists chiefly of red shale and sandy shale interbedded with generally massive sand in the upper part and white, gray, pink, and brown sand interbedded with red clay and shale in the lower part. The total thickness of the Travis Peak formation has not been drilled in the El Dorado field but is probably not less than 2,000 feet thick.

GLEN ROSE FORMATION

The Glen Rose formation has been penetrated in several wells in the area adjacent to the El Dorado field, but the most de-

TABLE 16.—*Generalized section of formations in the El Dorado field*

System	Series	Formation	Thickness in feet	Character of the beds
Tertiary	Eocene	Claiborne	1100-1150	Sand, sandy clay, and clay, in part ferruginous and lignitic; glauconitic sand and clay at base
		Wilcox	250	Lignitic sand and clay; siderite and limonite concretions abundant
		Midway clay	500	Blue and gray, mainly noncalcareous clay containing concretions
Cretaceous	Gulf	Unconformity Arkadelphia marl	90-100	Blue, greenish-gray to dark-gray shale and marl; some chalky shale in lower part
		Nacatoch sand	150-175	Chiefly gray and greenish-gray fine-grained argillaceous sand; sandy clay and shale at the base
		Saratoga chalk	20-30	Gray chalk
		Marlbrook marl	200-225	Gray and yellowish-green marl, clay, and chalky marl
		Ozan	140-150	Meakin sand at top (5-25 feet of argillaceous, micaceous, argillaceous fine-grained sand, micaceous clay, marl, and sandy clay). Buckrange (Graves) sand at base (20 to 30 feet thick); fine to medium-grained gray and greenish-gray sand
		Brownstown marl Tokio-Woodbine	450-650	Gray clay and sandy clay; white, gray and green tuffaceous sand and sandstone; red and brown clay and thin beds of tuff
	Comanche (Trinity group)	Unconformity Glen Rose	300-350	Thin beds of limestone; red, brown, and gray shale and white, pink, and brown sand and sandstone; decreases in thickness toward the east
		Travis Peak	1500+	Red, gray, and purple shale and white, pink, and brown sand and sandstone

tailed records are from the Gulf Refining Company's Rosa L. Cook No. 1 well in sec. 1, T. 18 S., R. 15 W. Section of this well follows:

Section in Gulf Refining Company's Rosa L. Cook No. 1 *well, sec.* 1, *T.* 18 *S., R.* 15 *W., Union County, Arkansas*

System	Series	Group	Formation	Depth in feet	Character of the beds
Cretaceous	Gulf		Tokio-Woodbine	3166-3169	Coarse-grained tuffaceous sand
				Unconformity	
	Comanche	Trinity	Glen Rose	3169-3174	Gray fossiliferous limestone; red, brown, and mottled, dominantly calcareous shale and sandy shale, few microfossils
				3220-3223 3223-3224	Greenish-gray hard sandy shale; gray calcareous shale
			Travis Peak	3244-3268	Red noncalcareous shale and lignitic sandy shale*

* For details of section see Figure 26.

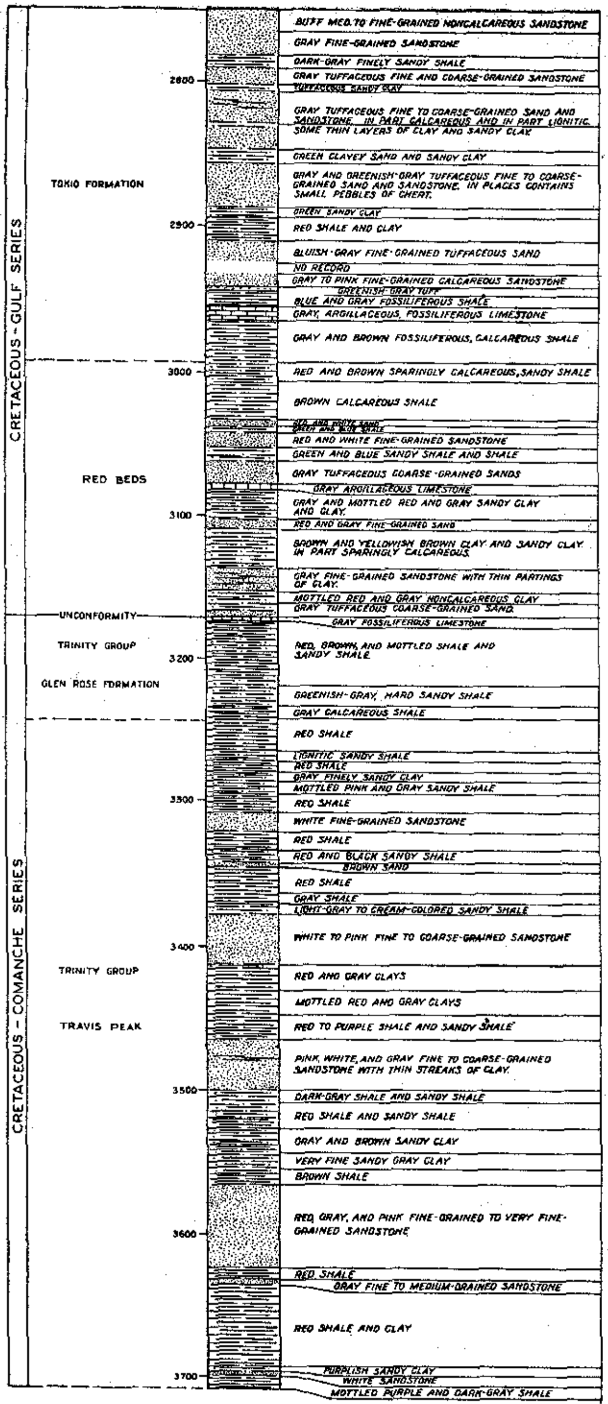


FIGURE 26.—Core record of a part of the Tokio formation and the Trinity group in Gulf Refining Company's Rosa L. Cook No. 1 well, sec. 1, T. 18 S., R. 15 W., Union County, Arkansas. Figures give depth below surface.

In the El Dorado field the Glen Rose is represented by the Lower Glen Rose which consists of gray fossiliferous limestone and shale interbedded with fine-grained sands and red and brown shales. The Glen Rose is probably less than 100 feet thick on the east side of the field but increases in thickness towards the west.

GULF SERIES

TOKIO-WOODBINE

The basal 200 to 300 feet of beds of the Gulf series consists principally of red and brown clays interbedded with white, gray, and greenish-gray tuffaceous sand and subordinate beds of light-colored clay and bentonitic clay.

The remainder of the Tokio-Woodbine section consists chiefly of white, gray, and greenish gray in part tuffaceous sands, interbedded with gray sandy clay, clay and shale, which are in part lignitic. The average thickness of the non-red Tokio-Woodbine section is about 400 feet.

OZAN FORMATION

The Ozan formation in this area is divisible into three members: Meakin sand at the top, an intermediate shale member, and the Buckrange sand at the base. It is 140 to 150 feet thick, and consists of fine to medium-grained quartz sand and gray to greenish-gray micaceous and glauconitic sandy marl and shale.

MARLBROOK MARL AND SARATOGA CHALK

The Marlbrook marl and Saratoga chalk consist principally of gray to yellowish-gray marl and chalky marl. On the east side of the El Dorado field, the Marlbrook marl contains small quantities of fine sand, and is 200 to 225 feet thick. The Saratoga chalk also contains argillaceous chalk. It is 20 to 30 feet thick. The combined thickness is, therefore, from 225 to 255 feet.

NACATOCH SAND

The Nacatoch sand consists principally of gray to greenish-gray argillaceous sand and gray to greenish-gray sandy shale and shale. The principal producing horizon of the El Dorado field is in the upper part of the Nacatoch sand. The Nacatoch sand is 150 to 175 feet thick in the El Dorado field but increases in thickness toward the west.

ARKADELPHIA MARL

The Arkadelphia marl consists of shale varying in color from blue to green and gray to dark-gray and chalky shale. It is 90 to 100 feet thick.

TERTIARY SYSTEM

EOCENE SERIES

MIDWAY FORMATION

The Midway formation consists principally of gray and blue noncalcareous clays containing many siderite concretions. The lower 50 to 75 feet of beds are calcareous and fossiliferous. In this area the Midway is about 500 feet thick.

WILCOX FORMATION

The Wilcox formation contains clays, sandy clay and sand and is in large part lignitic. It is 550 to 575 feet thick in the El Dorado field.

CLAIBORNE GROUP

The Claiborne group is represented in the El Dorado field by about 900 to 1,000 feet of beds. The Cockfield formation, consisting of lignitic clays and sands, is at the surface in the field. Depending upon the surface elevation it is from 150 to 200 feet thick. The Mount Selman formation consists of glauconitic sand and clay and is about 170 feet thick. The Sparta sand consists of generally massive sands and is 325 feet thick. The Mount Selman, chiefly glauconitic sand and clay, is 60 to 70 feet thick. The Queen City consists of sand and clay, in part lignitic, and is 115 feet thick. The Reklaw consists of lignitic clays and glauconitic sand and marl and is about 75 feet thick.

STRUCTURE

GENERAL FEATURES

The structure of the region in which the El Dorado field is situated is shown in Plates XX and XXI. It is an area of gentle uplift, bounded on the north by the Arkansas fault zone and on the south by the Monroe uplift of Louisiana. It is characterized by a series of generally northwestward-trending anticlines, which, toward the south, have the ends of their axes deflected to the east or to the west, marking the influence of the Monroe uplift.

The rocks at the surface in the El Dorado field consist in part of Recent sand, clay, and gravel and in part of massive sand of Claiborne age, which, owing to their character, are not suitable to detailed mapping. Subsurface maps were accordingly prepared which show the structure of the area.

SUBSURFACE STRUCTURE

The interpretation of the structure, as derived from contours drawn to the top of the Nacatoch sand, is difficult, owing to the fact that the field was developed by highly competitive and rapid drilling methods in order to reap the benefit of the large flush production obtained from wells completed in advance of the offset wells on adjoining leases. Such drilling does not ordinarily afford accurate logs of the formations penetrated and most of the records are unreliable. This fact and the lateral changes in the reservoir rock have caused different interpretations by geologists of the structural configuration on the top of the Nacatoch sand. These differences of opinion are illustrated in the published maps of the subsurface structure of the field[10], and differ widely.

The most satisfactory datum plane in this area is the Meakin sand, as a number of deep wells were drilled to this horizon and afforded sufficient data for the determination of the generalized structure.

The structure of the Meakin sand is shown in Plate XXI. The contour lines are drawn on top of the sand at intervals of 25 feet. As interpreted it is an elongated northwestward-trending anticline that extends from the southwest corner of T. 17 N., R. 16 W., to the north-central part of T. 19 S., R. 15 W. The 2,275-foot contour line incloses an area 2 miles wide on both sides of the line between T. 18 S., R. 16 W., and T. 18 S., R. 15 W. The highest part of the structure appears to be in a small area in sec. 1, T. 18 S., R. 16 W., inclosed by the 2,250-foot contour line.

STRUCTURE OF THE COMANCHE SERIES

The structure of the Trinity beds, which are separated frcm those of the overlying Gulf series by an angular unconformity, is not determinable except in a general way because only a few well have penetrated these beds. The Trinity beds strike southeast and dip southwest. Unless these beds have been locally deformed in the El Dorado field, the dip, as determined from the Shell Petroleum Company's Carroll No. 1 well in sec. 18, T. 18 S., R. 15 W., and the Gulf Refining Company's Rosa L. Cook No. 1 well in sec. 1, T. 18 S., R. 15 W., is to the southwest at the rate of about 50 feet to the mile.

RELATION OF STRUCTURE TO ACCUMULATION OF OIL AND GAS

The oil and gas accumulation in the deep sand coincides with a small dome outlined by the closure of the 2,250-foot contour line in sec. 1, T. 18 S., R. 16 W.

The structure of the Nacatoch sand is not readily determined but appears to be a terrace with a slight inclination toward the east. The sand is continuous in all directions beyond the pro-

[10] Heald, K. C., and Rubey, W. W., El Dorado oil field in Arkansas not on an anticline: Am. Assoc. Petrol. Geol., Bull., vol. 6, no. 4, p. 358, 1922.

Bell H. W., and Kerr, J. B., The El Dorado, Arkansas, oil and gas fields: Arkansas Bur. of Min., Manuf., and Agr., Little Rock, 1922.

Powers, Sidney, Review of Eldorado, Arkansas, oil and gas field: Am. Assoc. Petrol. Geol., Bull., vol. 6, p. 555, 1922

Ley, H. A., The relation of quality of oil to structure at El Dorado, Arkansas: Am. Assoc. Petrol.

ducing area of the El Dorado field. The character of the reservoir rock, chiefly the decrease in its porosity towards the west and north, is believed to have been the dominant factor in determining the localization of oil and gas at this horizon.

A cross section of the oil and gas-producing Nacatoch sand in the El Dorado field is shown in Figure 27.

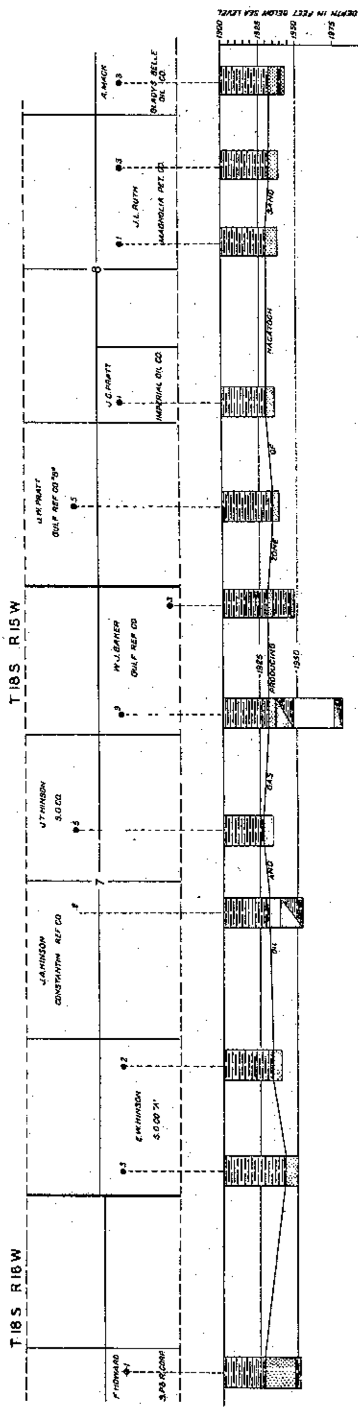


FIGURE 27.—Cross section of oil-producing horizons in the Nacatoch sand, El Dorado field, Arkansas.

PRODUCTION

PRODUCTIVE AREA

There are 7,740 acres in the productive area of the El Dorado field. The wells have not been spaced according to a definite plan, but the area per well ranged from 2 to 10 acres.

THE PRODUCING SANDS

The Nacatoch is the principal producing sand, but the Meakin sand at the top of the Ozan formation and the 2,900-foot sand in the Tokio-Woodbine section have yielded small quantities of oil and gas, especially in sec. 1, T. 18 S., R. 16 W., and the adjacent parts of the adjoining section, but neither was an important producing sand.

NACATOCH SAND

The Nacatoch sand is 150 to 175 feet thick and consists principally of gray to greenish-gray fine to medium-grained generally argillaceous quartz sand and sandy clay, but it aslo includes a gray shale member, 20 to 50 feet thick, at its base. The quantity of argillaceous material it contains varies from place to place, but in general the sand decreases and the clay increases from east to west.

The oil and gas are obtained from the upper 50 feet of the Nacatoch sand and generally from its uppermost 5 to 15 feet (See Fig. 23), but lenses of oil-saturated sand are found lower in the section. The oil and gas-saturated sand is underlain by salt water throughout the field and nearly all of the wells made considerable water with the oil. The production of the wells appears to have been determined primarily by the texture of the sand and the quantity of argillaceous material it contained.

Detailed records of the Nacatoch sand in the producing area are not available, but core records from the Gulf Refining Company's Rosa L. Cook No. 1 well in sec. 1, T. 18 S., R. 15 W., on the east side of the field (Fig. 28), and the Shell Petroleum

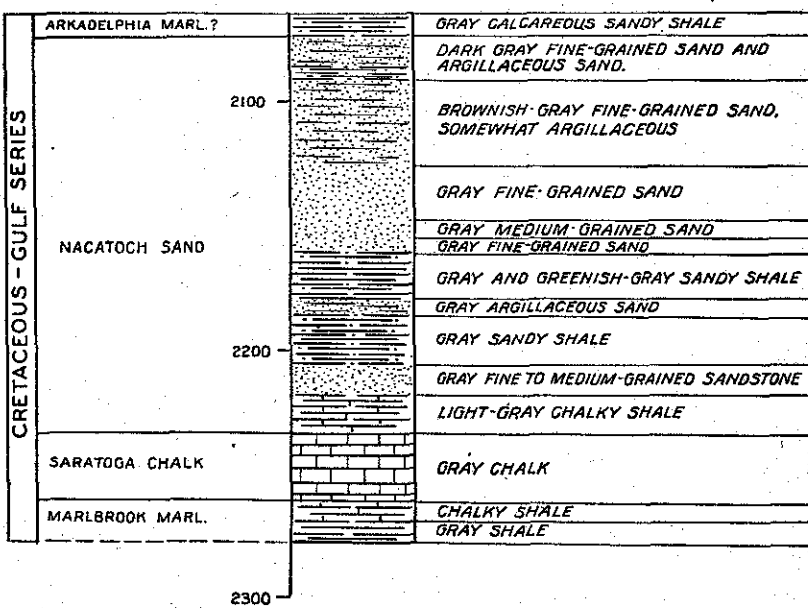


FIGURE 28.—Core record of Nacatoch sand and Saratoga chalk in Gulf Refining Company's Rosa L. Cook No. 1 well, sec. 1, T. 18 S., R. 15 W., Union County, Arkansas. Figures give depth below surface.

Company's Carroll No. 1 well in sec. 19, T. 18 S., R. 16 W., on the west side of the field, which are fairly representative sections, are as follows:

Section of Nacatoch sand in Gulf Refining Company's Rosa L. Cook No. 1 well in sec. 1, T. 18 S., R. 15 W.

Formation	Depth in feet
Arkadelphia marl:	
Gray calcareous sandy shale	2065–2074
Nacatoch sand:	
Dark-gray fine-grained argillaceous sand	2074–2092
Gray and brownish-gray fine-grained argillaceous sand	2092–2128
Gray fine-grained sand, in part argillaceous	2128–2147

Gray medium-grained sand	2147–2157
Gray very fine-grained sand	2157–2162
Gray and greenish-gray sandy shale	2162–2180
Gray slightly argillaceous sand	2180–2187
Gray sandy shale	2187–2206
Gray fossiliferous fine to medium-grained sandstone	2206–2219
Light-gray calcareous shale	2219–2235
Saratoga chalk:	
Gray chalk	2235–2262

Section of Nacatoch sand in Shell Petroleum Company's Carroll No. 1 *well in sec.* 18, *T.* 18 *S., R.* 16 *W.*

Formation	Depth in feet
Arkadelphia marl:	
Gray finely arenaceous clay	2032–2050
Nacatoch sand:	
Gray medium fine-grained sparingly glauconitic sandstone	2050–2053
Gray medium-grained slightly silty sand	2053–2063
Gray clay and fine-grained silty sand	2063–2073
Gray medium to fine-grained sand and argillaceous sand	2073–2080
Gray sandy shale	2080–2087
Gray compact shale and sandy shale	2087–2095
Sandy shale	2095–2105
Gray medium-grained silty sand	2105–2115
Gray sandy shale, sand, and clay	2115–2135
Gray silty sand and sandy shale	2135–2145
Gray sandy shale	2145–2155
Gray silty sand and sandy shale	2155–2175
Dark-gray marl shale and sandy shale	2175–2245
Saratoga chalk:	
Hard gray chalk	2245–2255

MEAKIN SAND

The Meakin sand is found throughout the El Dorado field at depths of 2,250 to 2,300 feet below sea level, but it has yielded oil and gas in considerable quantities only in sec. 1, T. 18 S., R. 16 W., and the adjacent parts of the adjoining sections, which constitute the highest part of the anticline as determined on the top of the Meakin sand. The records of the wells in that area indicate that the greater part of the total thickness of the sand is water-bearing and that only a thin layer at the top is saturated with oil and gas.

The Meakin sand in this area is 10 to 20 feet thick and consists of white and gray fine to medium-grained micaceous sand.

2,900-FOOT SAND

The 2,900-foot sand has been penetrated in several wells, especially in sec. 1, T. 18 S., R. 16 W., where it has produced oil and gas. Its stratigraphic position corresponds closely to that of the Third sand of the Smackover field. It consists of white to gray, fine to medium coarse-grained tuffaceous sand. The records available from the field show that it has a thickness of 20 to 25 feet.

The production from this sand was limited to a small area in sec. 1, T. 18 S., R. 16 W., which coincides with the highest part of the El Dorado anticline.

POSSIBILITY OF PRODUCTION FROM DEEPER SANDS

A number of deep wells drilled in different parts of the El Dorado field have penetrated and tested the Meakin and Graves sands and the several sands in the Tokio-Woodbine section. The negative results of these tests, although not final because of the generally lenticular structure of the sands in the basal part of the Gulf series, points to the conclusion that the possibility of obtaining oil and gas in these sands is not very promising.

The possibility that oil and gas have accumulated in the Comanche series will perhaps depend largely upon the presence of local structure in these beds, which has not yet been determined.

PRODUCTION 1921 TO 1933 INCLUSIVE

The largest oil wells completed in the El Dorado field had initial daily productions ranging from 5,000 to 10,000 barrels of fluid, of which about 60 per cent was water and emulsion. The largest gas wells produced from 30,000,000 to 50,000,000 cubic feet. During December 1933, the production from 231 wells was 54,415 barrels, a daily average production of 7½ barrels per well.

The oil produced from the Nacatoch and from the Deep sand was not separated, but as the Deep sand produced only a very small percentage of the total production of the El Dorado field; this fact is not important. Up to January 1, 1934, the field had produced 40,934,110 barrels of oil. The production in barrels by years is listed below:

Oil produced in the El Dorado field from 1921 *to* 1933 *inclusive*

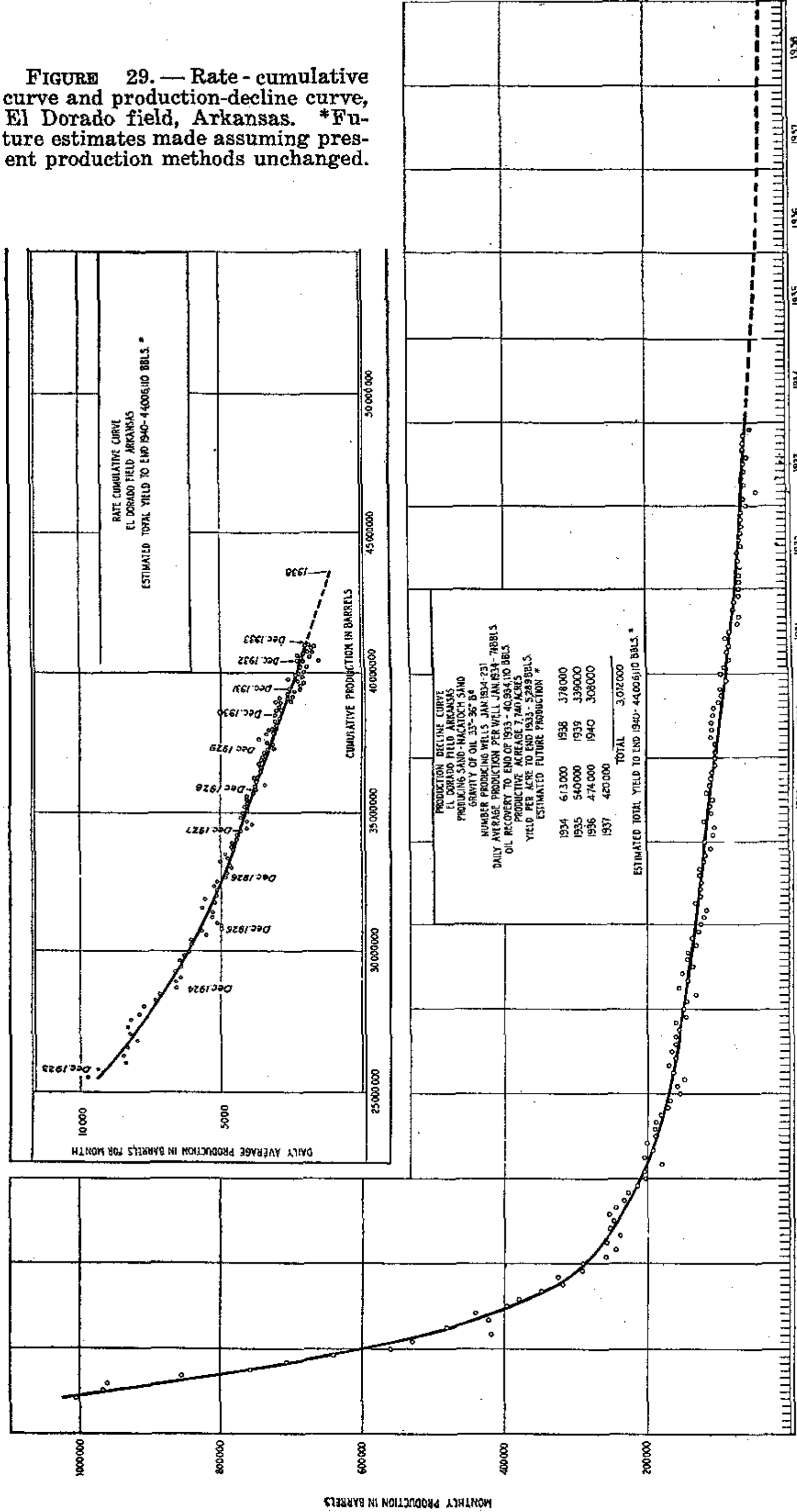
Year	Barrels*	Year	Barrels*
1921	10,630,228	1928	1,464,261
1922	10,560,841	1929	1,305,267
1923	4,640,075	1930	1,192,640
1924	2,871,310	1931	976,263
1925	2,220,713	1932	815,040
1926	1,894,382	1933	700,645
1927	1,662,445		
			40,934,110

* Pipe-line runs.

ESTIMATED FUTURE PRODUCTION

The future production of the El Dorado field, as estimated from production-decline curves and rate-cumulative curves, is shown in Figure 29, prepared by Roy T. Hazzard. These esti-

FIGURE 29. — Rate-cumulative curve and production-decline curve, El Dorado field, Arkansas. *Future estimates made assuming present production methods unchanged.



mates are made assuming present production methods are unchanged. The estimated future production by years follows:

Estimated future production in the El Dorado field from 1934 to 1940, inclusive

Year	Barrels	Year	Barrels
1934	613,000	1938	378,000
1935	540,000	1939	339,000
1936	474,000	1940	308,000
1937	420,000		
Total			3,072,000

The oil reserves of the El Dorado field are given below:

Oil reserves of the El Dorado field

	Barrels
Oil recovered to January 1, 1934	40,934,110
Estimated future production to end of 1940	3,072,000
Total estimated recovery of oil to the end of 1940	44,006,110

The producing area of the El Dorado field is 7,740 acres, giving an acre yield of 5,289 barrels to January 1, 1934, and an estimated total recovery per acre of 5,684 barrels to the end of 1940.

METHOD OF DRILLING AND OF HANDLING PRODUCTION

The methods of drilling and handling production employed in the El Dorado field have been described in detail by Bell and Kerr[11]. The rotary method of drilling was used in the El Dorado field, although many wells were drilled to the top of the producing sand and then completed with cable tools.

The common practice of casing the wells in the field was to set two strings of casings. The first string consisted of about 200 feet of 12½-inch conductor pipe to exclude the surface water; and a second string, usually 6-inch, was set on top of the producing sand or a few feet above it. The wells were completed with perforated liners, screen pipes, or a combination of liner and screen pipe.

No unusual difficulty was encountered in drilling, but considerable difficulty was experienced in completing the wells, owing to presence of bottom water in the producing sand and the lack of an impervious parting between the oil and water zones, which obtained in the southern part of the field.

CHARACTER OF THE OIL

The Nacatoch oil in the El Dorado field has a gravity ranging from 33° to 36°, according to the records of the Gulf Refining Company's properties in the field. Bell and Kerr[12] give 37.5° as

[11] Bell, H. W., and Kerr, J. B., The El Dorado, Arkansas, oil and gas field: State Bur. of Min., Manuf., and Agr., Little Rock, 1922.

[12] Bell, H. W., and Kerr, J. B., op. cit.

the maximum and 35.5° as the average gravity for the field. Ley[13] gives a gravity range of 28° to 36°, and points out that the gravity progressively increases from west to east. Although not offered as an explanation of the lateral variation in gravity, it is of interest to note that the decrease in gravity closely parallels the increase in the volumn of free gas contained in the sands.

The oil obtained from the 2,900-foot sand has a gravity of 32°.

An analysis of the Nacatoch oil follows:

Properties of crude oil from the Nacatoch sand in El Dorado field
(U. S. Bureau of Mines Bulletin 291)

Baume gravity	34.30	Specific gravity	0.852
Saybolt Universal viscosity at 70°F	57.0	Percentage water	0.1
Saybolt Universal viscosity at 100°F	46.6	Pour test	below 5°F
		Percentage sulphur	0.83

Distillation, Bureau of Mines (Hempel Method)

Temperature °C.	Per cent cut	Sum per cent	Sp. gr. cut	°B. cut	Viscosity	Cloud test (°F.)	Temperature (°F.)
AIR DISTILLATION BAROMETER, 749 MM. FIRST DROP, 31° C. (88°F.)							
Up to 50	----	----	----	----	----	----	Up to 122
50-75	4.5	4.5	0.680	75.9	----	----	122-167
75-100	4.2	8.7	.701	69.7	----	----	167-212
100-125	7.1	15.8	.722	63.9	----	----	212-257
125-150	6.2	22.0	.746	57.7	----	----	257-302
150-175	5.1	27.1	.772	51.3	----	----	302-347
175-200	3.6	30.7	.795	46.1	----	----	347-392
200-225	3.5	34.2	.810	42.8	----	----	392-437
225-250	4.4	38.6	.823	40.1	----	----	437-482
250-275	5.1	43.7	.833	38.1	----	----	482-527
VACUUM DISTILLATION AT 40 MM.							
Up to 200	5.5	5.5	853	34.1	40	18	Up to 392
200-225	6.5	12.0	.860	32.8	45	30	392-437
225-250	5.9	17.9	.874	30.2	60	52	437-482
250-275	5.4	23.3	.890	27.3	81	72	482-527
275-300	4.6	27.9	.903	25.0	132	91	527-572

Carbon residue of residuum 10.3.

APPROXIMATE SUMMARY

Gasoline and naphtha	30.7	0.735	60.5
Kerosene	13.0	.825	40.1
Gas oil	12.0	.857	33.4
Light lubricating distillate	11.3	.882	28.7
Medium lubricating distillate	4.6	.903	25.0

WATER CONDITIONS

Most of the wells producing oil in the El Dorado field made considerable water when first completed. Bell and Kerr[14] estimate that at least one-third of the gross production in October

[13] Ley, H. A., The relation of quality of oil to structure at El Dorado, Arkansas: Am. Assoc. Petrol. Geol., Bull., vol. 7, no. 4, pp. 350-361, 1925.
[14] Bell, H. W., and Kerr, J. B., op. cit.

921, was water. In December 1929, it was estimated that of the total fluid lifted, 10 per cent was oil and 90 per cent water.

The water produced in this field is primarily bottom water, which is in contact with and immediately underlies, the oil-saturated sand.

Bell and Kerr[15] state that "there is little doubt that over 90 per cent of the water produced at El Dorado is a combination of bottom water and edge water."

The trouble with water was aggravated by drilling too deep into the sand and by allowing the wells to flow to their full capacity.

The character of the water in the Nacatoch sand is shown in Table 17.

TABLE 17.—*Composition of water from the Nacatoch sand in the El Dorado field*
(U. S. Bureau of Mines Bull. 291)

Well	Location	Na	Ca	Mg	Cl	CO_3	Total solid parts per million of water	Analyst
Mich. Ark. No. 1	33-18-15	41.21	9.47	0.79	48.52	0.01	59,500	W. B. Larch, U. S. Bur. of Mines
Lucas Tomberlin Crawford No. 1	31-17-15	36.20	2.80	—	61.00	—	53,200	W. F. Fulton, La. Oil Refg. Co.
Chew Oil & Gas Rowland No. 1	5-18-15	37.20	1.90	—	69.9	—	74,650	W. F. Fulton, La. Oil Refg. Co.
Rowe & Rowe Pratt No. 1	7-18-15	38.40	0.90	—	60.7	—	65,600	W. F. Fulton, La. Oil Refg. Co.

[15] Bell, H. W., and Kerr, J. B., op. cit.

THE LISBON FIELD

LOCATION AND EXTENT

The Lisbon field lies 3 miles northeast of the El Dorado field and 5 miles south of the Smackover field in T. 17 S., R. 16 W., in Union County. It embraces an area of 2,640 acres.

HISTORY OF DEVELOPMENT

The discovery well in the Lisbon field, the Raines et al Dumas No. 1, in sec. 9, T. 17 S., R. 16 W., was completed December 31, 1925, with an initial daily production of 35 barrels of oil from the Nacatoch sand at depths ranging from 2,060 to 2,070 feet. The peak production was reached in 1926 when the field produced 2,338,062 barrels of oil. On January 1, 1934, the Lisbon field had produced 5,669,089 barrels of oil, and it is estimated that an additional 380,000 barrels will be produced during the next five years. In 1929 the production declined to 444,367 barrels. On January 1, 1934, there were 201 producing wells, which had an average daily production of 2 barrels.

STRATIGRAPHY

The rocks penetrated in the wells drilled in this area are essentially similar in character and thickness to those in the El Dorado field already described.

STRUCTURE

GENERAL STATEMENT

The surface rocks of the Lisbon field consist chiefly of marine sands and lignitic clays of Cockfield age, which, owing to their character, are not suitable for detailed structural mapping. The structure of the Lisbon field accordingly is illustrated by maps drawn on top of the Nacatoch and Meakin sands.

SUBSURFACE STRUCTURE

The generalized subsurface structure of the Lisbon field is shown on Plate I, contour lines drawn on the top of the Nacatoch sand, and in Plate XXI, contour lines drawn on top of the Meakin sand.

The structure of the Nacatoch sand is not readily determinable but appears to take the form of a structural terrace. As shown by contours drawn on the top of the Meakin sand, the Lisbon field is on an anticlinal structure which is apparently the northwest continuation of the El Dorado anticline. The highest part of the fold is represented by the closure of the 2,275-foot contour line, which inclosed an area of about 4 square miles. The northern part of the field extends into a syncline which parallels the anticline on the north and east.

RELATION OF STRUCTURE TO ACCUMULATION OF OIL AND GAS

In the Lisbon, as in the El Dorado field, the accumulation of oil and gas is not definitely related to anticlinal structure but appears to have been determined by the character and structure of the reservoir rock.

The occurrence of oil and gas deposits in Arkansas is intimately associated with regional uplifts involving deformation of the Tertiary and Cretaceous rocks. In general the area of accumulation coincides closely with local domes and anticlines. There are, however, several exceptional areas in which the accumulation of oil was controlled by the character of the reservoir rocks rather than by local foldings. For example, the principal factor that determined the distribution of oil in the Nacatoch sand of the Lisbon field appears to have been the lenticular structure of the reservoir sand.

PRODUCTION

PRODUCTIVE AREA

The producing area of the Lisbon field includes a total of 2,640 acres on which to January 1, 1934, 341 wells have been drilled. The average spacing is 7.7 acres per well. In the southern half of the field the spacing was 10 acres per well; in the northern half it ranged from 4 to 10 acres per well.

THE PRODUCING SAND

The producing horizon in the Lisbon field is the Nacatoch sand, which lies at depths of 2,075 to 2,125 feet. Oil and gas are obtained from the uppermost 25 to 30 feet of beds, which, according to the available records, consists of lenses of sands interbedded with shale and sandy shale. The sand lenses decrease in thickness and become increasingly argillaceous on the flanks of the producing area. The lateral changes in the character of the reservoir appear to have been one of the factors that determined the extent of the producing area. Typical records of the Nacatoch sand follow:

Section of Nacatoch sand in Ackerly and Buddleson's B. Murphy No. 1 well in sec. 1, T. 17 S., R. 16 W.

	Depth in feet
Hard sand; show of oil and gas	2112–2118
Hard sand, shale and boulders	2118–2125
False cap rock	2125–2126
Hard black sand; show of gas	2126–2130
Black rock	2130–2132
Brown sandy shale	2132–2138
Rock	2138–2140
Hard sand; gas show	2140–2145
Hard sandy limestone	2145–2155
Cap rock	2155–2158
Sand; oil show	2158–2168

Section of Nacatoch Sand in Roxana Petroleum Company's Flournoy No. 4 well in sec. 4, T. 17 S., R. 16 W.

	Depth in feet
Cap rock	2088–2089
Sand	2089–2095
Shale	2095–2097
Sand and hard shell rock	2097–2110
Sand with streaks of shale	2110–2122
Shale	2122–2124

Section of Nacatoch sand in Pure Oil Company's Dumas No. 2 well in sec. 9, T. 17 S., R. 16 W.

	Depth in feet
Oil sand	2084–2085
Sandy shale	2085–2090
Sand and shale; showing oil	2090–2109

Section of Nacatoch sand in Keen and Woolf Oil Company's Slaughter No. 1 well in sec. 10, T. 17 S., R. 16 W.

	Depth in feet
Oil sand; show of oil	2085–2093
Broken sand	2093–2101
Sand; water	2101–2102
Sand and shale	2102–2136
Shale and gumbo	2136–2165

Section of Nacatoch sand in Lion Oil Refining Company's Goodwin No. 2 well in sec. 16, T. 17 S., R. 16 W.

	Depth in feet
Cap rock	2082–2083
Soft sand	2083–2091
Soft sandy shale	2091–2105
Gumbo	2105–2108

Section of Nacatoch sand in Lion Oil Refining Company's Mitchell A-6 well in sec. 17, T. 17 S., R. 16 W.

	Depth in feet
Cap rock	2071–2072
Sand	2072–2082
Cap rock	2082–2082½
Sand	2082½–2100
Shale	2100–2104
Hard sandy shale	2104–2120
Gumbo	2120–2134
Sandy lime	2134–2175
Gumbo	2175–2215

Section of Nacatoch sand in Ohio Oil Company's Patterson and Mitchell No. 1 well in sec. 20, T. 17 S., R. 16 W.

	Depth in feet
Sand	2136–2140
Cap rock	2140–2141
Sand	2141–2149
Broken sand	2149–2150
Sandy shale	2150–2189

POSSIBILITY OF PRODUCTION FROM DEEPER SANDS

The Meakin and Graves, sands of the Tokio-Woodbine section, are present in the Lisbon field, but they have not been penetrated by deep wells sunk on the highest parts of the fold nor in the area inclosed by the 2,275-foot line. All of these formations are potential reservoirs of oil and gas, and they should be tested on the highest part of the fold, preferably near the southwest corner of sec. 15, T. 17 S., R. 16 W.

PRODUCTION 1926 TO 1933 INCLUSIVE

The initial daily production of the largest oil wells completed in the Lisbon field ranged from 500 to 700 barrels. The initial daily volume of the gas wells, which were drilled on the west side of the field, ranged from 500,000 to 40,000,000 cubic feet. The production during December 1933, was 11,612 barrels from 174 wells, a daily average production of slightly more than 2 barrels per well. From 1926 to 1933, inclusive, the Lisbon field has produced 5,669,089 barrels of oil. The yearly production in barrels is listed below:

Oil produced in the Lisbon field from 1926 to 1933, inclusive

Year	Barrels*	Year	Barrels*
1926	2,338,062	1930	331,653
1927	1,298,413	1931	242,388
1928	699,027	1932	178,539
1929	444,367	1933	136,640
			5,669,089

* Pipe-line runs

ESTIMATED FUTURE PRODUCTION

The future production of the Lisbon field is estimated from production-decline curves (Fig. 30), prepared by Roy T. Hazzard. These estimates are made assuming present production methods are unchanged. The estimated yearly production over a period of seven years is given as follows:

Estimated future production in the Lisbon field from 1934 to 1940, inclusive

Year	Barrels	Year	Barrels
1934	106,000	1938	50,000
1935	85,000	1939	43,000
1936	71,000	1940	37,000
1937	59,000		
			451,000

The oil reserves of the Lisbon field are shown below:

Oil reserves of the Lisbon field

	Barrels
Oil recovered to January 1, 1934	5,669,089
Estimated future production to end of 1940	451,000
Total estimated oil recovery to end of 1940	6,120,089

The producing area of the field is approximately 2,640 acres, giving an acre yield of 2,148 barrels to the end of 1933 and an estimated total recovery per acre of 2,318 barrels at the end of 1940.

METHOD OF DRILLING

The rotary method of drilling was used in the Lisbon field. The common practice was to set 150 to 200 feet of 10-inch or 12½-inch conductor pipe. The 6-inch casing was landed on

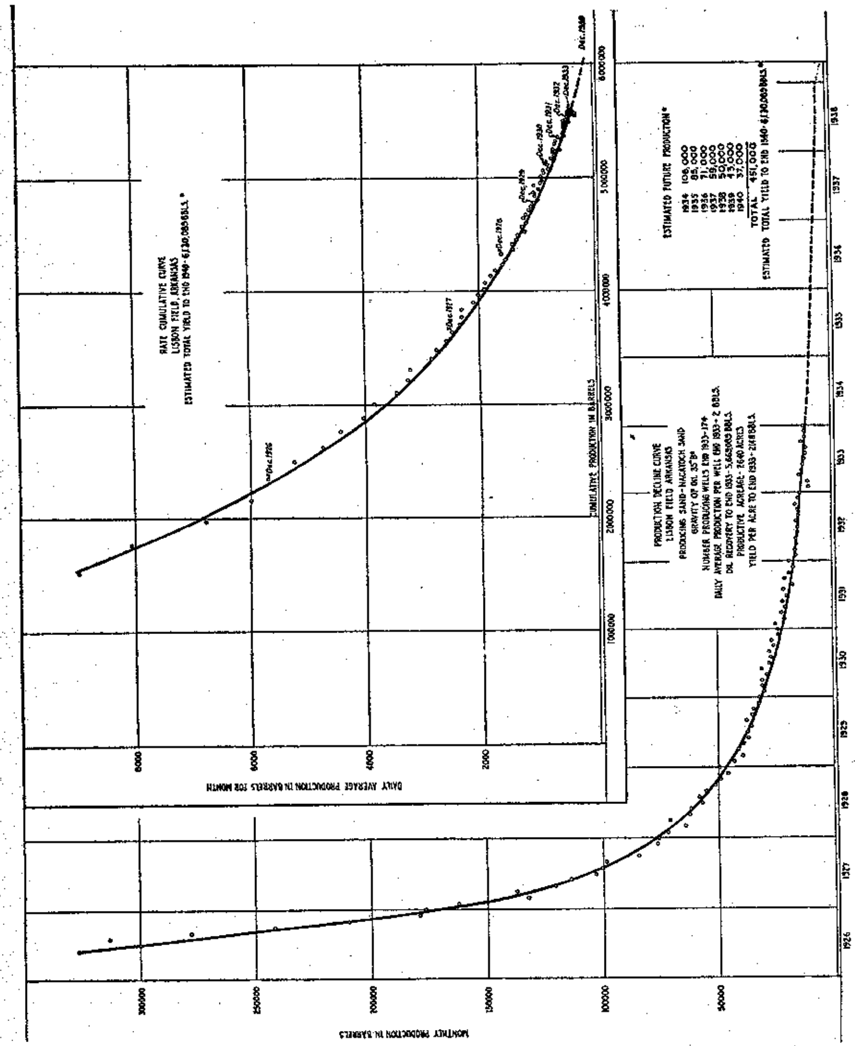


FIGURE 30.—Rate-cumulative curve and production-decline curve, Lisbon field, Arkansas. *Future estimates made assuming present production methods unchanged.

top of, or just above, the producing sand. All strings of casing were cemented. The wells were completed with perforated liner or screen pipe.

CHARACTER OF THE OIL

The gravity of the Lisbon oil ranges from 34° to 35° A. P. I.

A detailed analysis is not available, but a summary analysis follows:

Summary analysis of crude oil from Lisbon field

A. P. I. gravity (°)	34.3
Flash point °F. (°C)	Below 60
Sulphur per cent S. D.	1.02
Pour point	+20
Gasoline (per cent)	26.3

WATER CONDITIONS

In the Lisbon field the Nacatoch sand has produced little water except in wells drilled on the eastern edge of the field where a few wells showed water, most of which was due to faulty casing. The difference between the conditions in this field and those in the El Dorado field may, perhaps, be attributed to the fact that the productive zone of the Nacatoch sand in the Lisbon field is thin and low in porosity but completely saturated and, owing to the low porosity, the oil is removed faster than the normal movement of the water.

THE EAST EL DORADO FIELD

LOCATION AND EXTENT

The East El Dorado field is in the western part of T. 17 S., R. 14 W., Union County. The producing area is irregular in shape. It lies chiefly in secs. 17, 18, 19, and 20 but also includes a small area in sec. 12, T. 17 S., R. 15 W.

HISTORY OF DEVELOPMENT

The discovery well of the East El Dorado field, the Terry Summerfield Oil Company's Smith No. 1 well in sec. 30, T. 17 S., R. 14 W., was completed January 10, 1922, with an initial daily yield of 10,000,000 cubic feet of gas in the Nacatoch sand, recorded at depths of 2,200 to 2,207 feet. A total of 152 producing wells, or 143 oil and 9 gas wells, have been drilled in the field. The production peak was reached in 1923, when the field produced 2,111,509 barrels of oil. In December 1929, there were 81 wells with an average of 8 barrels per well.

TABLE 18.—*Generalized section of formations in the East El Dorado field*

Age	Series	Formation	Thickness in feet	Character of the beds
Tertiary	Eocene	Claiborne	1400-1450	Sand, sandy clay, and clay, in part lignitic and in part glauconitic
		Wilcox		Lignitic sand and clay
		Midway clay Unconformity	500	Blue and gray, chiefly noncalcareous clay containing siderite concretions
		Arkadelphia marl	75±	Blue, greenish-gray to dark-gray shale and marl; chalky shale in lower part
Cretaceous	Gulf	Nacatoch sand	150-160	Principally gray and greenish-gray argillaceous fine-grained sand and sandy chalk
		Saratoga chalk	20-30	Gray chalk
		Marlbrook marl	145-155	Gray and greenish-gray chalky marl, in part finely sandy
		Ozan	70-85	Micaceous gray and green sand and sandy clay
		Tokio-Woodbine	350-375	Chiefly tuffaceous sand and sandstone with interbedded clay, sandy clay, and thin lenses of tuff, in part lignitic
		Red beds Unconformity	250-300	Dominantly red clays interbedded with tuffaceous sand and light-colored clay
	Comanche (Trinity group)	Lower Glen Rose	0-50	Red, brown, and gray shale, with interbedded sand
		Travis Peak	1500+	Red, pink, purple, and gray shale, white to brown sand, and sandstone

STRATIGRAPHY

The character of the rocks penetrated in this field, except in minor details, is similar to those penetrated in deep wells in the El Dorado field. A generalized section of formations is given in Table 18.

RELATION OF STRUCTURE TO THE ACCUMULATION OF OIL AND GAS

The structural feature of the area in which the East El Dorado field is situated is a terrace defined by the 2,325-foot contour line, drawn on top of the Meakin sand in Plate XX. The producing area is, in part, on the terrace and in part on its flank and bears no direct relation to the structure of the beds including the producing sand. The localization of the oil and gas appears to have been determined by the character and structure of the producing sand, which consists of a lens or lenses of porous sand in the upper part of the Nacatoch. This bed decreases in porosity toward the west, apparently owing to a progressive westward increase in the argillaceous material in the sand.

PRODUCTION

PRODUCTIVE AREA

The producing wells, 143 oil and 9 gas wells, were not spaced according to a definite schedule but vary from 2½ to 160 acres

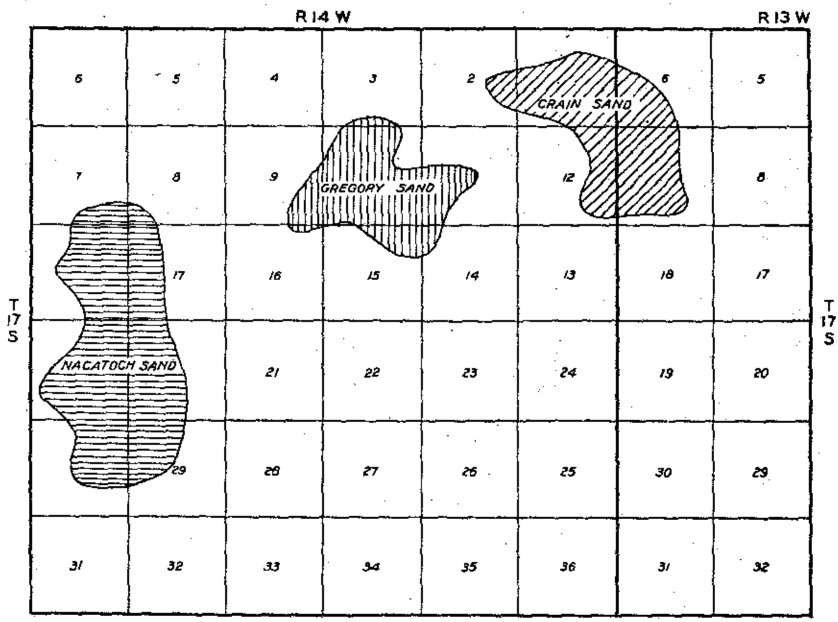


FIGURE 31.—Sketch map showing producing areas in East El Dorado and Rainbow City fields, Union County, Arkansas.

per well. To determine the total producing area of the field, it was assumed that a well will drain 10 acres, which was taken as the basis for the estimates in the areas where the wells were

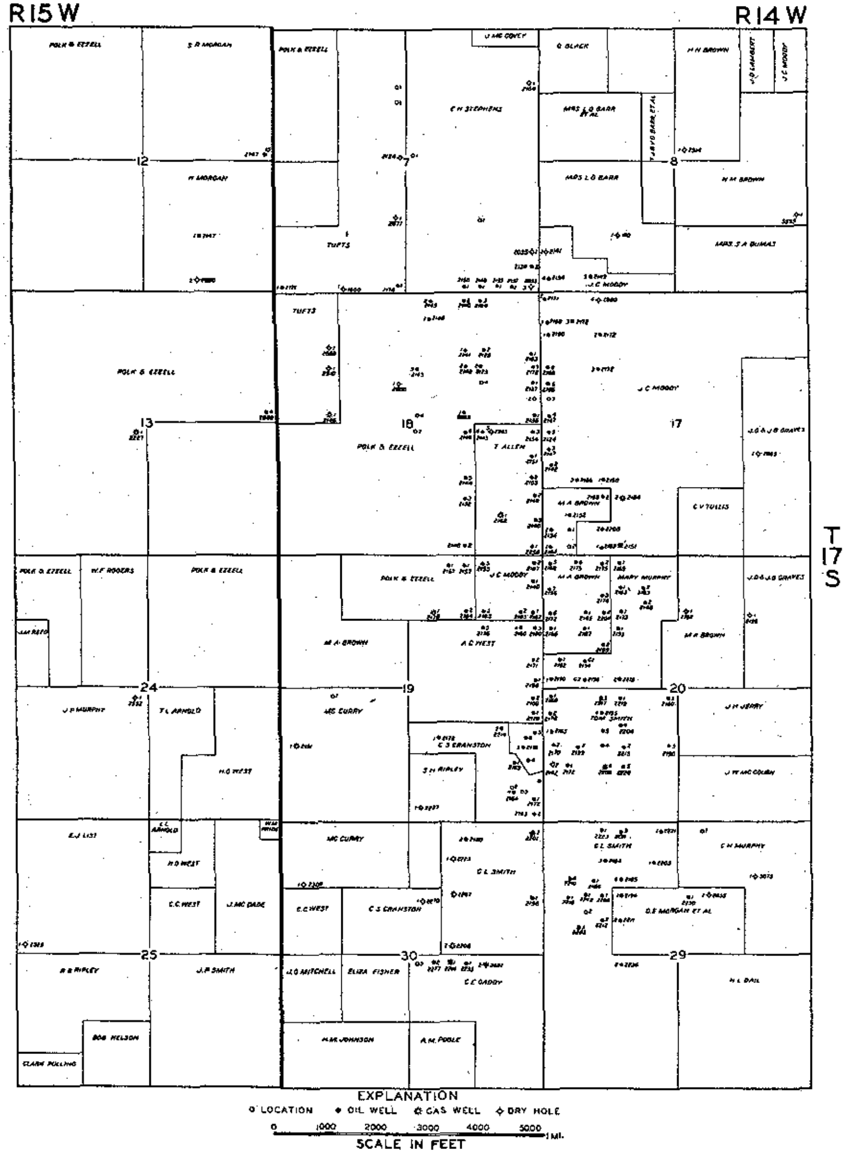


FIGURE 32.—East El Dorado field showing location of wells. Figures give depth below surface.

spaced at the rate of more than 10 acres per well. So measured, the total producing area of the field is 1,330 acres. (See Fig.

31. A map of the East El Dorado field showing locations of wells is shown in Figure 32.

THE PRODUCING SANDS

The principal producing bed in the East El Dorado field is a sand in the upper part of the Nacatoch sand. One well, in the southeast corner of the SW¼ of NE¼ of sec. 18, T. 17 S., R. 14 W., produces oil from the lower part of the Tokio-Woodbine section, 2,865 to 2,867½ feet in depth. This well is offset by a dry hole, and several other wells drilled to this horizon were dry, indicating that the prospect of additional oil production from that horizon is not favorable.

NACATOCH SAND

The Nacatoch sand is from 150 to 160 feet thick and consists chiefly of gray to greenish-gray, fine-grained argillaceous sand, sandy clay, and calcareous sandstone, and of subordinate beds of clay and shale. Production is obtained in the upper part of the Nacatoch at depths from 2,135 to 2,215 feet below the surface in a sand member, which, according to the available records, ranges in thickness from 2 to 20 feet. Toward the west there is an appreciable increase in the argillaceous material in the sand and a corresponding decrease in its porosity, which have determined the western limits of the accumulation of oil and gas. The variation in the porosity of the producing sand in the field is indicated by the initial daily production of the wells, which range from 5 to 3,000 barrels. Most of the gas wells are in the western part of the field. A typical section of the Nacatoch sand is as follows:

Section of Nacatoch sand in Patt Marr et al, Moody No. 2 well in sec. 16, *T.* 17 *S., R.* 14 *W.*

	Depth in feet
Cap rock	2248–2249½
Broken sand; show of oil and gas	2249½–2268
Gumbo	2268–2277
Hard limestone	2277–2285
Hard and soft limestone	2285–2298
Gumbo	2298–2312
Hard sandy limestone	2312–2322
Broken limestone	2322–2380
Hard sandy limestone	2380–2414

The Nacatoch sand has not been cored in the field, but its section probably does not differ essentially from that cored in the Gulf Refining Company's Rosa L. Cook No. 1 well in sec. 1, T. 18 S., R. 15 W., shown in Figure 28. The limestone recorded in the above section of the Nacatoch sand probably is fine-grained calcareous sandstone and sandy shale.

POSSIBILITIES OF PRODUCTION FROM DEEPER SANDS

The possibilities of obtaining oil and gas in the Upper Cretaceous sands below the Nacatoch is not promising, in view of the results attained by the deep wells which have penetrated these sands. The Meakin and several sands of the Tokio-Woodbine section in the East El Dorado field have been penetrated by the following wells given in Table 19:

TABLE 19.—*Deep wells drilled in the East El Dorado field*

Name of well	Location S. T. R.	Depth in feet	Bed tested	Production
Clark & Greer Drlg. Co.'s Tuffts No.1	7-17-14	2871	Lower part of Tokio-Woodbine section	Dry
Wingfield et al Polk & Ezzell No. 3	7-17-14	2865	Lower part of Tokio-Woodbine section	Dry
Magnolia Petrol. Co.'s Moody No. 4	17-17-14	2880	Lower part of Tokio-Woodbine section	Dry
Wingfield et al Tuffts No. 1	18-17-14	2860	Lower part of Tokio-Woodbine section	Dry
Nat. Gas. Prod. Co.'s Tuffts No. 1	18-17-14	2910	Lower part of Tokio-Woodbine section	Dry
Stock et al Ezzell No. 1	18-17-14	2867½	Lower part of Tokio-Woodbine section	180 bbls. oil
Zoder et al Allen No. 5	18-17-14	2981	Lower part of Tokio-Woodbine section	Dry
Gulf Refg. Co.'s McGough No. 1	29-17-14	3073	Lower part of Tokio-Woodbine section	Dry
Gulf Refg. Co.'s Gaddy No. 2	30-17-14		Lower part of Tokio-Woodbine section	Show of gas

PRODUCTION 1922 TO 1933

The East El Dorado field has produced 6,795,872 barrels of oil to the end of 1933. The production from 55 wells during the month of December 1933, was 10,943 barrels, a daily average production of 6½ barrels per well. The production in barrels distributed by years is listed below:

Oil produced in the East El Dorado field from 1922 to 1933, inclusive

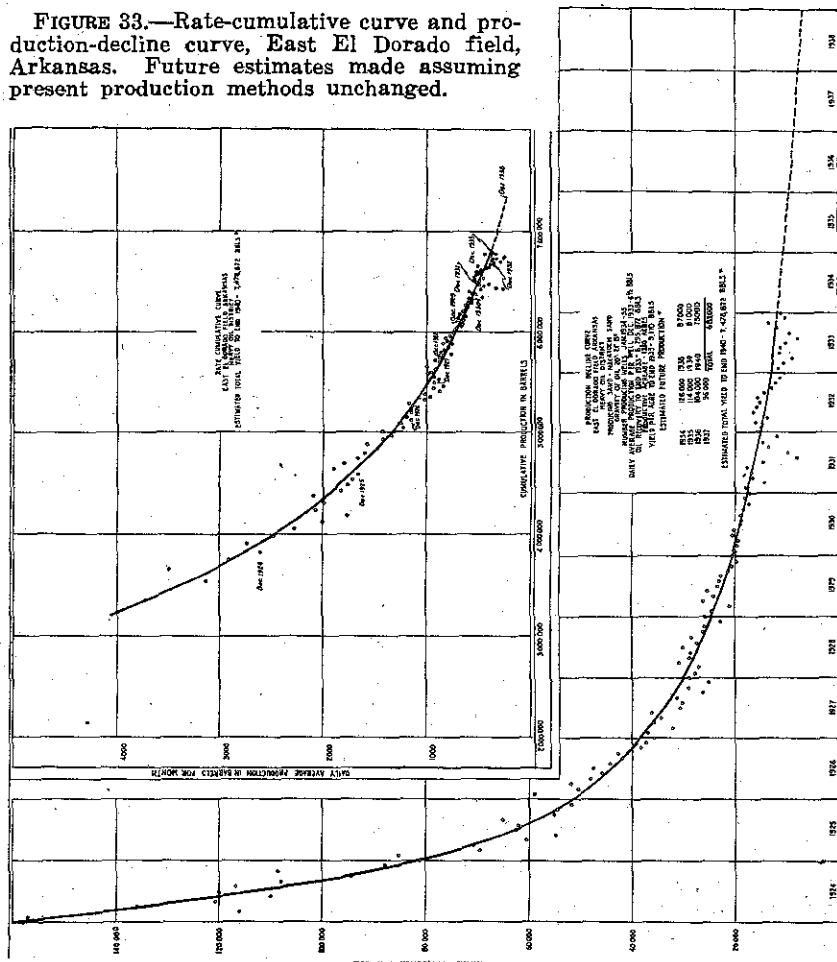
Year	Barrels*	Year	Barrels*
1922	363,408	1928	329,798
1923	2,119,158	1929	271,923
1924	1,348,681	1930	226,926
1925	742,898	1931	172,238
1926	542,663	1932	174,300
1927	376,860	1933	127,019
			6,795,872

* Pipe-line runs

ESTIMATED FUTURE PRODUCTION

The future production of the East El Dorado field, as estimated from production-decline curves and rate-cumulative curves, is shown in Figure 33, prepared by Roy T. Hazzard. These estimates are made assuming present production methods are unchanged. The estimated future production by years and the oil reserves are also listed.

FIGURE 33.—Rate-cumulative curve and production-decline curve, East El Dorado field, Arkansas. Future estimates made assuming present production methods unchanged.



Estimated future production in the East El Dorado field from 1934 to 1940, inclusive

Year	Barrels	Year	Barrels
1934	126,000	1938	87,000
1935	114,000	1939	81,000
1936	104,000	1940	75,000
1937	96,000		
			683,000

Oil reserves of the East El Dorado field

	Barrels
Oil recovered to January 1, 1934	6,795,872
Estimated future production to the end of 1940	683,000
Total estimated recovery of oil to end of 1940	7,478,872

The producing area of the East El Dorado field is 1,330 acres, giving an acre yield of 5,110 barrels to the end of 1933, and an estimated total recovery per acre of 5,623 at the end of 1940.

METHOD OF DRILLING

The rotary method of drilling was used in the East El Dorado field. The usual practice was to set 150 to 200 feet of 10-inch or 12½-inch pipe on top of the sand, or a few feet above the sand. Both strings were cemented. The wells were completed with liners.

CHARACTER OF THE OIL

The oil produced from the Nacatoch sand is brownish-black and has a naphthene base. Its gravity ranges from 19.5° to 21.5° A. P. I. Its properties are shown by the following analysis:

Analysis of crude oil from the Nacatoch sand in the East El Dorado field

(U. S. Bureau of Mines Bulletin 291)

Color	brownish-black
Specific gravity	.927
A. P. I. gravity	21.1
Viscosity at 70°F. (Saybolt seconds)	660°
Viscosity at 100°F. (Saybolt seconds)	260°
Pour point F,	below 5
First drop (°C)	75
First drop (°F)	167
Sulphur (per cent)	1.80

SUMMARY

	Per cent	Specific gravity	A. P. I. gravity
Gasoline, light ends	1.7		
Total gasoline and naphtha	11.5	.784	49.0
Gas oil	19.3	.866	31.9
Nonviscous lubricating distillate	9.4	.902–.920	25.4–22.3
Medium lubricating distillate	7.2	.902–.932	22.3–20.3
Viscous lubricating distillate	5.8	.932–.937	20.3–19.5
Total distillate	53.2		

Residuum	54.0
Carbon residue of residuum	13.4
Carbon residue of crude oil	7.2
Base of crude	Naphthene

WATER CONDITIONS

Most of the wells in the East El Dorado field made considerable water when they were completed, particularly the wells that were drilled more than 3 to 5 feet into the producing sand. At present, 80 to 85 per cent of the total fluid lifted is salt water.

THE WOODLEY POOL

LOCATION AND EXTENT

The Woodley pool is in the northwest corner of T. 18 S., R. 14 W., 2 miles south of the East El Dorado field and 4 miles east of the El Dorado field. The producing wells are distributed over an area of 690 acres, but the actual producing area, which is in secs. 5, 6, 7, and 8, T. 18 S., R. 14 W., is not more than 240 acres.

HISTORY OF DEVELOPMENT

The discovery well, known as Lovett No. 1, was drilled by T. J. Woodley et al, in sec. 5, T. 18 S., R. 14 W. It was completed April 12, 1922, with an initial daily volume of 40,000,000 cubic feet of gas in the Nacatoch sand from depth of 2,148 to 2,168 feet. In all, 16 oil and 8 gas wells have been drilled in the field. These wells had initial daily productions ranging from 10 to 150 barrels of oil and 500,000 to 40,000,000 cubic feet of gas.

The highest yearly production was 75,772 barrels which was produced during 1928. During November 1929, the field produced 180 barrels from 16 wells, a daily average of 11 barrels per well.

STRATIGRAPHY

The formations at the surface and those encountered in drilling in the Woodley pool are similar in character and thickness to those in the East El Dorado field to the north.

STRUCTURE

The subsurface structure of the Woodley pool is shown in Plate XX by contour lines drawn on top of the Meakin sand. (See also Fig. 34.) A small dome is defined by the closure of the 2,350-foot contour line, which incloses an area of about 3,000 acres, or slightly more than 4 square miles. A low saddle on the north separates this area from the terrace upon which the East El Dorado field is situated; a similar saddle on the west divides the Woodley dome from the El Dorado anticline. The beds on the east dip at the rate of 20 to 35 feet per mile.

RELATION OF STRUCTURE TO ACCUMULATION OF OIL AND GAS

The gas occupies the highest part and the oil the south and east flanks of the dome.

PRODUCTION

PRODUCTIVE AREA

The producing wells (16 oil wells and 8 gas wells) were not spaced according to a definite plan but are irregularly distributed

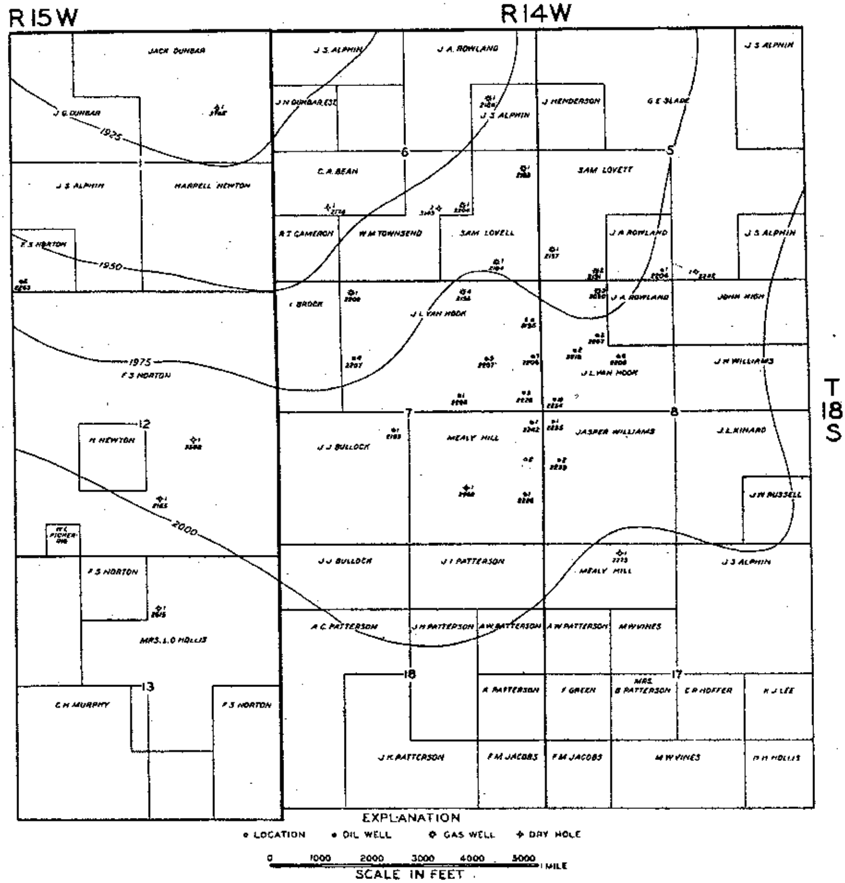


FIGURE 34.—Structure contour map of Woodley pool drawn on top of the Nacatoch sand. Figures give depth below sea level.

through secs. 5, 6, 7, and 8, T. 18 S., R. 14 W. The total producing area of the field, based on the assumption that one well will drain 10 acres, is 240 acres.

THE PRODUCING SAND

The oil and gas in the Woodley pool are obtained from the Nacatoch sand. The sand is known only from the driller's records but appears to be essentially similar in character to the Nacatoch sand in the East El Dorado field.

POSSIBILITY OF PRODUCTION FROM DEEPER SANDS

The possibility that oil and gas will be obtained from some of the sands which underlie the Nacatoch is not promising as several deep wells have tested many of these sands with negative results. The deepest well drilled, the Gulf Refining Company's Rosa L. Cook No. 1 well, in sec. 1, T. 18 S., R. 15 W., penetrated several hundred feet of the Travis Peak formation. (See Fig. 26.) The deep wells drilled in the Woodley pool are listed in Table 20.

TABLE 20.—*Deep wells drilled in the Woodley pool*

Company and name of well	Location	Depth in feet	Deepest formation penetrated
Gulf Refining Co.'s Rosa L. Cook No. 1	sec. 1, T. 18 S., R. 15 W.	3765	Travis Peak
Marr & Hoosier Norton No. 1	sec. 12, T. 18 S., R. 15 W.	3508	Travis Peak
Belmont et al Hollis No. 1	sec. 13, T. 18 S., R. 15 W.	2615	Meakin sand
Gulf Refining Co.'s Townsend No. 1	sec. 6, T. 18 S., R. 14 W.	3622	Travis Peak
Woodley et al Hill No. 1	sec. 7, T. 18 S., R. 14 W.	2966	Tokio-Woodbine red beds

PRODUCTION 1923 TO 1933, INCLUSIVE

The initial daily production of the oil wells drilled in the Woodley pool was 10 to 150 barrels. The gas wells had initial daily capacities of 500,000 to 40,000,000 cubic feet. In November 1929, the field produced 180 barrels of oil from 16 wells, a daily average of 11 barrels per well. The gas has been practically exhausted.

The Woodley pool produced oil and gas. The gas was in part piped into El Dorado and in part used as drilling fuel in the El Dorado and the East El Dorado fields. No records are available to show the quantity of gas produced. The total oil produced from 1923 to 1933 inclusive was 435,882 barrels. The production in barrels, distributed by years, is listed below.

Oil produced in the Woodley pool from 1923 to 1933, inclusive

Year	Barrels*	Year	Barrels*
1923	17,613	1929	43,526
1924	40,127	1930	49,667
1925	35,870	1931	26,995
1926	35,323	1932	28,601
1927	60,239	1933	22,167
1928	75,754		
			435,882

* Pipe-line runs.

Production during December 1933, was 2,277 barrels from 12 wells, a daily average production of 6 barrels per well. The estimated productive area is 160 acres from which 435,882 barrels of oil have been produced, giving an average yield of 2,722 barrels per acre to the end of 1933.

The data available are inadequate for estimating accurately the future production of the Woodley pool.

METHOD OF DRILLING

The rotary method of drilling was used in this field as in all the fields of this region. The common practice was to set 150 to 200 feet of 10 to 12½-inch conductor pipe and 6½-inch casing on top of the sand. Most of the wells were completed with 4½-inch liner.

CHARACTER OF THE OIL

The oil produced in the Woodley pool is essentially like that produced in the East El Dorado field. Its properties are shown by the following analysis:

Analysis of Nacatoch crude in Woodley pool

(U. S. Bureau of Mines Bulletin 291)

Specific gravity	.929	Viscosity at 100°F. (Saybolt seconds)	310
A. P. I. gravity	20.8°	Pour point	below 5°
Percentage of sulphur	1.90	First drop (°C.)	76
Viscosity at 70°F. (Saybolt seconds)	690	First drop (°F.)	169
Color	brownish-black		

	Per cent	Specific gravity	A. P. I. gravity
Gasoline light ends	4.2		
Total gasoline and naphtha	7.1	.786	48.5
Kerosene distillate			
Gas oil	23.2	.864	32.3
Nonviscous lubricating distillate	10.4	.897–.920	26.3–22.3
Medium lubricating distillate	5.9	.920–.927	22.3–21.1
Viscous lubricating distillate	4.6	.927–.933	21.1–20.2
Total distillate	51.2		

Residuum (per cent)	45.8	Carbon residue in crude oil (per cent)	5.8
Carbon residue of residuum	12.7	Base of crude oil	Naphthene

WATER CONDITIONS

The oil-producing wells in the Woodley pool began to produce water a short time after completion and at the present time it is estimated that of the total fluid lifted from the wells 50 to 80 per cent is salt water.

THE RAINBOW CITY FIELD

LOCATION AND EXTENT

The Rainbow City field, sometimes called the "Champagnolle" or the "Calion field," is in the northwestern part of T. 17 S., R. 14 W., and the northewestern part of T. 17 S., R. 13 W., in Union County.

HISTORY OF DEVELOPMENT

The discovery well of the Rainbow City field, the Ohio Oil Company's Crain No. 1 well in sec. 1, T. 17 S., R. 14 W., was completed January 22, 1927, with an initial daily production of 50 barrels of oil. The oil was obtained from a sand at a depth of 3,000 to 3,014 feet below the surface, or about 130 feet below the top of the red beds at the base of the Upper Cretaceous series. This sand, which had never before produced oil or gas, was named the "Crain sand."

A deeper producing sand was found after the completion of the Pure Oil Company's Gregory No. 1 well in sec. 10, T. 17 S., R. 14 W., on April 4, 1928. This well had an initial daily production of 2,037 barrels of oil from what is known as the "Gregory sand" which lies at a depth of 3,141 to 3,153 feet.

In the development of the field, gas and some oil were discovered in the basal beds of the non-red Tokio-Woodbine section at a depth of 2,750 to 2,850 feet. This sand, which corresponds closely with the Third sand of the Smackover field, produces chiefly gas but at some places yields small quantities of oil.

STRATIGRAPHY

The rocks at the surface in the Rainbow City field belong to the upper part of the Claiborne formation of the Tertiary system, but deep wells have penetrated several hundred feet of the Trinity group of the Lower Cretaceous. The data available indicate that the Glen Rose formation is absent in this field and that the basal bed of the Upper Cretaceous series rests unconformably upon the red shale and sand of the Trinity group. A generalized section showing the beds in the field is given in Table 21.

STRUCTURE

The structure of the Rainbow City field is shown in Plate XX by means of contour lines drawn on the top of the Meakin sand at intervals of 25 feet.

The principal structural feature of the area in which the Rainbow City field is situated is a generally northwest-south-

TABLE 21.—*Generalized section of formations in the Rainbow City field*

System	Series	Formation	Thickness in feet	Character of the beds
Tertiary	Eocene	Claiborne	1400-1500	Sand, sandy clay, and clay, in part lignitic; some beds of glauconitic sand and clay in the lower part
		Wilcox		Lignitic sand and clay. Siderite and limonite concretions
		Midway clays	500-550	Blue and gray dominantly noncalcareous clay. Siderite concretions abundant
		Unconformity		
Cretaceous	Gulf	Arkadelphia marl	70-100	Blue, greenish-gray to dark-gray calcareous shale and chalky shale
		Nacatoch sand	150-160	Chiefly fine - grained argillaceous sand, sandy clay, and calcareous sandstone
		Saratoga chalk and Marlbrook marl	175	10 to 20 feet of gray chalk at top; below this a gray to greenish-gray clay and marl with some fine sand; in part chalky
		Ozan	75	Chiefly gray micaceous sand, sandstone, and sandy clay; in part glauconitic
		Tokio-Woodbine	300-385	Chiefly gray to white sand and sandstone, in part tuffaceous, and gray to green clay with some tuff, in part lignitic
			650-700	
		Red beds	250-325	Dominantly red clay with interbedded light-colored clay, sand, and sandy clay; in part tuffaceous. Crain sand in upper part; Gregory sand in lower part
		Unconformity		
	Comanche (Trinity group)	Glen Rose		Not recognized; probably absent
		Travis Peak formation		Red, brown, purple, and gray clay shale and gray to purple sand

east trending anticline with the Norphlet dome of the Smackover field on the northwestern and the Urbana district on the southeastern end. The anticline plunges towards the southeast, but the plunge is arrested in several places by small closures and structural terraces. The Rainbow City as well as the East El Dorado field is situated on a broad structural terrace over which the Meakin sand lies from 2,300 to 2,350 feet below sea level.

The structure of the Crain and Gregory sands, the oil producing members of the field, show an even more pronounced flattening of the dip in this area.

RELATION OF STRUCTURE OF ACCUMULATION OF OIL AND GAS

The relation between structure and the accumulation of oil and gas in the Rainbow City field is obscure, for although the area coincides more or less closely with a structural terrace, only a part of the terrace is underlain by oil and gas-producing sands. The productive area is not confined to the terrace but extends beyond it, down the dip. The lenticular structure of the producing sands, rather than the structure of the inclosing strata, appears to have determined the distribution of oil and gas in this field.

PRODUCTION

PRODUCTIVE AREA

The producing oil and gas wells in the Rainbow City field were drilled within an area of 3,200 acres. (See Fig. 31.)

The producing area of the Gregory sand is about 1,000 acres on which 75 oil-producing wells were drilled. The spacing of the wells ranged from 3 to 10 acres per well. The most productive Gregory sand wells were in the NW¼ of SW¼ of sec. 11, the S½ of SE¼ of sec. 10, and in the adjacent part of sec. 15, T. 17 S., R. 14 W.

The producing area of the Crain sand is about 1,200 acres on which 46 oil-producing wells and 12 gas-producing wells were drilled. The spacing of the Crain-sand wells was on the basis of 10 acres per well.

The wells drilled to the base of the non-red Tokio-Woodbine section, which produced chiefly gas, are distributed over the western and southern part of the Rainbow City field.

A map of the Rainbow City field showing locations of wells is given in Figure 35.

THE PRODUCING SANDS

The oil and gas produced in the Rainbow City field is obtained from three zones in the Tokio-Woodbine section of the Gulf series. The upper producing zone is in the basal part of the non-red Tokio-Woodbine section. The second and third zones, called the "Crain" and "Gregory" zones, are in the red beds in the basal part of the Gulf series.

The upper producing zone is made up of lenses of sand interbedded with lignitic clay and sandy clay and has at its base a fairly persistent sand member which the drillers designate as the "salt and pepper sand." The zone is 90 to 115 feet thick. The sands in the upper part yield some oil and gas, but the principal producing member is the basal sand which lies at depths of 2,755 to 2,860 feet below the surface. The oil has an average gravity of 24°. Most of the producing wells outside of the main Gregory sand producing area, are in the western and southern part of the field. The production from this zone is chiefly gas but a few wells were completed which had initial daily productions ranging from 10 to 400 barrels of oil. Typical well sections of this zone are as follows. (See also Fig. 36.)

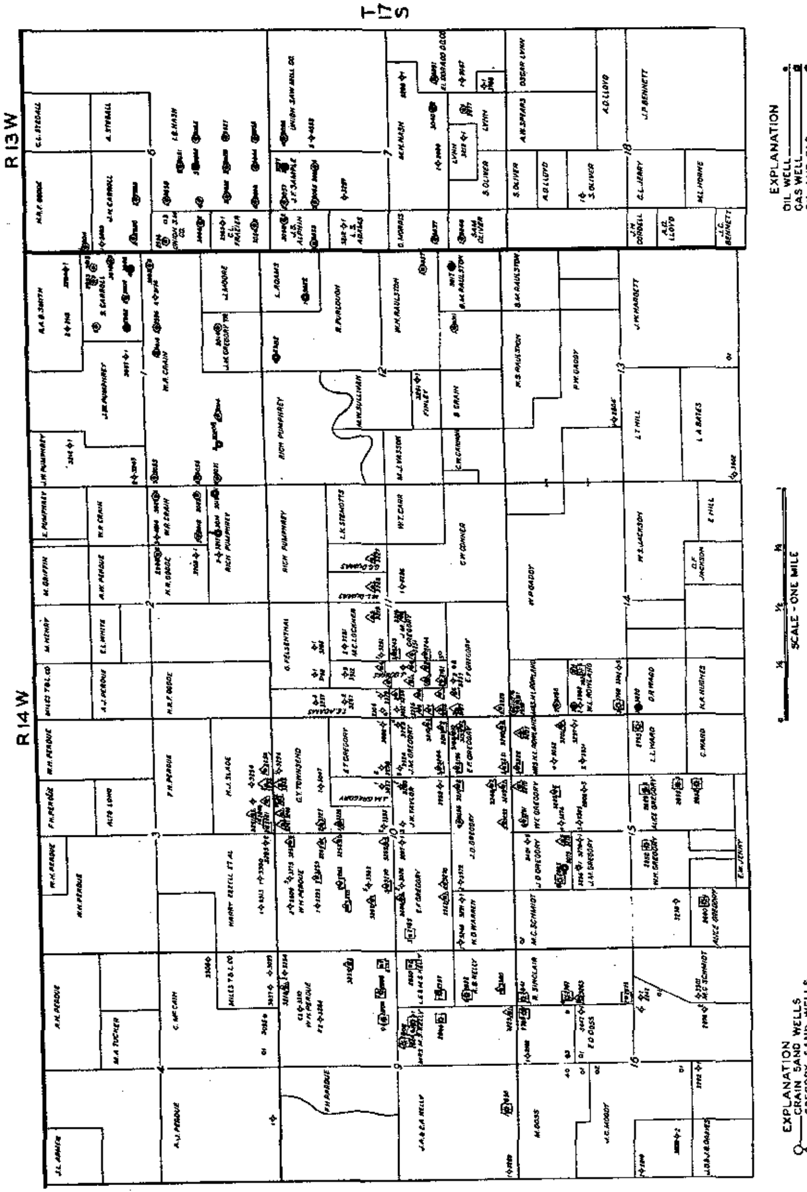


FIGURE 35.—*Map showing* well locations, Rainbow City field.

Section of upper oil and gas-producing zone in Magnolia Petroleum Company's W. K. Gregory No. 1 *well in sec.* 15 *T.* 17 *S., R.* 14 *W.*

	Depth in feet
Sandy shale	2746–2762
Oil sand and shale	2762–2763
Gumbo and streaks of oil sand	2763–2768

Gumbo	2768–2773
Gummy shale	2773–2777
Lignite and shale	2777–2779
Gumbo	2779–2782
Shale and streaks of oil sand	2782–2791
Sandy shale	2791–2798
Lime and shale	2798–2801
Sandy shale	2801–2813
Gray sand	2813–2817
Sandy shale	2817–2843
Sand	2843–2846
Sandy lime	2846–2848
Limy shale	2848–2849
Sand (salt and pepper sand)	2849–2851

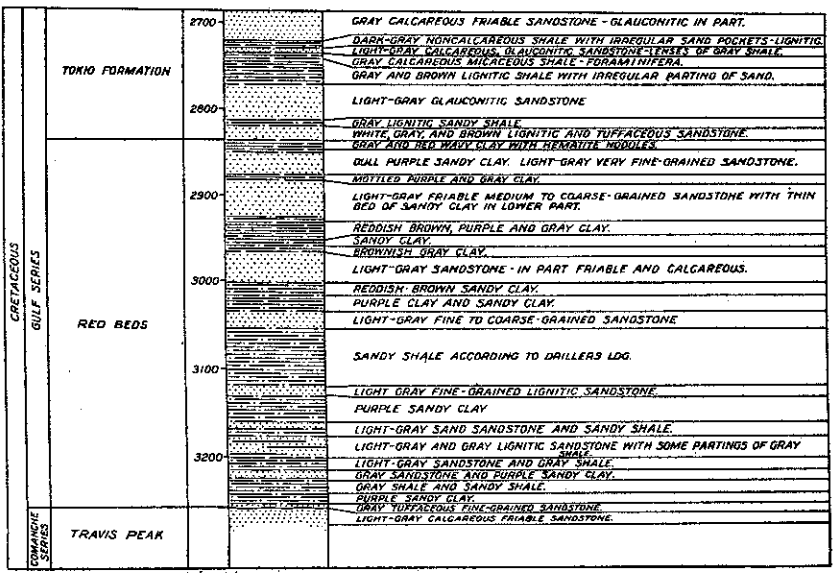


FIGURE 36.—Core record of a part of the Tokio formation and the Upper Cretaceous red beds in Pure Oil Company's Gaddy No. 1 well, sec. 13, T. 17 S., R. 14 W. Figures give depth below surface.

Section of upper oil and gas-producing zone in Magnolia Petroleum Company's W. K. Gregory No. 2 *well in sec.* 15, *T.* 17 *S., R.* 14 *W.*

	Depth in feet
Gumbo	2730–2738
Oil sand	2738–2740
Gumbo	2740–2743
Broken sand	2743–2744
Oil sand	2744–2745
Sandy shale	2745–2747
Oil sand	2747–2748
Shale and lignite	2748–2749
Salt water sand	2749–2754
Sand and lignite	2754–2756
Sandy shale	2756–2771
Gumbo	2771–2772
Salt water sand	2772–2803

Gumbo	2803–2805
Sandy shale	2805–2808
Hard sandy shale	2808–2809
Oil and gas sand	2809–2811
Broken gas sand	2811–2815
Hard gas sand	2815–2816
Broken gas sand	2816–2820
Hard gas sand	2820–2822

CRAIN SAND

The Crain zone, named after the farm on which the discovery well was completed, is about 100 feet thick. It is divided into two producing zones: (1) an upper sand, sometimes called the "Estes sand," which lies from 50 to 75 feet below the top of the old series, and (2) a lower sand, or the Crain sand proper. The latter is separated from the Estes sand by about 50 feet of red shale and sandy shale. In the western part of the field in the Gregory area a few wells produce oil from the Estes sand, and it is probable that oil from this sand has been passed up by many wells drilled to the Gregory sand in this area.

The Crain sand proper is productive chiefly in the eastern part of the field, in secs. 1 and 2, T. 17 S., R. 14 W., and secs. 6 and 7, T. 17 S., R. 13 W., where the top of the producing sand is found at an average depth of 3,000 feet below the surface. It is a persistent bed, 50 to 75 feet thick, made up of lenses of sand of varying thickness, interbedded with strata of sandy shale. The character of the sand, its texture, and the quantity of argillaceous and ashy material associated with it were the principal factors that determined the initial capacity of the wells.

The Crain sand has yielded chiefly oil, but gas has been obtained from it in a few wells drilled on the west and south sides of the Crain producing area.

A small quantity of oil produced on the extreme northwest flank of the Crain area was of low gravity (21° to 26°), but the normal gravity ranges from 31° to 34.5°. The low gravity of the oil obtained on the northwest flank is believed to be due to its association with salt water.

In the western part of the field the Crain sand is not easily recognized in the driller's logs, a fact which suggests that it is not as thick in that part of the field. Most of the wells, however, were drilled to the Gregory sand, and perhaps their logs do not accurately record the beds above that sand.

GREGORY SAND

The Gregory sand, named after the farm on which the discovery well was drilled, is found at an average depth of 3,200 feet below the surface. It appears to be recognizable throughout the Rainbow City field, but it is thickest in the western part of that field, especially in secs. 10 and 11, T. 17 S., R. 14 W., where the largest oil wells are situated.

The Gregory sand is 2 to 25 feet thick and is made up of fine to coarse-grained quartz sand, which laterally exhibits a wide range in its content of argillaceous material and, consequently, in its porosity.

The Gregory sand produces chiefly oil, which ranges in gravity from 32° to 35.5°, but a few wells produce considerable volumes of gas with the oil.

The following partial records show the driller's interpretation of the beds penetrated in the Crain and Gregory producing zone:

Section in Skelly Oil Company's Perdue No. 3 *well in sec.* 10, *T.* 17 *S., R.* 14 *W.*

		Depth in feet
Red beds		2966–3000
Broken limestone		3000–3030
Hard shale		3030–3038
Red beds		3038–3178
Sandy limestone		3178–3203
Sand; show of oil and gas	Gregory sand zone	3203–3204
Red gumbo	Gregory sand zone	3204–3207
Sand; show of oil	Gregory sand zone	3207–3211
Broken formation; show of oil	Gregory sand zone	3211–3224
Blue shale		3224–3228
Red shale		3228–3248

Section in Lion Oil and Refining Company's Kelly No. 1 *well in sec.* 9, *T.* 17 *S., R.* 14 *W.*

		Depth in feet
Red beds		2960–2967
Red shale and gumbo		2967–3010
Sandy limestone		3010–3019
Red beds		3019–3114
Sand and shale		3114–3117
Cap rock		3117–3118
Sand; salt water		3118–3121
Limestone		3121–3123
Sandy shale		3123–3137
Limestone		3137–3152
Shale		3152–3175
Hard sandy shale		3175–3180
Shale		3180–3187
Chalky sand; oil	Gregory sand zone	3187–3195
Limy oil sand	Gregory sand zone	3195–3204
Oil sand	Gregory sand zone	3204–3206
Red beds		3206–3210

Section in Ohio Company's Warren No. 1 *well in sec.* 10, *T.* 17 *S., R.* 14 *W.*

	Depth in feet
Red shale	3008–3067
Rock	3067–3068

Gray shale and sand		3068–3072
Blue and red shale		3072–3075
Red shale		3075–3077
Rock		3077–3078
Red shale and limestone		3078–3084
Red shale		3084–3151
Cap rock		3151–3152
Red shale		3152–3179
Cap rock		3179–3180
Sand; show of oil		3180–3185
Sand and red shale		3185–3197
Red shale and chalk		3197–3200
Sand and red shale		3200–3204
Chalk and red shale		3204–3208
Blue shale and sand	Gregory sand zone	3208–3214
Oil sand	Gregory sand zone	3214–3216
Limestone	Gregory sand zone	3216–3220
Red shale and lime		3220–3256

Section in Pure Oil Company's E. F. Gregory B-1 well in sec. 10, T. 17 S., R. 14 W.

		Depth in feet
Red gumbo and streaks of limestone		2955–2985
Red shale		2985–3016
Hard sand	Crain sand zone	3016–3032
Red shale and streaks of limestone	Crain sand zone	3032–3035
Hard sand	Crain sand zone	3035–3040
Red shale		3040–3082
Hard limestone		3082–3086
Red shale and streaks of limestone		3086–3100
Hard shale		3100–3110
Red gumbo		3110–3135
Hard limestone		3135–3141
Red gumbo and streaks of limestone		3141–3172
Hard red sandy shale		3172–3180
Red shale		3180–3194
Oil sand	Gregory sand zone	3194–3202
Red gumbo and soft sand	Gregory sand zone	3202–3206
Red gumbo		3206–3260

Section in Ohio Oil Company's Connor No. 1 well in sec. 11, T. 17 S., R. 14 W.

		Depth in feet
Red shale		2875–2908
Cap rock		2908–2909
Sand		2909–2915
Red shale		2915–2998
Broken sand and shale		2998–3010
Hard cap rock		3010–3011
Sand and shale; little oil		3011–3018
Blue shale		3018–3023
Cap rock		3023–3024
Red shale	Crain sand zone	3024–3025
Sand and shale; show of oil	Crain sand zone	3025–3036
Blue and red shale	Crain sand zone	3036–3044
Red shale		3044–3051
Cap rock		3051–3052
Red shale		3052–3063
Sand and hard shale		3063–3064

Red shale		3064–3074
Sand		3074–3080
Sand; little oil		3080–3083
Broken sand, shale and limestone		3083–3139
Limestone		3139–3140
Red shale		3140–3199
Chalky shale		3199–3202
Sandy shale		3202–3213
Hard cap rock	Gregory sand zone	3213–3214
Hard sand	Gregory sand zone	3214–3221
Sandy shale and limestone	Gregory sand zone	3221–3235

Section in Pure Oil Company's W. E. Gregory No. 3 well in sec. 15, T. 17 S., R. 14 W.

		Depth in feet
Red beds		3963–3028
Sand	(Crain sand zone)	3028–3045
Limestone and red beds		3045–3067
Hard sand and limestone		3067–3072
Red beds		3072–3150
Red sandy shale		3150–3162
Sandy chalk		3162–3164
Oil sand		3164–3167
Red and gray shale		3167–3175
Sand; show of oil		3175–3177
Shale and sand		3177–3190
Sandy limestone		3190–3192
Shale		3192–3198
Sand	(Gregory sand zone)	3198–3210
Gray shale		3210–3211
Sand and red shale		3211–3217

Section in H. L. Hunt et al, J. D. Gregory No. 1 well in sec. 15, T. 17 S., R. 14 W.

		Depth in feet
Red beds		2975–3004
Sandy limestone		3004–3008
Red beds		3008–3012
Black shale		3012–3018
Sand	(Crane sand zone)	3018–3022
Red beds		3022–3044
Limestone and sandy limestone		3044–3069
Sand; show of oil		3069–3079
Record missing		3079–3088
Limestone		3088–3092
Red shale and streaks of limestone		3092–3104
Sandy limestone		3104–3108
Cap rock		3108–3110
Hard sand		3110–3114
Tuffaceous		3114–3124
Sand		3124–3129
Limestone		3129–3130
Red beds		3130–3187
Hard limestone		3187–3188
Soft sand; show of oil	Gregory sand zone	3188–3209
Red beds	Gregory sand zone	3209–3213
Brown sand	Gregory sand zone	3213–3217
Shale and chalk		3217–3239
Red beds		3239–3243

PRODUCTION 1927 TO 1933, INCLUSIVE

The initial daily production of the wells in the Rainbow City field ranges from 5,000 to 6,000 barrels of oil, and from 2,000,000 to 60,000,000 cubic feet of gas.

The Gregory sand in secs. 10, 11 and 15, T. 17 S., R. 14 W., yielded the largest quantities of oil, and the upper sand the largest quantities of gas. The best wells in the Crain sand produced 1,000 to 1,800 barrels a day.

The initial closed-in pressure of the gas wells was 1,120 pounds, which had declined to 175 pounds on January 1, 1930, with a corresponding decline in the volume of gas.

In December 1929, the Rainbow City field produced 160,952 barrels of light oil from 97 wells, an average of 1,659 barrels per well, and 10,540 barrels of heavy oil from 7 wells, an average of 1,506 barrels per well for the month.

The oil produced in the Rainbow City field is obtained from three zones, which yield oils of different gravity. The total production to the end of 1929 was 6,115,222 barrels. The yearly production in barrels during the period from 1927 to 1929, inclusive, is given below.

Oil produced in the Rainbow City field from 1927 to 1929, inclusive

Year	Gregory area				Crain area	
	From Tokio sand	From Gregory sand	Mixed heavy*	Mixed light†	Crain heavy	Crain light
1927					7,734	24,693
1928	36,288	2,387,447	343,768	244,119	68,154	405,953
1929	49,103	1,282,302	72,289	316,983	40,984	833,405
Total	85,391	3,669,749	416,057	561,102	116,872	1,264,051

* Oils from Tokio and Crain sands mixed.
† Oils from Crain and Gregory sands mixed

For the years 1927, 1928, and 1929 it has been possible to separate the production according to the sand from which it was produced. Subsequent to 1929 it is not possible to separate the production either by sands or according to the classification of light oils and heavy oils.

During December 1933, the production was 33,694 barrels of oil from 76 wells, a daily average production of 14 barrels per well.

Oil production in the Rainbow City field from 1927 to 1933, inclusive

Year	Barrels*	Year	Barrels*
1927	34,427	1931	929,244
1928	3,487,396	1932	614,157
1929	2,597,623	1933	447,986
1930	1,471,141		
			9,581,974

* Pipe-line runs.

The estimated future production for Rainbow City field, as estimated by Roy T. Hazzard, is given below. These estimates were made assuming that present production methods are unchanged.

Estimated future production of Rainbow City field from 1934 to 1940, inclusive

Year	Barrels	Year	Barrels
1934	348,000	1938	158,000
1935	276,000	1939	134,000
1936	224,000	1940	117,000
1937	186,000		
			1,443,000

Oil reserves of the Rainbow City field

Oil recovered to end 1933	9,581,974
Estimated future production to end of 1940	1,443,000
Total estimated recovery to the end of 1940	11,024,974

Most of the gas produced in this field was obtained from the upper sand. The total volume of gas marketed outside of the field is not known, but it probably did not exceed 5,000,000,000 cubic feet.

METHOD OF DRILLING

The rotary method of drilling was used in the Rainbow City field. The common practice of casing the wells was to set 100 to 200 feet of 10-inch to 12½-inch conductor pipe and 6-inch to 6⅝-inch casing on top of the producing sand. Both strings were cemented. The wells were completed with liners.

CHARACTER OF THE OIL

Detailed analyses of the Rainbow City crude oils are not yet available, but the following summary analyses show the essential characteristics of these oils.

Analyses of crude oil from the Rainbow City field
(Summary analyses of Rainbow City crude)

Gregory sand			
A. P. I. gravity	33.4	Flash point (°F) below	60°
Sulphur (per cent) S. D.	1.09	Pour point (°C)	20°
Gasoline (per cent)	27	Naphtha (per cent)	0
Tokio sand			
A. P. I. gravity	21.0	Flash point (°F)	110°
Sulphur (per cent) S. D.	1.49	Pour point, below	0
Gasoline (per cent)	0	Naphtha (per cent)	6.4

WATER CONDITIONS

Most of the wells made a considerable volume of water when first completed, and 25 to 75 per cent of the total fluid now lifted is salt water. The character of the water in the Gregory sand zone is shown in the following analyses.

Analysis of water from the Gregory sand in Murdock Dumas No. 2 well in sec. 11, T. 17 S., R. 14 W.

Properties of reaction	Per cent
Primary salinity	74.6
Secondary salinity	25.0
Secondary alkalinity	0.4
Chloride salinity	100.0

Constituents	Parts per million
Iron and aluminum oxides (Fe_2O_3, Al_2O_3)	76.0
Silica (SiO_2)	68.0
Calcium (Ca)	5,555.0
Sodium (Na)	21,875.0
Magnesium (Mg)	568.0
Chloride (Cl)	44,992.0
Bicarbonate (HCO_3)	275.0
Sulphate (SO_4)	28.0

	Reacting value	Per cent
Alkalies		
Sodium (Na)	951.0	10.9
Alkaline earths		
Calcium (Ca)	277.7	1.8
Magnesium (Mg)	46.7	1.8
Strong acids		
Sulphate (SO_4)	0.5	----
Chloride (Cl)	1,270.0	49.8
Weak acids		
Bicarbonate (HCO_3)	4.5	0.2
	2,550.4	100.0

Hypothetically combined as	Parts per million	Grains per U. S. gallon
Calcium bicarbonate ($Ca[HCO_3]_2$)	239.9	13.91
Calcium sulphate ($CaSO_4$)	33.8	1.96
Calcium chloride ($CaCl_2$)	15,064.0	873.20
Magnesium chloride ($MmCl_2$)	2,217.2	128.52
Sodium chloride (NaCl)	55,602.0	3,223.30
	73,300.0	4,240.89

Analysis of water from the Gregory sand in the Pure Oil Company's E. L. Gregory No. 2 well in sec. 11, T. 17 S., R. 14 W.

Properties of reaction	Per cent
Primary salinity	74.2
Secondary salinity	25.0
Secondary alkalinity	1.4
Chloride salinity	100.0

Constituents	Parts per million
Iron and aluminum oxides (Fe_2O_3, Al_2O_3)	48.0
Silica (SiO_2)	44.0
Calcium (Ca)	5,915.0
Sodium (Na)	23,620.0
Magnesium (Mg)	841.0
Chloride (Cl)	48,218.0
Bicarbonate (HCO_3)	192.0
Sulphate (SO_4)	30.0

	Reacting value	Per cent
Alkalies		
Sodium (Na)	1,027.0	37.1
Alkaline earths		
Calcium (Ca)	295.7	10.7
Magnesium (Mg)	69.0	2.5
Strong acids		
Sulphate (SO_4)	—	—
Chloride (Cl)	1,370.0	49.6
Weak acids		
Bicarbonate (HCO_3)	3.1	.1
	2,765.4	100.0

Hypothetically combined as	Parts per million	Grains per U. S. gallon
Calcium bicarbonate ($Ca[HCO_3]_2$)	746.0	43.24
Calcium sulphate ($CaSO_4$)	51.0	2.89
Calcium chloride ($CaCl_2$)	14,791.0	857.44
Magnesium chloride (MgCl)	3,287.0	190.58
Sodium chloride (NaCl)	60,040.0	3,480.57
	78,915.0	4,575.72

Analysis of water from the Gregory sand at depths of 3117-3137 *feet in the Pure Oil Company's E. F. Gregory No.* 9 *well in sec.* 11, *T.* 17 *S., R.* 14 *W.*

Properties of reaction	Per cent
Primary salinity	79.6
Secondary salinity	17.4
Tertiary salinity	4.8
Secondary alkalinity	17.4
Chloride salinity	100.0

Constituents	Parts per million
Iron and aluminum oxide (Fe_2O_3, Al_2O_3)	58.0
Silica (SiO_2)	84.0
Calcium (Ca)	760.0
Sodium (Na)	4,986.0
Magnesium (Mg)	122.0
Chloride (Cl)	9,859.0
Bicarbonate (HCO_3)	213.0
Sulphate (SO_4)	8.0

	Reacting value	Per cent
Alkalies		
Sodium (Na)	217.0	39.8

Alkaline earths		
Calcium (Ca)	38.0	6.9
Magnesium (Mg)	10.0	6.9
Strong acids		
Sulphate (SO_4)	.2	----
Chloride (Cl)	278.0	50.9
Weak acids		
Bicarbonate (HCO_3)	3.5	.6

Hypothetically combined as	Parts per million	Grains per U. S. gallon
Calcium bicarbonate ($Ca[HCO_3]_2$)	470.0	27.24
Calcium sulphate ($SaSO_4$)	13.6	0.79
Calcium chloride ($CaCl_2$)	816.2	47.89
Magnesium chloride ($MgCl_2$)	477.7	27.69
Sodium chloride (NaCl)	14,170.0	821.45
	15,947.5	925.06

Analysis of water from the Gregory sand at depths of 3170-3178 *feet in the Pure Oil Company's E. F. Gregory No.* 9 *well in sec.* 11, *T.* 17 *S., R.* 14 *W.*

Properties of reaction	Per cent
Primary salinity	75.0
Secondary salinity	25.6
Secondary alkalinity	2.6
Chloride salinity	100.0

Constituents	Parts per million
Iron and aluminum oxides (Fe_2O_3, Al_2O_3)	48.0
Silica (SiO_2)	54.0
Calcium (Ca)	6,464.0
Sodium (Na)	24,738.0
Magnesium (Mg)	622.0
Chloride (Cl)	50,118.0
Bicarbonate (HCO_3)	228.0

	Reacting value	Per cent
Alkalies		
Sodium (Na)	1,076.0	37.5
Alkaline earths		
Calcium (Ca)	323.2	11.3
Magnesium (Mg)	51.2	1.8
Strong acids		
Sulphate (SO_4)	----	----
Chloride (Cl)	1,415.0	49.3
	2,869.5	100.0

Hypothetically combined as	Parts per million	Grains per U. S. gallon
Calcium bicarbonate ($Ca[HCO_3]_2$)	1,179.1	67.77
Calcium sulphate ($CaSO_4$)	----	----
Calcium chloride ($CaCl_2$)	15,281.9	855.90
Magnesium chloride ($MgCl_2$)	3,057.6	177.25
Sodium chloride (NaCl)	62,849.5	3,643.46
	82,368.1	4,744.38

THE STEPHENS FIELD

LOCATION AND EXTENT

The Stephens field, named for the town of Stephens, is located in T. 15 S., R. 20 W., Columbia County, and T. 15 S., R. 19 W., Ouachita County. The Louann district of the Smackover field lies 12 miles to the east, and the Irma field, 12 miles to the northwest.

HISTORY OF DEVELOPMENT

The discovery well in the Stephens field, in the Hude and Aarnes Brown No. 1 well in sec. 13, T. 15 S., R. 20 W., was completed June 8, 1922, at a depth of 2,082 feet. The initial daily production was 33 barrels of 29.3° Baume oil in the Buckrange sand at a depth of 2,076 to 2,082 feet.

Before the discovery well in the Stephens field had been completed S. S. Hunter et al and the Standard Oil Company had drilled several wells north and east of that field in T. 15 S., R. 19 W. The S. S. Hunter et al Lester and Holton No. 1 well in sec. 13, T. 15 S., R. 19 W., was completed July 16, 1920. It produced a small quantity of oil from depths of 2,125 to 2,131 feet. This well proved to be drilled in the graben that limits the Stephens field on the north. The showing of oil in this well, said to be the first authentic showing obtained in a well in southern Arkansas, stimulated a search for oil that led to the discovery of the Stephens field.

The quantity of oil produced in the Stephens field in 1922 was 28,325 barrels, and the greatest production was during the year 1924, when the field produced 787,133 barrels. The greatest monthly production was made in August 1923, when it was 88,899 barrels, which compared with the output in August 1930, 27,094 barrels, shows in a general way the decline of production in the field.

TOPOGRAPHY

The Stephens field is drained by Smackover Creek, which flows eastward in a broad, flat valley that stands at an average altitude of 190 feet above sea level. The interstream areas are gently rolling hill lands that range in altitude from 240 to 290 feet above sea level. The higher points are in the western part of the field.

STRATIGRAPHY

GENERALIZED SECTION

The rocks at the surface in the Stephens field consist of massive light-colored to reddish sand, sandy clay, and thin bedded ferruginous clay belonging to the Claiborne group of the Eocene series. Some beds are hard and contain limonite. Deep wells in the field have penetrated all the formations of the Gulf series and more than 1,900 feet of the Trinity group of the Comanche series; and wells a short distance away from the field have penetrated an even greater thickness of the Trinity group. A generalized section of formations underlying this field is shown in Table 22.

CRETACEOUS SYSTEM

COMANCHE SERIES

The Comanche series is represented in the Stephens field by the Lower Glen Rose and Travis Peak formations and, probably, by a series of marine beds of Neocomian age below the Travis Peak formation. The Comanche rocks have been penetrated in several wells drilled in the field, but notably in the Hude and Aarnes' Brown No. 1 well in sec. 13, T. 15 S., R. 20 W., and in the Louisiana Oil Refining Corporation's Manley No. 1 well in sec. 15, T. 15 S., R. 19 W. The greatest thickness slightly more than 1,900 feet of beds, was recorded in the last named well, but the total thickness of the Comanche series in the Stephens field is estimated to be not less than 3,500 feet. The upper beds of the Comanche series were removed by erosion before the beginning of Upper Cretaceous sedimentation, and the basal beds of the Gulf series now rest unconformably on the Lower Glen Rose of the Trinity group.

TRINITY GROUP

TRAVIS PEAK FORMATION

The greatest thickness of these beds in this area is recorded in the Louisiana Oil Refining Corporation's Manley No. 1 well, which penetrated slightly more than 1,000 feet of beds between depths of 3,468 and 4,502 feet below the surface. (See Fig. 37.) These beds consist of generally fine to medium-grained sand and sandstone, sandy clays and clays. The beds of the upper 400 feet range in color from light-gray to brick-red, red being the dominant color. The beds of the lower 600 feet range from light-gray to pink and purplish-red and include subordinate beds of red. The sand members increase in thickness towards the base of the section. Thin beds of conglomerate were recorded at depths of 4,086 and 4,185 feet. The first of these beds was made up of limestone pebbles in a sand matrix, firmly cemented. The lower bed of conglomerate, cored at 4,185 feet, consisted of chert pebbles. The largest of these, 1.5 inches in

TABLE 22.—*Generalized section of formations in the Stephens field*

System		Group	Formation	Thickness in feet	Character
Tertiary	Eocene	Claiborne	Undifferentiated	300-400	Sand, sandy clay, and ferruginous sand and clay. Some glauconitic sand at base
Cretaceous	Gulf	Navarro	Wilcox	550	Light-colored to brown sand, sandy clay, and clay. In part lignitic. Nonmarine
			Midway clays	500	Gray noncalcareous clay and shale. Lower 50 feet gray and dark-blue shale, with fossils
			Unconformity		
			Arkadelphia clays	90-100	Dark-gray to black shale; in part chalky
			Nacatoch sand	315	Sand and sandy shale, calcareous sandstone, and sandy limestone. Lower 100 feet gray shale
			Saratoga chalk	15-30	Gray and white chalk
		Taylor	Marlbrook marl	250	Gray marl and shale; in part chalky
			Annona chalk		White and bluish-gray chalk
			Ozan formation (Buckrange sand at base)	150-160	Gray shale and fine sandy shale. Buckrange sand (20 to 30 feet) at base
			Brownstown marl	100	Medium-gray to dark-gray shale and fine-textured sandy shale and sand
		Austin	Tokio and Woodbine sand	350-400	Gray shale, sandy shale, and sand. Some glauconite and volcanic ash
					Arkosic sand with matrix of volcanic ash
	Comanche		Unconformity		
		Washita	Absent		
		Fredericksburg	Absent		
		Trinity	Lower Glen Rose	825-950	Gray and greenish-gray shale. Some red and brown shale. Argillaceous limestone and sand
			Travis Peak	1500+	Light-gray to brick-red generally fine-grained sand and sandstone. Gray to red shale, clay and sandy clay. Full thickness not penetrated in Stephens field

diameter, was in a matrix of calcareous sand. It is estimated that the Travis Peak formation is from 1,800 to 2,000 feet thick in the Stephens field.

GLEN ROSE FORMATION

The Glen Rose formation is represented in the Stephens field by the Lower Glen Rose, consisting of fine-grained sand, sandstone, sandy shale, mudstone and sandy and argillaceous limestone. It is 900 to 1,000 feet thick. In physical appearance it bears some resemblance to the part of the Trinity formation at the outcrop in southwestern Arkansas, which includes the De Queen and the Dierks limestone members.

The most detailed section was obtained from the Louisiana Oil Refining Corporation's Manley No. 1 well in sec. 15, T. 15 S., R. 19 W., which penetrated 835 feet of beds of Lower Glen Rose age. (See Fig. 37.) The upper 375 to 400 feet of beds consisted mainly of fine-grained gray to green and purplish-gray sand and sandstone; red, brown, and greenish-gray clay; shale; and sandy shale; and subordinate beds of sandy limestone. The beds in the lower 500 to 525 feet are made up of green and gray mudstone, shale and sandy shale, some brown and red clay, and thin beds of sandy, earthy limestones and subordinate beds of sand and sandstone. The limestone is in part oolitic.

A few marine fossils have been obtained from the limestone members in the lower half of the formation. *Astarte pikensis*, *Ostrea sp.* and *Corbula sp.* have been recognized.

A typical core record of the Glen Rose and Lower Trinity formation is given as follows:

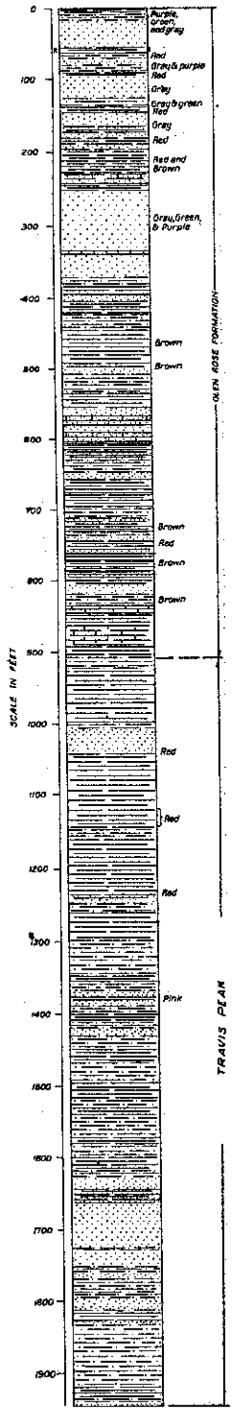


FIGURE 37.—Section of Trinity rocks penetrated in Louisiana Oil Refining Company's Manley No. 1 well, sec. 15, T. 15 S., R. 19 W., East Stephens field. Figures give depth below the Glen Rose formation.

Section of Trinity rocks recorded in Louisiana Oil and Refining Company's Manley No. 1 well in sec. 15, T. 15 S., R. 19 W.

Character	Depth in feet
Glen Rose formation:	
Hard red shale (Core 2635-2640 feet, mottled gray and pink, fine-textured sandstone; core 2640-2645 feet, light-gray, fine-textured sandstone mottled with brown)	2635–2646
Blue shale and streaks of sand (Core 2645-2650 feet, mottled brown, gray and purple sandy clays; core 2650-2652 feet, pale greenish-gray calcareous sandstone; core 2652-2654 feet, light-gray calcareous clay balls in a matrix of fine-textured sands)	2646–2657
Red shale (Core 2654-2660 feet, brick-red sand; sand and broken shale; core 2661-2686 feet, light-gray fine-grained sandstone)	2657–2686
Broken red shale (Core 2686-2689 feet, light-gray fine-grained sandstone and greenish-gray clay; core 2689-2696 feet, mottled brick-red and gray fine sandy clay; core 2696-2706 feet, brick-red fine sandy shale)	2686–2706
Red bed	2706–2712
Sand	2712–2722
Hard broken sand	2722–2738
Sand (Core 2712-2725 feet, light-gray fine-textured calcareous sandstone; core 2727 feet, interlaminated very fine-grained sandstone and shale; core 2735-2742 feet, light-gray fine-grained calcareous sandstone)	2738–2743
Red bed (Core 2743-2750 feet, reddish-brown mudstone; core 2750-2755 feet, mottled purple and yellow fine-textured sandstone; core 2755-2760 feet, mottled brick-red and gray clays; core 2760-2765 feet, brick-red clays; core 2775-2780 feet, yellow and brown fine sandy clays)	2743–2786
Sandy shale (Core 2784-2790 feet, greenish-gray shale containing numerous shell fragments and much pyrite)	2786–2794
Sandy limestone	2794–2799
Sand (Core 2790-2803 feet, light-gray calcareous, fine-grained sandstone)	2799–2803
Black shale and sand (Core 2803-2811 feet, medium-gray, noncalcareous shale)	2803–2811
Blue sandy shale (Core 2811-2817 feet, mottled pale-green and light gray fine-textured sandstone)	2811–2817
Soft blue sand (Core 2817-2822 feet, pale-green, fine-grained sandstone)	2817–2822
Red and blue sandy shale (Core 2822-2828 feet, medium gray, fine-grained sandstone)	2822–2828
Gray sandy shale and lignite (Core 2828-2836 feet, light to dark-gray, fine-grained sandstone, in part lignitic)	2828–2836
Red and blue sandy shale	2836–2840
Hard red shale (Cores 2836-2850 feet, purple, fine-grained sandstone)	2840–2850
Broken red shale	2850–2875
Soft sand	2875–2894
Hard shale (Core 2875-2894 feet, light-gray fine-grained sandstone; core 2894-2900 feet, medium-gray limestone containing shell fragments)	2894–2900
Shale and shells	2900–2910
Red shale	2910–2911
Oil sand	2911–2917

Red and blue shale (Core 2900-2914 feet, mottled purple and gray fine-grained sandstone)	2917–2929
Fine-grained sandstone (Core 2919-2931 feet, purple clay and mottled and purple and yellow, fine-grained sandstone)	2929–2931
Red and blue shale (Core 2931-2945 feet, purple sandstone and laminated dark-gray shale and sand; core 2945-2948 feet, medium-gray, finely sandy clay with pockets and patches of fine-textured sand; core 2948-2955 feet, gray sandy and argillaceous limestone, shell fragments; core 2955-2956 feet, light-gray fine-textured sandstone; core 2956-2964 feet, gray, fine-grained sandstone mottled with purple; core 2964-2975 feet, purple, finely sandy clays and shale; core 2975-2983 feet, mottled purple and gray finely sandy shale)	2931–2983
Red shale	2983–2997
Gumbo	2997–3000
Shale and streaks of sand	3000–3010
Hard, gray shaly limestone (Core 3030 feet, light-brown, dense limestone)	3010–3030
Sandy lime	3030–3045
Hard sandy shale	3045–3055
Hard sand (Core 3060-3064 feet, light-gray, mottled with rusty-brown, fine-grained sandstone)	3055–3064
Shale	3064–3068
Red and blue shale (Core 3094-3117 feet, olive-green calcareous clays containing some fine sand and shell fragments; core 3117-3118 feet, brown silty shale)	3068–3120
Hard lime	3120–3125
Hard sandy lime (Core 3119-3125 feet, light-brown, calcareous fine-grained sandstone; core 3125-3130 feet, alternating thin beds of dark and light-gray arenaceous, oolitic limestone; core 3130-3140 feet, light and medium-gray arenaceous and argillaceous limestone, shell fragments; core 3140-3145 feet, light-gray fine-grained calcareous sandstone and hard, gray, sparsely oolitic limestone; core 3145-3150 feet, light-gray calcareous fine-grained sandstone; core 3150-3164 feet, light-gray, impure limestone with partings of green fine-textured sandstone)	3125–3164
Hard green limestone (Core 3164-3167 feet, gray, dense limestone; shell fragments; core 3167-3178 feet, gray and greenish-gray calcareous shale; shell fragments; core 3178-3181 feet, greenish-gray, calcareous, very fine-grained sandstone)	3164–3181
Blue gummy shale (Core 3181-3183 feet, gray clay with thin streaks of light-gray sands)	3181–3183
Sandy lime (Core 3183-3186 feet, gray calcareous shale; shell fragments; core 3186-3189 feet, gray, calcareous clay sandstone)	3183–3193
Hard shale (Core 3189-3194 feet, gray claystone; core 3194-3199 feet, greenish-gray clay with interlaminated fine-grained gray sandstone)	3193–3199
Lime and shale (Core 3199-3208 feet, gray sandy shale with thin stringers of light-gray calcareous sandstone; core 3208-3209 feet, light-gray calcareous fine-grained sandstone)	3199–3215

Sandy lime	3215–3223
Hard shale (Core 3211-3216 feet, gray calcareous fine grained sandstones, shell fragments; core 3217-3230 feet, greenish-gray silty clay and shale; core 3230-3231 feet, gray, argillaceous limestone; *Ostrea* fragments)	3223–3231
Shale and lime (Core 3231-3235 feet, gray, argillaceous limestone; core 3235-3237 feet, gray calcareous silty shale, *Astarte pikensis* ?; core 3237-3240 feet, gray earthy limestone; shell fragments; core 3240-3247 feet, brownish-gray silty clays; containing a few casts of pelecypoda)	3231–3265
Lime and shale (Core 3280-3288 feet, chocolate-colored mudstone; core 3296-3300 feet, mottled reddish-brown and gray argillaceous fine-grained sandstone; core 3300-3308 feet, dull reddish-brown silty clay)	3265–3311
Red and blue shale (Core 3308-3314 feet, gray, yellow and brown shale; core 3314-3316 feet, gray, fine-grained sandstone; core 3318-3328 feet, medium-gray, earthy limestone containing *Astarte pikensis, Corbula sp.* and small *Ostrea sp.;* core 3328-3334 feet, medium-gray, calcareous silty shale; core 3334-3337 feet, gray argillaceous limestone)	3311–3337
Brown shale and streaks of lime (Core 3334-3340 feet gray and brown silty shale and gray earthy limestone)	3337–3354
Hard sand (Core 3347-3355 feet, hard gray slightly calcareous shale)	3354–3360
Broken red shale (Core 3355-3364 feet, white, fine-grained sandstone; core 3364-3396 feet, brown and purple silty shale)	3360–3400
Hard shale and streaks of lime (Core 3396-3404 feet, gray, calcareous shales and earthy limestone *Ostracods*)	3400–3406
Hard lime	3406–3445
Hard shale and streaks of lime	3445–3454
Hard lime	3454–3468

Travis Peak formation:

Shale and streaks of lime	3468–3520
Hard lime and sandy lime	3520–3545
Red shale	3545–3558
Red and black shale (Core 3560-3565 feet, medium-gray, fine-grained, sandstone)	3558–3565
Hard red shale	3565–3592
Red and blue shale (Core 3592-3598 feet, medium-gray sandstone)	3592–3602
Shale	3602–3644
Lime	3644–3654
Red shale (Core light greenish-gray silty clay)	3654–3659
Hard shale and lime	3659–3688
Hard shale and sandy shale (Core 3692-3698 feet, light-red medium-grained sandstone; core 3698-3705 feet, gray and reddish-brown clay in alternating thin bands)	3688–3708
Red shale and streaks of lime	3708–3791
Sand	3791–3806
Gummy shale (Core 3794-3796 feet, finely banded reddish-brown and gray clay; core 3796-3807 feet, pink sandstone with small patches of calcareous sand; core 3807-3808 feet, light-gray, fine-grained sandstone)	3806–3808

Sand	3808-3820
Red and blue shale	3820-3921
Hard sand	3921-3937
Sandy shale (Core 3936-3940 feet, mottled purple and gray shales; core 3940-3946 feet, brick-red, very fine-grained sandstone)	3937-3946
Red and blue shale	3946-4084
Hard sandy lime (Core 4086-4087 feet, conglomerate made up of limestone pebbles up to half an inch in diameter in a sand matrix; core 4087 feet, purple silty clay)	4084-4087
Rock sand	4087-4092
Shale	4092-4094
Broken red sandy shale	4094-4110
Hard sand	4110-4111
Red sandy shale	4111-4125
Hard sand	4125-4130
Sandy shale	4130-4135
Red sandy shale (Core 4130-4140 feet, purple clay)	4135-4154
Hard shale and lime	4154-4173
Broken sandy shale (Core 4185 feet, purplish conglomerate made up chiefly of chert pebbles up to 1½ inch in diameter in a matrix of calcareous sandstone)	4173-4185
Hard red sand	4185-4198
Shale (Core 4185-4202 feet, purple sandstone)	4198-4202
Hard sand and broken sand (Core 4207-4222 feet, mottled green and gray clay and pink sandstone; core 4222-4235 feet, mottled purple and green sandstone; core 4239-4245 feet, pale-pink sandstone; core 4245-4259 feet, mottled purple and green slightly calcareous, fine-grained sandstone; core 4259-4270 feet, light-gray, pink, and purple fine-grained sandstone)	4202-4275
Red shale with streaks of hard sand (Core 4263-4283 feet, light-gray and purple sandstone)	4275-4295
Hard sand and shale	4295-4311
Hard red shale and sand (Core 4310-4318 feet, mottled purple and yellow sandy clay and light-gray sandstone; core 4318-4325 feet, light-pink, friable sandstone; core 4433 feet, mottled purple and yellow sandstone; core 4349-4353 feet, gray shale with laminae of fine sand)	4311-4369
Hard shale and sand (Core 4367-4375 feet, light-gray sandstone; core 4375-4385 feet, light-pink friable sandstone, and light-gray clay with siderite pellets)	4369-4386
Hard shale	4386-4403
Hard sand	4403-4421
Sandy shale	4421-4427
Hard sand	4427-4439
Hard sand with streaks of shale	4439-4455
Hard sand	4455-4473
Hard shale and streaks of lime	4473-4493
Hard sand (Core 4502 feet, light-gray sandstone)	4493-4502

GULF SERIES (UPPER CRETACEOUS)

A section of Upper Cretaceous formations in the Stephens field is shown in Figure 38.

TOKIO FORMATION AND WOODBINE SAND

The few wells in the Stephens field that have passed through the basal beds of the Gulf series have supplied but a partial record of the lithology of these strata. The total thickness of the Tokio formation and the Woodbine sand is from 350 to 400 feet, with the larger thickness in the southwestern part of the area.

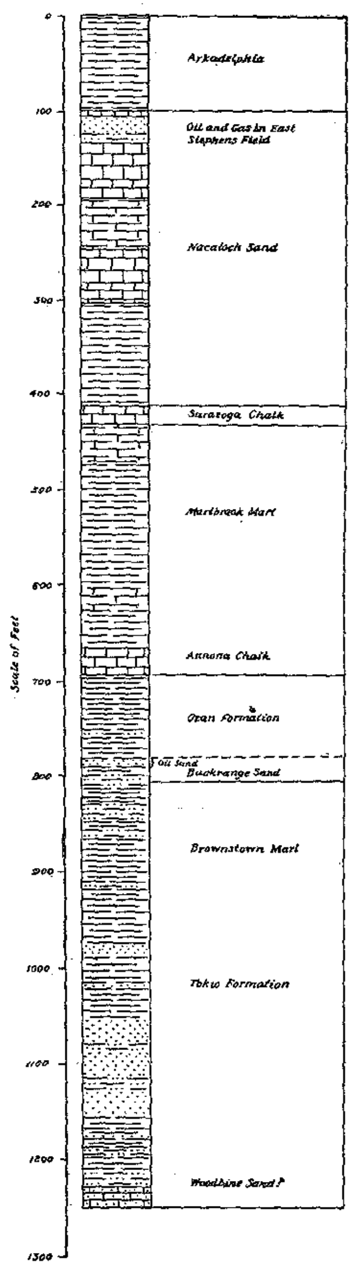


FIGURE 38.—Section of Upper Cretaceous formations in Stephens field.

The upper beds are composed of generally gray and greenish-gray sands and sandstones interbedded with gray shales and sandy shales. These beds are in part lignitic and contain some volcanic materials and lentils of gravel at the base. The basal 100 to 125 feet of beds consists principally of gray to green, generally tuffaceous sandstone, with subordinate beds of shale and clays, which in places are pink, reddish-brown, and purple in color.

BROWNSTOWN MARL

The Brownstown marl is 90 to 100 feet thick, composed of gray shales, marls, and sandy shale with thin lentils of glauconitic sandstone.

OZAN FORMATION

The Ozan formation is composed of gray to greenish-gray shales, marls and sandy shales. The upper 15 to 20 feet of beds are thin sandstones interbedded with sandy shale, yielding shows of oil in many places within the field. The lower 15 to 20 feet of beds are included in the Buckrange sand, the basal member of the Ozan formation, including the Buckrange sand is 150 to 160 feet thick in the Stephens field.

MARLBROOK MARL AND ANNONA CHALK

The Marlbrook marl is composed of generally light-colored clays and marls, in part chalky, which in the lower part grade into gray and white chalks of Annona age. Their total thickness is 250 feet in this area.

SARATOGA CHALK

The Saratoga chalk, composed of hard gray and white chalk is 15 to 30 feet thick in the area of the Stephens field.

NACATOCH FORMATION

The Nacatoch formation consists of three more or less well-defined members. The upper 10 to 35 feet of beds is composed of sandy shale interbedded with generally soft sands. The intermediate member, 150 to 175 feet thick, consists chiefly of calcareous sandstone and arenaceous limestone with subordinate thin beds of shale; the lower 100 feet of beds consists of gray and blue shales. The total thickness of the Nacatoch formation is 300 to 315 feet.

ARKADELPHIA MARL

The Arkadelphia marl, 75 to 100 feet thick, is composed of dark-gray calcareous shale and marl.

TERTIARY SYSTEM

EOCENE SERIES

MIDWAY CLAYS

The Midway consists chiefly of noncalcareous gray and blue clays containing an abundance of siderite concretions. The basal 25 to 50 feet of beds are calcareous and fossiliferous. The Midway clays are 500 to 550 feet thick in the Stephens field.

WILCOX FORMATION

The Wilcox formation in the Stephens field is made up of sands, sandy clays, and clays which are in part lignitic. In general the basal 150 to 175 feet of beds are gray sandy clays with sands at the base. These beds are overlain by 250 to 300 feet of massive light-colored sands. Resting upon the massive sand member is 75 feet of gray clays characterized by an abundance of limonite and siderite concretions. The uppermost 100 feet of beds consists of gray micaceous and lignitic sands.

The total thickness of the Wilcox formation is 500 to 550 feet.

CLAIBORNE GROUP

The Claiborne beds in the Stephens field are 300 to 400 feet thick and consist of massive sands in which are included thin beds of clays, containing glauconite and concretions of limonite and siderite. The basal beds consist of glauconitic sand and clays.

PRODUCING HORIZONS

BUCKRANGE SAND

The Buckrange sand, the basal member of the Ozan formation, is the correlative of the Graves sand in the Smackover field and the producing sand of the Haynesville, Louisiana, field. It is commonly designated as the Blossom sand by the drillers, based on an erroneous correlation of the sand with the Blossom sand of Texas.

The Buckrange sand in the Stephens field is from 30 to 50 feet thick, made up of alternating beds of sands and sandy shales. The oil is obtained from the uppermost 5 to 10 feet of beds. The sand is made up of fine to medium-textured generally subrounded quartz grains, with some grains of glauconite, fine particles of mica and fine particles of igneous rock. The porosity is uniformly low, but variable, depending on the amount of secondary cementation and the amounts of argillaceous material it contains. In the main part of the Stephens field the sand is fairly uniform in character and thickness but decreases in porosity and in thickness to the west, and by reason of this change determines the limits of the producing area in that direction. The Buckrange sand in the Stephens field lies from 1,890 to 1,960 feet below sea level.

NACATOCH SAND

The Nacatoch sand has yielded shows of oil and gas in the main part of the Stephens field, and a few small oil and gas wells in the area east of the town of Stephens, but is not an important producing horizon.

The oil and gas are obtained from the uppermost 15 feet of the Nacatoch sand which is made up of thi nalternating beds of sands and clays. The depths to the top of the Nacatoch sand range from 1,150 to 1,300 feet below sea level.

STRUCTURE

The surface expression of the structure of the Stephens field is not easily determined owing to the slight structural relief and to the character of the strata exposed at the surface.

SUBSURFACE STRUCTURE

The structure of the Stephens field and the adjacent area is generalized in Figure 39. The contour lines are drawn on the top of the Nacatoch sand at intervals of 50 feet. The structure is a terrace or structural nose which is limited on the north by a graben. The regional dip is to the south and the southeast. The faults that define the graben have a general northwest trend and the graben is about 2 miles wide. The displacement of the faults is not less than 250 feet to the north of the field but decreases to a few feet in the area northwest of the field. In the area southeast of the field the data are not sufficient to permit an estimate of the displacement. The dip of the fault planes are not readily determined because of lack of accurate data, but probably approximate 45 degrees.

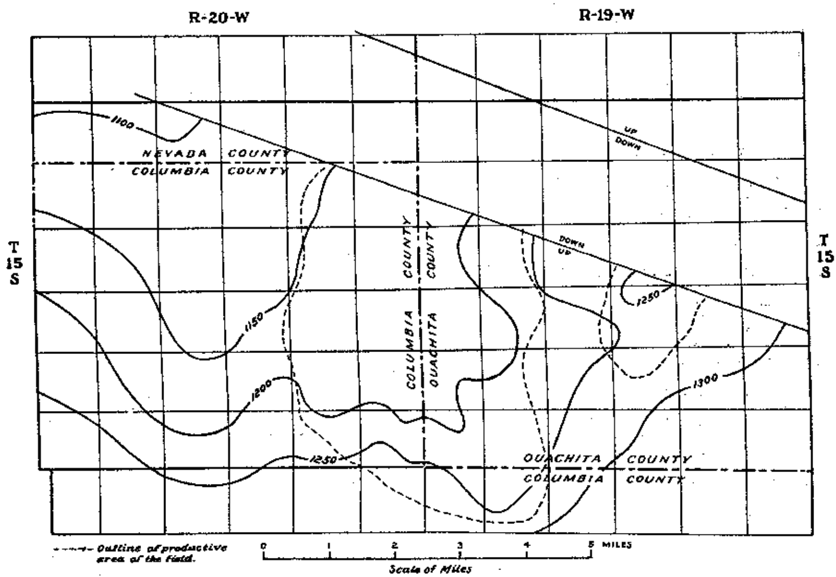


FIGURE 39.—Structure contour map of region around the Stephens field. Contours drawn on top of Nacatoch sand. Contour interval 50 feet. Figures give depth below sea level.

The structure of the main producing area is shown in detail in Plate XXII. The contour lines are drawn on top of the Buckrange sand at intervals of 20 feet. Mapped in detail, the structure is a low-dipping, southeastward-plunging structural nose. The dips along the axis range from 15 to 25 feet per mile but increase toward the south and north to 50 and 75 feet per mile.

The structure of what is commonly called the "East Stephens field" is shown in Figure 40. The contour lines are drawn on top of the Nacatoch sand at intervals of 10 feet. By using the smaller contour interval it is possible to show a contour line closing against the fault.

STRUCTURE OF THE COMANCHE SERIES

The structure of the Comanche strata differs essentially from the structure of the Upper Cretaceous and Tertiary strata owing to the unconformity that separates the Comanche from the Gulf series. As only a few deep wells have been drilled into these beds, it is not possible to determine the structure in detail, but it is generalized in Plate XII. This map suggests that the beds dip to the southwest at the rate of 75 to 90 feet per mile.

RELATION OF STRUCTURE TO ACCUMULATION OF OIL AND GAS

The accumulation of oil in the Stephens field may have been determined by the gentle arching of the strata inclosing the oil and gas-producing sands. The local distribution of the oil, how-

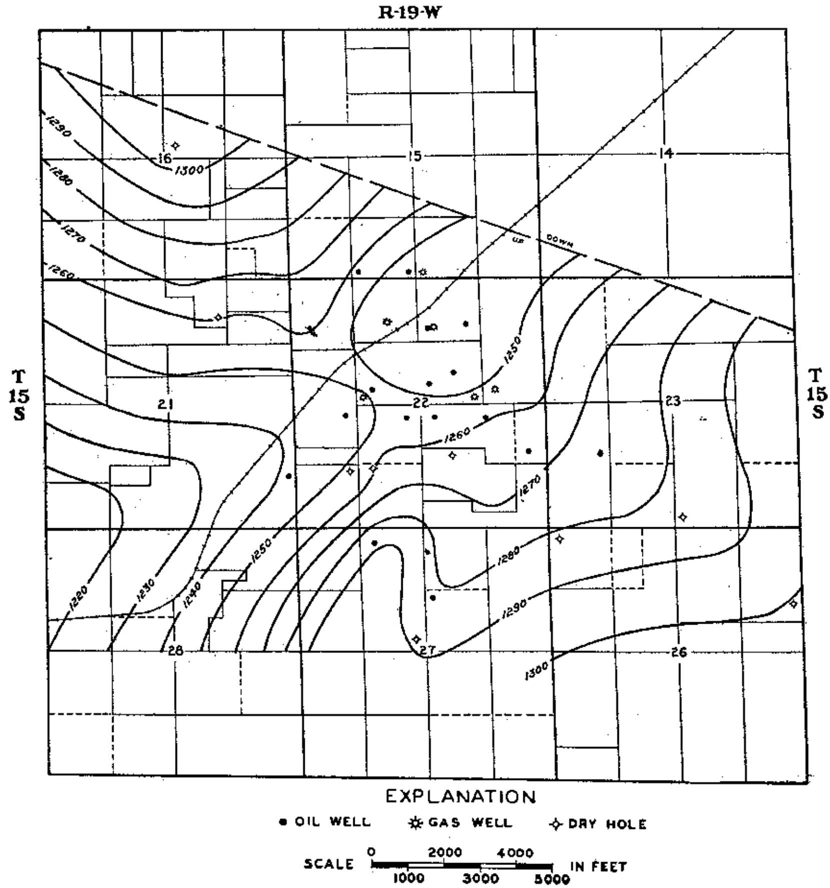


FIGURE 40.—Structure contour map of East Stephens field. Contours drawn on top of Nacatoch sand. Interval 10 feet. Figures give depth below sea level.

ever, appears to have been determined by the character of the reservoir rocks, chiefly by its lenticular structure and by its lateral gradation from sand to argillaceous sand.

PRODUCTION

PRODUCTIVE AREA

The total area capable of producing oil in the Stephens field cannot easily be determined, for, owing to the small initial production of the wells, the field was not drilled according to a definite plan of well spacing. On the leases that were completely drilled, the wells were spaced to give 10 acres per well, and, in order to determine a representative acre yield for the field, it has been assumed that the producing area includes 10 acres for each well drilled. On that basis the producing area is 2,850 acres.

THE PRODUCING SANDS

BUCKRANGE SAND

The principal producing sand in the Stephens field is the Buckrange sand, the basal member of the Ozan formation. This sand is also called the "Stephens sand" and "Blossom sand." It is correlated with the Graves sand of the Smackover field and with the producing sand of the Haynesville field in Louisiana. The Buckrange sand member in the Stephens field is from 30 to 50 feet thick and is made up of alternating beds of sands and sandy shale. The oil is obtained from the upper 5 to 10 feet of sand which consists of small, generally subrounded grains of quartz, some grains of glauconite, fine particles of igneous rock and fine flakes of mica. Its porosity is uniformly low but variable, depending upon the quantity of argillaceous matter it contains and on the degree of secondary cementation. The depths to the top of the Buckrange sand in the producing area range from 1,890 to 1,960 feet below sea level.

NACATOCH SAND

The Nacatoch sand has yielded shows of oil and gas in wells drilled in the main part of the Stephens field but not in commercial quantities. In the area east of the town of Stephens some oil and gas are produced from the uppermost 15 feet of the Nacatoch sand, which consists of alternating thin beds of sand and shale. The sand is reached at depths ranging from 1,150 to 1,300 feet below sea level.

PRODUCTION 1922 TO 1933, INCLUSIVE

The initial production of the wells in the Stephens field was low compared with that of other fields in Arkansas. The Buckrange sand yielded wells with an initial production of 75 to 100 barrels a day, but the average was about 25 barrels a day. It is worthy of note that no gas was produced from the Buckrange sand. The wells in the Nacatoch sand had higher initial productions, ranging from 50 to 400 barrels a day. The gas wells had initial yields from 3,000,000 to 15,000,000 cubic feet a day.

A total of 289 wells was completed; 283 oil and 6 gas wells. In December 1933, the field had 177 producing wells, all in the Buckrange sand, which produced 17,444 barrels, an average daily production of slightly more than 3 barrels per well.

The total production to January 1, 1934, was 4,816,057 barrels. This production distributed by years is given below:

Oil produced in the Stephens field from 1922 to 1933, inclusive

Year	Barrels*	Year	Barrels*
1922	28,325	1929	363,533
1923	625,218	1930	315,937
1924	787,133	1931	272,368
1925	642,967	1932	167,401
1926	552,131	1933	141,296
1927	501,674		
1928	418,074		4,816,057

* Pipe-line runs.

With an estimated productive area of 2,850 acres the average yield to the end of 1933 is 1,700 barrels per acre.

ESTIMATED FUTURE PRODUCTION

The future production of the Stephens field, as estimated from production decline curves and rate cumulative curves, is shown in Figure 41, prepared by Roy T. Hazzard. These future estimates are made assuming that present production methods are unchanged. The estimated yearly production over a period of seven years and the oil reserves to the end of 1940 are given as follows:

Estimated future production in the Stephens field from 1934 to 1940

Year	Barrels	Year	Barrels
1934	209,000	1938	158,000
1935	192,000	1939	148,000
1936	180,000	1940	139,000
1937	168,000		
			1,194,000

Oil reserves of the Stephens field

	Barrels
Oil recovered to January 1, 1934	4,816,057
Estimated future production to end of 1940	1,194,000
Total ultimate oil recovery to the end of 1940	6,010,057

Assuming the producing area of the Stephens field to be 2,850 acres, the acre yield to the end of 1933 is 1,690 barrels and the estimated total recovery per acre is 2,112 barrels to the end of 1940.

METHOD OF DRILLING

The rotary method of drilling was used in the Stephens field, and neither the drilling nor the completion of the wells presented any notable difficulty. The common practice was to set 100 to 150 feet of 10-inch casing to exclude the surface waters. The wells completed in the Buckrange sand set 1,975 to 2,025 feet of 6-inch casing and the wells were completed with 70 to 90 feet of 4½-inch blank and 35 to 45 feet of 4½-inch perforated liner.

In the wells completed in the Nacatoch sand 1,450 to 1,510 feet of 6-inch casing were set and the wells were completed with 40 to 100 feet of 4½-inch liner.

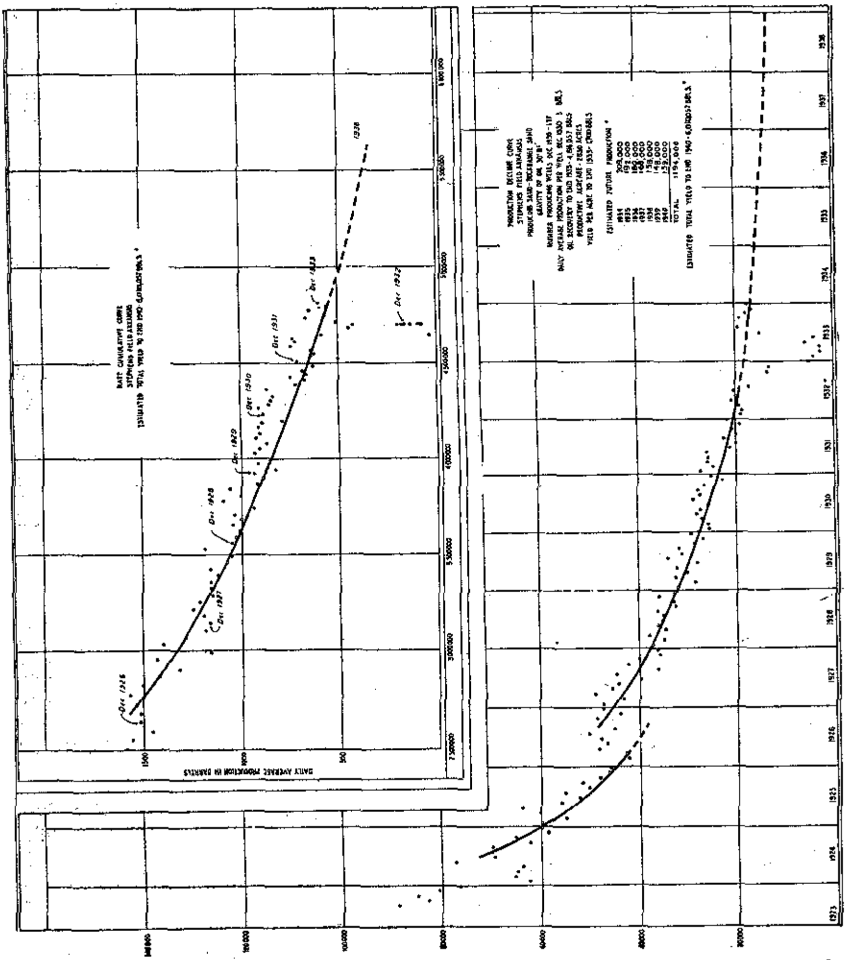


FIGURE 41.—Rate-cumulative curve and production-decline curve, Stephens field, Arkansas. Future estimates made assuming present production methods unchanged.

PROPERTIES OF CRUDE OIL IN THE STEPHENS FIELD

The properties of the oil in the Stephens field follow:

Sample No. 281001, Mark A. Stephens field, Ouachita County Arkansas, Nacatoch sand, Well No. 3, sec. 21, *T.* 15 *S., R.* 19 *W.*

Specific gravity	0.877	Saybolt Universal viscosity at 100° F.	80 sec.
A. P. I. Gravity	29.9	Percentage of water	0.7
Percentage of sulphur	1.63	Pour point	below 5° F.
Saybolt Universal viscosity at 70° F.	130 sec.	Color	brownish black

Distillation by Bureau of Mine (Hempel method)

Temperature (°F)	Per cent cut	Sum per cent	Sp. gr. cut	°A. P. I. cut	Viscosity at 100°F.	Cloud Test (°F)	Temperature (°F)
AIR DISTILLATION BAROMETER, 744 MM. FIRST DROP, 49 C. (120°F.)							
Up to 5							Up to 122
50-75	4.7	4.7	0.683	75.7			122-167
75-100	3.9	8.6	.707	68.6			167-212
100-125	1.1	9.7					212-257
125-150	3.5	13.2	.736	60.8			257-302
150-175	4.0	17.2	.758	55.2			302-347
175-200	4.2	21.4	.778	50.4			347-392
200-225	4.4	25.8	.795	46.5			392-437
225-250	4.6	30.4	.810	43.2			437-482
250-275	5.8	36.2	.826	39.8			482-527
VACUUM DISTILLATION AT 40 MM.							
Up to 200	4.1	4.1	0.851	34.8	41	10	Up to 392
200-225	5.3	9.4	0.858	33.4	45	25	392-437
225-50	5.6	15.0	0.874	30.4	57	45	437-82
250-75	5.8	20.8	0.890	27.5	80	65	482-527
275-300	5.7	26.5	0.901	25.6	130	80	527-72

Residuum, per cent 36.9

Carbon residue of residumm, per cent 15.1

Distillation loss, per cent 0.4

Carbon residue of crude, per cent 5.6

APPROXIMATE SUMMARY

	Percentage	Specific gravity	A. P. I.	Viscosity
Light gasoline (end-point,212°F)	8.6	0.694	72.4	
Total gasoline and naphtha	21.4	0.731	62.1	
Kerosene distillate	9.0	0.803	44.7	
Gas oil	15.0	0.844	36.2	
Nonviscous lubricating distillate	11.0	0.865–0.894	32.1–26.8	50–100
Medium lubricating distillate	6.3	0.894–0.906	26.8–24.7	100–200
Viscous lubricating distillate	0.0			Above 200
Residuum	36.9	0.985	12.2	
Distillation loss	0.4			

Sample No. 281002, Mark B: Arkansas, Stephens field, Ouachita County, Nacatoch sand sec. 21, *T.* 15 *S., R.* 19 *W., well No.* 1

Specific gravity 0.982

A. P. I. gravity 12.60

Percentage of sulphur 2.87

Saybolt Universal viscosity at 70° F. .... sec.

Saybolt Universal viscosity at 100° F. .... above 2,000 sec.

Percentage of water 29.2

Pour point .... 25 F.

Color .... brownish-black

Distillation: Bureau of Mines—Hempel Methods

Temperature (°F)	Per cent cut	Sum per cent	Sp. gr. cut	°A. P. I. cut	Viscosity at 100°F.	Cloud Test (°F)	Temperature (°F)
AIR DISTRIBUTION.	BAROMETER, 745 MM. FIRST DROP, 230° C. (446°F.)						
Up to 50	----	----	----	----	----	----	Up to 122
50-75	----	----	----	----	----	----	122-67
75-100	----	----	----	----	----	----	167-212
100-125	----	----	----	----	----	----	212-57
125-50	----	----	----	----	----	----	257-302
150-75	----	----	----	----	----	----	302-47
175-200	----	----	----	----	----	----	347-92
200-225	----	----	----	----	----	----	392-437
225-50	2.0	2.0	----	----	----	----	437-82
250-75	5.4	7.4	0.860	33.0	----	----	482-527
VACUUM DISTILLATION AT 40 MM.							
Up to 200	1.9	1.9	0.889	27.7	45	Too	Up to 392
200-225	6.5	8.4	0.895	26.6	54	dark	392-437
225-50	6.4	14.8	0.913	23.5	75	to	437-82
250-75	7.7	22.5	0.929	20.8	135	obtain	482-527
275-300	6.1	28.6	0.942	18.7	260	cloud	527-72

Residuum, per cent 63.1
Carbon residue of residuum, per cent 16.5
Distillation loss, per cent 0.9
Carbon residue of crude, per cent 10.4

APPROXIMATE SUMMARY

	Percentage	Specific gravity	A. P. I.	Viscosity
Light gasoline (end-point, 212°F.)	0.0	----	----	----
Total gasoline and naphtha	0.0	----	----	----
Kerosene distillate	0.0	----	----	----
Gas oil	10.8	0.869	31.3	----
Nonviscous lubricating distillate	11.1	0.892–0.920	27.1–22.3	50–100
Medium lubricating distillate	7.7	0.920–0.936	22.3–19.7	100–200
Viscous lubricating distillate	6.4	0.936–0.947	19.7–17.9	Above 200
Residuum	63.1	1.006	----	----
Distillation loss	0.9	----	----	----

WATER CONDITIONS

The oil and gas-producing horizon in the Nacatoch sand was underlain by water and the wells produced a considerable volume of water a short time after completion.

The Buckrange sand contained no water and the wells at the present time are producing no measurable quantity of water, although some of the wells in the field show from 1 to 2 per cent of basic sediments at this time.

THE IRMA FIELD

LOCATION AND EXTENT

The Irma oil field, named for the town of Irma, which is situated 2 miles northwest of the field, is in T. 14 S., R. 21 W., and T. 14 S., R. 20 W., in Nevada County. The producing area is 4 miles long from northeast to southwest and has an average width of half a mile. The producing area is about 640 acres.

The Irma oil field has been described in detail by Teas[16] in a report from which many of the facts here stated have been obtained. Some additional facts have been incorporated in the present bulletin, but only minor changes in the thickness assigned to certain formations by Teas have been made.

HISTORY AND DEVELOPMENT

The discovery well of the Irma field, the Ames and Zengy T. P. Waters No. 1 well, drilled in the center of the west side of the NW¼ of sec. 11, T. 14 S., R. 21 W. ,was completed October 17, 1921. The top of the Nacatoch sand was struck at a depth of 1,166 feet, and the well was completed at a depth of 1,192 feet. After the well had been bailed, oil of 14.4° Baume slopped over the casing head at the rate of 5 barrels a day until March 1923, when it was standardized and pumped at the rate of 25 barrels a day. A total of 137 wells was drilled in the field, of which 128 wells produced oil and 9 produced gas. On January 1, 1929, there were 73 oil-producing wells with an estimated daily capacity of 1,570 barrels, an average of 21½ barrels per well.

TOPOGRAPHY

The topography of the Irma field is shown on the United States Geological map of the Gurdon quadrangle. The field lies in an upland area, where the tops of the ridges stand 350 to 375 feet above sea level. The broad valleys of the streams stand 225 to 250 feet above sea level, so that the total relief is 150 feet. Caney Creek flows northward across the central and structurally highest part of the field; a branch of Sanders Creek, a tributary of Caney Creek, traverses the west end of the field; Black Creek, which flows northwestward into Caney Creek, drains the eastern part of the field.

STRATIGRAPHY

The Irma field extends along the contact of the Wilcox and Claiborne formations. The oldest rocks exposed at the surface

[16] Teas, L. P., The Irma oil field, Nevada County, Arkansas, in Structure of typical American oil feilds, vol. 1, pp. 1-17, Am. Assoc. Petrol. Geol., Tulsa 1929.

are beds of gray sand and sandy clay belonging to the upper member of the Wilcox formation. These beds crop out in a narrow, irregular band along the south side of the fault that limits the field on the north. The Wilcox sand is overlain by ferruginous clay and sand of basal Claiborne age. In the Irma graben to the north of the producing area younger Claiborne strata are exposed at the surface. The Wilcox formation again appears at the surface immediately north of the graben. (See Pl. II.)

In addition to the Claiborne formation, deep wells in the Irma field have penetrated all of the beds of the Gulf series and most of those of the Comanche series of the Cretaceous system. The general stratigraphic succession in the field is shown in Table 23.

TABLE 23.—*Generalized section of formations in the Irma field*

System	Series	Formation	Thickness in feet	Character of the beds
Quaternary			0-5	Superficial gravel
		Unconformity		
Tertiary	Eocene	Claiborne	0-500	Gray sand—glauconitic and ferruginous clay and sand
		Wilcox	600	Gray sand and clay with beds of lignite. Siderite boulders and quartzite
		Midway clays	450	Dark-blue noncalcareous clay and shale
		Unconformity		
Cretaceous	Gulf	Arkadelphia marl	75-100	Calcareous clay and shale
		Nacatoch sand	300-310	Gray and green calcareous sand with clay and marl in lower part
		Saratoga chalk	30-40	White chalk and marly chalk
		Marlbrook marl	200	Gray clay and chalky marl
		Annona chalk	50	Hard white and gray chalk
		Ozan formation (Buckrange sand at the base)	125	Gray, sandy, micaceous marl and clay. Glauconitic sand and sandy marl
		Brownstown marl	150	Dark-gray, fossiliferous clay
		Tokio formation and Woodbine sand	225	Clay, sandy clay, sand and volcanic ash. Sand and sandy clay, coarse ash, cemented sands and volcanic ash
		Unconformity		
	Comanche	Glen Rose	835	Gray, green and pink sand and sandstone and sandy shale; gray, green, brown and red shale and impure limestone
		Travis Peak	1800-2000	Light-gray to red sand and sandstone and medium to fine-textured gray to red shale and clay. Locally thin beds of conglomerate

Section exposed in NE¼ sec. 5, T. 14 S., R. 20 W.
(After L. P. Teas)

System and series	Formation	Thickness in feet	Character of beds
Tertiary (Eocene)	Claiborne	20	Gray sands
		6	Glauconitic clay, weathering to reddish-brown, and platy, ferruginous sandstone
		22	Ferruginous sandy clays with platy limonitic concretionary materials
		13	Platy ferruginous, limonitic clay
	Wilcox	100	Gray sandy clays and sands; base not exposed

CRETACEOUS SYSTEM

COMANCHE SERIES (LOWER CREATCEOUS)

The Humble Oil and Refining Company's Hein No. 2 well in sec. 1, T. 14 S., R. 21 W., the deepest well drilled in the Irma field, passed through nearly 1,700 feet of Comanche rock, of which 835 feet (2,185-3,020 feet) is assigned to the Glen Rose formation, and 715 feet (3,020-3,735 feet; depth of well 3,735) is assigned to the Travis Peak formation.

In the Irma field the basal bed of the Gulf series lies unconformably on the Lower Glen Rose. The Lower Glen Rose consists of gray, green, brown, and red shales; gray, green, and pink sandstones with subordinate beds of argillaceous and arenaceous limestones. The shale beds are in part calcareous and in part noncalcareous and contain fossils at many horizons. The limestones are generally fossiliferous and in part oolitic in structure.

The Travis Peak formation is composed of generally fine-grained sands, sandstones, and sandy clays, which range in color from light-gray to purple, interbedded with gray, red, and brown clays. Thin beds of conglomerate made up chiefly of chert and novaculite pebbles occur at a few horizons in the section. The Travis Peak formation is estimated to be from 1,800 to 2,000 feet thick.

The Travis Peak formation is probably underlain by marine beds of indeterminate thickness belonging to the Neocomian.

GULF SERIES (UPPER CRETACEOUS)

TOKIO FORMATION AND WOODBINE SAND

These formations are represented by from 225 to 250 feet of beds composed of gray clays, shales and sandy clays, which in the upper part of the section are interbedded with fine-grained, generally argillaceous sandstones. The lower part consists chiefly of gray, fine to medium-grained sandstones interbedded with gray to dark-gray lignitic sandy shale. The basal beds are in part lignitic and tuffaceous.

BROWNSTOWN MARL

The Brownstown marl in this area consists of gray shale and marl and finely sandy shale in which are imbedded thin lenses of fine-grained, micaceous and glauconitic sands. The Brownstown marl is 130 to 140 feet thick.

OZAN FORMATION

This formation is made up of gray to greenish-gray marl and micaceous sandy marl and clays. The Buckrange sand is represented by the lower 25 feet of beds, which consist of interbedded micaceous and glauconitic sands and sandy clays. The Ozan formation is 125 to 135 feet thick in the Irma field.

ANNONA CHALK

The Annona chalk in the field is represented by 30 to 40 feet of hard white and gray chalk.

MARLBROOK MARL

This formation is composed principally of gray shale and chalky marl but includes some finely sandy shale. It is about 200 feet thick in this area.

SARATOGA CHALK

The Saratoga chalk is 35 to 40 feet thick in the Irma field and is composed of hard white and grayish-white chalk and chalky marl.

NACATOCH SAND

The producing horizon of the Irma field is in the upper part of the Nacatoch sand which in this area is composed of gray and green calcareous, in part glauconitic sandstone and arenaceous limestones with sandy clays and marls in the basal portion. The Nacatoch sand is 300 to 310 feet thick in this area.

ARKADELPHIA MARL

The Arkadelphia marl, 75 to 100 feet thick, is composed of gray to dark-gray shales and marls.

TERTIARY SYSTEM

EOCENE SERIES

MIDWAY CLAYS

The Midway clays consist of grayish-blue and gray noncalcareous clays and shale containing an abundance of siderite concretions. These beds are 450 feet thick in the Irma field.

WILCOX FORMATION

The Wilcox formation, 600 feet thick in the field, may be divided into four lithologic members: The upper 125 feet is composed of gray lignitic sands; the succeeding 50 feet consists of gray and brown clays, slightly sandy, in part lignitic, and containing numerous concretions of limonite; below the clay member is 175 to 200 feet of massive gray and reddish-gray sands; the basal 200 feet of beds is composed of light-gray to gray sandy clays and sands.

STRUCTURE

GENERAL FEATURES

The Irma field is limited on the north by a fault, having a displacement from 325 to 470 feet. The producing area is situated on the south or upthrown side of the fault. The evidence of faulting is apparent from a study of the surface structure.

SURFACE EXPRESSION OF STRUCTURE

The fault, as well as the closure of the producing area, is expressed in the areal distribution of the formations at the surface. From the southwest corner of sec. 9, T. 14 S., R. 21 W., to sec. 5, T. 14 S., R. 20 W., the Wilcox sand on the upthrown side is in contact with Claiborne beds on the downthrown side of the fault.

The fault is visible at the surface on the west side of the highway at the center of the east line of sec. 9, T. 14 S., R. 21 W., where, near the base of the north slope of a hill, cross-bedded sand of the Upper Wilcox formation lies in contact with thin-bedded chocolate-colored selenitic red weathering clay of the Claiborne formation. A parting of limonite, a quarter of an inch thick, represents the actual plane. The hade of the fault measured at this locality is about 60°. The horizontal distance from the surface trace to the fault trace of the Nacatoch sand is 950 feet, representing an angle of 53° which corresponds closely to the average inclination of the fault planes throughout this fault zone.

Several wells were drilled in the graben north of the Irma field. A list of these wells and the result of drilling on the downthrown side of the fault is given in Table 24

The structure of the proven area and vicinity were determined by the construction of subsurface maps using the top of the Nacatoch or producing sand as a datum plane.

SUBSURFACE STRUCTURE

The subsurface structure of the region wherein the Irma field is situated is generalized in Plate I.

The principal structural feature of the area is a generally northeast-trending graben—the Irma graben. The faults forming the graben are from 1½ to 2 miles apart with a throw of 325 to 470 feet. The dip, where determined by drilling, is toward the center of the graben at an angle of approximately 45

TABLE 24.—*Wells drilled in Irma graben*
(Listed by L. P. Teas)

Company and farm name	Location Sec. T. R.	Top of Nacatoch in ft. below sea level	Throw of fault in feet
Smitherman and McDonald, T. P. Waters No. 2	10-14-21	Cut fault plane below top of Nacatoch sand	
Owings et al, T. P. Waters No. 1	3-14-21	Nacatoch sand not reached at 996 feet	
Wooten et al, Ellis No. 1	2-14-21	Nacatoch sand not reached at 1012 feet	
Greeson et al, Grove No. 1	2-14-21	Nacatoch sand not reached at 1100 feet	
W. F. Fruen et al, Grove No. 1	2-14-21	Nacatoch sand not reached at 1184 feet	
Steele et al, Martin No. 1	13-14-21	Nacatoch sand not reached at 1140 feet	
Houston Oil Co. Grove No. 1	36-13-21	1379	337
Danciger Oil Co. Waters No. 1	4-13-21	1319	489

degrees. The regional strike is northeast and the dip is southeast. In the area of the Irma field the strata are gently warped, producing a closure of slightly more than 50 feet against the fault. The producing area, 4½ miles in length and half a mile to three-quarters of a mile in width, parallels the fault trace. The dips within the field are to the south and southeast at the rate of 40 to 60 feet per mile.

Figure 42 shows the structure in detail of the producing area. The contour lines, which are drawn at intervals of 10 feet, have a general east to west trend and, aside from slight irregularities, are parallel with the fault to the north and with the producing area.

RELATION OF STRUCTURE TO THE ACCUMULATION OF OIL AND GAS

The oil and gas in the Irma field occupies the highest part of the structure.

PRODUCTION

PRODUCTIVE AREA

The productive area of the Irma field lies along a narrow strip half a mile to three-quarters of a mile wide and 4½ miles long, which trends slightly north of east through the northern part of T. 14 S., Rs. 20 and 21 W.

The total area in the Irma field that is productive of oil is probably not less than 1,100 acres, a part of which probably will not be drilled owing to the character of the oil, the high cost of production, and the small initial yield of the wells. Where leases

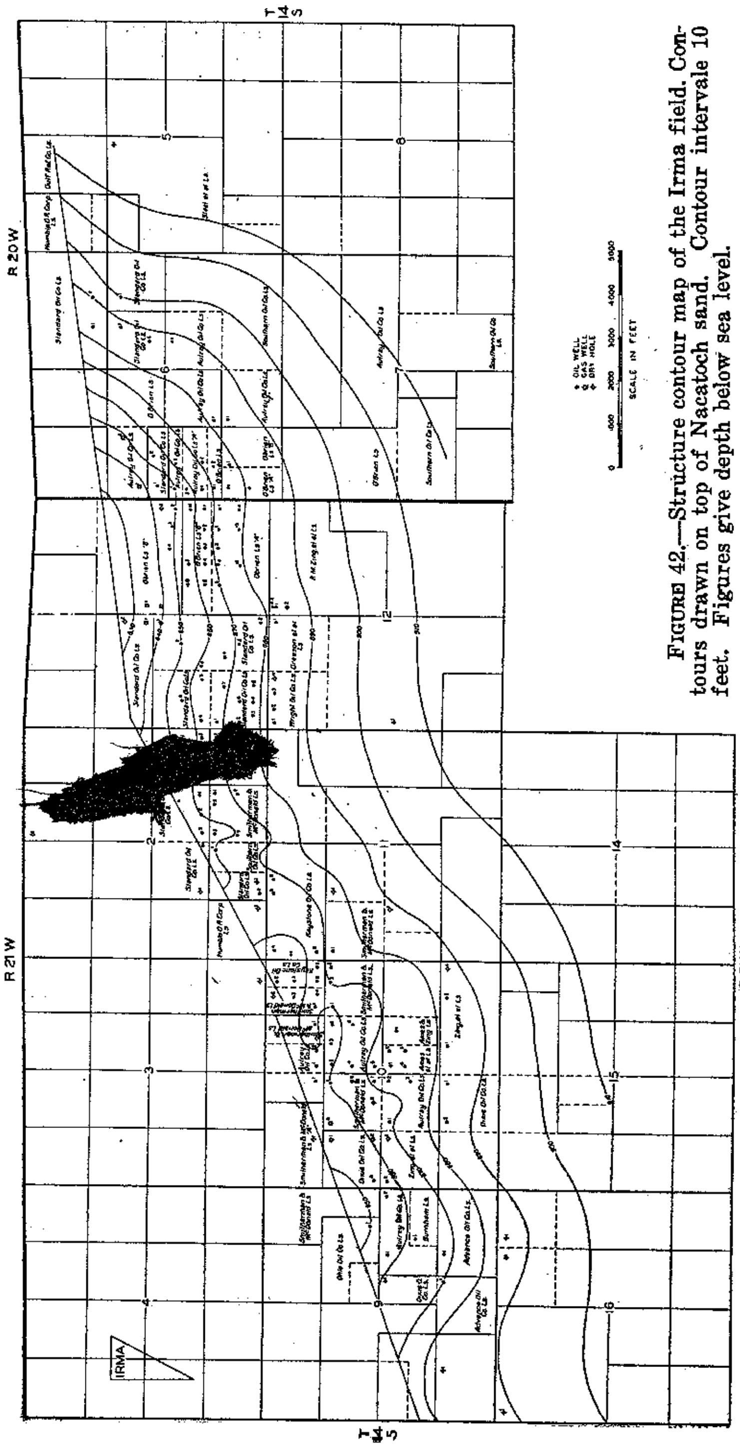


FIGURE 42.—Structure contour map of the Irma field. Contours drawn on top of Nacatoch sand. Contour intervale 10 feet. Figures give depth below sea level.

have been fully developed, the wells are spaced at the rate of one well to each 5 acres. Based upon 5 acres to each well, the total present productive area is 640 acres.

THE PRODUCING SAND

NACATOCH SAND

The oil produced in the Irma field is obtained from the upper 15 to 25 feet of the Nacatoch sand, which consists mainly of soft, fine to medium-grained calcareous sand interbedded with thin lenses of hard calcareous sandstone (the cap rock of the drillers) and lenses of clay and sandy clay. The relative amount of calcareous sandstone and clay in the producing sand is an important factor in determining the initial volume and ultimate production of individual wells. The Nacatoch sand is found at depths ranging from 825 to 900 feet below sea level.

The character of the producing horizon as recorded in wells is shown in the following sections:

Section of producing sand in C. F. Steel et al Haynie No. 1 *well, sec.* 1, *T.* 14 *S., R.* 21 *W., initial production* 35,000,000 *cu. ft. of gas*

Character	Depth in feet
Nacatoch sand:	
Lime rock	1077–1090
Hard gas sand	1090–1115
Gumbo and shale	1115–1118
Cap rock	1118–1119
Sand (some salt water)	1119–1123

Section of producing sand in Humble Oil and Refining Company's Grove B-3 well in sec. 1, *T.* 14 *S., R.* 21 *W.*

Character	Depth in feet
Nacatoch sand:	
Gumbo	1130–1141
Gas sand	1141–1144
Sandy shale and lime	1144–1145
Oil sand	1145–1147

Section of producing sand in Humble Oil and Refining Company's Ellis A-3 well in sec. 2, *T.* 14 *S., R.* 21 *W.*

Character	Depth in feet
Nacatoch sand:	
Sandy shale	1150–1152
Rock	1152–1153
Gas sand	1153–1155
Rock	1155–1156
Sand	1156–1163

Section of producing sand in Smitherman and McDonald's R. R. Womach No. 3 *well in sec.* 11, *T.* 14 *S., R.* 21 *W.*

Character	Depth in feet
Nacatoch sand:	
Gumbo	1140–1197
Cap rock	1197–1198

Oil sand	1198–1208
Cap rock	1208–1209
Oil sand	1209–1211
Record missing	1211–1260
Hard sand and lime rock	1260–1330
Hard sand and streaks of lime	1330–1400
Shale and gumbo	1400–1510

PRODUCTION 1923 TO 1933, INCLUSIVE

The initial production of the oil wells in the Irma field ranges from a few barrels to 200 barrels a day, and that of the gas wells ranges from 5,000,000 to 35,000,000 cubic feet a day. In all, 137 wells have been completed, or 128 oil wells and 9 gas wells.

On January 1, 1931, there were 70 producing oil wells in the Irma field having an estimated daily production of 1,260 barrels, or a daily average of 18 barrels per well.

Assuming that the productive area of the Irma field is 640 acres, the acre yield to January 1, 1934, was 5,142 barrels. The record of some leases has averaged higher, that of one lease being as high as 11,000 barrels per acre.

The production from the Irma field is not accurately determined because there has been no consistent demand for the grade of oil produced. This fact and the low prices of oil prevailing at times have caused periodic shut-downs of wells after the storage was filled. The approximate yearly production of the Irma field is given in Table 25.

TABLE 25.—*Oil production in the Irma field*

Year	[illegible] bls. [illegible]	Record of oil shipments in bbls.	Data compiled by Ark. Tax Comm. in bbls.
1923	70,600	———	———
1924	510,250	117,181	239,833
1925	518,550	189,417	244,332
1926	786,000	616,413	566,234
1927	788,750	647,122	592,544
1928	576,650	332,152	296,607
1929	412,600	370,908	———
1930	339,550	296,728	———
1931	390,000	350,558	———
1932	387,550	109,074	———
1933	231,550	261,540	———
	5,212,450	3,291,093*	

* Pipe-line runs.

The larger total is estimated production and includes the oil produced and used in drilling of wells and in lifting, treating, and heating of the oil prior to shipments, which, because of the properties of the oil, no doubt has been a considerable part of the total production.

ESTIMATED FUTURE PRODUCTION

The future production of the Irma field cannot be accurately estimated from the available production records. The volume produced in the future will probably depend on the demand and the price received for the grade of crude oil produced in this field.

METHOD OF DRILLING

The wells in the Irma field were drilled by the rotary method and without notable difficulty. The common practice was to set 6-inch casing on top of the sand and complete the well with 4½-inch perforated liner, in the sand.

The heavy, viscous oil and the large quantities of sand brought in with the water, which soon appears in all the wells, cause many operating problems. The cups are cut quickly and the liner becomes clogged with sand, necessitating frequent replacement and clean out jobs. After the first few months of production, the volume of the sand decreases.

The oil flows or is pumped into open pits, from which it is picked up and passed through treating plants.

As no pipe line serves the field, the oil is heated, if necessary, to about 100° F., and is then pumped to loading racks for shipment in tank cars, equipped with heating coils.

The character of the oil is given in the following analysis:

CHARACTER OF THE OIL

Analysis of crude oil from the Irma field
(Analysis by Humble Oil & Ref. Co. Laboratory, Baytown, Texas)

Gravity	14.7° A. P. I.
Water	5 per cent

DRY CRUDE DISTILLATION

Per cent	°Be.
5	28.8
10	27.0
20	25.6
30	27.6
80	18.3

Total, 80 per cent gravity, 26.6° B.
Coke and loss, 20.7 per cent.

Taking the 80 per cent distillate and rerunning all percentages based on the original charge:

Per cent	°Be.
5	48.4
10	48.4—44.8
15	36.3
20	32.3
25	32.6—30.2
35	27.6
45	25.0
80	18.3

SUMMARY

	Per cent	(°F.)	A. P. I gravity	Viscosity at 100° in sec.
Kerosene	10.0	----	44.8	----
Gas oil	15.0	----	32.6	----
Light lube	20.0	----	26.7	58
Lube oil	35.0	----	18.3	260
Flash	----	390	----	----
Fire	----	450	----	----
C. T. (paraffin)	----	37	----	----
Coke and loss	20.0	----	----	----
Coke by weight	20.7	----	----	----

Analyses of Irma crude oil

(By U. S. Bureau of Mines)

Specific gravity	0.970
A. P. I. gravity	14.4°
Percentage of sulphur	2.70
Viscosity at 70°F. (Saybolt seconds)	6,000
Viscosity at 100°F. (Saybolt seconds)	5,700
Pour point (°F.)	20
First drop (°C.)	164
First drop (°F.)	327
Color	Brownish-black

WATER CONDITIONS

The producing horizon is generally divided into an upper and a lower sand member, separated by shale or indurated sands.

The upper sand carries only a small quantity of water, and the edge water is about 880 feet below sea level. The oil and water appear to be imperfectly separated in the lower sand, and wells that penetrated it made considerable water soon after completion. All the wells now make considerable water.

The water in the oil-producing bed of the Irma field is brackish rather than salty, owing to its location 25 miles down the dip from the outcrop. A few miles north of the field the Nacatoch yields potable water and is an important water-bearing sand. The following gives the chlorine content of the water in the Irma field:

Analysis of water accompanying the oil in the Irma field

(Barrow-Agee Laboratories, Shreveport, La., after L. P. Teas)

Humble Oil and Refining Co.'s Grove A-3, sec. 2, T. 14 S., R. 21 W.

	Parts per million
Chlorine	5,670
Sulphur trioxide	144

OTHER PRODUCING AREAS

In addition to the oil-producing fields described there are six areas which have, or are now producing oil, but at this time are not important producing fields. These areas are:

The Urbana district in Union County.

Sec. 14, T. 18 S., R. 14 W., in Union County.

Sec. 2, T. 18 S., R. 15 W., in Union County.

Mount Holly in Ouachita County.

Bradley district in Lafayette County.

Garland City district in Miller County.

URBANA DISTRICT

The Urbana district, as yet incompletely developed, comprises an area including parts of sec. 2, 3, and 10, T. 18 S., R. 13 W., Union County. The producing area and location of wells are shown in Figure 43.

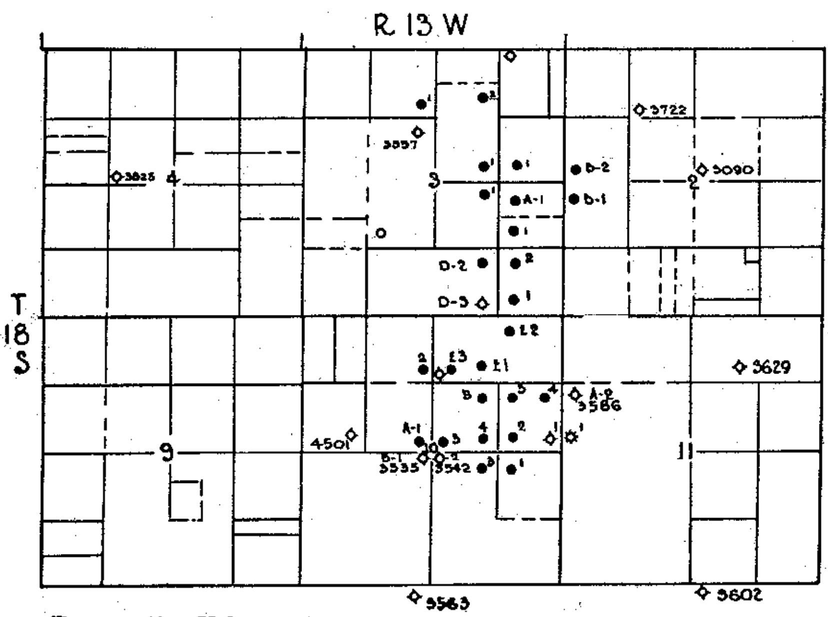


FIGURE 43.—Urbana field showing location of wells. Figures give depth below surface.

A number of wells were drilled in this area, many of which yielded oil and gas in various sands in the Gulf series, but no production of importance. In December 1929, the Marine Oil Company's Thompson No. A-3 well in sec. 10, T. 18 S., R. 13 W., was completed with an initial production of 600 barrels per day from a depth of 3,535 feet.

The production is obtained from a sand in the Travis Peak formation of the Trinity group which lies about 350 feet below the base of the Gulf series.

The oil is black, asphaltic base 19° to 20° A. P. I. gravity.

The structure of the oil-producing horizon in the Urbana district is not definitely known. The regional dip of the Comanche strata is estimated to lie 75 to 150 feet per mile to the west. If the production is obtained from one sand, which is not contrary to the available data, the structure may be interpreted to be a well-defined structural terrace or an anticline with a few feet of closure. Considering that the regional dip is to the west, the deformation of the oil-bearing beds may have been of considerable magnitude as contrasted with the deformation of the overlying Upper Cretaceous strata.

During the month of December 1933, the production from 14 wells was 66,146 barrels; equal to a daily average production of 152 barrels per well. The production of the Urbana district is as follows:

Production—Urbana district

Year	Barrels*
1930	221,836
1931	289,482
1932	159,593
1933	447,310
Total	1,118,221

* Pipe-line runs.

SEC. 14, T. 18 S., R. 14 W.

This is a small area in which a number of wells have been drilled. The production is from the Nacatoch formation. January 1, 1934, there were two producing wells with a daily average production of 11½ barrels per well. The yearly production is as follows:

Production (sec. 14, T. 18 S., R. 14 W. area)

Year	Barrels*
1930	16,232
1931	18,206
1932	14,797
1933	12,190
Total	61,425

* Pipe-line runs.

SEC. 2, T. 18 S., R. 15 W.

This area produced a small amount of oil from the Nacatoch sand but was abandoned during the year 1933. The production from this area is as follows:

Production (*sec.* 2, *T.* 18 *S.*, *R.* 15 *W.*)

Year	Barrels*
1930	1,195
1931	1,094
1932	966
1933	183
Total	3,438

* Pipe-line runs.

MOUNT HOLLY DISTRICT

The Mount Holly district includes a small producing area in sec. 25, T. 15 S., R. 18 W., southwestern part of Ouachita County. It is situated between the Stephens and Smackover fields.

The first producing well was McDonald Brothers Wilson No. 1 well in sec. 25, T. 15 S., R. 18 W., completed March 9, 1929, with an initial daily production of 225 barrels from the upper part of the Lower Glen Rose formation. The producing sand was recorded from 2,863 to 2,866 feet below the surface. The gravity of the oil is 31° A. P. I. The Mount Holly area was abandoned in 1931 after producing a total of 112,509 barrels of oil. The production by years is as follows:

Production Mount Holly District

Year	Barrels*
1929	74,306
1930	34,449
1931	3,754
Total	112,509

* Pipe-line runs.

BRADLEY DISTRICT

The Bradley district is situated in T. 19 S., R. 24 W., Lafayette County. The producing area is limited to sec. 18.

The first producing well in the area, Arkansas Fuel Oil Company's F. M. Allen No. 1 well, sec. 18, T. 19 S., R. 24 W., was completed in December 1925, with an initial daily production of 20 barrels from the Buckrange sand, recorded from 2,786 to 2,789 feet below the surface. A total of five producing wells were drilled but most of the production was obtained from two wells.

The production is obtained from the Buckrange sand at an average depth of 2,790 feet below the surface. The well records indicate that the producing sand is 5 to 10 feet thick, made up of fine to medium-grained sand and argillaceous sand.

The structure of the area is not well defined but apparently is a large structural terrace.

The wells drilled below the Buckrange sand in this area have shown water in all sands penetrated.

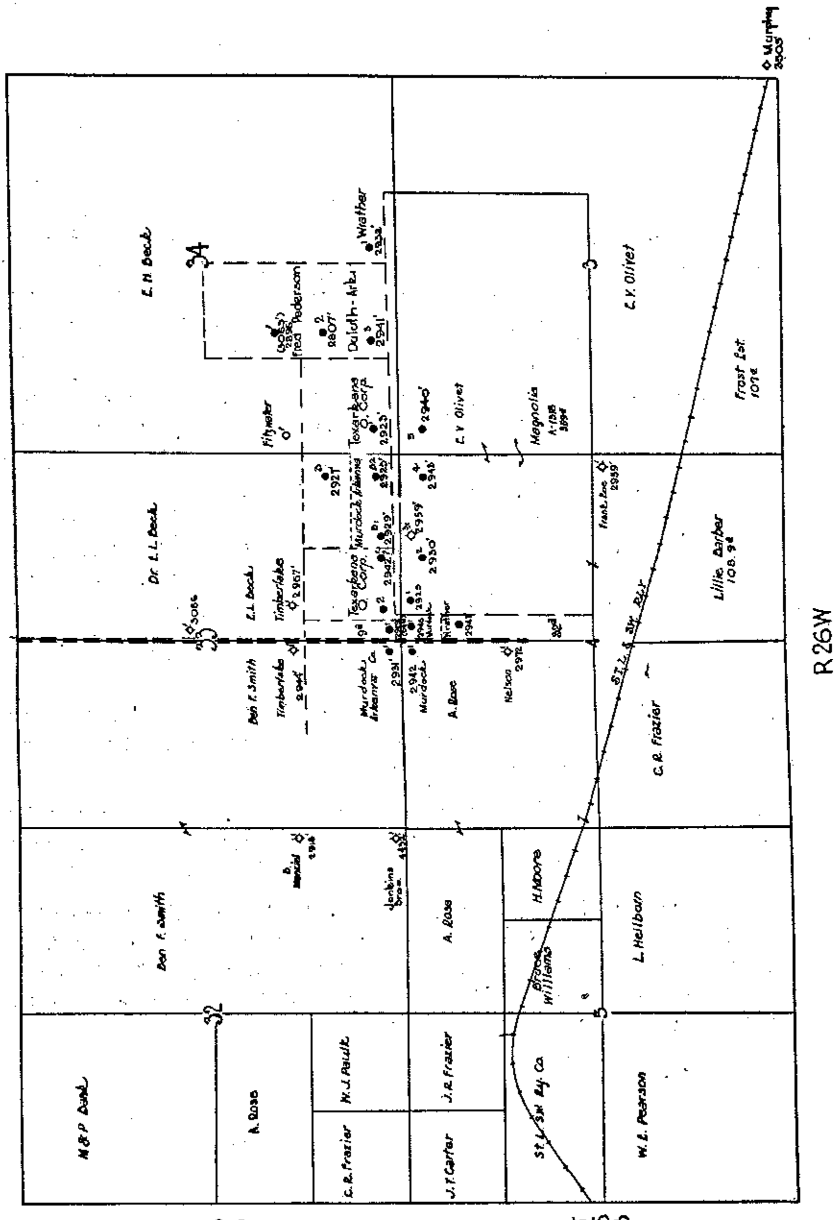


FIGURE 44.—Garland City field showing location of wells. Figures give depth below sea level.

The Bradley district was abandoned in 1931 after producing a total of 84,223 barrels of oil.

Production—Bradley district

Year	Barrels*
1928	34,582
1929	23,963
1930	20,425
1931	5,253
Total	84,223

* Pipe-line runs.

GARLAND CITY DISTRICT

The producing area of the Garland City district is not completely defined. The producing wells are located in secs. 33 and 34, T. 15 S., R. 26 W., and secs. 3 and 4, T. 16 S., R. 26 W., Miller County. The producing area and the location of wells are shown in Figure 44.

The first oil-producing well drilled in the Garland City district was Lenz et al Johnson No. 1 well in sec. 24, T. 15 N., R. 16 W. This well was completed July 30, 1930, with an estimated production of 50 barrels per day. The depth of the oil-bearing sand is not accurately known. The real discovery well is Baker and McMurray (formerly Fitzwater et al) Beck No. 1 well in sec. 33, T. 15 S., R. 26 W., which was completed December 18, 1932, with an initial estimated production of 350 barrels of oil. The producing sand was recorded from 2,914 to 2,926 feet below the surface.

The production is obtained from one or more sand lenses in the upper part of the Trinity group, in what is probably the equivalent of the Paluxy sand of Texas.

The structure of the producing horizon is not accurately known but the well records indicate the presence of a structural terrace.

The oil produced ranges from 29.5° to 32° A. P. I. gravity. The production from this area prior to 1933 is not accurately known; the production for 1933 was 87,265 barrels. In December 1933, there were five wells producing at a daily average rate of 165 barrels per day.

PART III

COUNTY BY COUNTY

ARKANSAS COUNTY

LOCATION

Arkansas County is bounded on the south by Desha and Jefferson counties; on the west by Jefferson County; on the north by Prairie and Monroe counties; and on the east by Monroe, Phillips, and Desha counties.

GENERAL FEATURES

The general surface is a slightly undulating plain, sloping from an elevation of about 215 feet above sea level in the northern part to 150 feet in the southern part of the county, and comprising the prairies, which include most of the interstream areas and the flood plains bordering the streams. The prairies are open grassy tracts forming Grand prairie; they cover the northern part of the county and form interstream areas, a few miles to 10 miles wide, extending southward 5 or 6 miles south of Gillett. In the east the prairies closely border White River, which has cut into their edges in places. The general level of the prairies is 45 to 50 feet above low-water level of Arkansas and White rivers.

The gently undulating interstream timbered lands border the shallow valleys and intertongue irregularly with the prairie lands. The flood plains lie a few feet to 30 feet below the level of the prairies, and form poorly drained wooded or cultivated tracts 10 to 12 miles in maximum width. The broadest plains are in the west, bordering Arkansas River and Bayou Meto, and in the south, where the bottom lands of Arkansas and White rivers merge into the Mississippi bottom.

STRATIGRAPHY

The surface of Arkansas County is underlain by Pleistocene alluvium ranging in thickness from 100 to 180 feet, which rests unconformably on strata of Eocene age. The Eocene is estimated to range in thickness from about 2,600 feet in the northwestern to about 4,500 feet in the southeastern part of the county. The Cretaceous strata are estimated to range in thickness from about 400 feet to more than 1,000 feet, with the greater thickness in the southeastern part.

A generalized section of formations is given in Table 26.

BASEMENT ROCKS

The basement rocks are not definitely known to have been penetrated in any of the deep wells drilled in this area, but the drillers' record of the B. F. Pettitt Home No. 1 well, sec. 6, T.

TABLE 26.—*Generalized section of formations in Arkansas County*

System	Series	Formation	Thickness in feet	Character
Quaternary	Pleistocene and Recent		100-180	Alluvial sands, gravel, clays, and loams.
		Unconformity		
Tertiary	Eocene	Jackson Claiborne Wilcox	2500-4500	Sands, clays, and sandy clays, in part lignitic; glauconitic sand and clays in the Jackson and the basal Claiborne.
		Midway clays	500-600	Gray and bluish gray, clays containing abundant siderite concretions.
		Unconformity		
Cretaceous	Gulf	Arkadelphia marl	50-100	Gray to dark-gray calcareous shale.
		Nacatoch sand and Saratoga chalk	225-350	Sand and sandstone, in part glauconitic; shale, chalky shale and chalk in basal beds.
		Marlbrook marl and older	200-500+	Marls, chalk and sands; probably some red beds in lower part.

2 S., R. 5 W., indicate that the Paleozoic rocks were encountered at a depth of about 3,235 feet below the surface. The materials assigned to the Paleozoic era consist of dark-blue and black shales and slate, and gray limestone.

It is estimated that the basement rocks lie about 3,000 feet below sea level in the northwestern part and more than 6,000 feet below sea level in the southeastern part of the county.

CRETACEOUS

GULF SERIES

The Cretaceous rocks underlying this area are known only from the records of two deep wells, both located in the northwestern part of the county. From studies of regional sedimentation and structure, it is believed that these rocks will range widely in thickness and in lithology from northwest to southeast. The southeastern part is situated in a sedimentary basin, which reached its fullest development farther to the east in Mississippi, and the sediments may be expected to resemble more closely the standard Mississippi than the Arkansas section. This sedimentary basin expanded toward the northwest with a consequent overlap of younger strata over the older, resulting not only in a thinning of the total Cretaceous section, but also in a lateral change in the character of the sediments.

It is estimated that the total thickness of the Cretaceous is about 400 feet in the northwestern part, where the Arkadelphia marl, Nacatoch sand, Saratoga chalk and the Marlbrook marl are represented and more than 1,000 feet thick in the southeastern part of the county.

The increased thickness of the Cretaceous from northwest to southeast is believed to be mainly in the Saratoga chalk and Marlbrook marl—equivalents of the Selma chalk of Mississippi and in the Tokio formation, or its equivalent the (Tuscaloosa formation of Mississippi).

The stratigraphic relationships of the Cretaceous is shown graphically in Plate X, a generally east-west cross section, which, although farther to the south, shows essentially the same conditions.

TERTIARY

EOCENE

The well records of this area are not sufficiently detailed to distinguish accurately the boundaries between the different formations included within the Eocene. It is estimated that the total thickness of the Eocene strata ranges from about 2,500 feet in the northwestern part to about 4,500 feet in the southeastern part of the county, comprising the following formations: Jackson, Claiborne, Wilcox, and Midway.

The Midway is estimated to be from 500 to 600 feet thick, and to consist of gray, noncalcareous clay and shale, containing an abundance of siderite concretions, with calcareous shale and, perhaps, limestones in the basal part in southeastern Arkansas county.

The Wilcox formation attains a maximum thickness of not less than 2,000 feet, made up chiefly of sands, clays, and sandy clays, in part lignitic.

The Claiborne reaches a maximum thickness of about 1,500 feet. It consists chiefly of sands and clays, with 300 to 400 feet of glauconitic sand and clay at the base.

The Jackson formation is not readily distinguished in the well records, as most of the wells failed to set pipe through the Pleistocene, which resulted in caving of sands and gravels, obscuring the true character of the Jackson.

QUATERNARY

PLEISTOCENE AND RECENT

The surface is underlain by Pleistocene alluvium, consisting of clays, sands, and gravels, ranging in thickness from 100 to 180 feet. The materials are irregularly bedded but, in general, grade downward from fine, compact, gray and reddish clay, through fine sand to coarse water-bearing sands and gravels at the base.

The surface distribution of the Pleistocene alluvium is coextensive with the interstream areas of the county. The stream valleys are filled with Recent alluvium.

STRUCTURE

The data in this area are entirely inadequate to show the structural features with any degree of accuracy. An interpretation of the generalized structure of the area, drawn on top of the

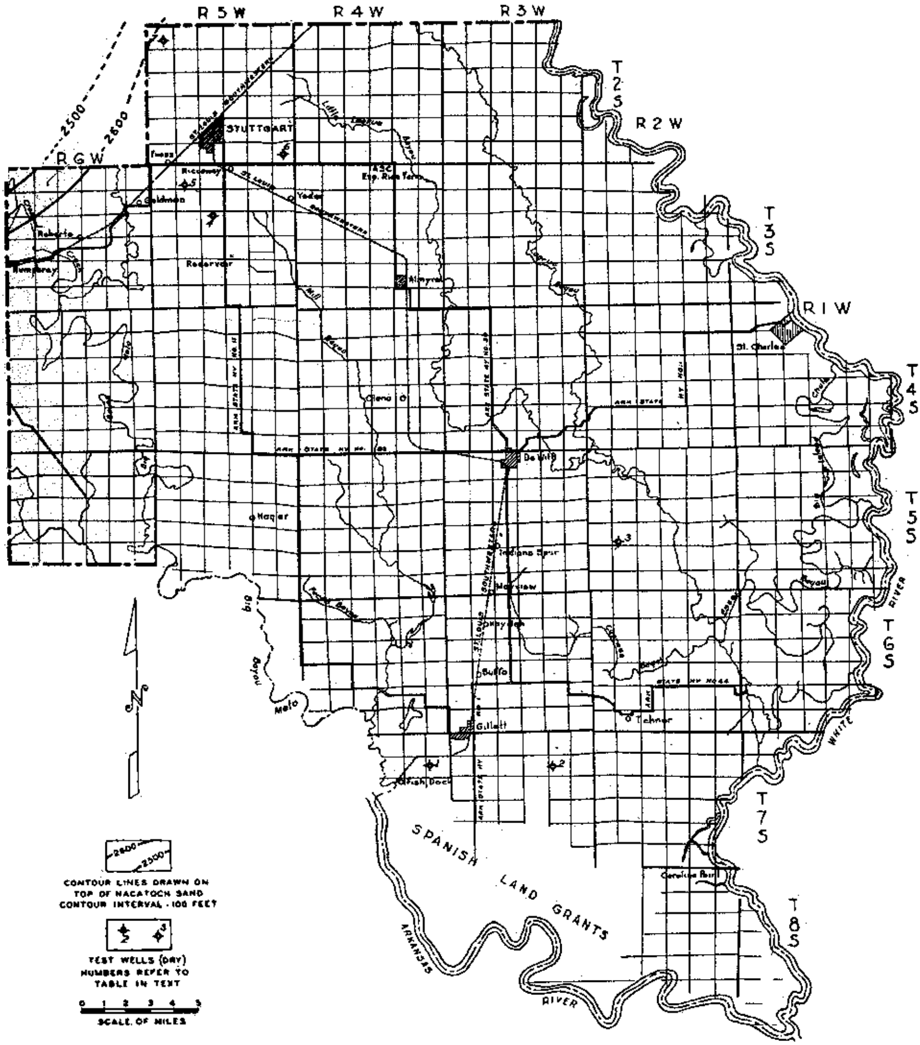


FIGURE 45.—Structure contour map of Arkansas County. Figures give depth below sea level in feet.

Cretaceous at intervals of 500 feet, is shown in Figure 17. The top of the Nacatoch sand lies at a depth of about 2,500 feet below sea level in the northwestern corner, and is estimated to be about 5,000 feet below sea level in the southeastern corner. (See Fig. 45.)

List of wells drilled in Arkansas County

No., Company, Farm & Number	Location Sec.	Twp.	R.	T. D.	Elev.*	Depth to Nacatoch feet	Depth to red shale feet	Oldest formation penetrated
1 H. A. Strode, Gillett No. 2	12	7S	4W	2224	155.1[c]	------	------	Claiborne or Wilcox
2 Ark. Development Co., Charlie Rose No. 1	11	7S	3W	2133	------	------	------	Claiborne or Wilcox
3 Old Glory O. & G. Co., Art Perry No. 1	20	5S	2W	2050	200[a]	------	------	Wilcox
4 L. P. Johnson, Weaver No. 1	17	3S	5W	3250	250[a] 216[a]	3150	------	Nacatoch
5 Stuttgart O. & G. Co., Goldman No. 1	5	3S	5W	1200	119.1	------	------	Claiborne
6 Chas. Lorrance (Chr. Lorenz) Loring No. 1	36	2S	5W	785	------	------	------	Claiborne
7 B. F. Pettit & Co., Griffith No. 1	6 or 7	2S	5W	2360	240[h]	2805	------	Paleozoic

* Letters refer to source of datum for elevation. The following letters will be used throughout well lists in Part III.

[a] Log. [d] Pure Oil Co. [g] Gulf Refg. Co. [j] K. C. S. depot. [m] Houston Oil Co.
[b] Estimate [e] Texas Co. [h] Roxana Oil Co. [k] Louisiana Oil Refg. Co. [n] Ohio Oil Co.
[c] Aneroid [f] Arkansas Fuel Oil Co. [i] Standard Oil Co. [l] Humble Oil Co.

ASHLEY COUNTY

LOCATION

Ashley County, situated in southeastern Arkansas, is bounded on the south by Louisiana, on the west by Union and Bradley counties, on the north by Drew County, and on the east by Chicot County.

GENERAL FEATURES

The larger part of Ashley County is a generally flat or gently undulating surface standing 160 to 180 feet above sea level, to which Veatch[1] applied the name "Hamburg terrace." Only a small area in the north-central part of the county stands more than 200 feet above sea level.

The flood plain of Bayou Bartholomew in the western part of the county slopes gently from 130 feet in the north to 110 feet above sea level in the south. It is separated from the Hamburg terrace by a line of low bluffs or sharp slopes about 30 feet in height. A series of low bluffs, 30 to 50 feet in height, separates the Hamburg terrace from the flood plains of Saline and Ouachita rivers, which form the western boundary of Ashley County.

STRATIGRAPHY

Ashley County, except for a small area in the north-central part where the Jackson formation appears at the surface, is mantled by sands, gravels, and loams of Quaternary and Recent age. Deep wells have passed through all of the Tertiary and the Cretaceous strata. A generalized section of formations in Ashley County is given in the following table.

BASEMENT ROCKS

In Ashley County three wells have penetrated rocks which are believed to be older than the Cretaceous and probably of Paleozoic age. The Texas Company's Gay No. 1 well in sec. 33, T. 16 S., R. 4 W., entered igneous rocks at a depth of 3,114 feet, after passing through 248 feet of Upper Cretaceous beds of Navarro age. The Texas Company's Kieffer No. 1 well in sec. 11, T. 18 S., R. 4 W., records Monroe gas rock from 2,801 to 2,810 feet; light-colored, hard, quartzitic sandstones; hard gray, greenish-gray to black, noncalcareous, in part carbonaceous shales with intercalated thin beds of red shale from 2,810 to 3,574 feet. The March et al Williams No. 1 well in sec. 8, T. 18 S., R. 4 W., penetrated a series of rocks beneath the Monroe gas

[1] Veatch, A. C., Geology and underground water resources of northern Louisiana and southern

TABLE 27.—*Generalized section of formations in Ashley County*

System	Series	Formation	Thickness in feet	Character
Quaternary	Pleistocene and Recent	Terrace and river deposits	0-150	Alluvial sands, gravels, clays and loams.
Tertiary	Eocene	Jackson	0-50	Sands and gray to blue clays, fossiliferous and glauconitic marl and sandy marl.
		Claiborne	1200-1500	Glauconitic sand, clays and marls and nonmarine sands and clays. In part lignitic . .
		Wilcox	600-1000	Lignitic sands and clays.
		Midway	400-500	Gray and blue, clays and shale, calcareous and fossiliferous in lower 50 feet of beds.
		Unconformity		
Cretaceous	Gulf	Arkadelphia marl	0-75	Gray to dark-gray calcareous and fossiliferous marle and shale.
		Nacatoch and Saratoga chalk (Including Monroe gas rock)	50-310	Calcareous sands, clays and chalks in the western part and limestone in the eastern part.
		Marlbrook marl	0-200	Marl, sandy marl and sand.
		Tokio-Woodbine (0-100) red beds (0-275)	0-375	Non-red clays and sands in upper part. Red clays and sands in lower part.
		Unconformity		
	Comanche	Travis Peak	0-1500+	Red clays, shales and sands.
		Neocomian ?		Not penetrated in wells but may include a part of area. Marine limestone, shale and sand.
		Unconformity		
Paleozoic		Undifferentiated		Hard generally light - colored quartzitic sandstone, and hard dark-gray shale with intercalated thin beds of red shale.

rocks which lithologically are essentially similar to the section between 2,810 and 3,574 feet in the Texas Company's Kieffer No. 1 well. These rocks contain no fossils except small fragments of plant remains which were too fragmentary to be identified. The lithology and induration of these rocks differentiates them from the Trinity sediments, which have been cored in many wells, and although their age is not determinable they resemble the Paleozoic much more than the Trinity sediments. Considering the rocks from 2,810 to 3,574 feet deep in the Texas Company's Kieffer No. 1 well to be pre-Cretaceous in age, the basement floor lies at depths of 2,900 to 3,000 feet below sea level in the southeastern corner of the county. However, the basement floor increases in depth below sea level to the north and west. The character of the pre-Cretaceous rocks in the Texas Company's Kieffer No. 1 well is given in table following:

The Texas Company's Kieffer No. 1 *well, sec.* 11, *T.* 18 *S., R.* 4 *W.*

Upper Cretaceous:	
Hard white rock—Monroe gas rock	2801–2810
Paleozoic ?:	
Hard sand rock	2810–2811
White gas rock	2811–2900
Broken gas rock with streaks gumbo	2900–2936
Hard sand rock (Cores 2952-2954 light-gray to grayish-white medium to coarse-grained, sugary, noncalcareous, hard sandstone)	2936–2953
Hard sand with pyrites	2953–2978
Sand and gravel with pyrite	2978–3000
Rock	3000–3006
Red shale	3006–3008
Hard sandy lime (Core 3008 to 3009, light-gray, with slight greenish tinge, hard, fine-grained noncalcareous sandstone)	3008–3009
Rock	3009–3014
Blue shale	3014–3038
Rock	3038–3040
Shale	3040–3047
Rock	3047–3054
Shale and broken lime	3054–3079
Hard sand and shale (Core 3091 to 3095; gray, hard, fine-grained noncalcareous sandstone or siltstone)	3079–3093
Hard sand and pyrite	3093–3122
Rock	3122–3135
Hard sand and pyrite	3135–3144
Hard sand rock (Core 3150-3152, brown hard medium-grained quartzitic, noncalcareous, carbonaceous sandstone; carbonized plant stems; cuttings 3153-3160 fragments of fissile black shale and fine-grained sandstone; fragments of carbonaceous material, may be gilsonite; the sand is mineralized and strained with iron; core 3160-3162 is dark-gray to almost black very hard micaceous, carbonaceous, noncalcareous shale; and very hard gray fine to medium-grained noncalcareous, quartzitic sandstone, faintly laminated witb thin layers of gilsonite in silty partings)	3144–3184
Hard sand and shale	3184–3204
Hard sand rock (Core 3204-3214 gray, medium-grained, banded sandstone cemented with silica; core 3225-3226 gray; hard, fine-grained noncalcareous, quartzitic sandstone)	3204–3244
Hard sand and pink shale	3244–3249
Hard sand and shale	3249–3260
Hard gumbo (Core 3261-3271 red noncalcareous shale; may be false core; core 3271-3273 gray to greenish-gray hard very fine-grained noncalcareous sandstone or siltstone; core 3273-3276 gray, hard, very fine-grained, noncalcareous sandstone or siltstone)	3260–3276
Hard black rock	3276–3286
Hard sandy lime and hard rock	3286–3294
Hard rock (Core 3297-3299, light-gray very hard brittle very fine-grained noncalcareous sandstone or siltstone, cut bv veinlets stained bv limonite)	3294–3299

Hard sand rock	3299–3311
Hard rock (Core 3314, dark-gray to black very hard noncalcareous shale with veinlets of calcite)	3311–3394
Red shale and lime	3394–3407
Red gumbo and lime	3407–3412
Red gumbo (Core 3402-3407, hard gray to greenish-gray shale or siltstone with red blotches; core 3407-3412, hard gray to greenish-gray shale or siltstone; core 3412-3416 light-green very hard, brittle noncalcareous shale, with lenses or blotches of red; core 3416-3421 poor core but apparently consists of hard light-green, with some red, noncalcareous shale or siltstone)	3412–3421
White shale	3421–3423
Red shale	3423–3425
Blue shale	3425–3432
Hard greensand	3432–3435
Hard blue sand (Core 3421-3426 light-green hard, brittle, noncalcareous shale; core 3432-3435 top of core gray and reddish-gray argillaceous quartzite; middle and bottom of core igneous rock of diabasic or basaltic type; the fragments show no evidence of tuff structure since it has a homogenous structure throughout; the rock is highly altered and is now largely calcite; sepentine, secondary quartz and perhaps clay material; some of the feldspar and sparse apatite remain fresh)	3435–3448
Hard rock	3448–3529
Red shale and hard rock (Core 3527-3533, dark-red, hard siltstone)	3529–3533
Hard rock	3533–3534
Broken rock with red shale	3534–3537
Hard rock	3537–3574

CRETACEOUS

COMANCHE SERIES

The Comanche series is represented in Ashley County chiefly by the Travis Peak formation of the Trinity group, but it appears probable that the Travis Peak formation may be underlain by marine beds of Neocomian age in the western part of the county. The Travis Peak formation consists principally of red and brown clays, shales, sandy shales, and light-colored to brown sands and sandstones. These beds have been penetrated to a depth of more than 600 feet in the western part of Ashley County, but their total thickness in that part of the county may be 1,400 to 1,500 feet.

GULF SERIES

The Gulf series increases in thickness from east to west; it is less than 200 feet thick in the southeastern corner; and about 800 feet thick in the western part of the county.

The Tokio-Woodbine, consisting of non-red clays and sands in the upper part and of red clays and sands in the lower part, is about 375 feet thick in the northwestern part but decreases in thickness and lenses out in the eastern part of the county.

The Brownstown marl and the Ozan formation are not recognized in Ashley County. The Brownstown marl lenses out in Union County, and the Ozan formation, if present in the western part of the county, is not separable from the upper part of the non-red Tokio-Woodbine section.

The Marlbrook marl consists of thin beds of marl and sandy marl, which becomes increasingly sandy towards the east. It is about 200 feet thick in the western part but decreases in thickness to the east where it is overlapped by the Saratoga chalk and the Nacatoch in the eastern part of the county.

The Nacatoch formation and the Saratoga chalk are not easily separated; they are about 300 feet thick in the northwestern part but decrease in thickness and change laterally in lithology to the east and southeast, where they are represented by the Monroe gas rock.

The Arkadelphia marl is present only in the western part of the county; in the eastern part it is either absent by nondeposition, lateral gradation into the Monroe gas rock, or it has been removed by erosion. It is 50 to 75 feet thick in the western part of Ashley County.

TERTIARY

EOCENE SERIES

The Jackson formation crops out in a small area on the southern end of Monticello Ridge in the north-central part of the county. This formation consists of sands, bluish-gray to greenish-gray clay, in part fossiliferous and glauconitic, interbedded with sand.

The Claiborne, which underlies all of Ashley County, is from 1,200 to 1,500 feet thick with the greater thickness in the northeastern part of the county. The different formational units of the Claiborne recognized elsewhere in Arkansas are no doubt present in this area, but none of the deep wells have sampled and cored these sediments.

The Wilcox formation made up of lignitic sands and clays ranges in thickness from 600 feet in the western part to 1,000 feet in the northeastern part of the county.

The Midway formation is 400 to 500 feet thick and consists of gray and blue noncalcareous clays in the upper part and calcareous and fossiliferous clay and shale in the basal 25 to 50 feet of beds.

PLEISTOCENE AND RECENT SERIES

Alluvial deposits of Pleistocene and Recent age underlie the surface except over Monticello Ridge, to depths of 150 to 175 feet.

STRUCTURE

The structure of Ashley County, represented by contour lines drawn on top of the Nacatoch formation or the Monroe gas rocks, as recorded in deep wells, is shown in Figure 46. The

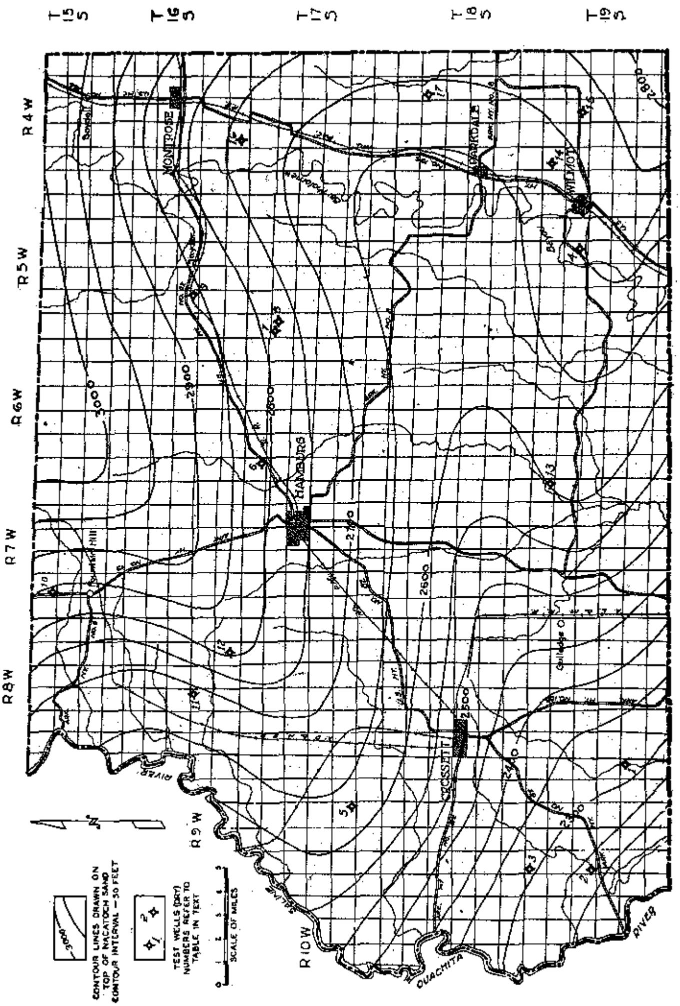


FIGURE 46.—Structure contour map of Ashley County Figures give depth below sea level in feet.

depths to the top of the Nacatoch sand or its equivalent range from 2,200 feet in the southwestern corner to 3,000 feet in the northeastern corner of the county. The principal structural feature is a generally east-west trending structural nose with marked flattering of the dip in T. 18 S., Rs. 5 and 6 W.

List of wells drilled in Ashley County

No., Company, Farm & Number	Location Sec.	Twp.	R.	T. D.	Elev.*	Depth to Nacatoch feet	Depth to red shale feet	Oldest formation penetrated
1 Morehouse O. & D. Co., Childress No. 1	25	19S	9W	2883	87[d]	2355	2710	Basal Upper Cretaceous red beds
2 E. L. Brown, Tr., Ark. Tbr. Co. No. 1	17	19S	9W	3800	70[d]	2375	2730	Travis Peak
3 H. C. Morris, Tr., Crossett Lbr. Co. No. 5	5	19S	9W	3262	80[b]	2295	2788	Travis Peak
4 A. C. Glassell et al, Keller No. 1	10	19S	5W	3082	102[a]	2800	------	Tokio-Woodbine
5 H. C. Morris, Tr., Crossett Ld. & Tbr. Co. No. 8	22	17S	9W	3280	136[d]	2775	------	Tokio-Woodbine
6 Ark. Petrol. Co., Haley No. 1	5	17S	6W	2240	145[a] 135[d]	------	------	Wilcox
7 Bush & Brown, Pine Prairie No. 1	7	17S	5W	2664	174[d] 150[a]	------	------	Midway
8 Pine Prairie Oil Co., Pine Prairie No. 1	7	17S	5W	3654	180[a]	2960	3462	Travis Peak
9 La.-Ark. O. & Dev. Co., Streitmiers No. 1	20	16S	5W	2615	135[d]	------	------	Wilcox or Midway
10 W. H. Rhodes et al, Bledsoe No. 1	20	15S	7W	3058	188	------	------	Arkadelphia
11 Atlantic O. & R. Co., Moffett No. 1	28	16S	8W	3951	132	2830	3365	Travis Peak
12 Seidlitz, Thomason No. 1	35	16S	8W	3009	172	2975	------	Nacatoch
13 Ark. Fuel Oil Co., Crossett Lbr. Co. No. 1	1	19S	7W	3570	120[b]	2715	3055	Travis Peak
14 Marcum, De Yampart No. 1	5	19S	4W	3312	109	2780	3103	Travis Peak
15 Marcum, McGarry No. 1	10	19S	4W	3550	109	------	------	Travis Peak
16 The Texas Co., Gay No. 1	33	16S	4W	3187	128[e]	2866	------	Igneous rock
17 The Texas Co., Koiffer No. 1	11	18S	4W	3574	107	2801	3407	Paleozoic

* Letters refer to key to datum for elevation on page 258.

BRADLEY COUNTY

LOCATION

Bradley County is bounded on the south by Ashley and Union counties, on the west by Calhoun County, on the north by Cleveland County, and on the east by Drew County.

GENERAL FEATURES

The larger part of Bradley County is slightly undulating uplands, 250 to 300 feet above sea level in the northern part but sloping gently southward to 100 feet above sea level, where it meets the flood plain of Ouachita and Saline rivers. In the western part of the county the uplands presents an abrupt change front towards Saline River. The flood plain of Saline River slopes southward from 140 feet above sea level in the north to 65 feet in the south. The southern part of the county lies within the flood plain of Ouachita and Saline rivers.

STRATIGRAPHY

The southwestern part of Bradley County is mantled with Quaternary deposits which also extend northward along Moro Creek and Saline River to the northern border of the county. The Cockfield formation of Claiborne age crops out in a generally southeast-trending belt, 4 to 7 miles wide, which extends from the northwestern corner of the county to Sumpter on Saline River. The Jackson formation crops out in the northeastern part of the county. Deep wells have penetrated all of the Tertiary and most of the Cretaceous sediments in southern Bradley County. A generalized section of formations is given in Table 28.

BASEMENT ROCKS

The basement rocks have not been reached in deep wells drilled in Bradley County. They are probably not less than 5,000 feet below the surface in any part of the area (See Pl. III).

CRETACEOUS

COMANCHE SERIES

The Comanche series, represented by the Travis Peak formation, is believed to underlie most, if not all, of Bradley County. The Travis Peak formation is separated from the overlying Gulf series by an unconformity which, towards the east, brings progressively older beds in contact with the basal beds of the Upper Cretaceous. It is estimated that the Travis Peak is not less than 1,000 feet thick in the western part of the county.

TABLE 28.—*Generalized section of formations in Bradley County*

System	Series	Formation	Thickness in feet	Character
Quaternary	Pleistocene and Recent	Terrace and river deposits	0-100	Alluvial sands, gravels, clays, and loams.
		Unconformity		
Tertiary	Eocene	Jackson	0-100	Sands, clays and glauconitic marl and sandy marl.
		Claiborne	1100-1400	Glauconitic sands, clays, and marl and nonmarine sands and clays—lignitic.
		Wilcox	600-1000	Lignitic sands and clays.
		Midway	450-550	Noncalcareous gray and blue clays with calcareous fossiliferous clays and shale in basal 50 feet.
		Unconformity		
Cretaceous	Gulf	Arkadelphia marl	50-100	Gray and black fossiliferous marls and shales.
		Nacatoch and Saratoga chalk	250-300	Sands, clays, and chalks.
		Marlbrook marl	95-150	Marls, marly chalk, and sandy marl.
		Ozan	0-75	Micaceous and glauconitic sand and sandy marl.
		Tokio-Woodbine (Including red beds at the base)	200-400	Non-red clays and tuffaceous sands (0-300 feet) red clays and sands (0-200 feet).
		Unconformity		
	Comanche	Travis Peak	1000+	Red clays and sands.

GULF SERIES

The Gulf series maintains a fairly constant thickness of between 800 and 900 feet, but the formational units vary in thickness and in lithology. The Tokio-Woodbine section decreases in thickness from west to east and the basal red beds decrease in thickness and lense out in the northern part of the county. The decrease in thickness of the red beds is in part compensated for by the increase in thickness of the upper, non-red member of the Tokio-Woodbine section. The Ozan formation decreases in thickness and disappears in the eastern part of the county. The Nacatoch formation, Saratoga chalk, and Marlbrook marl increases in thickness to the east. The Arkadelphia marl decreases in thickness to the southeast.

TERTIARY

EOCENE SERIES

The Tertiary sediments are from 2,200 to 2,300 feet thick in the southern and southwestern part but increase in thickness to the northeast. They are estimated to total more than 3,000 feet in the northeastern part of the county. The Midway formation maintains its regional lithologic characteristic and a nearly uniform thickness of 450 to 500 feet. The Wilcox formation consists of lignitic sands and clays which are 600 feet thick in the southern part but increase in thickness to the northeast to an estimated thickness of about 1,000 feet in the northeastern part of the county. The Claiborne sediments increase in thick-

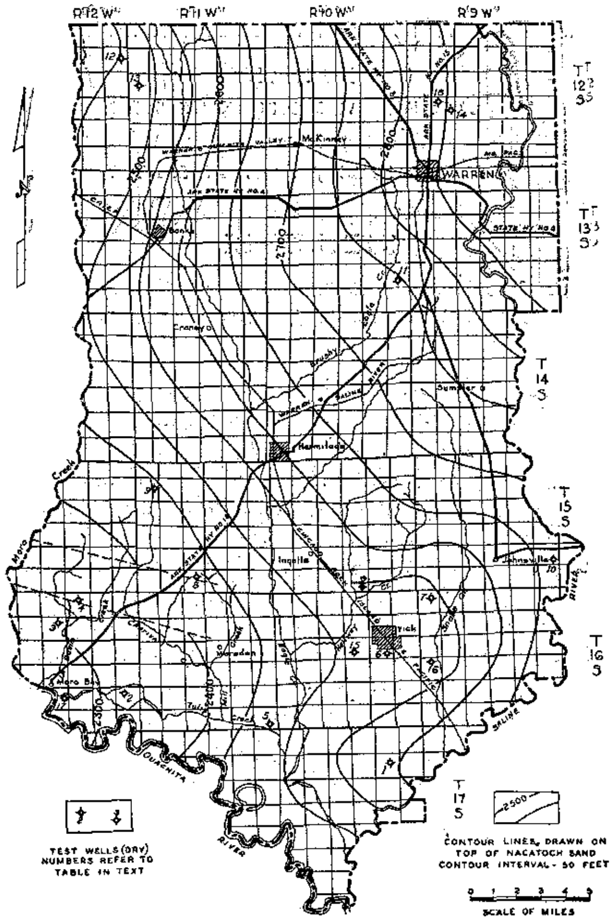


FIGURE 47.—Structure contour map of Bradley County. Figures give depth below sea level in feet.

ness in the same direction from 1,100 feet to 1,400 feet. The following section of the Claiborne was recorded in the Seton Oil Company's Murphy No. 1 well:

Section of the Claiborne group in Seton Oil Company's Murphy No. 1 well in sec. 34, T. 15 S., R. 10 W.

	Thickness in feet
Quaternary:	
Alluvium	80

	Thickness in feet
Claiborne group:	
Cockfield	230
Cook Mountain	205
Sparta sand	285
Mount Selman	
Weches	70
Queen City	225
Reklaw	115

QUATERNARY

PLEISTOCENE AND RECENT SERIES

Alluvial deposits of Pleistocene and Recent age underlie the southwestern part of the county to a maximum depth of about 100 feet.

STRUCTURE

The structure of the Comanche series is not determinable but it is probable that, where present, these strata dip to the west and southwest.

The structure of Bradley County, represented by contour lines drawn on the top of the Nacatoch formation at intervals of 50 feet, is shown in Figure 47. The depth to the top of the Nacatoch ranges from less than 2,300 feet below sea level in the southwestern part to more than 3,000 feet below sea level in the northeastern part of the county. The dips range from a few feet to 50 feet or more per mile. The Smackover graben is continuous into western Bradley County at least as far as the middle of T. 16 S., R. 11 W. The most conspicuous structural feature that can be mapped with the data available is the terrace in the eastern half of T. 16 S., R. 10 W., and extending into T. 16 S., R. 9 W., which is generally known as the "Vick area."

Driller's record of Seton Oil Company's C. H. Murphy No. 1 well, sec. 34, T. 15 S., R. 10 W.

Geologic age	Depth in feet
Quaternary	
Alluvium	
Clay	10
Sand	61
Sand and gravel	78
Tertiary	
Eocene series	
Cockfield formation	
Lignite	90
Shale	120
Rock	121
Sand and gravel	128
Rock	129
Sand streaks gravel	183
Sand shale and gravel	243

Geologic age	Depth in feet
Cook Mountain formation	
Shale and sand	333
Rock	334
Shale and boulders	367
Rock	368
Sparta sand	
Sand and shale	672
Shale	731
Shale ticky	756
Rock	757
Shale and clay	862
Sand	1002
Rock	1005
Sticky shale	1116
Rock	1127
Shale and boulders	1145
Rock	1146
Shale and boulders	1178
Wilcox formation	
Sandy shale	1248
Rock	1286
Soft sand	1293
Brown sandy shale; mucky streaks	1530
Shale	1554
Shale sandy (Core 1556-1564)	1570
Shale and shells	1644
Sand	1647
Sand streaks lignite	1657
Sandy shale	1661
Rock	1662
Sandy shale	1748
Rock	1750
Sand rock and streaks sand	1827
Sandy shale	1872
Sandy shale; streaks sand	2011
Midway	
Sticky shale	2024
Gray mucky shale	2048
Black sticky shale	2090
Sticky shale and boulders	2227
Shale and boulders	2240
Black shale and boulders	2445
Gray limy shale	2485
Sticky shale	2490
Sandy shale	2513
Arkadelphia marl	
Chalk cored	2516
Hard chalk	2520
Black shale, chalk streaks (Core 2598-2610)	2587
Nacatoch sand and Saratoga chalk	
Shale with thin streaks lime (Core 2610-2618)	2608
Hard sand and lime (D. S. T. 2603-2616, 2 trebles drill mud, 7 trebles salt water)	2618
Sandy lime and shells, streaks sand	2642

Geologic age	Depth in feet
Hard lime and shells (Core 2694-2706)	2694
Sand and shells, streaks sandy lime	2706
Sand and shells, streaks sandy lime	2716
Sandy shale and lime streaks	2771
Shale	2795
Chalky shale	2810
Shaly chalk	2842
Chalk rock (S. L. M. 2902-2908)	2908
Broken chalk (Core 2915-2921)	2912
Marlbrook marl	
Chalk; thin shale streaks	2940
Shaly chalk (Core 2980-2998)	2998
Chalky shale; shells (Core 2998-3027)	3027
Hard shale	3051
Hard lime rock (Core 3052-3057)	3052
Shaly chalk	3057
Hard shale	3076
Hard sandy shale (Core 3072-3084)	3084
Ozan formation (?)	
Sand rock	3085
Soft sand (Core 3084-3092)	3111
Tokio-Woodbine section	
Shale	3117
Sandy broken lime and sand	3143
Sand	3177
Sandy shale	3182
Red sand, shale, and lignite	3186
Sandy shale, lignite (Core 3182-3194)	3197
Sandy lime	3215
Hard sand, lime and sand	3237
Sand with hard streaks	3257
Red shale	3262
Hard lime cap (Core 3289-3294)	3290
Red-purple shale	3295
Red shale (Core 3294-3299)	3299
Sandy shaly ash (Core 3299-3302)	3300
Hard sand and ash (Core 3302-3312)	3302
Soft sand and ash	3312
Sand	3318
Sand shale and lime streaks	3337
Hard red shale, streaks lime	3362
Hard sand and ash cap	3366
Very coarse sand S. W. (Core 3366-3370)	3370
Very coarse sand	3374
Hard sand, ash and gravel, conglomerate	3381
Red shale and sand	3396
Red shale; hard sticky streaks	3430
Hard sticky red shale	3440
Red shale with hard and sticky streaks	3496
Red shale with hard and sticky streaks	3507
Hard red sandy shale (Core 3509-3514)	3509
Hard broken red sand and shale	3514
S. L. M. 3509-3514 ft. 3 in.	

List of wells drilled in Bradley County

No., Company, Farm & Number	Location Sec.	Twp.	R.	T. D.	Elev.*	Depth to Nacatoch feet	Depth to red shale feet	Oldest formation penetrated
1 The Texas Co., Sabine Lbr. Co. No. 1 (McHeavey)	11	17S	10W	3250	89.25a	2605	3172	Basal Upper Cretaceous red beds
2 Ark. Fuel Oil Co., Ark. Tbr. & Ld. Co.	25	16S	12W	3476	80.49a	2375	2936	Travis Peak
3 Caldwell Oil Co., Sou. Lbr. Co. No. 1	9	16S	12W	3014	110.28f 105.2g	2470	-------	Tokio-Woodbine
4 Wingfield et al, Sou. Lbr. Co. No. 1	2	16S	12W	3007	110h	2595	-------	Tokio-Woodbine
5 Phillips Petrol. Co., Ark. Lbr. Co. No. 1	36	16S	11W	3203	88.6f 78.6a	2545	3168	Tokio-Woodbine
6 Vick Oil Co., W. F. Ferrell No. 1	14	16S	10W	3002	137.4a	2600	2885	Basal Upper Cretaceous red beds
7 Stand. Oil Co. of La., Sou. Lbr. Co. No. 1	6	16S	9W	2815	137 100a	2682	-------	Nacatoch
8 Magnolia Petrol. Co., Ark. Lbr. Co. No. 1	33	15S	11W	4370	128a	2797	3412	Travis Peak
9 McMurray et al, So. Lbr. Co. No. 1	7	15S	11W	3275	180h 143a	2570	-------	Tokio-Woodbine
10 Gulf Ref. Co. of La., Joe Benson No. 1	25	15S	9W	3361	114.08a	2770	3342	Tokio-Woodbine
11 La. O. & Refg. Co., (Southern O. & Ld. Co.) Bradley No. 1	25	13S	10W	3559	230 217	2965	-------	Tokio-Woodbine
12 Johnson & Adams, Sou. Lbr. Co. No. 1	12	12S	12W	3160	220b	2670	-------	Tokio-Woodbine
13 Caldwell O. & G. Co., Sou. Lbr. Co. No. 2	18	12S	11W	3115	210b	2690	-------	Tokio-Woodbine
14 Brambridge et al, Blankenship No. 1	20	12S	9W	1960	190	-------	-------	Wilcox
15 Ohio Oil Co., Sou. Lbr. Co. No. 1	15	16S	10W	3609	128	2644	3471	Basal Upper Cretaceous red beds
16 Ohio Oil Co., Sou. Lbr Co. No. 2	19	16S	9W	3510	117	2645	3209	Travis Peak
17 Phillips Petrol. Co., Kline No. 1	28	16S	12W	2908	86	2195	2860	Basal Upper Cretaceous red beds
18 Southern Oil Co., Blankenship No. 2	20	12S	9W	3040	190	2010		Nacatoch

* Letters refer to key to datum for elevation on page 261.

CALHOUN COUNTY

LOCATION

Calhoun County is bounded on the south by Union County, on the west by Ouachita County, on the north by Dallas County, and on the east by Cleveland and Bradley counties.

GENERAL FEATURES

The northeastern part of Calhoun County is an upland area which coincides with the outcrop of the Cockfield formation. The altitudes are from 250 to 300 feet above sea level in the northeastern corner but the terrain slopes southwestward to about 200 feet above sea level where it meets the wide river terrace, which separates the uplands area from the flood plain proper of Ouachita River. The southern and western parts of the county form a wide river terrace which slopes southward from an altitude of 200 feet to an altitude of 100 feet where it merges into the flood plain of Ouachita River.

STRATIGRAPHY

The southern and western parts of Calhoun County are mantled with sands, gravels, and loams of Pleistocene and Recent age, but in the northeastern part of the county the Cockfield formation of Claiborne age is at the surface. Deep wells have penetrated all of the Tertiary and Upper Cretaceous formations, and a few wells have drilled into strata of Trinity age.

A generalized section of formations in Calhoun County is given in Table 29.

BASEMENT ROCKS

The basement rocks are believed to have been penetrated in the northwestern part of the county in the Murdock et al Eagle Mills No. 1 well, sec 29, T. 12 S., R. 15 W. The interpretation of the attitude of the basement floor is shown in Plate III and Figure 2. According to this interpretation the Murdock et al Eagle Mills No. 1 well is on the upthrow side of a northeast-southwest trending fault. To the north of the fault the basement rocks lie at depths of 2,500 to 3,000 feet below sea level, to the south the depth to these rocks are not known.

CRETACEOUS

COMANCHE SERIES

Calhoun County, except for the extreme northwestern part, is underlain by rocks of Comanche age belonging to the Travis Peak formation of the Trinity group. These sediments, as elsewhere in Arkansas, consist chiefly of red clays and sand, which

TABLE 29.—*Generalized section of formations in Calhoun County*

System	Series	Formation	Thickness in feet	Character
Quaternary	Pleistocene and Recent	Terrace and river deposits	0-75	Alluvial sands, gravels, clays, and loams.
		Unconformity		
Tertiary	Eocene	Claiborne	700-1200	Glauconitic sand, clay, and marl, and nonmarine sand and clay. In part lignitic.
		Wilcox	550-850	Lignitic sand and clay.
		Midway	500	Gray to blue noncalcareous clays with siderite concretions. Calcareous and fossiliferous in lower 50 feet.
		Unconformity		
Cretaceous	Gulf	Arkadelphia marl	60-75	Gray to black calcareous marl and shales.
		Nacatoch and Saratoga chalk	270-330	Calcareous sands, clays and chalks.
		Marlbrook marl	80-140	Marls, marly chalk, clays, and sandy clays.
		Ozan	45-75	Glauconitic, micaceous sand, and sandy clays.
		Tokio-Woodbine	200-450	Non-red sand and clay, in part tuffaceous, 200-300 feet thick in northern part. In southern part non-red sand and clay underlain by red beds: (0-250 feet thick in southern part).
		Unconformity		
	Comanche	Travis Peak	2000 Maximum thickness	Red clays and sands.
		Neocomian ?		A part of the county probably underlain by marine beds.

are estimated to be 2,000 feet thick in the southern part of the county; but decrease in thickness to the east and northeast.

The Travis Peak is probably underlain in parts of Calhoun County by marine beds of Neocomian age.

GULF SERIES

The total thickness of the Gulf series ranges from 650 feet in the northern part to slightly more than 1,000 feet in the southern part of the county. The Tokio-Woodbine section exhibits the widest variations in thickness and in lithology. The basal red beds of the Upper Cretaceous are from 200 to 250 feet thick in the southern part but decrease in thickness and lense out in the northern part of the county. The upper non-red member of the Tokio-Woodbine section is from 200 to 300 feet thick with the lesser thickness in the eastern and northeastern parts of the county. The formations above the Tokio-Woodbine increase slightly in thickness towards the south.

TERTIARY

EOCENE SERIES

The Tertiary sediments increase in thickness from about 1,700 feet in the western part to about 2,500 feet in the eastern part of the county. The Midway maintains a nearly constant thickness of about 500 feet. The Wilcox formation ranges in thickness from 550 feet in the southwestern part to about 850

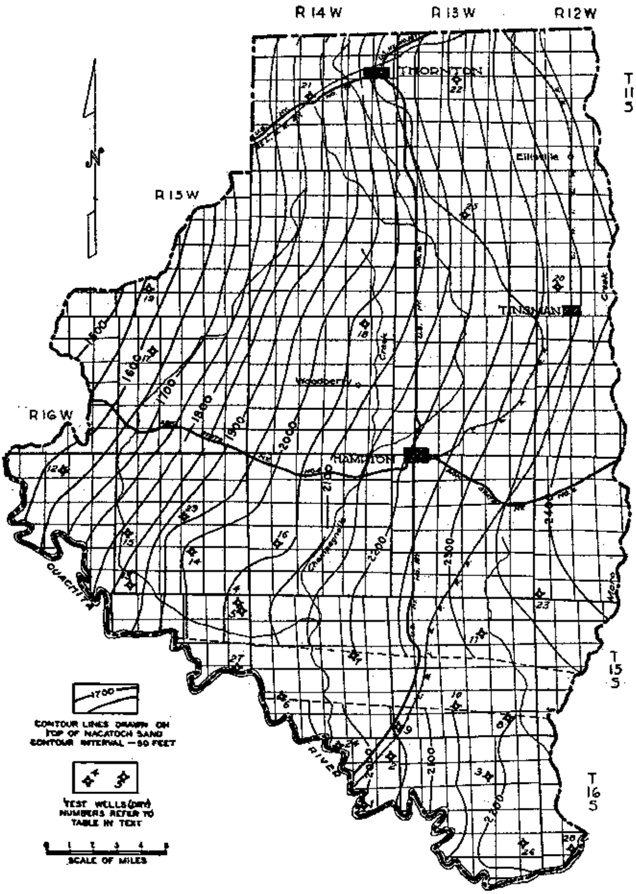


FIGURE 48.—Structure contour map of Calhoun County. Figures give depth below sea level in feet.

feet in the northeastern corner of the county; and the Claiborne varies in thickness from 700 to 1,200 feet with the greater thickness in the eastern part.

PLEISTOCENE AND RECENT SERIES

The southern and western parts of Calhoun County are mantled with sand, gravel, clays, and loams of Pleistocene and Recent age with an estimated thickness of 75 feet in the flood plain of Ouachita River.

STRUCTURE

The structure of the Comanche strata is not known but they probably dip to the south and west.

The structure of Calhoun, represented by contour lines drawn on top of the Nacatoch formatoin, as recorded in deep wells, is shown in Figure 48. The top of the Nacatoch ranges from 1,450 feet below sea level in the western part to 2,450 feet below sea level in the eastern part of the county. The prevailing dip is to the east at rates of 20 to 50 feet per mile. The principal structural feature is the Smackover graben trending in a general east-west direction through T. 15 S.

List of wells drilled in Calhoun County

No.,	Company, Farm & Number	Location Sec.	Twp.	R.	T. D.	Elev.*	Depth to Nacatoch feet	Depth to red shale feet	Oldest formation penetrated
1	Klotsch & Thomas, For. City Box Co. No.1	14	16S	14W	2810	93.3[g]	2160	2804	Basal Upper Cretaceous red beds
2	Sou. Cr. O. Pur. Co., Calion Lbr. Co. No. 1..	1	16S	14W	2818	86.94[a]	2126	2828	Travis Peak
3	Barnesdale-Foster, Freeman-Smith No. 1..	10	16S	13W	3003	91	2270	......	Tokio-Woodbine
4	Ark. Nat. Gas. Co., J. G. Childers No. 1.....	1	15S	15W	2741	106	2173	......	Tokio-Woodbine
5	Ark. Fuel Oil Co., J. G. Childers No. 2....	1	15S	15W	3005	100.25[f]	2165	2750	Travis Peak
6	Magnolia Petrol. Co., Calion Lbr. Co. No. 1..	29	15S	14W	4557	......	2225	3032	Travis Peak
7	Barnesdale-Foster, Freeman-Smith No. 4..	14	15S	14W	3341	110[a]	......	3000	Travis Peak
8	Jerrell et al, Freeman-Smith No. 1..	35	15S	13W	3008	108[a]	2290	......	Tokio-Woodbine
9	Gulf Refg. Co., Freeman-Smith No. 1..	31	15S	13W	2865	84[a]	2135	......	Tokio-Woodbine
10	Barnesdale-Foster, Freeman-Smith No. 6..	28	15S	13W	3016	106.3[a]	2290	......	Tokio-Woodbine
11	Barnesdale-Foster, Freeman-Smith No. 5..	10	15S	13W	3035	121[a] 106[f]	......	......	Tokio-Woodbine
12	Ginther et al, Stout Lbr. Co. No. 1.....	3	14S	16W	3008	103[a]	1746	2535	Travis Peak
13	Barnesdale-Foster, Freeman-Smith No. 1..	31	14S	15W	2584	96.6[a]	1980	2525	Basal Upper Cretaceous red beds
14	Barnesdale-Foster, Freeman-Smith No. 2..	27	14S	15W	2918	98[a]	2108	2918	Travis Peak
15	Sou. Cr. O. Pur. Co., Freeman-Smith No. 1..	19	14S	15W	2713	103.06[a]	1925	2710	Basal Upper Cretaceous red beds
16	Checkerboard Synd. (Berry & LeGrande) Abbott No. 1	20	14S	14W	2524	131.9[a]	2175	......	Marlbrook
17	Barnesdale-Foster, Freeman-Smith No. 1..	8	13S	15W	......	190[b]	......	2540	Travis Peak

No., Company, Farm & Number	Location Sec.	Twp.	R.	T. D.	Elev.*	Depth to Nacatoch feet	Depth to red shale feet	Oldest formation penetrated
18 Ark. Nat. G. Co., Stout Lbr. Co. No. 1	2	13S	14W	3074	237	2307	3060	Basal Upper Cretaceous red beds
19 C. E. Murdock, Eagle Mills No. 1	29	12S	15W	2551	167.7[a]	1740	-------	Tokio-Woodbine
20 Sure Oil Co., (Lucas et al) Adams No. 1	29	12S	12W	2995	205.7[a]	2525	-------	Tokio-Woodbine
21 Delmar Oil Co. & Foster, Fanny Guibor No. 1	16	11S	14W	3005	340[a]	2215	2785	Travis Peak
22 Calhoun O. & Dev. Co., Hearnesb'g'r No. 1	16	11S	13W	2930	276.1[b]	2475	-------	Nacatoch
23 Ohio Oil Co., Stout Lbr. Co. No. 1	36	14S	12W	3615	158	2520	3358	Travis Peak
24 Tidal Oil Co., Ark. Tbr. Co. No. 1	3	16S	14W	3507	88	2093	2863	Travis Peak
25 Amerada Petrol. Co., Matlock No. 1	10	12S	13W	3730	242	2415	3118	Travis Peak
26 Phillips Petrol. Co., Freeman-Smith Lbr. Co. No. 1	25	16S	13W	3332	92	2306	2925	Travis Peak
27 Gunther et al, Freeman-Smith No. 1	24	15S	15W	2907	-------	-------	-------	-------
28 J. B. Hurley, Ark. Tbr. Co. No. 1	29	16S	12W	3302	83	2269	2877	Travis Peak

* Letters refer to key to datum for elevation on page 261.

CHICOT COUNTY

LOCATION

Chicot County adjoins the State of Louisiana on the south, Ashley and Drew counties on the west, Desha County on the north, and Mississippi River on the east.

GENERAL FEATURES

Chicot County lies in the flood plains of the Mississippi and Boeuf rivers. It is a flat, generally wooded plain with altitude ranges from 100 to 135 feet above sea level.

STRATIGRAPHY

The surface of Chicot County is underlain by Quaternary alluvial loams, clays, and sands of Recent and Pleistocene age to estimated depths of 75 to 150 feet. These beds rest unconformably on strata of Claiborne age.

The Eocene strata have an estimated thickness of 2,650 feet in the southern part and 3,200 feet in the northern part of the county. The Cretaceous series is represented chiefly by the upper part of the Taylor group and by the Navarro group. It is estimated to be less than 100 feet thick in the southern part and about 500 feet thick in the northern part of the county. A generalized section of formations is given in Table 30.

TABLE 30.—*Section of formations in Chicot County*

System	Series	Formation	Thickness in feet	Character
Quaternary	Pleistocene and Recent	Terrace and river deposits	75-150	Alluvial sands, gravels, clays, and loams.
		Unconformity		
Tertiary	Eocene	Claiborne	1400-1500	Sands, clays, and glauconitic sands and marls, in part iigintic.
		Wilcox	800-1200	Lignitic sands, sandy clay, and clays.
		Midway	450-500	Gray and blue noncalcareous with fossiliferous and calcareous clays and shale in basal part.
		Unconformity		
Cretaceous	Gulf	Arkadelphia marl	0-50	Gray to black calcareous and fossiliferous marl and shale.
		Nacatoch sand and Saratoga chalk and older (Including Monroe gas rock)	50-450	Principally fine, calcareous sands in northern part — limestone (Monroe gas rock) in southern part.
		Unconformity		
	Paleozoic			

BASEMENT ROCKS

The basement rocks have not been definitely recognized in Chicot County. The Texas Company's Hammond No. 1 well in sec. 23, T. 17 S., R. 2 W., encountered igneous rock immediately beneath the base of the Monroe gas rock at a depth of 3,240 feet below the surface but it is not established that these rock are of Paleozoic age. Based on data available from the adjacent area, it is estimated that the depth to the basement rocks ranges from 2,800 feet in the southern part to 3,500 feet in the northern part of the county.

CRETACEOUS

COMANCHE SERIES

The Comanche series, according to the above interpretation of the basement floor, is absent from Chicot County.

GULF SERIES

The Gulf series is estimated to be from 50 to 100 feet thick in the southern part of the county where it is represented by the Monroe gas rock. It increases in thickness to about 500 feet in the northern part of the county where it consists principally of fine-grained sand with subordinate beds of limestone, shale, and marl. The Nacatoch formation and the Saratoga chalk, and perhaps a part of the Marlbrook marl, are believed to be represented in that part of the county.

TERTIARY

EOCENE SERIES

The Midway formation is from 450 to 500 feet thick. The Wilcox formation ranges in thickness from 800 feet in the southern part to about 1,200 feet in the northern part of the county. These formations are lithologically similar to some of the formations in Ashley County. The Claiborne is estimated to be from 1,400 to 1,501 feet thick. The lower 400 feet of the Claiborne, correlated with the Mount Selman of Texas and the Cane River of Texas, consists of predominantly brown lignitic, glauconitic clays, sand, and sandy clay.

QUATERNARY

PLEISTOCENE AND RECENT SERIES

Alluvial deposits of Pleistocene and Recent age underlie the surface of Chicot County to depths of 75 to 150 feet.

STRUCTURE

The structure of Chicot County, represented by contour lines drawn on top of the Monroe gas rock is shown in Figure 49. The depth to the top of the Monroe gas rock range from 2,750 feet in the southeastern part to an estimated depth of 3,500 feet in the northeastern part of the county. The dips vary from 20 to 50 feet per mile towards the east and northeast. The presence of local structure is not determinable owing to lack of detailed data.

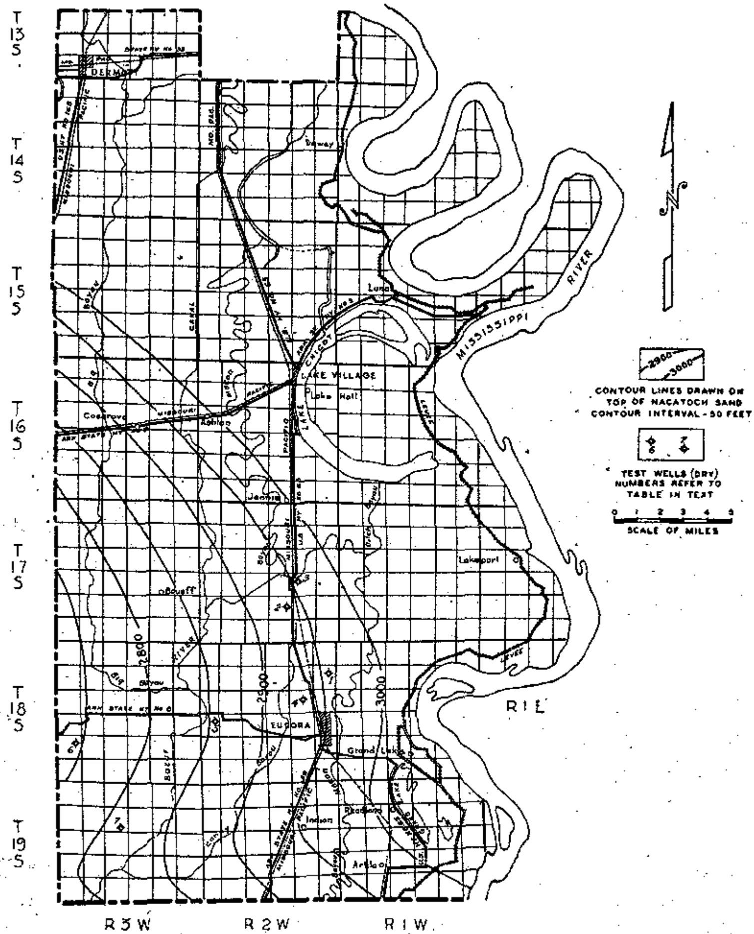


FIGURE 49.—Structure contour map of Chicot County. Figures give depth below sea level in feet.

List of wells drilled in Chicot County

No., Company, Farm & Number	Location Sec.	Twp.	R.	T. D.	Elev.*	Depth to Nacatoch feet	Depth to red shale feet	Oldest formation penetrated
1 Duncan Oil Co., Reed No. 1	12	18S	2W	———	139[a]	———	———	———
2 Hoffman Petrol. Co., R. S. Ralph (Masters) No. 1	27	17S	2W	3012	125 [a]	———	———	———
3 Texas Co., Hammond No. 1	23	17S	2W	3496	128	3099	———	Igneous rock
4 Crawford, Cochran No. 1	14	18S	2W	2336	122	———	———	Wilcox
5 Hunter et al, Sawyer No. 1	19	18S	2W	3365	107	2973	3165	Travis Peak
6 Smith, Lytle No. 1	31	18S	2W	2908	———	2889	———	Nacatoch
7 Hunter et al, Lytle No. 1	9	19S	3W	3128	108	2920	3094	Travis Peak

CLARK COUNTY

LOCATION

Clary County adjoins Ouachita and Nevada counties on the south, Pike County on the west, Hot Spring County on the north, and Dallas County on the east.

STRATIGRAPHY

The northern part of Clark County lies in the Ozark province and the central and southern parts lie in the Gulf Coastal Plain. The Upper Cretaceous strata, striking northeast and dipping to the southeast, are exposed at the surface in the central part, and the Midway and Wilcox formations of Tertiary age form the surface rocks in the southeastern part of Clark County.

BASEMENT ROCKS

The Paleozoic rocks at the surface in the northern part slope southward beneath the Cretaceous of the Coastal Plain to depths of 2,500 feet below sea level in the southeatern part the county.

CRETACEOUS

COMANCHE SERIES

Rocks of Comanche age are present only in the southern and southwestern parts of Clark County where they are represented by red clays and sands of the Travis Peak formation. Their estimated thickness is 500 to 600 feet.

GULF SERIES

The truncated edges of the soueastward dipping Upper Cretaceous strata form the surface rocks in the central part of Clark County. The Tokio formation overlaps the Woodbine sand as defined by Dane[7] to lie directly on the basement rocks. In the southeastern part of the county where the Upper Cretaceous underlies the Tertiary strata, the Tokio-Woodbine section is from 150 to 170 feet thick and contains volcanic material in the lower part which apparently is continuous into the volcanic material exposed at the surface to the west of Clark County. The Gulf series in the southeastern part of the county ranges in thickness from 600 to 800 feet with the greater thickness to the south. The sediments, except for the appearance of volcanic material, are essentially similar to sediments exposed at the surface.

TERTIARY

EOCENE SERIES

The Midway formation is exposed in a northeast-trending belt 4 to 6 miles wide. The basal 20 to 25 feet of beds consists

[7] Dane, C. H., Upper Cretaceous formation of southwestern Arkansas; Arkansas Geol. Sur., Bull. 1, 1929.

CLARK COUNTY

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Clary County adjoins Ouachita and Nevada counties on the south, Pike County on the west, Hot Spring County on the north, and Dallas County on the east.

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GULF SERIES

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[7] Dane, C. H., Upper Cretaceous formation of southwestern Arkansas; Arkansas Geol. Sur., Bull. 1, 1929.

of slightly calcareous gray and greenish-gray clays which are fossiliferous in the lower part. The upper part consists of gray noncalcareous clay. The Midway formation is overlain by lignitic sands and clays of the Wilcox formation.

STRUCTURE

The structure of the southeastern part of Clark County, drawn on top of the Nacatoch formation, is shown in Figure 50.

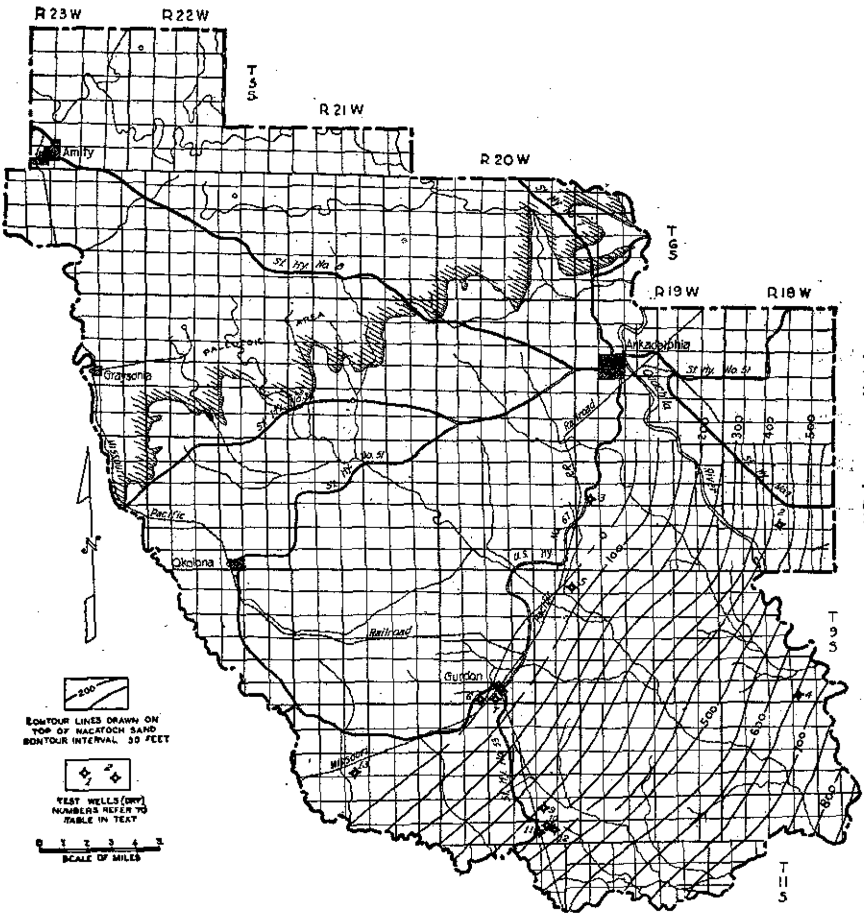


FIGURE 50.—Structure contour map of Clark County. Figures give depth below sea level in feet.

The top of this formation slopes from the outcrop to the east and southeast to depths of 810 feet below sea level in the southeastern corner of the county.

List of wells drilled in Clark County

No., Company, Farm & Number	Location Sec.	Twp.	R.	T. D.	Elev.*	Depth to Nacatoch feet	Depth to red shale feet	Oldest formation penetrated
1 United Petrol. Co., Langford No. 1	28	5S	23W	2000	----	----	----	----
2 Littlejohn, Hall & Gann, Littlejohn No. 1	22	8S	18W	1321	188[a]	550	----	Paleozoic
3 H. K. Casey, Sloan No. 1	18	8S	19W	1096	300.7[a]	445	----	Paleozoic
4 Ralph Dudney, Grayson No. 1	35	9S	18W	1402	287[a]	887	----	Paleozoic
5 Virgil Heath, Arnold No. 1	12	9S	20W	834	160[a]	210	----	Paleozoic
6 Ark. Nat. Gas. Co., J. W. McAlpine No. 1	32	9S	20W	2950	----	220	----	Paleozoic
7 Ark. Fuel Oil Co., J. W. Alpine No. 2	32	9S	20W	1114	205[a]	205	----	Paleozoic
8. Thornton & Chancellor, Bierne No. 1	17	10S	19W	----	----	----	----	Paleozoic
9 Ark. Oil Synd., J. A. Borringer No.1	26	10S	20W	2191	247[a]	513	1280	Paleozoic
10 So. Drlg. Co., Burrows No. 1	35	10S	20W	714	259[a]	575	----	----
11 Sou. Drlg. Co., (Whelan Oil Co.) Burrows No. 2	35	10S	20W	2351	----	----	1462	----
12 Whelan Oil Co., Burrows No. 3	35	10S	20W	1375	----	----	----	----
13 H. C. Wilson Synd., (Hunter et al) J. G. Clark No. 1	16	10S	21W	1942	200[a]	----	952	----

* Letters refer to key to datum for elevation on page 261.

CLAY COUNTY

LOCATION

Clay County is bounded on the south by Greene County, on the west by Randolph County, and on the north and east by the State of Missouri.

GENERAL FEATURES

Clay County, except for a small area in the extreme northwest corner which belongs to the Ozark province, lies in the Mississippi embayment. It comprises parts of three topographic divisions: Crowley's Ridge, the Advance lowland, and the Mississippi lowland.

Crowley's Ridge is a broken, hilly area, 5 to 10 miles wide, extending from the northwestern corner of the county southwestward beyond the county line. Its maximum elevation is about 550 feet above sea level, or 250 feet above the Advance lowland to the west.

The advance lowland, which includes most of the county west of Crowley's Ridge, is a nearly level plain 275 to 300 feet above sea level.

The area to the west of Crowley's Ridge is included in the Mississippi lowland and lies 275 to 300 feet above sea level.

STRATIGRAPHY

The Powell limestone and the Cotter dolomite of Lower Ordovician period crop out in an area comprising a few square miles in the extreme northwestern corner of the county. Sands and clays of Eocene age form the body of Crowley's Ridge and crop out in places on the sides and slopes of the hills. Most of the county is mantled by Quaternary sand, gravel, clays, and loess, which attain a maximum thickness of about 100 feet.

A generalized section of formations is given in Table 31.

BASEMENT ROCKS

The floor upon which the Coastal Plain sediments were deposited probably consists of limestones and dolomites of the Ordovician age, such as crop out in the adjacent part of the Ozark province. These rocks were folded in late Paleozoic time, truncated and subsequently downwarped to the east to accommodate the Coastal Plain sediments. The basement floor dips at a fairly uniform rate toward the southeast and lies at a depth of 1,400 to 1,500 feet below the surface in the southeastern part of Clay County.

TABLE 31.—*Generalized section of formations in Clay County*

System	Series	Formation	Thickness in feet	Character
Quaternary	Pleistocene and Recent		0-200	Alluvium sand, gravel, and clays with light-yellow to dark-red loess at the base.
		Unconformity		
Tertiary	Pliocene	Lafayette	0-40	Sand and gravel.
		Unconformity		
	Eocene	Wilcox	0-500	Sand and clays, in part lignitic.
		Midway clays	0-400	Chiefly gray and bluish-gray to black clay and some glauconitic sand.
		Unconformity		
Cretaceous	Gulf	Arkadelphia marl	0-50	Dark-gray to black calcareous shale.
		Nacatoch sand and older formations	0-450	Chiefly glauconitic sand and calcareous sandstone, and subordinate beds of shale and chalk.
		Unconformity		

Basement rocks—Paleozoic or older.

CRETACEOUS ROCKS

The Cretaceous rocks, which underlie most of Clay County, are known only from the driller's records of deep wells. However, the correlation of these wells is believed to be essentially accurate, owing to the lithologic characteristics of the formations, beginning with the dominantly sandy Wilcox above the dark Midway shales and clays which, in turn, overlie the gray to green sands of Cretaceous age.

The Cretaceous is made up principally of gray to green sand and subordinate beds of sandy shale and shale, which include the Arkadelphia marl, the Nacatoch sand and, perhaps, the equivalent of the Marlbrook marl in the southeastern part of the county. The maximum thickness of the Cretaceous is estimated to be from 400 to 500 feet in the extreme southeastern corner of Clay County, but the thickness diminishes eastward; in part the result of thinning of individual members, and in part the result of overlap.

TERTIARY

EOCENE SERIES

The Eocene of Clay County is divisible into an upper member, made up of sand, sandy clay, and clay, in part lignitic, assigned to the Wilcox formation, and a lower member, consisting of dark clays belonging to the Midway.

The Midway clays are estimated to be 400 feet thick in the southeast corner but diminish in thickness towards the west.

The maximum thickness of the Wilcox formation is estimated to be 500 feet in the southeastern corner, decreasing in thickness westward.

PLIOCENE

LAFAYETTE FORMATION

The Lafayette formation is represented by a few feet to 30 feet or more of sands and gravel which are exposed on Crowley's Ridge.

QUATERNARY

PLEISTOCENE AND RECENT SERIES

The Lafayette formation over Crowley's Ridge is overlain by light-yellow or brown to dark-red noncalcareous loess and loess-like clays of Pleistocene age.

The Advance lowland, west of Crowley's Ridge, according to Stephenson and Crider,[3] is underlain to a depth of 150 to 200 feet by alluvial sands, clays, and gravels of Pleistocene age, but in part the Recent.

The Mississippi lowland east of Crowley's Ridge, according to the same authorities,[4] is underlain by 150 feet or more of alluvial sand, clay, and gravel, probably for the most part of Recent, but perhaps in part, of Pleistocene.

The following well record gives a typical well section in northeastern Clay County.

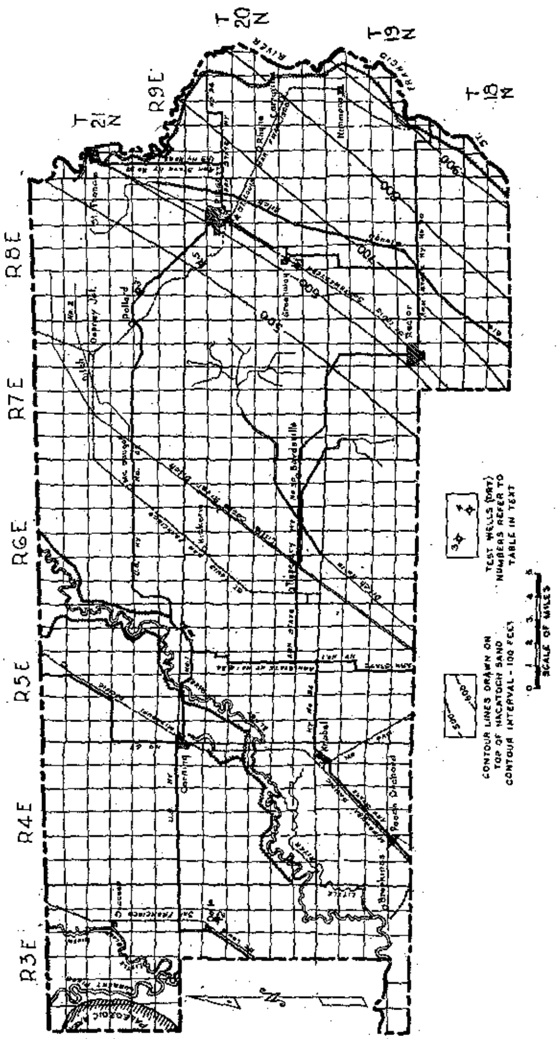
Driller's record of Texas Piggott Company's Sallie No. 1 well sec. 11, T. 20 N., R. 8 E

Geologic age	Depth in feet
Quaternary	
Recent and Pleistocene Series	
Surface sand	25
Water sand	71
Sandy clay	75
Clay	90
Clay and sand	139
Tertiary	
Eocene series	
Wilcox formation	
Rock	140
Soapstone	147
Packed sand	152
Soapstone	159
Shale	182
Sand and gumbo	185
Gumbo	200
Shale	208
Packed sand	217

[3] Stephenson, L. W., and Crider, A. F., Geology and ground-water resources of northeastern Arkansas: U. S. Geol. Survey Water-Supply Paper 399, p. 161, 1916.

[4] Stevenson, L. W., and Crider, A. F., op. cit., p. 161.

Geologic age	Depth in feet
Shale	298
Gumbo	308
Sand	310
Shale	339
Gumbo	355
Shale	367
White limy shale	392
Chalky lime	412
Limestone	428
Shale	452
Shale and gumbo	491
Rock	492
Midway clay	
Shale	567
Shale (blue-black)	570
Shale	611
Soapstone	696
Gpmbo	720
Shale and gumbo	736
Lime	739
Sandy shale	748
Shale and gumbo	860
Rock	861
Sticky shale	877
Rock	878
Sticky shale	880
Unconformity	
Cretaceous	
Gulf series	
Arkadelphia marl, Nacatoch sand, and older	
Soft sandy lime	885
Rock	890
Water sand	900
Sticky shale	920
Water sand	990
Shale	994
Water sand	1005
Hard rock	1007
Sandy shale	1027
Green sand rock	1029½
Sand	1040
Sandy shale	1044
Shale and gumbo	1094
Sandy shale	1186
Rock	1187
Sandy shale	1189
Sand rock	1199
Hard flint rock	1200
Broken rock	1220
Sand and gravel; lignitic	1224
Paleozoic	
Rock	1233



STRUCTURE

The regional structure of Clay County is shown by means of contour lines on top of the Upper Cretaceous and Nacatoch sand in Plate X and Figure 51, respectively. The normal dip is to the southeast, and the top of the Cretaceous lies from 800 to 1,000 feet below sea level in the southeastern corner of the county.

FIGURE 51. — Structure contour map of Clay County. Figures give depth below sea level in feet.

List of wells drilled in Clay County

No., Company, Farm & Number	Location Sec.	Twp.	R.	T. D.	Elev.*	Depth to Nacatoch feet	Depth to red shale feet	Oldest formation penetrated
1 A. G. Hildreth, Richardson, Marshall No. 1	28	20N	8E	1519	305+	1026	.....	Paleozoic
2 Calark Dev. Co., Rawlings No. 1	11	20N	3E	.....	.....	.....	.....	.....
3 Arkmo O. & G. Co., Gassett No. 1	29	21N	8E	907	.....	.....	.....	.....
4 Tex. Piggott O. Co., Sallie No. 1	11	20N	8E	1223	295	860	.....	Paleozoic
5 S. C. Jeffus, Tr., Underwood No. 1	4	20N	8E	1214+	310	875	.....	Paleozoic

* Letters refer to key to datum for elevation on page 261.

CLEVELAND COUNTY

LOCATION

Cleveland County is bounded on the south by Bradley County, on the west by Calhoun and Dallas counties, on the north by Grant and Jefferson counties, and on the east by Lincoln and Drew counties.

GENERAL FEATURES

The principal streams draining Cleveland County are Saline River, traversing the area from northwest to southeast, Moro Creek forming the western boundary, and Big Creek and Hudgins Creek, tributaries to Saline River; Big Creek and Hudgins Creek flow through flood plains, the flood plains of Saline River, 2 to 10 miles wide. The interstream areas are rolling uplands with a general elevation of 200 to 250 feet above sea level but with a few small areas 300 feet or more above sea level.

STRATIGRAPHY

The Cockfield formation of Claiborne age is exposed at the surface in the western and northwestern part; in the remainder of the county, except the flood plains of the streams traversing the area, the Jackson formation is at the surface. The weathering of the Jackson sediments produces the characteristic red lands of Cleveland County. A generalized section of formations is given in Table 32.

BASEMENT ROCKS

The basement floor in Cleveland County slopes towards the southeast from an estimated depth of 2,500 feet in the northwestern part to 5,000 feet below sea level in the southeastern part of the county. The Arkansas Natural Gas Company's Tate No. 1 well in sec. 4, T. 19 S., R. 11 W., penetrated what appears to be altered Paleozoic rock from 3,310 to 3,563 feet and igneous rock from 3,563 to 3,620 feet. Clarence S. Ross of the U. S. Geological Survey reported as follows on the core materials from this well:

"The rocks from a depth of 3,310 to about 3,563 feet appear to be sedimentary rock (shale, limestone, and possible chert) which have been partly altered; with the development of ferromagnesian minerals by contact metamorphism of the peridotite. Peridotite seems to have been encountered at about 3,561 feet, where a serpentine derived from a nearly pure olivine rock was encountered. At an approximate depth of 3,600 feet, the rock is peridotite composition. Some parts are characterized by abundant magnetite and perovskite and others by mica, diapside, and magnetite. The igneous rocks from this well are probably most

TABLE 32.—*Generalized section of formations in Cleveland County*

System	Series	Formation	Thickness in feet	Character
Quaternary	Pleistocene and Recent	Terrace and river deposits	0-50	Alluvial sands, gravels, clays, and loams.
		Unconformity		
Tertiary	Eocene	Jackson Claiborne	1000-1800	Sand, clay, and glauconitic marl and sandy marl. Glauconitic, in part lignitic, sands and clays and nonmarine sands and clays.
		Wilcox	600-1400+	Lignitic sands and clays.
		Midway	450-550	Gray to blue noncalcareous clays with siderite concretions. Calcareous and fossiliferous in lower 50 feet.
		Unconformity		
Cretaceous	Gulf	Arkadelphia marl	75-100	Gray to black calcareous, fossiliferous marls and shales.
		Nacatoch and Saratoga chalk	220-325	Calcareous sands, clays, and sandy limestone with chalk and chalky shale in lower part.
		Marlbrook marl	100-140	Calcareous sands, marls, and chalky marls.
		Tokio-Woodbine	0-280	Sands with thin beds of clay; and brown sand in basal part.
		Unconformity		
	Comanche	Travis Peak	0-500 Est.	Sand with thin beds of clay. Brown sand in basal part.
		Unconformity		
Paleozoic		Undifferentiated		

closely related in mineral composition with the diamond-bearing peridotite of Pike County, Arkansas. The gabbro-pyroxenite of Chicot County, Arkansas, may also be related. Both rocks show hydrothermal metamorphism but no evidence of regional or dynamic alteration. This may mean that these igneous rocks are later than pre-Cambrian, and are related to the Cretaceous peridotites of Pike County in age as well as in mineral composition."

Core material from depth of 3,600 feet is described as follows:

"This rock is nearly black in hard specimen and contains conspicuous magnetite. The mineral composition of this perovskite peridotite is as follows:"

	Per cent
Olivine altered to serpentine	24
Olivine altered to magnetite	29
Primary magnetite	13
Perovskite	31
Mica	3

Very small amount of diopside.

Peridotite from depth of 3,616 feet has the following mineral composition:

	Per cent
Calcite	8
Olivine	2
Diapside	4
Mica	11
Magnetite	32
Serpentine	34
Perovskite	9

CRETACEOUS

COMANCHE SERIES

Rocks of Comanche age have not been penetrated in deep wells drilled in Cleveland County, but it seems probable that a part of the Travis Peak formation of the Trinity group underlies the southeastern part of the county.

GULF SERIES

The Gulf series are 500 feet thick in the northern part and about 800 feet thick in the southern part of the county. The Tokio-Woodbine section, made up chiefly of sands with subordinate beds of clays, increases in thickness from 100 feet or less in the northwestern part to 280 feet in the southern part, but is probably absent in the northeastern corner of Cleveland County. See Figure 8. The Ozan formation is not recognized as a formational unit in this area although it may be in part represented in the Marlbrook marl. The Nacatoch formation and the Saratoga chalk increase in thickness to the southeast.

TERTIARY

EOCENE SERIES

The Eocene sediments increase markedly in thickness from west to east through Cleveland County; they are 2,000 to 2,100 feet thick in the western part and are estimated to be from 3,500 to 3,700 feet thick in the eastern part of the county. The Midway formation is estimated to be from 450 to 5560 feet thick with the greater thickness in the eastern part. The Wilcox formation in general increases in thickness to the east. In the western part it ranges in thickness from 600 feet in the north to 800 feet in the south; in the eastern part from 1,200 feet in the south to 1,400 feet in the north. The Jackson and Claiborne sediments cannot be separated in the driller's records. The Claiborne group is about 2,000 feet thick in the western part, and the combined thickness of the Claiborne and Jackson is about 1,800 feet in the northeastern part of the county.

PLEISTOCENE AND RECENT SERIES

The flood plains of the major streams are underlain by sands, gravels, and loams of Pleistocene and Recent age to a depth of 50 feet.

STRUCTURE

The generalized structure of the western part of Cleveland County drawn on top of the Nacatoch formation is shown in Figure 52. The top of the Nacatoch is 2,000 to 2,400 feet below sea level in the western part, but is estimated to be from 3,200 to 3,400 feet below sea level in the eastern part of the county. The data are inadequate for determining local structural features which may be present in the area.

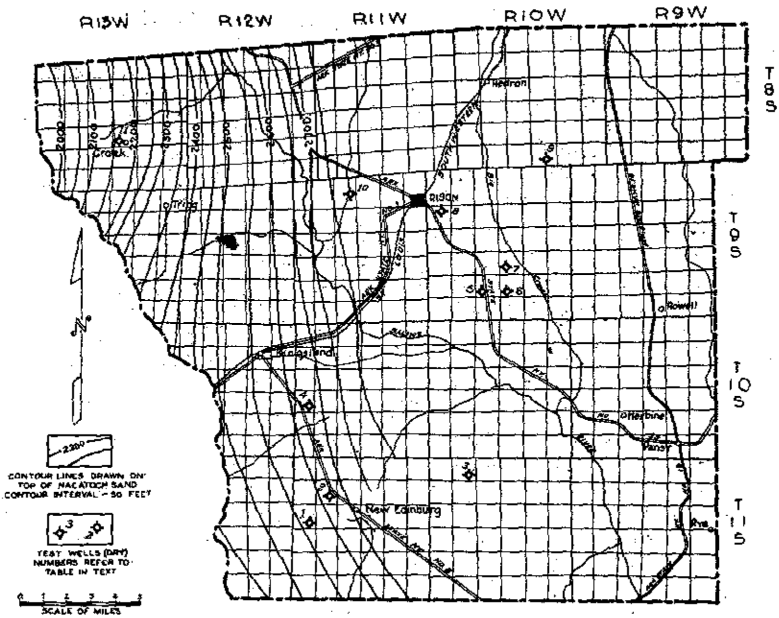


FIGURE 52.—Structure contour map of Cleveland County. Figures give depth below sea level in feet.

List of wells drilled in Cleveland County

No., Company, Farm & Number	Sec.	Twp.	R.	T. D.	Elev.*	Depth to Nacatoch feet	Depth to red shale feet	Oldest formation penetrated
1 Stark & O'Mara, (Rex O. & G. Co.) Ward No. 1	18	11S	11W	1827				Wilcox
2 Penn-Ark. Oil Co., (Combination Oil Co.) Tipton No. 1	8	11S	11W	2750	264[a]			Midway
3 Acme Oil Co., Mosley No. 1 (Hall)	5	11S	10W	3440	172	3028		Nacatoch
4 Simms Oil Co., Mosley No. 1	19	10S	11W	3500	241.8[a]	2885	3488	Tokio-Woodbine
5 Haley et al, (Deadman) Moore No. 1	28	9S	10W	3210	267[a]			Midway
6 South Ark. Oil Co., Moore No. 1	27	9S	10W	3324	247			Midway
7 Markle Drlg. Co., Lydia Plummer No. 1	22	9S	10W	2703	174[a]			Wilcox

No., Company, Farm & Number	Location Sec.	Twp.	R.	T. D.	Elev.*	Depth to Nacatoch feet	Depth to red shale feet	Oldest formation penetrated
8 Gladys Belle O. Co., (Ark. Oil Corp.) Fore No. 1	7	9S	10W	3210	271.94[a]	....	....	Midway
9 Success Drlg. Co., Tolson No. 1	34	8S	10W	1400	210[a]	.... *	....	Claiborne or Wilcox
10 Ark. Nat. Gas Co., Tate No. 1	4	9S	10W	3620	154	2930	....	Igneous rock
11 Littlejohn & Hall, Littlejohn	22	18S	13W	1050	.....	....	....	Claiborne

* Letters refer to key to datum for elevation on page 261.

Arkansas Natural Gas Corporation's Mrs. D. J. Tate No. 1 well, northeast corner lot 6, NE¼ sec. 4, T. 9 S., R. 11 W. Clevealnd County, Arkansas.

(Comm. Aug. 27, 1928. Comp. Oct. 11, 1928)
Elevation, not shown. Initial production, none.

Geologic age	Depth in feet
Tertiary	
Eocene series	
Jackson and Claiborne formation	
Sand and clay	40
Bouders	50
Gumbo	90
Sand and shale	115
Sand	140
Sand and shale	245
Sand and boulders	286
Gumbo and boulders	330
Rock	332
Gumbo and shale	410
Gumbo and streaks shale	495
Shale and boulders	550
Sand	575
Shale and boulders	670
Hard stick shale	690
Sandy shale and boulders	775
Sticky shale	825
Sandy shale and streaks of sand	860
Rock	862
Sand with brown streaks shale	905
Sand	912
Sticky sand and shale	1025
Sandy shale and boulders	1060
Sticky shale	1115
Rock	1117
Sand and shale	1128
Rock	1130
Broken streaks sand	1169
Gummy shale	1208
Rock	1211
Sand and boulders	1225
Shale and boulders	1280
Sand and boulders	1295
Sand and shale	1432
Gummy shale and sand	1485

Geologic age	Depth in feet
Wilcox formation	
Rock	1487
Sand and boulders	1522
Sand	1530
Sand (Cored)	1437
San dand streaks shale	1560
Soft white sand	1583
Sand; streaks shale	1620
Rock	1623
Limy shale and boulders	1655
Rock	1659
Gummy lime	1664
Hard brown shale and lime	1680
Sandy shale and lime	1703
Sand, shale, and lignite	1760
Shale and boulders	1769
Rock	1784
Shale and boulders	1805
Chalky shale	1845
Hard shale; streaks sand	1875
Hard gummy shale	1987
Shale and boulders	2005
Sticky shale	2025
Hard sticky shale	2040
Sandy shale	2049
Lime rock	2051
Sand and lim erock	2053
Hard lime	2056
Sand	2065
Hard gummy shale	2095
Sticky shale	2118
Hard lime and shale	2129
Limy shale	2165
Hard lime	2166
Hard lime streaks shale	2193
Gummy shale	2198
Rock	2200
Hard sticky shale	2234
Gumbo	2294
Hardy sandy shale	2308
Midway clays	
Hard gummy shale	2335
Hard sticky shale	2444
Hard soft sticky shale	2555
Gumbo	2565
Soft gummy shale	2675
Hard gummy shale	2700
Hard sticky shale	2739
Rock	2740
Hard shale; cored	2743
Hard shale	2754
Gummy shale	2810
Gumbo	2819
Hard gummy shale	2826
[illegible]	2834

Geologic age	Depth in feet
Cretaceous	
Gulf series (Upper Cretaceous)	
Arkadelphia marl	
Shale	2892
Chalk and shale	2898
Hard shale and lime	2928
Hard sandy lime	2930
Nacatoch sand and Saratoga chalk	
Sand	2955
Sand and shale	2961
Sandy lime	2977
Sand and lime	2992
Hard shale and lime	3030
Hard sandy shale	3048
Shale and streaks of lime	3080
Lime	3097
Chalk and hard shale	3127
Marlbrook marl and older	
Lime	3293
Sandy lime	3295
Gummy shale	3307
Base of formation	3310
Paleozoic	
Undifferentiated metamorphic sediments	
Sand; soft water	3312
Sand	3321
Sand; soft water	3326
Sand and shale	3335
Lime	3350
Gummy shale	3361
Sandy shale	3363
Chalk and streaks of sand	3375
Broken lime	3438
Gray shale	3452
Chalky sand; cored	3462
Rock	3465
Sand chalk and lime	3475
Sand and lime	3495
Chalk	3545
Base of formation	3563
Igneous rock	
Hard lime	3567
Broken lime	3592
Crystallized sand and lime	3597
Rock; hard sand	3611
Rock and pyrites	3613
Rock	3620
T. D.	3620

COLUMBIA COUNTY

LOCATION

Columbia County adjoins Louisiana on the south, Lafayette County on the west, Nevada and Ouachita counties on the north and Union County on the east.

GENERAL FEATURES

Columbia County is a dissected upland area. A broad ridge, forming the drainage divide between Ouachita and Red rivers, traverses the area from the north-central part nearly to the southeastern corner of the county. The general level of the ridge is between 350 and 400 feet above sea level, but in local areas the altitudes are more than 400 feet. Westward the terrain slopes gently to merge with the broad flood plain of Bayou Dorcheat.

STRATIGRAPHY

Rocks of Claiborne age are at the surface in Columbia except in the southwestern part where sands, gravels, and loams of Pleistocene and Recent age mantle the Tertiary strata. A generalized section of formation is given in Table 33.

CRETACEOUS

COMANCHE SERIES

The upper surface of the Comanche strata is a plane of truncation which from southwest to northeast brings progressively older beds in contact with the base of the Gulf series. The Upper Glen Rose and the anhydrite zone underlie all but the northeastern part of Columbia County where the Lower Glen Rose is in contact with the base of the Upper Cretaceous (See Plate VI and Figure 5). The maximum thickness of the Trinity above the anhydrite zone is estimated to be about 1,000 feet in the southwestern corner and the anhydrite zone 525 feet in the same area. The base of the Travis Peak formation has not been reached in deep wells, but it is estimated to be about 2,000 feet thick. The Travis Peak formation is underlain by marine shales, sands, and limestones which are estimated to be not less than 1,000 feet thick.

GULF SERIES

The Gulf series increases in thickness from about 1,100 feet in the northeastern part to about 1,650 feet in the southwestern part of Columbia County. The Tokio-Woodbine section increases in thickness to the southeast where they are more than 100 feet thick. The Annona chalk, as a lithologic unit, is not present in the eastern part of the county although its equivalent may be represented in part in the Marlbrook marl. The Upper Creta-

TABLE 33.—*Generalized section of formations in Columbia County*

System	Series	Formation	Thickness in feet	Character
Quaternary	Pleistocene and Recent	Terrace and river deposits	0-40	Alluvial sand, gravel, clay and loam.
		Unconformity		
Tertiary	Eocene	Claiborne	550-675	Sand, sandy shale, clay in part lignitic; glauconitic sand and marl.
		Wilcox	600-850	Lignitic sand and clay.
		Midway	475-500	Gray to blue noncalcareous clay with siderite concretions. Calcareous and fossiliferous in lower 25 to 50 feet.
		Unconformity		
Cretaceous	Gulf	Arkadelphia marl	90-100	Gray to dark-gray calcareous shale and marl.
		Nacatoch	250-350	Sand, calcareous sandstone and thin limestone with shale in basal part.
		Saratoga chalk	50-100	Gray chalk.
		Marlbrook marl	130-180	Light-colored shale, marl, and chalky marl.
		Annona chalk	0-110	Gray and white chalk and chalky shale.
		Ozan (Buckrange sand at the base)	125-175	Gray and greenish-gray micaceous marl and chalky marl. Buckrange sand member at base.
		Brownstown marl	100-200	Gray clays and shales.
		Tokio-Woodbine	375-500	Lignitic sand and clay at top; gray shale and sandy shale; tuffaceous sandstone interbedded with thin beds of bentonitic clay, red beds at the base 25-100 feet thick.
		Unconformity		
	Comanche (Trinity group)	Upper Glen Rose	0-100	Impure limestone, gray to green shale, sand and sandy shale with intercalated beds of red clay.
		Anhydrite zone	0-525	Gray to white thin-bedded and massive anhydrite interbedded with limestone and shale.
		Lower Glen Rose	800-1000	Chiefly impure limestone, calcareous and noncalcareous shale with thin beds of fine grained sand and red-brown shale.
		Travis Peak	2000+	Dominantly red clays and sandstones.
	Comanche	Neocomian ?	1000+	Marine limestone, shale, and sand.

ceous formation in general contains more sands in the eastern than in the western part of the county.

TERTIARY

EOCENE SERIES

The Midway formation is from 475 to 500 feet thick and maintains its regional characteristic throughout the area. The Wilcox

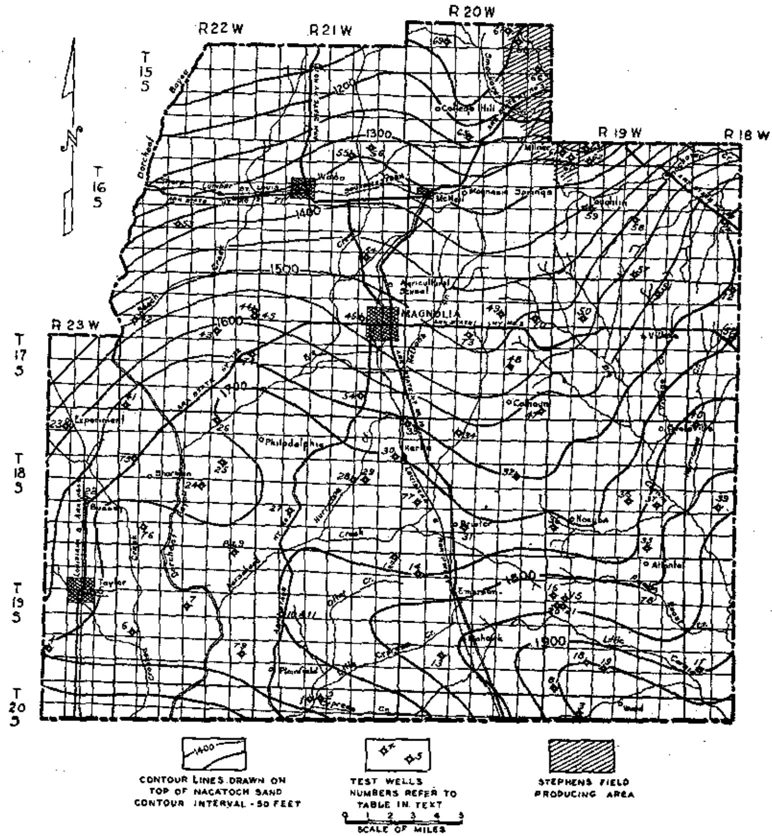


FIGURE 53.—Structure contour map of Columbia County. Figures give depth below sea level in feet.

formation is about 575 feet thick in the southeast corner; about 600 feet thick in the northeastern part; and about 850 to 900 feet thick in the southwestern part of the county.

PLEISTOCENE AND RECENT SERIES

Alluvial deposits of Pleistocene and Recent age underlie the flood plain of Bayou Dorcheat to an estimated depth of 40 feet.

STRUCTURE

The generalized structure of the Comanche strata, based on a very few scattered wells is shown in Plate XII. The datum plane is the base of the anhydrite zone of the Glen Rose formation and the contour interval is 500 feet. The strike of the Comanche strata is generally northwest-southeast and the dip is to the southwest at the rate of 70 to 150 feet per mile. Local structural details which may be present are not determinable.

The structure of Columbia County drawn on the top of the Nacatoch formation is shown in Figure 53. The Upper Cretaceous strata are inclined in a general south and southeast direction. The top of the Nacatoch formation ranges in depth from 1,100 feet below sea level in the northwestern to 1,950 feet below sea level in the southeastern corner of the county. A structural nose extends from the Stephens field in T. 15 S., R. 20 W., in a general south and southeast direction to the southeast corner of the county. Several terraces, indicated by the swing in the contour lines and in the flattening of the rate of dip, are situated along the axes of the structural nose. A syncline, plunging from west to east extends across the southern part of the county, and in general separates the area of relatively steep-inclined strata in the northern part of the county from the folded area in Lousiana on which the Haynesville, Shongaloo, Spring Hill, and Cartersville fields are situated. A wide structural terrace embraces most of T. 18 S., R. 22 W. The structure of this area has not been definitely determined by wells and may prove to be a domal structure of low relief.

List of wells drilled in Columbia County

No., Company, Farm & Number	Location Sec.	Twp.	R.	T. D.	Elev.*	Depth to Nacatoch feet	Depth to red shale feet	Oldest formation penetrated
1 Wingfield & Mitchell, Bodcaw No. 1	4	20S	21W	2050	217[d]	1917	———	Nacatoch
2 Mitchell & Eylers, Bodcaw No. 2	4	20S	21W	2804	217[a]	1942	———	Tokio-Woodbine
3 Ohio Oil Co., J. A. Smith No. 1	5	20S	19W	3420	262[d]	2232	———	Tokio-Woodbine
4 Tunica Petrol. Co., Bodcaw Lbr. Co. No.1	27	19S	23W	3239	249[a]	1949	———	Tokio-Woodbine
5 Columbia Oil Synd., Whitehead No. 1	14	19S	23W	2350	251.3[g]	1932	———	Marlbrook
6 Morris & Allen, Pickler No. 1	19	19S	22W	2610	235[a] 271[a]	1960	———	Tokio-Woodbine
7 Jones et al, Souter No. 1	15	19S	22W	2756	290[b] 251.92[d]	2002	———	Annona
8 Ark. Fuel Oil Co., W. E. Hardy No. 1	1	19S	22W	3097	228.86[a]	1954	———	Tokio-Woodbine
9 Ark. Fuel Oil Co., W. E. Hardy No. 2	1	19S	22W	773	231.64[a]	———	———	Wilcox
10 Okla. Petrol. Co., Walker No. 1	17	19S	21W	1408	300[a] 257[a] 285[a] 270[a]	———	———	Wilcox
11 Boger et al, Walker No. 1	17	19S	21W	3007	270[d] 277[c]	2020	———	Tokio-Woodbine
12 Virgil Heath, Tr., William No. 1	1	19S	21W	2916	257.4[d]	1980	———	Annona

No., Company, Farm & Number	Sec.	Twp.	R.	T. D.	Elev.*	Depth to Nacatoch feet	Depth to red shale feet	Oldest formation penetrated
13 Ken-Ark. Petrol. Co., Peter Doss No. 1	29	19S	20W	....	278[d] 272[d]	2092	....	Ozan
14 South Ark. Oil Co., Waller No. 1	6	19S	20W	....	291[d] 292.5[a]	1978	....	Marlbrook
15 Russell & Kent, Sorrells-Thomas No. 1 (Emerson No. 1)	18	19S	19W	2940	300.9[g]	2190	....	Brown-town
16 Russell et al, Rushton No. 1	7	19S	19W	2450	218[g] 327[c]	2150	....	Nacatoch
17 Hosey-McDonald, (Nat. Gas & Fuel Co.) W. G. Hayes No. 1	30	19S	18W	3262	273[d] 259.9[a]	2153	....	Tokio-Woodbine
18 Jones et al, Ware No. 1	29	19S	19W	2955	224.8[d]	2180	....	Ozan
19 South Ark. Oil Co., (Lone Star Drlg. Co.) Ware No. 1	28	19S	19W	2955	233[d] 224.8[a]	2185	....	Nacatoch
20 Haynesville Trust., Wingfield-Moody No. 1	18	19S	19W	2357	287[d] 300[a]	2100	....	Nacatoch
21 State Line Drillers & Producers, Wingfield-Moody No. 1	18	19S	19W	3003	280[a]	2120	....	Browns-town
22 E. T. Brown et al, L. C. Robertson No. 1	23	18S	23W	3171	303[a]	1998	....	Tokio-Woodbine
23 Col. O. & G. Co. Weitnicht (Experiment 2) No. 1	2	18S	23W	2689	273[d]	1872	....	Tokio-Woodbine
24 R. C. Neibert et al, Barge No. 1	22	18S	22W	2970	256.06[f] 253.3[d]	1920	....	Tokio-Woodbine
25 Ark. Fuel Oil Co., Barge No. 1	14	18S	22W	3271	257.10[a]	1913	....	Tokio-Woodbine
26 Houston Oil Co., Joe Joiner No. 1	2	18S	22W	3019	218.3[d]	1928	....	Browns-town
27 Hercules Oil Co., Wise No. 1	29	18S	21W	2548	291.71[f] 262[d]	1988	....	Ozan
28 E. S. Phillips, Davis Loan & Inv. Co. No. 1	14	18S	21W	2860	250[d]	1985	....	Ozan
29 Guy Cox et al, Davis No. 1	14	18S	21W	....	269.6[f] 305[a]	1985	....	Nacatoch
30 Haskell et al, Davis No. 1	12	18S	21W	3270	305[a]	2007	....	Tokio-Woodbine
31 Stough et al, Brown No. 1	28	18S	20W	1200	308[f]	....	....	Wilcox
32 Ark. Fuel Oil Co., Longino & Goode No. 1	14	18S	20W	3108	312.39[a]	1965	....	Tokio-Woodbine
33 E. S. Phillips, Davis Loan & Inv. Co. No. 2	6	18S	20W	....	327[g] 321[d]	1985	....	Nacatoch
34 Greeson et al, Pearce No. 1	3	18S	20W	2110	304.71[f] 303[a]	1920	....	Nacatoch
35 Smith & Cox, Duffer No. 1	35	18S	19W	2129	239[d] 230[a]	1989	....	Nacatoch
36 Magnolia Dev. Co., F. Lindsey No. 1	30	18S	19W	3012	244[d] 235.9[a] 244.66[b]	1965	....	Tokio-Woodbine

No., Company, Farm & Number	Location Sec.	Twp.	R.	T. D.	Elev.*	Depth to Nacatoch feet	Depth to red shale feet	Oldest formation penetrated
37 Grace Wooden, (Colquitt) Jesse Duffer No. 1	23	18S	19W	———	184.8[a]	1944	———	Tokio-Woodbine
38 Haskell et al, Price No. 1	22	18S	19W	3017	249[d] 238.9[a]	1985	———	Tokio-Woodbine
39 Lion O. & R. Co., Tatee No. 1	20	18S	18W	3097	231[a]	2056	———	Tokio-Woodbine
40 Marr Oil Co. Hollingsworth No. 1	6	18S	18W	2869	202[d]	1900	———	Tokio-Woodbine
41 Gulf Refg. Co. of La., Huggins No. 1	31	17S	22W	2910	212[a] 212[d]	1884	———	Tokio-Woodbine
42 D. W. Johnson et al, Sailes No. 1 (Sorrels)	18	17S	22W	———	266[d]	———	———	Wilcox
43 El Dorado Oil Co., (Grand Prairie O. Co.) Guntt No. 1	14	17S	22W	2820	411[d]	2041	———	Tokio-Woodbine
44 J. B. Moore et al, Fullenwider No. 1	12	17S	22W	2400	307.9[d] 307[a]	1878	———	Ozan
45 Dowdy et al, Roy & Fullenwider No. 1	12	17S	22W	2675	305[a]	1822	———	Ozan
46 T. S. D., Mc.Gale No. 1	11	17S	21W	3000	294[a]	1828	———	Tokio-Woodbine
47 South Ark. Oil Corp., Crisp No. 1	36	17S	20W	3200	322.7[a] 313.7[a]	1950	———	Tokio-Woodbine
48 Atlantic Oil Co., Couch No. 1	23	17S	20W	3151	359.5[a]	1864	3117	Tokio-Woodbine
49 Haskell et al, Brown No. 1	10	17S	20W	3031	357[a] 372[d]	1878	———	Tokio-Woodbine
50 The Texas Co., Alexander No. 1	8	17S	19W	3003	314.60[a]	1822	———	Tokio-Woodbine
51 Texolean Oil Co., Lockett No. 1	2	17S	19W	3085	291.3[d]	1896	———	Tokio-Woodbine
52 Gulf Refg. Co., J. D. Hines No. 1	17	17S	18W	3459	282[d]	1972	3100	Glen Rose
53 Am. Fuel & Trans. Co., L. L. Nix No. 1	21	16S	22W	3000	377[d]	1770	———	Tokio-Woodbine
54 Ohio Oil Co., Witt No. 1	35	16S	21W	2762	298.6[a] 293	1780	———	Tokio-Woodbine
55 Big Creek Oil Co., (Sunny Jim O. Co.) Runyon No. A-1	3	16S	21W	3110	252.3[a]	1612	2926	Glen Rose
56 Waldo Oil Co., Dean No. 2	2	16S	21W	2750	340[a] 305[d]	1620	———	Tokio-Woodbine
57 Murphy et al Booth No. 1	34	16S	19W	2527	344.2[a]	1732	2822	Glen Rose
58 Timberlake-Woolfley, J. A. Wilson No. 1	22	16S	19W	2504	240[a]	1775	———	Tokio-Woodbine
59 Murphy et al, Wilson No. 1	17	16S	19W	1700	264[a] 258.4[a]	1648	———	Nacatoch
60 Transcon. Oil Co., F. B. Thomas No. 1	6	16S	19W	2355	284.4[a]	1440	———	Tokio-Woodbine
61 Transcon. Oil Co., S. W. McClurkin No. 1	6	16S	19W	2188	260.2[a]	1525	———	Ozan
62 Transcon. Oil Co., J. M. Curry No. 1	5	16S	19W	———	268[d] 255.9[a]	1540	2680	Glen Rose
63 Ark. Nat. Gas Co., H. L. Curry No. 1	5	16S	19W	2239	297.82[a]	1568	———	Ozan

No., Company, Farm & Number	Location Sec.	Twp.	R.	T. D.	Elev.*	Depth to Nacatoch feet	Depth to red shale feet	Oldest formation penetrated
64 Miller et al, Watt No. 1	20	16S	18W	1981	197.4[d] 190.2	1217	-------	Ozan
65 Pure Oil Co., Webfer No. 1	33	15S	20W	3358	389[d] 379[c]	1600	2822	Glen Rose
66 Hude & Aarnes, Brown No. 2	13	15S	20W	2590	208.17[a]	1400	2552	Travis Peak
67 Tate et al, Hall No. 1	11	15S	20W	-------	281.3[g]	1440	-------	Ozan
68 Columbia O. & G. Co., Hall No. 1	11	15S	20W	2164	256[h]	1406	-------	Ozan
69 Magnolia Petrol. Co., Gunter No. 1	8	15S	20W	3268	298[d] 285.9[a]	1420	2650	Glen Rose
70 Geo. W. Dawley Tr., Fullenwider No. 1	12	17S	22W	2847	328	1901	-------	Tokio-Woodbine
71 Nev. Meyer Lbr. Co., Water well	17	16S	21W	1038	-------	-------	-------	Wilcox
72 -------	-------	-------	-------	-------	-------	-------	-------	-------
73 Ark. Drlg. Co., Tom Jones No. 1	5	17S	18W	3302	268	1917	3080	Glen Rose
74 Sam M. Dorfman, Merritt No. 1	16	17S	20W	2803	378	1868	-------	Tokio-Woodbine
76 Hargis et al, Sauter	24	17S	22W	75	-------	-------	-------	-------
77 Brown et al, Spencer No. 1	18	18S	22W	3503	268[d]	1864	3235	Glen Rose
78 T. R. Brown, Longino No. 1	32	18S	22W	2338	-------			
79 Olvey et al, Kate George No. 1	19	18S	20W	3501	-------	2005	3356	Glen Rose
80 Atlantic-Brown, C. W. Jeans No. 1	11	19S	19W	2317	234	2053	-------	Tokio-Woodbine
82 Mitchell et al, Franks No. 1	25	19S	22W	2835	-------	-------	-------	-------
83 Arpeco Synd., Dennis No. 1	11	20S	23W	3628	268	1942	3478	Glen Rose
84 Russell et al, Flint No. 1	3	20S	20W	-------	-------	-------	-------	-------
85 Talbot & Markle, Copeland No. 1	31	19S	19W	-------	329	2250	3607	Anhydrite zone

* Letters refer to key to datum for elevation on page 261.

CRAIGHEAD COUNTY

LOCATION

Craighead County is bounded on the south by Poinsett County, on the west by Jackson and Independence counties, on the north by Greene County, and on the east by Mississippi County.

GENERAL FEATURES

Crowley's Ridge, a belt of hilly land, extends north and south through Craighead County, rising to a maximum elevation of about 475 feet above sea level, or 200 to 225 feet above the lowlands to the east and west. From the northern boundary of the county southward, the ridge is 10 to 12 miles wide to a point 3 or 4 miles south of Jonesboro, where it narrows abruptly to a width of from half a mile to 4 miles. A deep gap in the vicinity of Dee is traversed by the Helena branch of the St. Louis, Iron Mountain, and Southern Railway.

The area weest of Crowley's Ridge is included in the Advance lowland, a gently undulating plain 250 to 260 feet above sea level.

All of the county east of Crowley's Ridge is included in the Mississippi lowlands, which is divided into the post oak flats, a narrow strip of slightly undulating land bordering Crowley's Ridge and lying 255 to 260 feet above sea level, and the "sunk lands", which lie to the east. The "sunk lands" are gently undulating, partly wooded, swampy depressions, separated by low ridges of dark sandy loam.

STRATIGRAPHY

The Wilcox formation of Eocene age and the Lafayette formation of Pliocene age crops out in narrow bands on the flanks of Crowley's Ridge; the remainder of Craighead County is covered with alluvial sand, gravels, and clay, chiefly of Pleistocene age, but in part of Recent age. Deep wells have penetrated all the Tertiary and Cretaceous in the western and central parts of the county. A generalized section of formations is given in Table 34.

BASEMENT ROCKS

The Cretaceous strata of this area were deposited upon a nearly level floor of folded and truncated Paleozoic rocks. This floor now slopes southwestward and ranges in depth from about 700 feet in the northwest corner to 2,800 feet or more in the southeast corner.

TABLE 34.—*Generalized section of formations in Craighead County*

System	Series	Formation	Thickness in feet	Character
Quaternary	Pleistocene and Recent		10-200	Alluvial sand, gravel, clay and loess.
		Unconformity		
Tertiary		Lafayette	0-60	Sand, gravel and clay.
		Unconformity		
	Eocene	Wilcox	200-1200	Lignitic sand and clays.
		Midway clays	100-400	Gray to dark-gray clay with an abundance of siderite concretions.
		Unconformity		
Cretaceous	Gulf	Arkadelphia marl	0-50	Shale, sand, sandy limestone and limestone in part glauconitic.
		Nacatoch sand and Saratoga chalk	100-350	Chiefly shale and sand with subordinate beds of sandy limestone.
		Older than Nacatoch	0-200	
		Unconformity		
Basement rocks—Paleozoic or older				

CRETACEOUS

GULF SERIES

The Cretaceous rocks increase in thickness from about 200 feet in the northeastern corner to about 600 feet in the southeastern corner of the county. They consist of shale, sands, sandy shale, chalks, and limestone, representing the following formations: Arkadelphia marl, Nacatoch sand, Saratoga chalks, and Marlbrook marl.

TERTIARY

EOCENE SERIES

The Eocene, represented by the Midway clays and the Wilcox formation, increases in thickness from about 300 feet in the southeastern corner.

The Midway is made up of gray to dark-gray clays containing abundant siderite concretions, and is from 100 to 400 feet thick.

The Wilcox formation, 200 to 1,200 feet thick, is made up of sand, sandy clays and clay, in part lignitic.

PLIOCENE SERIES

LAFAYETTE FORMATION

The Wilcox formation of Crowley's Ridge is unconformably overlain by irregularly bedded gravels and reddish sands, reaching a maximum thickness of 50 feet or more. These sands and gravels are assigned to the Lafayette formation.

QUATERNARY

PLEISTOCENE AND RECENT SERIES

The Lafayette formation is overlain by materials ranging in composition from typical loess to reddish loess-like clay, from a few feet to 40 feet thick, of Pleistocene age.

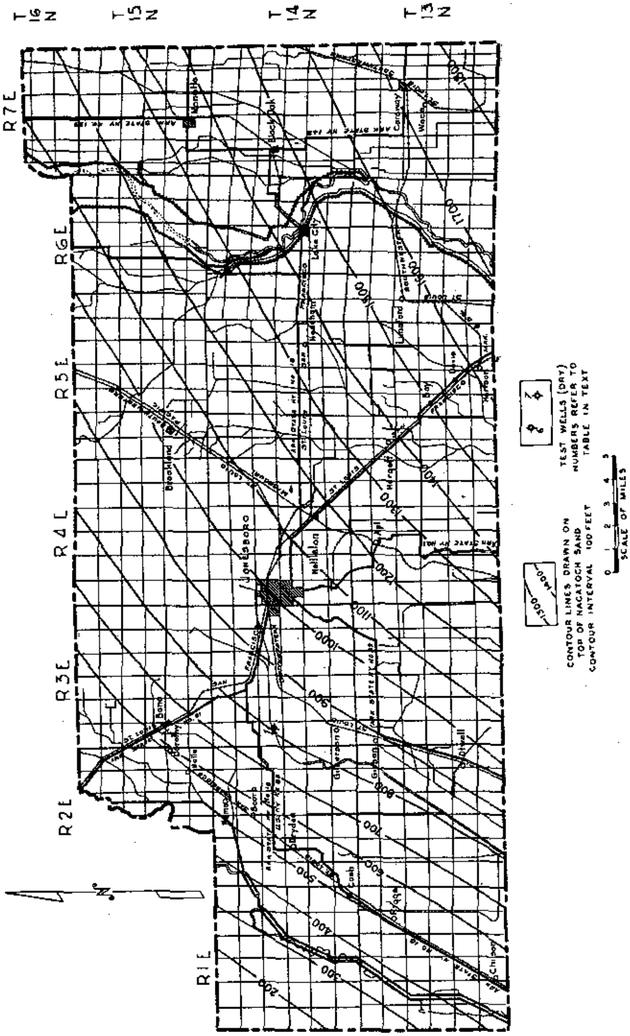


FIGURE 54.—Structure contour map of Craighead County. Figures give depth below sea level in feet.

The Advance lowland west of Crowley's Ridge is underlain by 130 to 150 feet of allvial sands, clays, and gravels of the Pleistocene age.

The Mississippi lowland, east of Crowley's Ridge, is underlain by 130 to 200 feet of undifferentiated sands, clays, and gravels of Pleistocene age.

STRUCTURE

The structure of Craighead County is shown in Plate I, and Figure 54 by means of contour lines drawn on top of the Nacatoch sand at intervals of 100 feet. The structure is generalized, owing to the lack of detailed data. The Nacatoch sand lies at a depth of about 100 feet below sea level in the northwestern corner and about 1,900 feet below sea level in the southeastern corner. The dip is toward the southeast at the rate of 35 to 70 feet per mile, with the steepest dip in the western part of the county.

List of wells drilled in Craighead County

No., Company, Farm & Number	Location Sec.	Twp.	R.	T. D.	Elev.*	Depth to Nacatoch feet	Depth to red shale feet	Oldest formation penetrated
1 Chal. Daniel Drlg. Co., Cof C. (Scott) No. 1	18	14N	3E	2231	260+	1055	....	Paleozoic

* Letters refer to key to datum for elevation on page 261.

CRITTENDEN COUNTY

LOCATION

Crittenden County is bounded on the south and east by Mississippi River, on the west by Cross County, and on the north by Poinsett and Mississippi counties.

GENERAL FEATURES

Crittenden County is included in the Mississippi lowlands, lying 200 to 235 feet above sea level. The highest land lies immediately west of Mississippi River; from there is a slight slope to the west and southwest. Ponds, abandoned stream channels, and bayous are numerous, and much of the area is subject to overflow from Mississippi River.

STRATIGRAPHY

The surface rocks throughout the county consist of Recent alluvial sands and clays, deposited by the waters of Mississippi River. The Recent deposits are probably underlain by sand, gravels and clays of Pleistocene age; the Quaternary is estimated to be 150 to 200 feet thick. The Tertiary deposits are estimated to be 2,800 feet thick, and the Cretaceous formation between 800 and 900 feet thick in the southern part of Crittenden County. A generalized section of formations penetrated in deep wells is given in Table 35:

TABLE 35.—*Generalized section of formations in Crittenden County*

System	Series	Formation	Thickness in feet	Character
Quaternary	Pleistocene and Recent		150-200	Alluvium sands, gravels, clays, and loams.
		Unconformity		
Tertiary	Eocene	Undifferentiated	1500-2300	Chiefly sands, clays and sandy clays; in part glauconitic and in part lignitic.
		Midway	400-500	Gray to dark-gray clays with an abundance of siderite concretions.
		Unconformity		
Cretaceous	Gulf	Arkadelphia marl	75-100	Dark-gray shales.
		Nacatoch sand and Saratoga chalk	400-475	Gray to greenish-gray sand, sandy shale and calcareous sandstone, with thin beds of shale. Shale and chalk in lower part.
		Marlbrook marl and older	200-300	Shale, chalky shale, chalk and sandy shale, with thin sand in the lower part.

Basement rocks—Paleozoic

BASEMENT ROCKS

The Coastal Plain sediment was deposited upon a nearly level floor of folded and truncated Paleozoic strata. This floor, owing to subsequent warping, now slopes toward the southeast from about 2,600 feet below sea level in the northwestern part, to about 3,700 feet below sea level in the southeastern part of Crittenden County.

CRETACEOUS

GULF SERIES

The Cretaceous rocks underlying Crittenden County are composed of shales, sandy shales, sands, limestone, and chalk, with an estimated thickness of about 700 feet in the northwestern corner, and about 1,000 feet in the southeastern corner. These beds include the following formations: Arkadelphia marl, Nacatoch sand, Saratoga chalk, and Marlbrook marl. A part of the Tokio formation, or its equivalent (the Tuscaloosa formation of Mississippi) is probably present in the eastern part of the county, as indicated in Figure 11.

TERTIARY

EOCENE SERIES

The Eocene strata have an estimated thickness ranging from 1,900 feet in the northwestern to 2,800 feet in the southeastern part. The Midway clay (basal Eocene) is 400 to 500 feet thick, consisting of gray clays containing an abundance of siderite concretions.

The overlying Eocene strata, belonging to the Wilcox and Claiborne formations, are 1,500 to 2,300 feet thick, and consist of sand, clay and sandy clays, in part lignitic, but containing a few thin beds of glauconitic sand.

QUATERNARY

PLEISTOCENE AND RECENT SERIES

The surface materials throughout the county are Recent alluvial sands and clays, deposited from the water of Mississippi River. The Recent alluvium probably rests on alluvial sands, clays, and gravels, of Pleistocene age. The thickness of the Pleistocene and Recent age is estimated to be from 150 to 225 feet.

Driller's record of J. Painter, Jr., Hunter No. 1 *well, sec.* 24, *T.* 9 *N., R.* 7 *E.*

Geologic age	Depth in feet
Quarternary	
Pleistocene and Recent series	
Surface clay	10
Sand and gravel	38
Lignite	41
Sand and gravel	170
Rock	171
Unconformity	

Geologic age	Depth in feet
Tertiary	
Eocene series	
Jackson, Claiborne, and Wilcox formations	
Gray gumbo	240
Sand and gravel	370
Sandy shale	407
Sand and gravel	442
Sand with hard streaks	495
Gumbo	535
Sand	920
Brown shale	935
Hard sand	950
Gumbo	980
Sand (water)	1030
Gumbo	1045
Rock with pyrites	1049
Brown shale	1060
Sand and sand rock	1135
Gumbo	1172
Sand rock	1177
Gumbo	1272
Sand (fresh water)	1283
Shale	1340
Sand	1595
Gumbo	1600
Sand	1625
Sand and shale	1648
Hard sand	1675
Gumbo	1695
Sandy shale	1720
Gumbo	1726
Sandy shale	1777
Water sand	1789
Lignitic shale	1821
Soft sand and shale	1865
Sand	1871
Fine sand and shale	1887
Sandy shale	2000
Midway clays	
Gumbo	2010
Layers of sandy lime and shale	2030
Gummy shale	2275
Broken lime and shale	2300
Gummy shale	2350
Chalky shale	2450
Gummy shale	2500
Unconformity	
Arkadelphia marl	
Chalky shale	2540
Black shale	2560
Black sandy lime	2578
Nacatoch sand and Saratoga chalk	
Gray water sand	2610
Shale	2645

Geologic age		Depth in feet
	Sandy lime	2660
	Shale	2730
	Lime and shale	2760
	Sand (water)	2920
	Hard sandy shale	2960
	Chalky shale	3020
	Chalk rock	3065
Marlbrook marl and older		
	Sandy lime	3085
	Chalk	3130
	Chalky shale	3220
	Shale and shells	3245
	Sand	3265
	Chalky shale	3285
	Shale and broken lime	3335
	Unconformity	
Paleozoic		
	Hard lime	3585
	T. D.	3614

STRUCTURE

The structure of Crittenden County is shown in Plate XV and Figure 55, by means of contour lines drawn on top of the Nacatoch sand at intervals of 100 feet. The structure is generalized, owing to lack of detailed information.

The Nacatoch sand lies at a depth of 2,100 feet below sea level in the northwest corner of the county, and dips towards the southeast at the rate of 30 to 40 feet per mile.

List of wells drilled in Crittenden County

No., Company, Farm & Number	Location Sec.	Twp.	R.	T. D.	Elev.*	Depth to Nacatoch feet	Depth to red shale feet	Oldest formation penetrated
1 J. Painter, Hunter or Nixon No. 1	24	9N	7E	3614	220	2578	......	Paleozoic
2 Crittenden County Oil & Gas Co., Stanley No. 1	23	8N	7E	2840	221	2700	......	Nacatoch
3 Memphis Nat. G. Co., Hen & Chicken Island No. 1	...	7N	9E	1794	......	......	......	Wilcox
4 J. Painter Jr., Patterson No. 1	35	9N	7E	3516	220	2594+	......	Paleozoic
5 J. Painter Jr., Painter No. 1	25	9N	7E	2710	220	......	......	......

* Letters refer to key to datum for elevation on page 261.

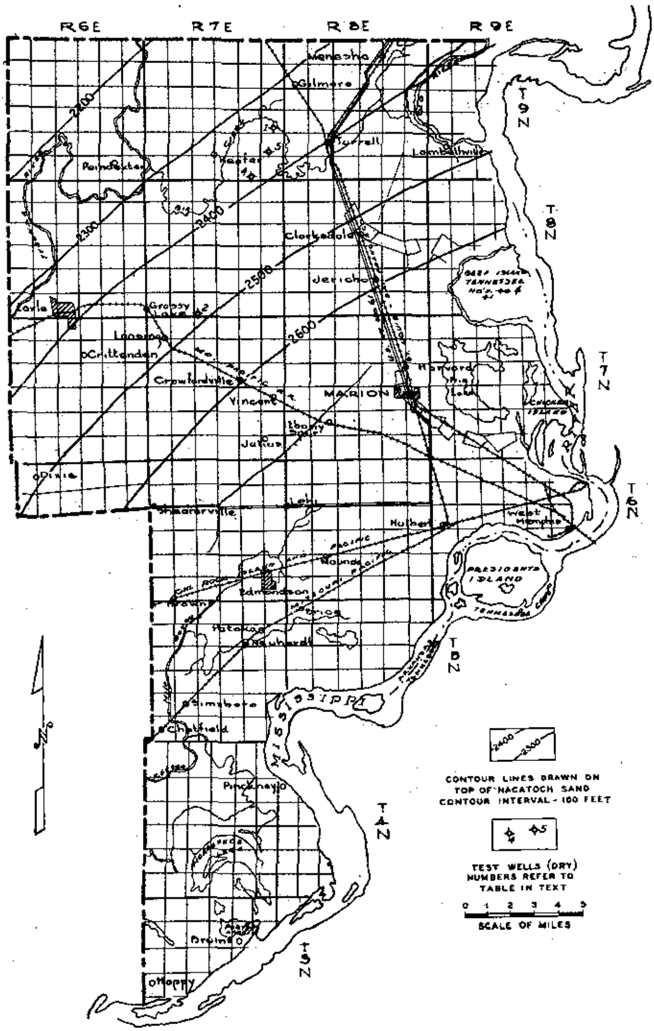


FIGURE 55.—Structure contour map of Crittenden County. Figures give depth below sea level in feet.

CROSS COUNTY

LOCATION

Cross County is bounded on the south by St. Francis County, on the west by Jackson and Woodruff Counties, on the north by Poinsett County, and on the east by Crittenden County.

GENERAL FEATURES

The county includes parts of three recognizable topographic subdivisions—Crowley's Ridge, the Advance lowland, and the Mississippi lowland.

Crowley's Ridge is a belt of hilly land 3 to 6 miles wide, extending north and south through the center of the county, and rising 350 to 375 feet above sea level, or 120 to 150 feet above the lowlands to the east and west.

The area west of Crowley's Ridge is included in the Advance lowlands, a nearly level plain 230 to 245 feet above sea level, and sloping slightly to the south.

The Mississippi lowland, east of Crowley's Ridge, is 220 to 225 feet above sea level. The surface of the lowland is diversified by numerous ponds and abandoned stream channels, separated by wooded areas of low swamp land and low ridges.

STRATIGRAPHY

The core of Crowley's Ridge to a height of more than 50 feet above the lowlands to the east and west is composed of sands and clays, in part lignitic of Eocene age. The lowlands on both sides of Crowley's Ridge are underlain by from 125 to 225 feet of alluvial sands, gravels, clays, and loams of Pleistocene and Recent age. A generalized section of formations is given in Table 36:

BASEMENT ROCKS

The Coastal Plain sediments were deposited upon a nearly level floor, consisting of folded Paleozoic rocks probably of the same general character as rocks in the Arkansas valley to the west. This floor now slopes southeastward and reaches a maximum depth of about 3,500 feet in the southeastern corner of Cross County.

CRETACEOUS

GULF SERIES

The Cretaceous strata underlying Cross County belong to the Gulf series. They have an estimated thickness ranging from about 300 feet in the northwestern corner, to about 750 feet in the southeastern corner of the county and are made up of sands,

TABLE 36.—*Generalized section of formations in Cross County*

System	Series	Formation	Thickness in feet	Character
Quaternary	Pleistocene and Recent		10-200	Alluvium, sand, gravel, and loess.
		Unconformity		
Tertiary		Lafayette	0-45	Sand and gravel.
		Unconformity		
	Eocene	Jackson Claiborne Wilcox	600-1800	Sands, sandy clays, and clay; in part lignitic.
		Midway	300-500	Gray clays; abundant siderite concretions.
		Unconformity		
Cretaceous	Gulf	Arkadelphia marl	50-100	Dark-gray to black calcareous shale.
		Nacatoch sand and Saratoga chalk	200-425	Gray to green sand and sandstones, calcareous sandstone, shale and impure chalk.
		Marlbrook marl and older	0-225	Gray to greenish-gray shale, shale and some thin sand members.
Basement rocks—Paleozoic or older				

clays, chalk, and limestone, in part glauconitic, representing the folowing formations: Arkadelphia marl, Nacatoch sand, Saratoga chalk, and Marlbrook marl.

TERTIARY

EOCENE SERIES

The Eocene strata increase in thickness from about 900 feet in the northwestern part to 2,300 feet in the southeastern part of the county. The Jackson, Claiborne, and Wilcox formations have been recognized on Crowley's Ridge, and the Midway clays have been penetrated in deep wells. The Midway, 300 to 500 feet thick, consists principally of gray to dark-gray clays, characterized by siderite concretions. The strata above the Midway are made up of sands, clays, and sandy clays, in part lignitic, containing some thin beds of glauconitic sand. The relative thicknesses of the formations included in these beds have not been determined.

PLIOCENE ?

LAFAYETTE FORMATION

The Eocene strata in Crowley's Ridge are unconformably overlain by 10 to 40 feet of irregularly bedded sands and gravels of the Lafayette formation. The gravels, in places, have been indurated to a conglomerate.

QUATERNARY

PLEISTOCENE AND RECENT SERIES

The sands and gravels of the Lafayette formation are overlain by 20 to 60 feet of yellow, red, and brown massive loess, in part calcareous, which forms the capping material of Crowley's Ridge.

The Advance lowland west of Crowley's Ridge is underlain by 140 to 160 feet of alluvial gravels, sands, clays, and loams of Pleistocene age. The coarsest material is generally foun in the basal part of the section lying unconformably upon the Eocene strata.

The Mississippi lowland, east of Crowley's Ridge, is underlain by 150 to 200 feet of undifferentiated Recent and Pleistocene loams, clays, sands, and gravels.

List of wells drilled in Cross County

No., Company, Farm & Number	Location Sec.	Twp.	R.	T. D.	Elev.*	Depth to Nacatoch feet	Depth to red shale feet	Oldest formation penetrated
1 J. F. Scott et al, O'Day No. 1	9	7N	4E	1822	200+	----	----	Midway
2 Ark. Dev. Co., Chas. Rose No. 1	11	7N	3E	2133	300+	----	----	Midway
3 J. E .Stock, R. Block No. 1	Lot 7	7N	4E	2573	258	2220 ?	----	----

* Letters refer to key to datum for elevation on page 261.

STRUCTURE

The structure of Cross County is shown in Plate XV and Figure 56, by means of contour lines drawn on top of the Nacatoch

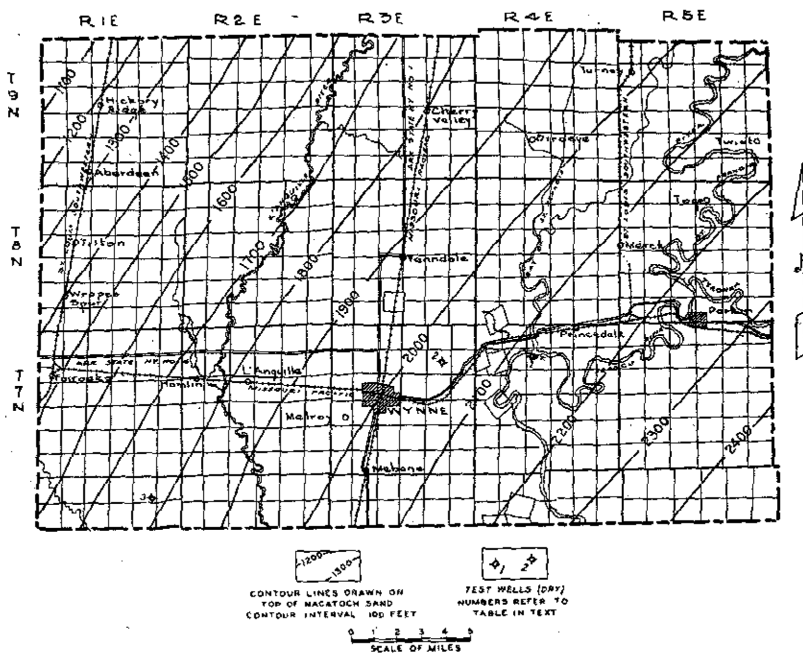


FIGURE 56.—Structure contour map of Cross County. Figures give ... level in feet.

sand at intervals of 100 feet. The data is obtained from deep wells and structure is necessarily generalized. The Nacatoch sand lies at a depth of about 1,000 feet below sea level in the northwestern corner and about 2,500 feet below sea level in the southeastern corner of the county. The normal dip is slightly south of east at the rate of 30 to 50 feet per mile, with the greater rate of dip in the western part.

DALLAS COUNTY

LOCATION

Dallas County is bounded on the south by Calhoun and Bradley counties, on the west by Clark County, on the north by Hot Spring and Saline counties, and on the east by Grant and Cleveland counties.

GENERAL FEATURES

Dallas County is a dissected uplands area. The central part is broad, flat ridges, forming the drainage divide between Ouachita and Saline rivers, which slopes from an altitude of more than 500 feet in the northern part to 300 feet or less in the southern part of the county. The area adjacent to the ridges is dissected into more or less rugged hills which, as the Saline and Ouachita rivers are approached, become gently undulating.

STRATIGRAPHY

The Wilcox formation is exposed at the surface over most of the western half and the Claiborne over most of the eastern half of Grant County. Deep wells drilled in this area have penetrated all of the Tertiary and the Cretaceous sediments and a number of wells have drilled into rocks of Paleozoic age. A generalized section of formations in Dallas County is shown in Table 37.

BASEMENT ROCKS

The basement floor, which has been reached in a number of deep wells, lies at depths of less than 500 feet below sea level in the northwestern corner, and at a depth of 3,000 feet or more below sea level in the southeastern corner of Dallas County. The basement rocks recorded in these wells consist chiefly of quartzitic sandstone and hard dark shales.

CRETACEOUS

COMANCHE SERIES

Sediments of Comanche age are generally absent through Dallas County, but it is possible that the Travis Peak formation may be represented by a few feet of beds in the southwestern part of the county.

GULF SERIES

The Gulf series is about 400 feet thick in the northwestern part but increases in thickness to 700 feet in the southeastern part of the county. The Tokio-Woodbine section is absent in the northern part and slightly more than 200 feet thick in the southern part. The Ozan formation decreases in thickness from west to east and the Marlbrook marl, Saratoga chalk, and Nacatoch formation increase in thickness to the south and southeast.

TABLE 37.—*Generalized section of formations in Dallas County*

System	Series	Formation	Thickness in feet	Character
Quaternary	Pleistocene and Recent	Terrace and river deposits	0-50	Alluvial sand, gravel, clay and loams.
		Unconformity		
Tertiary	Eocene	Claiborne	0-1200	Sand, clay, and glauconitic sand and marl, in part lignitic.
		Wilcox	150-800	Lignitic sand and clay.
		Midway	300-500	Gray to blue noncalcareous clay with siderite concretions. Fossiliferous and calcareous shale in lower 25 to 50 feet of beds.
		Unconformity		
Cretaceous	Gulf	Arkadelphia marl	75-100	Gray to black calcareous and fossiliferous shale and marl.
		Nacatoch sand and Saratoga chalk	150-250	Calcareous sand, thin beds of shale in upper part, sandy shale, marl and chalk in lower part.
		Marlbrook marl	125-150	Marls, shales, and sandy marl.
		Ozan	0-150	Micaceous sand and sandy marl.
		Tokio-Woodbine	0-200	Principally sand and sandstone, in part tuffaceous.
		Unconformity		
Paleozoic		Undifferentiated		

TERTIARY

EOCENE SERIES

The Tertiary sediments increase in thickness to the southeast. The Midway formation ranges in thickness from about 300 feet in the northwestern part to about 500 feet in the southeastern part of Dallas County. The maximum thickness of the Wilcox is believed to be between 800 and 900 feet in the southeastern part of the county and the Claiborne in the same area is about 1,200 feet thick. There is not sufficient information available from deep wells to subdivide the Claiborne into formational units.

PLEISTOCENE AND RECENT SERIES

Alluvial deposits of Pleistocene and Recent age underlie the flood plain of the principal streams to a maximum depth of about 50 feet. The gravels which mantle the higher ridges of Dallas County have not been definitely correlated but may be the age equivalent of the Lafayette formation of northeastern Arkansas.

STRUCTURE

The generalized structure of Dallas County, drawn on the top of the Nacatoch formation, is shown in Figure 57. The depth to the top of the Nacatoch formation ranges from 400 feet below sea level in the western part to 2,400 feet below sea level in the eastern part of the county. The dip is to the east at the rates of

20 to 50 feet per mile. The structure as shown in Figure 56 departs from the prevailing strike and dip in several areas, but there is no evidence of the existence of marked anticlinal or domal structure in the area.

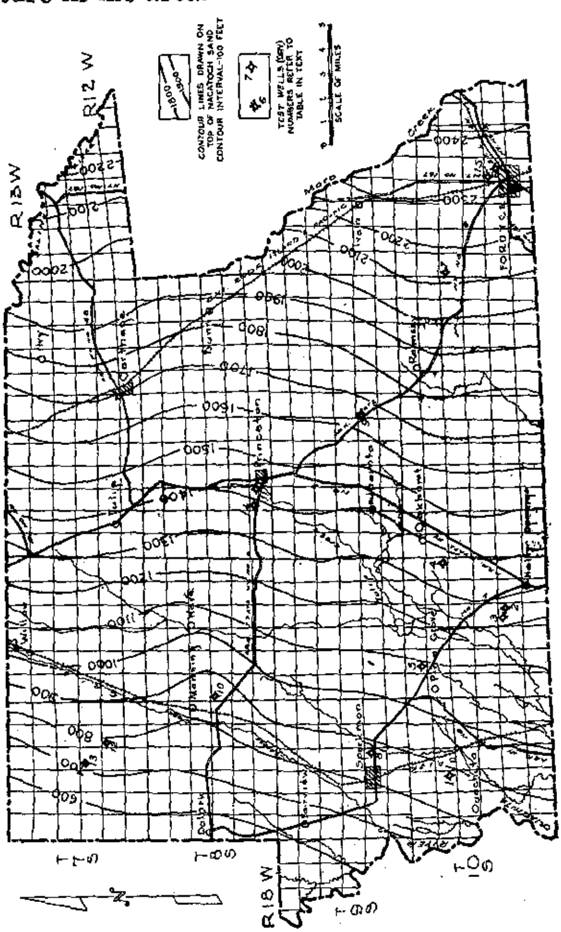


FIGURE 57.—Structure contour map of Dallas County. Figures give depth below sea level in feet.

List of wells drilled in Dallas County

No., Company, Farm & Number	Sec.	Twp.	R.	T. D.	Elev.*	Depth to Nacatoch feet	Depth to red shale feet	Oldest formation penetrated
1 Grayson-McCloud, Sparkman No. 1	9	10S	17W	1993	160[h]	1040	....	Paleozoic
2 Dudley et al, Owens No. 1	27	10S	16W	2238	236[a]	1535	....	Paleozoic
3 McNeill et al, Owens No. 1	27	10S	16W	2210	246[g]	1570	....	Paleozoic
4 West Peterson & Latimer,	12	10S	16W	2253	242[g]	1590	....	Paleozoic

No., Company, Farm & Number	Location Sec.	Twp.	R.	T. D.	Elev.*	Depth to Nacatoch feet	Depth to red shale feet	Oldest formation penetrated
5 Stahl et al, Taylor No. 1	5	10S	16W	2189	280[g] 275[a]	1380	......	Paleozoic
6 Fordyce-Dallas O. Co., R. I. R. R. No. 1	26	10S	13W	595	269.03[a]	......	......	Claiborne
7 Newblock-Kemp, (Kemp-Sing O. C.) Green No. 1	18	10S	13W	3155	285[a]	2444	......	Paleozoic
8 Ohio Oil Co., Taylor No. 1	27	9S	17W	1857	190[a] 220	1051	......	Paleozoic
9 Helibron Oil Co., Eagle Lbr. Co. No. 1	30	9S	14W	3210	360[h]	2045	......	Paleozoic
10 Ohio Oil Co., Jackson No. 1	19	8S	16W	1881	330[a]	1165	......	Paleozoic
11 Conway et al, Matlock & Riggs	33	8S	15W	1770	280[a]	1740	......	Nacatoch
12 Yore et al, (Youree) Wisconsin-Arkansas Lbr. Co. No. 2	35	7S	17W	1544	425[b] 400[b]	1245	......	Marlbrook or Ozan
13 Yore et al, (Youree) Wisconsin-Arkansas Lbr. Co. No.	27	7S	17W	1701	400[b]	1265	......	Prob. in Paleozoic
14 New-Ark. Oil Co., Matlock No. 1........8	33	8S	15W	2438	......	......	......	......
15 Arkansas Synd., Baringer No.	26	10S	13W	3120	......	......	......	......

* Letters refer to key to datum for elevation on page 261.

DESHA COUNTY

LOCATION

Desha County is bounded on the south by Chicot County, on the west by Lincoln and Drew counties, on the north by Arkansas and Phillips counties, and on the east by Mississippi River.

GENERAL FEATURES

The general surface of Desha County is a gently undulating plain, sloping from an elevation of 175 feet above sea level in the northern part to 145 feet in the southern part. The interstream area, an irregularly shaped tract in the western part of the county, lying between the flood plains of Bayou Bartholomew on the west, Arkansas River on the north, and Mississippi River on the east, is a terrace a few feet higher than the wide flood plains of the principal streams.

STRATIGRAPHY

The surface is underlain by Pleistocene alluvium, consisting of clays, sands, and gravels, ranging in thickness from 100 to 200 feet, which lies unconformably on strata of Eocene age. The total thickness of the Eocene strata has not been penetrated in deep wells, but it is estimated to range in thickness from about 3,300 feet in the southwestern part to about 5,000 feet in the eastern part of the county. The Cretaceous strata underlying this area are estimated to be 400 feet thick in the southern part and more than 1,000 feet thick in the northeastern part of the county. A generalized section of formations is given in Table 38.

Desha County and the adjacent parts of Arkansas and Phillips counties lie within the deepest part of the Desha basin, a sedimentary basin developed principally in Eocene time. The Upper Cretaceous strata, although not penetrated in deep wells, are, as a result of regional studies, believed to be thicker in this area than in any other part of southeastern Arkansas. They were presumably deposited in a Cretaceous sedimentary basin which reached its fullest development to the east in Mississippi. The basis for the above statements and for the estimates that follow is more fully outlined in the paragraphs dealing with the regional stratigraphy and structure.

BASEMENT ROCKS

The basement rocks underlying Desha County are estimated to range in depth from about 4,000 feet below sea level in the southern part to about 6,000 feet in the northern part of the county.

TABLE 38.—*Estimated section of formations in Desha County*

System	Series	Formation	Thickness in feet	Character
Quaternary	Pleistocene and Recent		100-200	Alluvial sands, gravels, clays and loams.
		Unconformity		
Tertiary	Eocene	Jackson Claiborne Wilcox	3500-5000	Sands and clays, in part glauconitic; sands and clays and glauconitic sand and clay in lower part; sands, clays, and sandy clays, dominantly lignitic.
		Midway clays	500-600	Gray and dark-gray clays and shale, generally noncalcareous but calcareous at the base; siderite concretions.
		Unconformity		
Cretaceous	Gulf	Arkadelphia marl	400-1000+	Gray and black, calcareous shale.
		Nacatoch sand and Saratoga chalk		Generally fine-textured sand and sandstone, in part glauconitic; shale and chalk in lower part.
		Marlbrook marl and older		Shale, marl, chalk, and sand; perhaps red shale in lower part.

CRETACEOUS

COMANCHE SERIES

Near-shore facies of the Trinity group were probably deposited over this area but were subsequently removed by erosion in the interval between the end of the Comanche and the beginning of the Gulf series deposition.

GULF SERIES

The Cretaceous strata are estimated to range in thickness from about 400 feet in the southern part to about 1,000 feet in the northern part of the county. The Arkadelphia marl and Nacatoch sand are thought to be fairly uniform in character and thickness throughout the area but with an increased thickness in the Marlbrook marl, toward the north, where this formation probably will show close affinity to the Selma chalk of Mississippi. The Tokio formation, or the Tuscaloosa formation of Mississippi, is probably present beneath the chalk and marls in the northern part of the county. The stratigraphic relationship is indicated in the generalized cross section, Figure 12.

TERTIARY

EOCENE SERIES

The maximum thickness of the Eocene strata in Arkansas is found in Desha County, where they are estimated to range from 3,500 feet in the southern part to about 5,000 feet in the northern part of the county.

The Midway is estimated to be 600 feet or more in thickness, the Wilcox formation 2,000 feet or more, and the Claiborne formation 1,500 to 1,600 feet thick. Owing to lack of data from this area it is not possible to delimit accurately these formations.

QUATERNARY

PLEISTOCENE AND RECENT SERIES

The surface is underlain by Pleistocene alluvium consisting of clays, sands, and gravels, ranging in thickness from 100 to 200 feet. The surface distribution of the Pleistocene aluvium is coextensive with the interstream areas. The streams have eroded away the Pleistocene alluvium to undetermined depths, and the valleys thus formed have been partly refilled with Recent alluvium, which constitutes the material of the present flood plains.

STRUCTURE

An interpretation of the generalized structure of Desha County is shown in Plate XIV. The datum plane is the top of the Cretaceous and the contour interval 500 feet. According to this interpretation, the northern part of the county lies in a basin, extending northwestward from Mississippi into Arkansas, into which the strata dip from the south, west, and northwest. The top of the Cretaceous is estimated to lie at a depth of about 3,500 feet below sea level in the southern part, and about 5,000 feet in the east-central part of the county. (See also Fig. 58.)

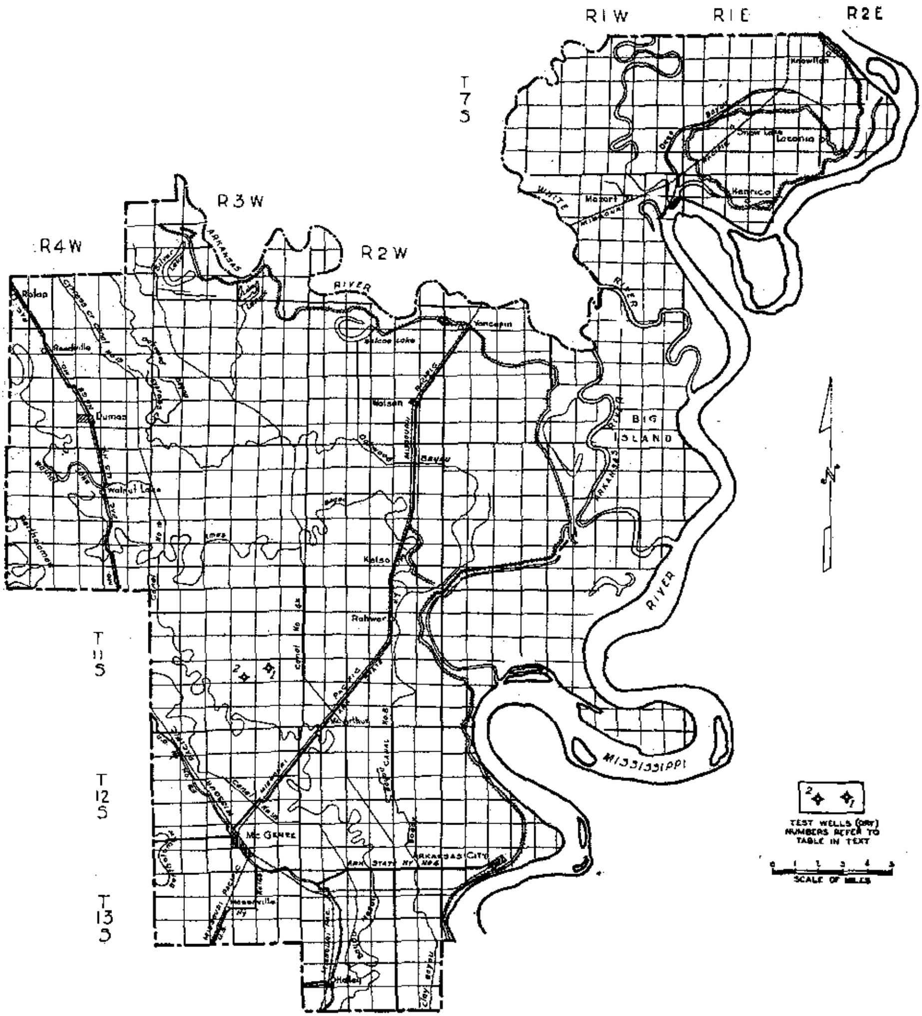


FIGURE 58.—Map showing Desha County.

DREW COUNTY

LOCATION

Drew County, situated in southeastern Arkansas, is bounded on the south by Ashley County, on the west by Bradley and Cleveland counties, on the north by Lincoln County, and on the east by Chicot and Desha counties.

The principal topographic feature is Monticello Ridge, which trends north-south through the west-central part of the county. This ridge ranges in width from about 8 miles in the southern part to about 12 miles in the northern part. Along its highest part the elevation is slightly more than 300 feet above sea level.

Monticello Ridge is limited on the east by the Hamburg terrace[5], a gently southeastward sloping terrace, 200 feet above sea level in the northern part and about 150 feet above sea level in the southeastern part of the county. The Hamburg terrace extends eastward to the flood plain of Bartholomew Bayou.

The area west of Monticello Ridge lies chiefly within the flood plain of Saline River and ranges from less than 100 feet above in the southern part to nearly 200 feet in the northern part.

STRATIGRAPHY

Rocks of Jackson age crop out along Monticello Ridge in the west-central part of Drew County; the remainder of the area is mantled with sands, gravels, and loams of Pleistocene and Recent age to an estimated depth of 200 feet. Few wells have been drilled in the county, two of which reached the Cretaceous. It is estimated that the following section is present in this area.

BASEMENT ROCKS

The basement rocks have not been reached in deep wells drilled in Drew County unless the igneous rocks underlying the Upper Cretaceous in the Ohio Oil Company's Jerome Lumber Company No. 1 well in sec. 13, T. 15 S., R. 3 W., in the southeastern corner of the county, may be considered as belonging to the basement rocks. The igneous rock was encountered at a depth of 3,250 feet below sea level.

CRETACEOUS

COMANCHE SERIES

Rocks of Comanche age have not been recorded in Drew County but studies of the underground distribution of the Trinity group indicate that the Travis Peak formation underlies the

[5] Veatch, A. C., *Geology and underground water resources of northern Louisiana and southern* [illegible] Prof. Paper 6, pp. 50-51, 1906.

TABLE 39.—*Generalized section of formations in Drew County*

System	Series	Formation	Thickness in feet	Character
Quaternary	Pleisto-cene and Recent	Terrace and river deposits	0-200	Alluvial sands, gravels, and loams.
		Unconformity		
Tertiary	Eocene	Jackson and Claiborne	1300-2000	Sand and clay in part glauconitic and fossiliferous; lignitic sand and clay.
		Wilcox	800-1400	Lignitic sand and clay.
		Midway	450-575	Gray to blue noncalcareous clay calcareous and fossiliferous clay and shale in lower part..
		Unconforimty		
Cretaceous	Gulf	Arkadelphia marl	0-75	Gray to black fossiliferous marl and shale.
		Nacatoch and Saratoga chalk	200-350	Generally fine-grained calcareous sandstone, chalk in lower part.
		Older than Saratoga	0-500	Probably sand and chalks.
		Unconformity		
	Comanche	Travis Peak	0-800+	Red clays and sands.
		Unconformity		

southwestern part of the county. It is estimated that these sediments may have a maximum thickness of not less than 800 feet.

GULF SERIES

The Gulf series underlying Drew County has been reached in only a few wells, and the total thickness has been penetrated only in the Ohio Oil Company's Jerome Lumber Company No. 1 well, located in the extreme southwest corner of the county, where the total thickness recorded was about 300 feet. The variations in the thickness of the Upper Cretaceous sediments, shown by isopach lines in Figure 7, indicate that the Upper Cretaceous ranges in thickness from 300 feet in the southeastern corner to 800 feet in the northern part of Drew County.

TERTIARY

EOCENE SERIES

The Jackson formation exposed in Monticello Ridge is described by Harris[6], as consisting of sands and bluish-gray and greenish-gray clay, in part fossiliferous. Where weathered, these beds are in part red. In the deep wells it is impossible to separate the Jackson formation from the underlying Claiborne sediments.

The Midway formation has an estimated range in thickness of 450 to 575 feet with the greater thickness in the northeastern part of the county. The Wilcox formation is 800 feet thick in the southwestern part and is estimated to be 1,400 feet thick in the northeastern part of the county. The Claiborne sediments

[6] Harris, G. D., The Tertiary geology of southern Arkansas: Arkansas Geol. Survey, Ann. Rept. for 1892, vol. II, pp. 111-117, 1894.

are 1,300 feet thick in the western part, and the combined Jackson and Claiborne sediments are estimated to be 2,000 feet thick in the northeastern part of Drew County.

QUATERNARY

PLEISTOCENE AND RECENT SERIES

Alluvial deposits of Pleistocene and Recent age underlie the surface, except over Monticello Ridge, to an estimated depth of 200 feet.

STRUCTURE

The generalized structure of a part of Drew County, drawn on top of the Nacatoch or its equivalent, the Monroe gas rock,

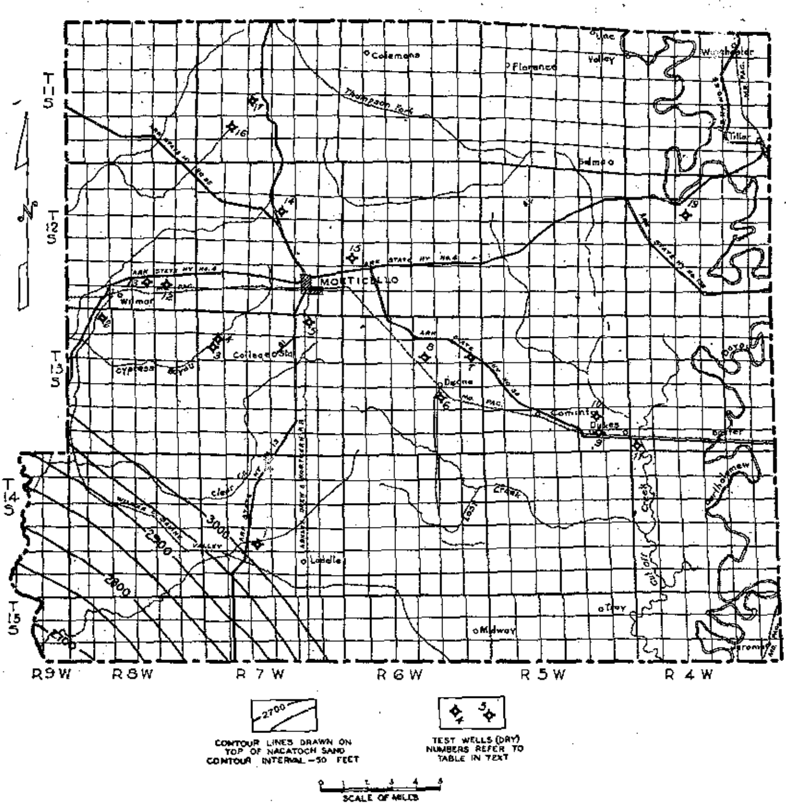


FIGURE 59.—Structure contour map of Drew County. Figures give depth below sea level in feet.

is given in Figure 59. The top of the Nacatoch formation is 2,700 feet below sea level in the southwestern corner and is estimated to be about 4,000 feet below sea level in the northeastern corner of the county. The general direction of the dip is north and northeast.

Record of Cooperative Development Company's Ogles No. 1 *well in sec.* 35, *T.* 13 *S., R.* 5 *W.*

Geologic age	Depth in feet
Quaternary	
Pleistocene and Recent series	
Sand, gravel, and clay	136
Unconformity	
Tertiary	
Eocene series	
Jackson and Claiborne	
Gumbo or black shale	139
Sand and shale	215
Shale and shells	245
Tough gumbo	334
Gummy shale	380
Sand	413
Sand and shale	497
Water sand	643
Gumbo	645
Sand	707
Gumbo	712
Gravel	730
Gumbo	739
Sand	772
Sand and shale	795
Hard sand	828
Sand and shale	838
Gumbo and shale	876
Shale with streaks of sand	918
Gumbo	930
Sand and shale	945
Shale	968
Gumbo	975
Sand and shale	990
Sand	1065
Gumbo and shale	1126
Sand and shale	1185
Hard sand	1197
Sandy lime	1226
Sand and shale	1269
Gummy shale	1290
Hard sand	1303
Shale and gumbo	1313
Hard sand	1328
Sand and shale	1337
Hard sand	1346
Shale	1363
Brown sand; upper 8 inches rock	1372
Sand and shale	1383
Sand	1407
Sand and shale	1410
Tough shale	1416
Sand and shale	1428
Gumbo and shale (Cored 1566-1569)	1594
Rock cored	1595
Cane River sand (Approximate top of Cane River formaiton)	1670

Geologic age		Depth in feet
	Gumbo	1683
	Sand and shale	1698
	Green and brown sand with hard streaks	1732
	Sand and shale	1751
	(6-in. rock) sand (hard)	1763
	Gumbo	1774
	Shale, hard	1786
	Gumbo	1800
	Brown sand (cored)	1816
Wilcox formation		
	Brown sand (cored)	1834
	Gumbo	1840
	Sandy shale	1860
	Brown sand (cored)	1865
	Sand and shale	1877
	Sand, shale, and gray clay	1886
	Chalky sand and clay	1908
	Sand	1910
	Sand	1918
	Sand (cored)	1924
	Sand	1927
	Gumbo	1932
	Sandy shale	1940
	Sand	1956
	Green sand and shale	1979
	Hard sand	2000
	Hard sand and shale	2018
	Chalk	2023
	Chalk	2029
	Chalk	2060
	Sand, chalk and shale	2066
	Sandy shale	2080
	Sandy shale and lignite	2089
	Blue chalk	2107
	Lime rock (cored)	2108
	Sand and chalk (cored)	2111
	Sandy chalk	2127
	Chalky shale	2135
	Chalky shale	2152
	Lime rock (cored)	2154
	Lime and shale	2176
	Lime and shale	2179
	Lime and shale	2189
	Gumbo	2195
	Rock (cored)	2196
	Rock (cored)	2199
	Rock (cored)	2201
	Sandy shale	2209
	Gumbo	2218
	Sandy lime	2224
	Gumbo	2246
	Sandy shale	2273
	Gummy chalk	2289
	Gumbo and sandy shale	2448
	Lignite	2456
	Gumbo	2469

Geologic age	Depth in feet
Sand	2475
Gummy shale	2487
Sand	2492
Sandy shale	2502
Gumbo and shale	2594
Hard sandy shale	2604
Gumbo and shale; streaks of sand	2637
Sand	2664
Gumbo	2671
Sandy shale and gumbo	2692
Sand; salt water	2716
Limy shale	2725
Hard sand	2735
Hard shale	2779
Rock	2784
Midway formation	
Tough gumbo and hard shale	2894
Sandy shale (black)	2920
Hard shale and gumbo	3007
Black shale, gumbo, and boulders	3230
Black shale and gumbo	3364
Unconformity	
Cretaceous	
Gulf series	
Arkadelphia marl	
Shale with gummy streaks	3378
T. D.	3378

List of wells drilled in Drew County

No., Company, Farm & Number	Location Sec.	Twp.	R.	T. D.	Elev.*	Depth to Nacatoch feet	Depth to red shale feet	Oldest formation penetrated
1 H. C. Ratcliff, Spencer No. 1	21	14S	7W	1650	....	....	....	Wilcox
2 Rhodes et al, Harrison No. 1	5	13S	8W	2305	150[b]	....	....	Wilcox
3 Business Men's Synd., Hardy No. 1	7	13S	7W	2180	200[a]	....	....	Wilcox
4 Dunn-Marr, Hardy No. 1	7	13S	7W	1883	200[b]	....	....	Wilcox
5 Ark. Nat. Gas Co., H. W. Wells No. 1	2	13S	7W	3081	260[b]	....	....	Basal Wilcox
6 Steinks O. & G. Co., Fee No. 1	23	13S	6W	2031	....	....	....	Wilcox
7 King & Wilson, Strong (Trotter) No. 1	12	13S	6W	....	190[a]	....	....	Claiborne
8 Graves Oil Co., Karnes No. 1	10	13S	6W	3033	190[b]	....	....	Wilcox
9 McClintock & Goodke, Ogles No. 1	35	13S	5W	....	179[c]	....	....	Wilcox
10 Garrison, Oswald No. 1	26	13S	5W	3083	175[a] 180[a]	....	....	Wilcox
11 Joynt et al, (Hanley et al) Bullock No. 1	31	13S	4W	3303	125[b]	....	....	Midway

No., Company, Farm & Number	Location Sec.	Twp.	R.	T. D.	Elev.*	Depth to Nacatoch feet	Depth to red shale feet	Oldest formation penetrated
12 C. F. Wiatt et al, Montgomery No. 1	36	12S	8W	....	211[a]	....	....	Wilcox
13 Rhodes et al, Martin No. 1	27	12S	8W	2003	162	....	....	Wilcox
14 Monticello Ridge O. Co., (Drew Oil Trust) Wilson No. 1	10	12S	7W	2505	321[b] 256[a]	....	....	Wilcox
15 Drew Co. O. & G. Co., McCloy No. 1	19	12S	6W	2411	243[a]	....	....	Wilcox
16 Richardson, Busey No. 1	29	11S	7W	3516	260[a]	....	....	Midway or Arkadelphia
17 Monticello Rdg. O. Co., D. C. Graves No. 1	22	11S	7W	2120	315[a]	....	....	Wilcox
18 Ohio Oil Co., Jerome Lbr. Co. No. 1	13	15S	4W	3748	128	3163	....	Igneous rock
19 Holland et al, Desbaugh No. 1	9	12S	4W	2300	....			

* Letters refer to key to datum for elevation on page 261.

GRANT COUNTY

LOCATION

Grant County is bounded on the south by Cleveland and Dallas counties, on the west by Hot Spring County, on the north by Saline County, and on the east by Jefferson County.

GENERAL FEATURES

The flood plain of Saline River, flowing in a general southeasterly direction, ranges from less than 3 miles wide in the northwestern part to 6 miles wide in the southeastern part of Grant County. It slopes to the southeast from more than 225 feet in the northwestern to less than 175 feet above sea level in the southeastern part of the county. The principal tributaries are Lost, Hurricane and Derrisaux creeks. The interstream areas are rugged uplands with altitudes of 400 to 500 feet above sea level.

STRATIGRAPHY

The Jackson formation appears at the surface in a narrow belt in the northeastern part of the county. The Claiborne, striking slightly east of north, forms the surface of the eastern, and the Wilcox forms the surface of the western part of Grant County. Deep wells have penetrated all of the Tertiary and Cretaceous formations in this area. A generalized section is given in Table 40.

BASEMENT ROCKS

The basement floor slopes to the southeast from about 450 feet below sea level in the northwestern corner to about 3,000 feet below sea level in the southeastern corner of Grant County (See Plate III). The basement rocks encountered in deep wells consisted chiefly of light-colored to gray quartizitic sandstones and dark gray slaty shale. The Shaffer Oil and Refining Company's Youngblood No. 1 well in sec. 34, T. 4 S., R. 13 W., encountered igneous rock, either pyroxenite or gabbro at a depth of 2,258 feet below the surface.

CRETACEOUS

COMANCHE SERIES

Sediments of Comanche age are not present in Grant County where they are absent either by nondeposition or by erosion.

GULF SERIES

The Upper Cretaceous sediments increase in thickness from north to south; they are a few feet thick in the northwestern part and about 450 to 500 feet thick in the southern part of the county.

TABLE 40.—*Generalized section of formations in Grant County*

System	Series	Formation	Thickness in feet	Character
Quaternary	Pleistocene and Recent	Terrace and river deposits	0-50	Alluvial sands, gravels, clays, and loams.
		Unconformity		
Tertiary	Eocene	Jackson	0-40	Dark clays, lignitic, and fossiliferous.
		Claiborne	0-1350	Lignitic sand and clay in upper part. Sands and calys, glauconitic sand and marl, in part lignitic.
		Wilcox	100-850	Lignitic sands and clays.
		Midway	200-500	Gray to blue noncalcareous clays with siderite concretions. Fossiliferous clay and sandy limestone in basal 25 to 50 feet of beds.
		Unconformity		
Cretaceous	Gulf	Arkadelphia marl	0-100	Gray to black calcareous and fossiliferous marls and shales.
		Nacatoch and Saratoga chalk	50-250	Sand and clays in upper part; marls and chalks in lower part.
		Marlbrook marl and older	5-150	Sands, marls, and shales.
		Unconformity		
Paleozoic		Undifferentiated		Chiefly quartzitic sandstone and hard dark shales.

The decreased thickness of the Gulf series to the north is due in part to overlap and in part to thinning of the formational units. The oldest sediments recognized are of Marlbrook age, estimated to lie 150 feet thick in the southeastern part but thinning to the north and overlapped by the Saratoga chalk. The combined thickness of the Nacatoch formation and the Saratoga chalk is estimated to range from 50 feet in the north to 250 feet in the south. The Arkadelphia marl appears to be present in the northwestern part of the county or else is represented by a sandy facies and not separable from the underlying Nacatoch formation. It is about 100 feet thick in the southern part of Grant County.

TERTIARY

EOCENE SERIES

The Midway formation is estimated to be about 200 feet thick in the northwestern and about 500 feet thick in the southeastern part of the county. The Wilcox formation attains its maximum thickness in the southeastern corner of the county where it is estimated to be 800 to 850 feet thick. The Claiborne sediments increase in thickness to the southeast and are estimated to reach a maximum thickness of 1,250 feet.

QUATERNARY

PLEISTOCENE AND RECENT SERIES

Alluvial deposits of Pleistocene and Recent age underlie the flood plain of Saline River to an estimated maximum depth of 50 feet. Irregularly distributed patches of gravels on the higher ridges are not definitely correlated but may represent the Lafayette formation of northeastern Arkansas.

STRUCTURE

The generalized structure of Grant County, drawn on top of the Nacatoch formation, is shown in Figure 60. The dip is to

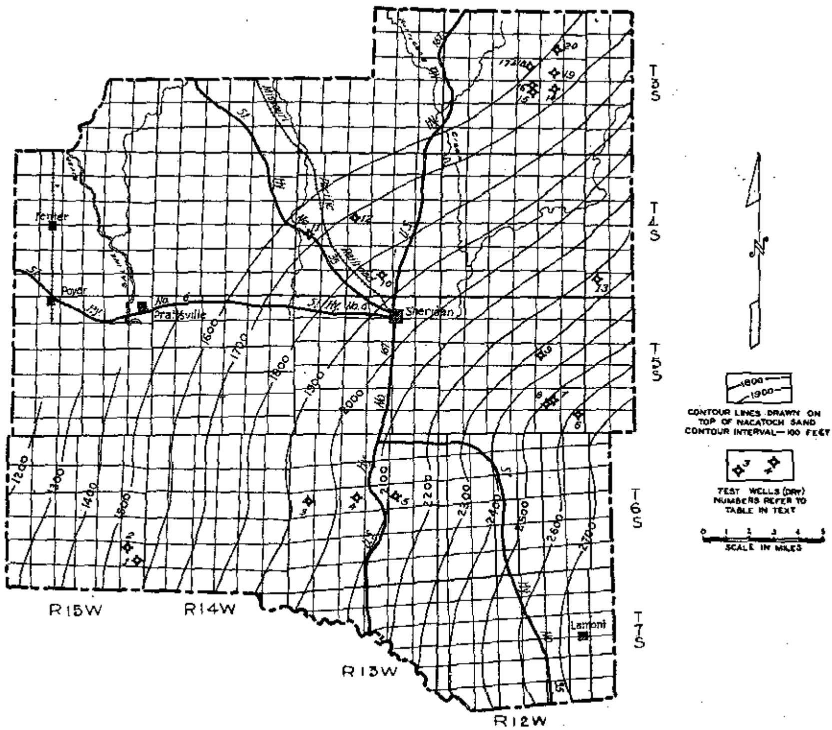


FIGURE 60.—Structure contour map of Grant County. Figures give depth below sea level in feet.

the east and southeast at the rate of 25 to 50 feet per mile. The top of the Nacatoch formation lies at a depth of about 600 feet below sea level in the northwest corner and at a depth of about 2,600 feet below sea level in the southeast corner of Grant County. The interpretation of the structure given in Figure 60 is based on a relatively few scattered wells and does not indicate local structural features which may be present in the area.

Shaffer Oil and Refining Company's Youngblood No. 1 well sec. 34, T. 4 S., R. 13 W., Grant County, Arkansas.

(Comm. Feb. 15, 1927. Comp. March 9, 1927)

Geologic age	Depth in feet
Tertiary	
Eocene series	
Claiborne formation	
Soft red clay	15
Loose red gravel	25
Gummy red gravel	47
Soft gray sand	95
Tough gray gumbo	102
Soft gray sandy clay	233
Soft gray sandy shale	248
Soft gray sand, fresh water	280
Tough blue clay	315
Loose gravel	472
Sandy gravel	512
Sandy gravel	627
Soft gray sand fresh water	791
Wilcox formation	
Hard brown broken shale	792
Hard brown broken shale	793
Medium brown sandy shale	807
Hard brown lime	808
Medium brown sandy shale	815
Soft gray sand	820
Hard blue shale	897
Hard brown shale	880
Hard brown sand rock	881
Hard brown sandy shale	892
Hard brown sand rock	894
Medium brown gummy shale	905
Medium brown gummy shale	915
Hard blue sand rock	916
Medium gray sandy shale	945
Hard gray sandy shale	949
Hard gray gummy shale, streaks lignite	975
Medium brown sandy shale, streaks lignite	1022
Medium brown gummy shale	1040
Tough brown gumbo	1080
Medium brown gummy shale	1150
Soft brown gummy shale	1200
Hard sand rock	1269
Medium sandy shale	1274
Tough brown gumbo, lignite	1335
Soft gray sand, fresh water	1360
Soft gray sandy shale	1413
Broken gray sand rock	1440
Broken gray sand rock	1442
Medium gray sandy shale	1564
Medium gray broken lime	1566
Hard gray broken lime	1568
Tough blue gumbo	1588
Hard gray sand rock	1589
Soft white sand, fresh streaks	1634

Geologic age	Depth in feet
Midway clays	
Medium white sandy lime	1637
Medium gray sandy shale	1645
Medium gray sandy shale	1658
Tough blue gumbo	1664
Hard brown sand rock	1685
Tough blue gumbo	1696
Tough blue gumbo	1710
Hard brown rock	1711
Medium gray sandy shale	1778
Medium gray shale	1797
Tough blue gummy shale	1893
Hard gray lime	1906
Hard gray gumbo	1924
Soft gray limy shale	2042
Cretaceous	
Gulf series	
Arkadelphia marl	
Hard gray limy shale	2059
Hard limestone	2061
Hard black gumbo	2086
Medium gray sandy lime	2110
Tough blue gummy shale	2129
Nacatoch sand and Saratoga chalk	
Gummy sandy lime	2142
Sandy gray gummy lime	2155
Medium gray gummy shale	2184
Hard sandy lime	2186
Hard gray lime	2195
Sandy lime, fresh water	2227
Hard brown sandy lime	2257
Igneous rock	
Tough gray gummy lime	2268
Broken brown sandy lime	2278
Hard brown broken lime, traces of lignite, pyrite hard rock pyrite and mica	2284

List of wells drilled in Grant County

No., Company, Farm & Number	Location Sec.	Twp.	R.	T. D.	Elev.*	Depth to Nacatoch feet	Depth to red shale feet	Oldest formation penetrated
1 Harry Winters, Butler & Lamb No. 1	25	6S	15W	2153	230[e]	1768	......	Paleozoic
2 Harry Winters, Butler & Lamb No. 3	25	6S	15W	1875	308[a]	1865	......	Nacatoch
3 The Texas Co., Chicago Land & Tbr. Co. No. 1	18	6S	13W	2521	243[a]	2140	......	Paleozoic
4 The Texas Co., Chicago Land & Tbr. Co. No. 2	16	6S	13W	2597	246[a]	2307	......	Paleozoic
5 The Texas Co., Chicago Land & Tbr. Co. No. 3	14	6S	13W	2786	270[a]	2371	......	Paleozoic
6 Shaffer O. & R. Co., Long-Bell No. 1	36	5S	12W	3313	240	2859	......	Paleozoic

No., Company, Farm & Number	Location Sec.	Twp.	R.	T. D.	Elev.*	Depth to Nacatoch feet	Depth to red shale feet	Oldest formation penetrated
7 Parr Oil Co., Cargile No. 1	26	5S	12W	----	----	----	----	Claiborne
8 McKenzie & Endsley, Prague or Cargile No. 1	26	5S	12W	2199	400b	----	----	Wilcox
9 Parr Oil Co., Stupka or Partgue No. 1	15	5S	12W	2022	200b	----	----	Wilcox
10 Shaffer O. & R. Co., Youngblood No. 1	34	4S	13W	2286	281	2129	----	Igneous rock
11 W. W. Haley, Ark. Short Leaf Lbr. Co. No. 1	19	4S	13W	1779	225a	----	----	Midway
12 Gladys Belle O. Co., Cargile or Strange No. 1	16	4S	13W	2102	250a	1975	----	Paleozoic
13 Parr Oil Co., Bretch No. 1	31	4S	11W	2300	300a	----	----	Midway
14 Cambrian Tr. Co., Well No. 5	23	3S	12W	----	342a	----	----	Claiborne
15 Cambrian Tr. Co., Well No. 5	22	3S	12W	----	342a	1960	----	Paleozoic
16 Cambrian Tr. Co., Well No. 6	22	3S	12W	----	342a	----	----	Wilcox
17 Cambrian Tr. Co., Well No. 1	15	3S	12W	----	342.10a	----	----	Claiborne
18 Cambrian Tr. Co., Well No. 2	15	3S	12W	----	342.97a	----	----	Wilcox
19 Cambrian Tr. Co., Well No. 3	14	3S	12W	----	340+a	----	----	Wilcox
20 Trinity Petrol. Co., Boyle-Ferrall No. 1	11	3S	12W	----	340b	1950	----	Paleozoic

* Letters refer to key to datum for elevation on page 261.

GREENE COUNTY

LOCATION

Greene County is bounded on the south by Craighead County, on the west by Lawrence and Randolph counties, on the north by Clay County, and on the east by St. Francis River—the boundary between Arkansas and Missouri.

GENERAL FEATURES

Greene County lies entirely within the Coastal Plain province. Crowley's Ridge forms a belt of hilly land 8 to 12 miles wide, extending northeast and southwest through the center of the county. The ridge attains a maximum elevation of about 500 feet above sea level, or 200 to 225 feet above the lowlands to the east and west.

The area west of Crowley's Ridge is included within the Advance lowland, a gently undulating plain 260 to 275 feet above sea level. All of the county east of Crowley's Ridge is included in the Mississippi lowland.

STRATIGRAPHY

With the exception of a narrow band of sand and clay on the flanks of Crowley's Ridge belonging to the Wilcox formation, Greene County is mantled by sand, gravel, and clay, of Pleistocene and Recent age, to a depth of from a few feet to 175 feet or more. A deep well located on the eastern flank of Crowley's Ridge penetrated all of the Coastal Plain sediments and a part of the Paleozoic. A generalized section of formations penetrated in deep wells is given in Table 41.

BASEMENT ROCKS

The Coastal Plain sediments were deposited upon a nearly level floor, which probably consists of limestone and dolomites similar to those that crop out in the Ozark province, a few miles to the west of Greene County. These rocks were folded in late Paleozoic time, truncated, and subsequently downwarped to the southeast. The basement floor slopes at a fairly uniform rate towards the southeast and lies at a depth of 1,700 to 1,800 feet below the surface in the eastern part of the county.

CRETACEOUS

GULF SERIES

The Upper Cretaceous strata are made up chiefly of gray to green sand and thin beds of gray to greenish-gray shale and calcareous sandstone, which are the correlative of the Arkadelphia marl, the Nacatoch sand and, perhaps, older formations. It is estimated that these rocks attain a maximum thickness of 400

TABLE 41.—*Generalized section of formations in Greene County*

System	Series	Formation	Thickness in feet	Character
Quaternary	Pleistocene and Recent		10-200	Alluvium; sand, gravel, clays, and loess.
		Unconformity		
Tertiary	Pliocene?	Lafayette	0-40	Sand and gravel.
	Eocene	Wilcox	100-750	Sand and clay, in part lignitic.
		Midway clay	100-400	Gray and bluish-gray clay.
		Unconformity		
Cretaceous	Gulf	Arkadelphia marl	0-50	Dark-gray shale and sandy shale.
		Nacatoch sand and older	100-300	Gray and green sand and subordinate beds of shale.
		Unconformity		
Basement rocks—Paleozoic or older				

to 500 feet in the eastern and southern part of Greene County. The Upper Cretaceous decreases in thickness towards the west and is probably not more than 100 feet thick along the western boundary of the county.

TERTIARY

EOCENE SERIES

The Eocene stratum consists of an upper member made up chiefly of sand and clays, in part lignitic, assigned to the Wilcox formation; and a lower member made up of gray to dark-gray clay and shale and siderite concretions belonging to the Midway formation.

The Midway is estimated to be 400 feet thick in the southeastern part but probably not more than 100 feet thick in the western part of Greene County.

The Wilcox formation increases in thickness from west to east, and attains a maximum thickness of 700 feet in the southwestern part of the county.

PLIOCENE SERIES

LAFAYETTE FORMATION

The Lafayette formation is represented in Greene County by a few feet to 30 feet or more of sands and gravels exposed at the surface on Crowley's Ridge.

QUATERNARY

PLEISTOCENE AND RECENT SERIES

The Lafayette formation in Crowley's Ridge is overlain by 10 to 30 feet or more of loess, representing various facies of reddish and yellowish argillaceous loam and sandy clay. The Advance lowland west of Crowley's Ridge, according to Stephenson and Crider[7], is underlain to a depth of 150 to 175 by alluvial gravels,

[7] Stephenson, L. W., and Crider, A. F., Geology and ground-water resources of northeastern Arkansas: U. S. Geol. Survey Water-Supply Paper 399, pp. 187-188, 1916.

sands, clay, and loams, for the most part of Pleistocene age, but in part of Recent age, which rest upon the Eocene strata. In general, the Pleistocene deposits grade downward from fine clays and silts at the surface, through fine sands to coarse sands and gravels at the base.

The Mississippi lowland is underlain by alluvial, clays, sands, and gravels of Pleistocene and Recent age to an estimated depth of 150 to 200 feet.

Driller's record of Volcanic Oil and Gas Company's McDaniels No. 1 well, sec. 16, T. 16 N., R. 5 E.

Geologic age	Depth in feet
Quaternary	
Pleistocene and Recent series	
Clay and gravel	25
Yellow clay	30
Unconformity	
Undifferentiated	
Fine sand (blue and gray)	165
Gravel and boulders	208
Tertiary	
Eocene series	
Undifferentiated	
Water sand	230
Gray clay	231
Lignite	235
Pipe clay	237
Fine sand and gravel	284
Blue gumbo	290
Sand with streaks of shale	330
Blue gumbo	333
Gray pack sand	368
Lime and flint	370
Blue sand rock and pack sand	397
Lime shells	399
Water sand	410
Hard sand and lignite	488
Blue and gray sand	505
Black gumbo	520
Gray sand	525
Blue marl and lime shells	584
Sand and sand rock	610
Blue marl	630
Lignite	635
Gray and blue sand	670
Blue marl	685
Midway formation	
Black gumbo	725
Sand (water)	745
Chalk rock	747
Gumbo	749
Gray sand	765
Sand and gumbo	772

Geologic age	Depth in feet
Gumbo	775
Sand	780
Gumbo	835
Water sand	840
Gumbo	1010
Black gumbo	1040
Unconformity	
Cretaceous	
Gulf series	
Arkadelphia marl and Nacatoch sand	
Water sand	1075
Gumbo	1104
Water sand	1175
Gumbo and boulders	1206
Water sand	1215
Gumbo	1260
Sand	1360
Gumbo	1400
Sandstone	1575
Unconformity	
Paleozoic	
Undifferentiated	
Hard lime rock	1650
Hard granite lime	1694
T. D.	1694

STRUCTURE

The generalized geologic structure of Greene County is shown by means of contour lines drawn on top of the Nacatoch sand in Plate XV and Figure 61. The normal dip is to the southeast at

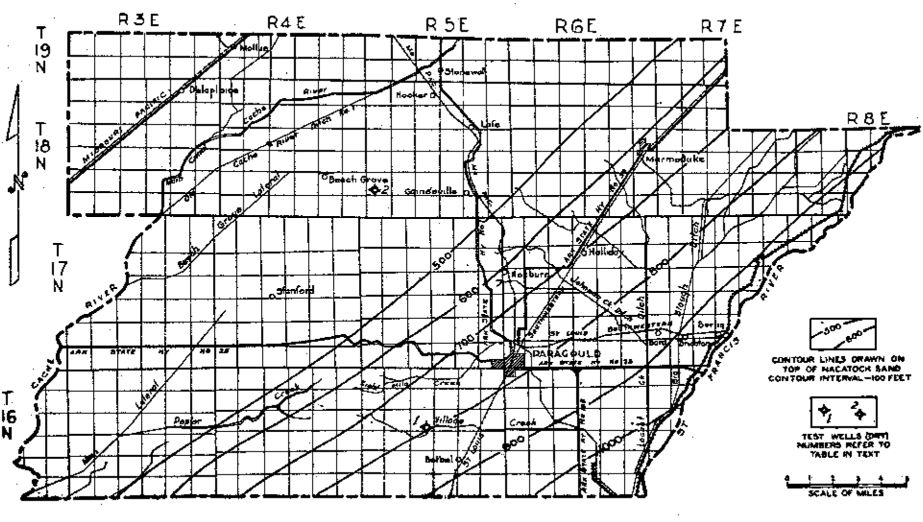


FIGURE 61.—Structure contour map of Greene County. Figures give depth below sea level in feet.

the rate of 50 to 75 feet per mile. The top of the Nacatoch sand lines at a depth of from 100 to 200 feet below sea level in the northwestern part, and from 1,000 to 1,100 feet below sea level in the southeastern part of Greene County.

List of wells drilled in Greene County

No., Company, Farm & Number	Location Sec.	Twp.	R.	T. D.	Elev.*	Depth to Nacatoch feet	Depth to red shale feet	Oldest formation penetrated
1 Volcanic O. & G. Co., McDaniels No. 1	16	16N	5E	1740	305	1040	....	Paleozoic
2 Paragould well, ...	....	17N	6E	727	....	....	....	Midway

* Letters refer to key to datum for elevation on page 258.

HEMPSTEAD COUNTY

LOCATION

Hempstead County adjoins Miller and Lafayette counties on the south, Little River and Howard counties on the west, Pike County on the north, and Nevada County on the east.

STRATIGRAPHY

Upper Cretaceous strata, ranging in age from Arkadelphia marl in the south to the Tokio formation on the north, form the surface rocks in the central and northern parts of the county. The Midway formation is exposed at the surface in a belt 4 to 6 miles wide and the Wilcox formation forms the surface rocks in in the southern part of Hempstead County.

BASEMENT ROCKS

Rocks of Paleozoic age, forming the basement floor on which the Cretaceous sediments were deposited, have been reached in several wells in this area. The basement rocks slope from a depth of 500 below sea level in the north to a depth of 2,500 feet below sea level in the central part of the county. A sharp flexure carries the basement rocks to an undetermined depth in the southern part of the county.

CRETACEOUS

COMANCHE SERIES

The Comanche sediments underlying Hempstead County thin to the north and east, in part the result of lateral thinning of the sediments and in part the result of truncation prior to the Upper Cretaceous deposition. In the southwestern part of the county the Upper Glen Rose formation is in contact with the base of the Gulf series. The upper half consists of red clays and sands, and the lower half consists of impure limestones, shales, and sand with some thin beds of red clays and shale. It is 600 to 900 feet thick. In the central and eastern part the Upper Glen Rose is represented by a few feet of marine beds above the anhydrite zone, and it is absent in the northeastern part of the county. The anhydrite zone of the Glen Rose formation underlies all but the northeastern part of the county. It is estimated to be 200 feet thick in the southwestern part but decreases in thickness to a few feet in the northern part of the county. The Lower Glen Rose consists of shales, sands, and impure limestone with interbedded red clays and shales. These beds are not less than 700 feet thick in the southwestern part but decrease in thickness to the north and northeast. The Travis Peak formation is made up of red clays and sands which in the extreme southern part of the county are estimated to be about 2,000 feet thick. This formation thins to the north and northeast. It seems probable that the Travis Peak formation is underlain by marine beds of Neocomian age in the extreme southern part of Hempstead County.

GULF SERIES

The Gulf series, in the area where they underlie the Tertiary strata, range in thickness from 1,000 to 1,600 feet with the

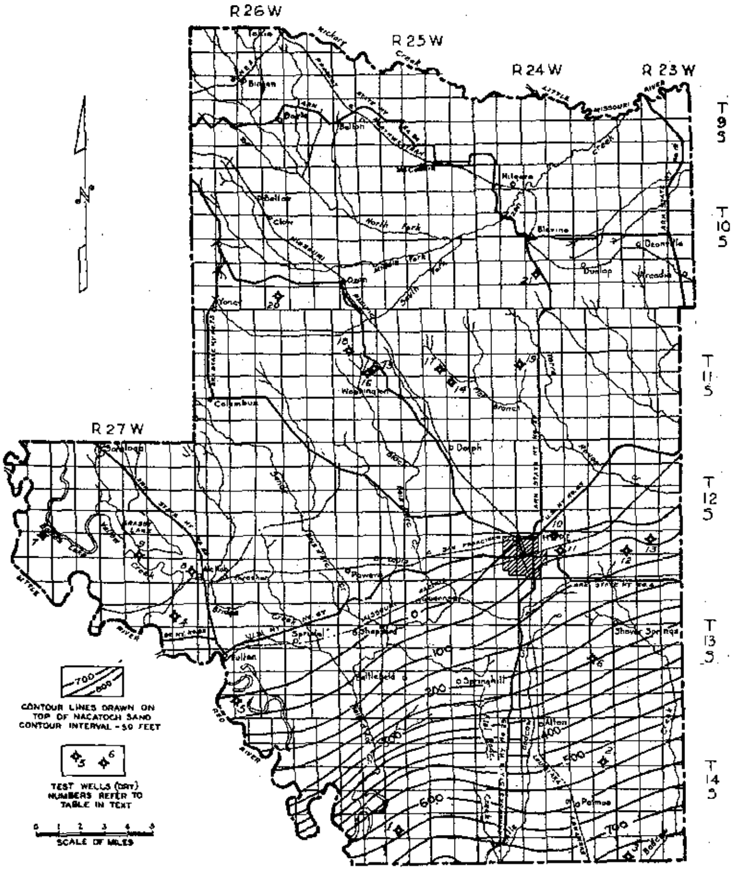


FIGURE 62.—Structure contour map of Hempstead County. Figures give depth below sea level in feet.

greater thickness in the southwestern part of the county. The sediments are essentially similar in character to the sediments exposed at the surface.

TERTIARY

EOCENE SERIES

The Midway formation consists of gray to dark-gray non-calcareous clays, containing an abundance of siderite concretions, with 25 to 30 feet of calcareous and fossiliferous clays and marls at the base. It increases in thickness southward from the outcrop and is estimated to be 400 to 450 feet thick in the southeastern part of Clark County. The Midway formation is overlain by sands and sandy clays of Wilcox age.

STRUCTURE

The generalized structure of the Comanche strata, using the base of the anhydrite zone of the Glen Rose formation as a datum plane, is shown in Plate XII. The base of the anhydrite zone lies at depths of 500 to 1,000 feet below sea level in the north-central part and at depths of 2,500 to 3,000 feet below sea level in the southwestern part. The dip is to the south and southwest at the rate of 75 to 150 feet per mile.

The structure of the Upper Cretaceous strata in the southern part of Hempstead County, drawn on top of the Nacatoch formation, is shown in Figure 62. These beds dip to the south and southeast at rates of 50 to 100 feet per mile.

List of wells drilled in Hempstead County

No., Company, Farm & Number	Location Sec.	Twp.	R.	T. D.	Elev.*	Depth to Nacatoch feet	Depth to red shale feet	Oldest formation penetrated
1 V. K. F. Drlg. Co., Jones No. 1	26	14S	25W	2537	354[a]	1140	2375	Trinity
2 White Oil Corp., Jones No. 1	12	14S	24W	3040	356	882	2165	Trinity
3 Fullilove Drlg. Co., (Hansen et al) Ford No. 1	31	14S	23W	2519	263.50[g]	1044	———	Tokio
4 Ralph Dudney, C. Spates No. 1	12	13S	27W	2505+	285[d]	90	———	Trinity
5 Gulf Refg. Co., Shultz No. 1	33	13S	26W	3025	256.7[d]	256	1628	Trinity
6 Secrest & Allen, Duckett No. 1	24	13S	24W	2245	375[d]	643	1875	Trinity
7 White Cliffs Stock Farm Co., White Cliffs No. 1	25	12S	28W	2635	———	———	692	Travis Peak
8 McNab, Adams No. 1	36	12S	27W	———	334[a]	———	1480	Travis Peak
9 Grassy Lake O. Co., Gun Club No. 1	27	12S	27W	2275	267.5[a]	———	1340	Travis Peak
10 Hope Water Co., Hope No. 3	28	12S	24W	560	———	422	———	Nacatoch
11 Hope Water Co., Hope No. 4	28	12S	24W	2685	352[d] 375[b]	375	1225	Travis Peak
12 Allen Oil Co., (Lawsen Ark. Synd.) Henry No. 1	30	12S	23W	2880	438[d]	520	1885	Trinity
13 Robinson & Spafford, Toner No. 1	29	12S	23W	2900	325[a]	350	1660	Pre-Cretaceous
14 Columbus Hope O. Co., Oking No. 1	24	11S	25W	2102	369[d]	———	1015	Travis Peak

No., Company, Farm & Number	Location Sec.	Twp.	R.	T. D.	Elev.*	Depth to Nacatoch feet	Depth to red shale feet	Oldest formation penetrated
15 Frank S. Meyers, Nichols No. 2	17	11S	25W	2500	396[d]	—	1142	Lower Trinity
16 Frank S. Meyers et al, (Hempstead Oil Co.) Nichols No. 1	17	11S	25W	—	400[d]	—	1090	Lower Trinity
17 A. H. Tarver, Swoffard No. 1	14	11S	25W	2988	437[a]	—	1065	Lower Trinity
18 Tycap, Mason No. 1	7	11S	25W	2370	400[d]	—	1110	Trinity
19 Ga. & Ark. Petrol. Co.,	16	11S	24W	1850	400[a]	—	1050	Trinity
20 Ark. Nat. Gas Co., D. E. Goodlet No. 1	34	10S	26W	—	398.5[f]	—	827	Paleozoic
21 Georgia Oil Synd., Duckett No. 1	28	10S	24W	950	350[a]	—	891	Trinity

* Letters refer to key to datum for elevation on page 261.

HOT SPRING COUNTY

The western and northwestern parts of Hot Spring County lie in the Ozark province. The surface rocks in this area consist of sandstone, shales, and novaculites of Paleozoic age. The south-

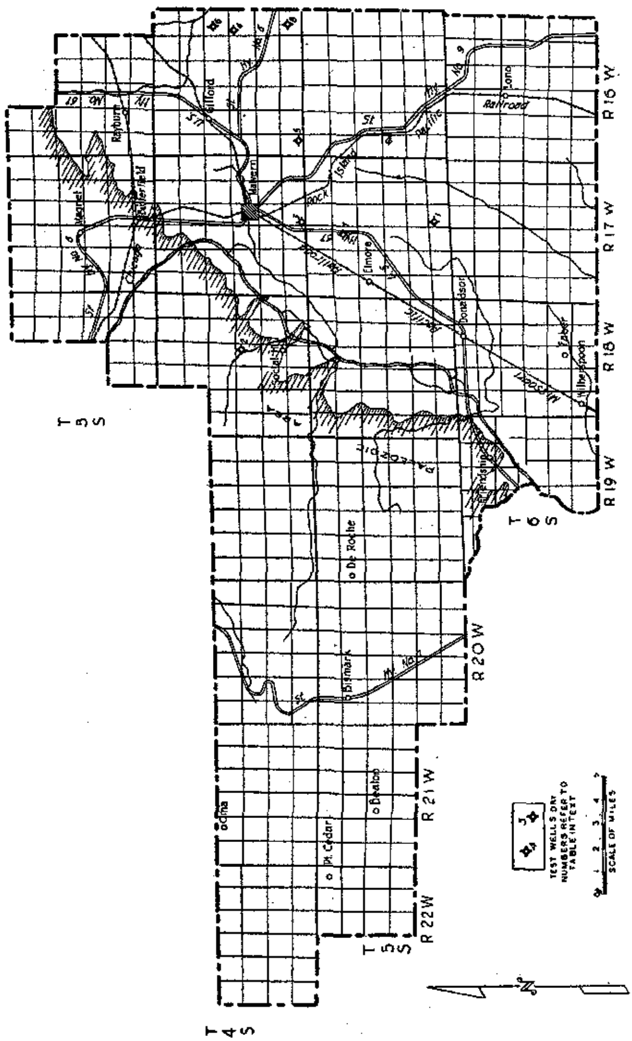


Figure 63.—Map of Hot Spring County.

eastern part of the county lies in the Gulf Coastal Plain. The surface rocks in the Coastal Plain area consist of sands and clays belonging in the Midway and Wilcox formations of Eocene age.

The Paleozoic rocks which form the surface in the western part of the county dip under the Coastal Plain sediments and lie at estimated depths of 1,000 feet below sea level in the southeastern part of Hot Spring County.

The rocks at the surface in the Coastal Plain area consist of clays and sands belonging to the Midway and Wilcox formations of Tertiary age. The Midway formation is exposed in a more or less continuous belt extending in a southwesterly direction from the northeast corner of the county into the southwest corner of T. 5 S., R. 18 W. The Wilcox sands and clays form the surface rocks in the southeastern part of the county.

The Comanche series is not represented but most of the Coastal Plain area of Hot Spring County is underlain by strata of Upper Cretaceous age. The Upper Cretaceous includes beds of Arkadelphia, Nacatoch (See Pl. XI) and Marlbrook age, which increase in thickness to the south and southeast and total about 400 feet in the southeastern corner of the county. The Cretaceous and the Tertiary strata dip to the southeast. The top of the Nacatoch formation is estimated to lie between 1,200 and 1,400 feet below sea level in the southeastern corner of Hot Spring County. Map of Hot Spring County is shown in Figure 63.

List of wells drilled in Hot Spring County

No., Company, Farm & Number	Location Sec.	Twp.	R.	T. D.	Elev.*	Oldest formation penetrated
1 Malvern O. & G. Co., J. K. Hall No. 1	34	5S	17W	9754	471[a]	No information; probably Paleozoic
2 J. O. Knox et al, Jachine (Latherier) No. 1	21	4S	18W	1228	....	Paleozoic
3 Frank Lesh, Manning No. 1	34	4S	17W	865	+315[a]	Paleozoic
4 Blayne-Holcomb, Delaney No. 1	24	4S	16W	1210	397[a]	Log incomplete; probably abandoned in Paleozoic rock
5 Taylor-Henson, Henson No. 1	19	4S	16W	1307	....	Paleozoic
6 W. H. Rowe, Malvern Lbr. Co. No. 1	18	4S	13W	1353	....	No information
7 Lesh-Eger, Malvern Lbr. Co. No. 1	9	5S	17W	916	....	No information
8 White No. 1	36	4S	16W	230	....	No information

* Letters refer to key to datum for elevation on page 261.

HOWARD COUNTY

The northern part lies in the Ozark province and the remainder of the county in the Gulf Coastal Plain. The rocks at the surface in the Ozark province are sandstones and shales belonging to the Jackfork sandstone and Stanley shale of Paleozoic

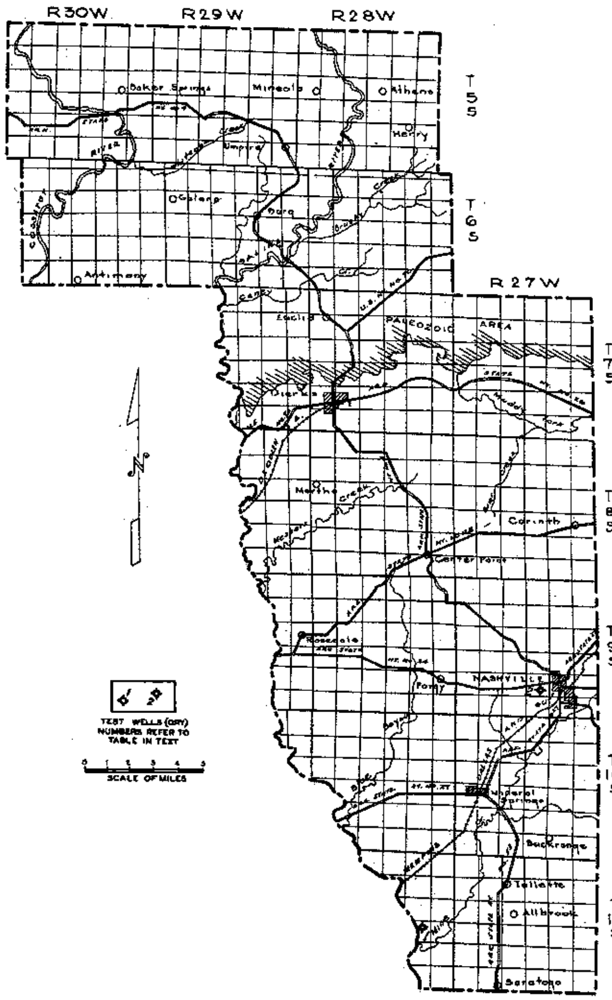


FIGURE 64.—Map of Howard County.

age. These rocks dip under southward and pass under Coastal Plain sediments to lie at estimated depths of 2,500 feet below sea level along the southern boundary of the county. The Comanche series, represented by the Trinity group, is exposed in a belt 6 to 9 miles wide extending across the north central part of the county. In the remainder of the county the surface rocks are of Upper Cretaceous age, ranging from the Woodbine sand to the Saratoga chalk, the last named formation is exposed in the extreme southern part.

The Trinity group of the Comanche series has been described as the Trinity formation by Miser and Purdue[8]. The total thickness of the formation is 600 to 800 feet, made up of several members as follows: Gray cross-bedded sand with some clay at the top; DeQueen limestone member, fossiliferous limestone, green clays, and gypsum and celestite near base; variegated clays containing the Ultima Thule gravel lentil; the Dierk's limestone lentil of fossiliferous limestone and a smaller amount of green clays; and gray cross-bedded sands with the Pike gravel member at the base.

The Trinity strata increase in thickness to the south; the DeQueen limestone member, the Dierks limestone member, and the intervening beds of variegated shale, sand, and gravel expands underground where they are included in the Glen Rose formation. The Trinity group is estimated to be 1,500 to 2,000 feet thick in the southern part of Howard County.

The Trinity strata dip to the south at the rate of 75 to 100 feet per mile. Map showing test wells drilled in Howard County is shown in Figure 64.

List of wells drilled in Howard County

No., Company, Farm & Number	Location Sec.	Twp.	R.	T. D.	Elev.*	Depth to Nacatoch feet	Depth to red shale feet	Oldest formation penetrated
1 Baker, Tr., Toland No. 1	23	11S	28W	1733	....	....	....	Paleozoic
2 Perpetual O. Co., Fee Farm No. 1	26	9S	27W	1280	....	....	....	Paleozoic

* Letters refer to key to datum for elevation on page 261.

[8] Miser, D. H., and Purdue, A. H., Asphalt deposits and oil conditions in southwestern Arkansas: U. S. Geol. Survey Bull. 691-J, 1918.

———. Geology of the DeQueen and Caddo Gap quadrangle, Arkansas: U. S. Geol. Survey Bull. 808, 1929.

INDEPENDENCE COUNTY

The greater part of the county is included within the Ozark province. The remainder of the area, embracing a strip 3 to 6 miles wide bordering the county on the east and an area a few miles wide extending up the valley of White River as far as Batesville, is included in the Gulf Coastal Plain. The Paleozoic

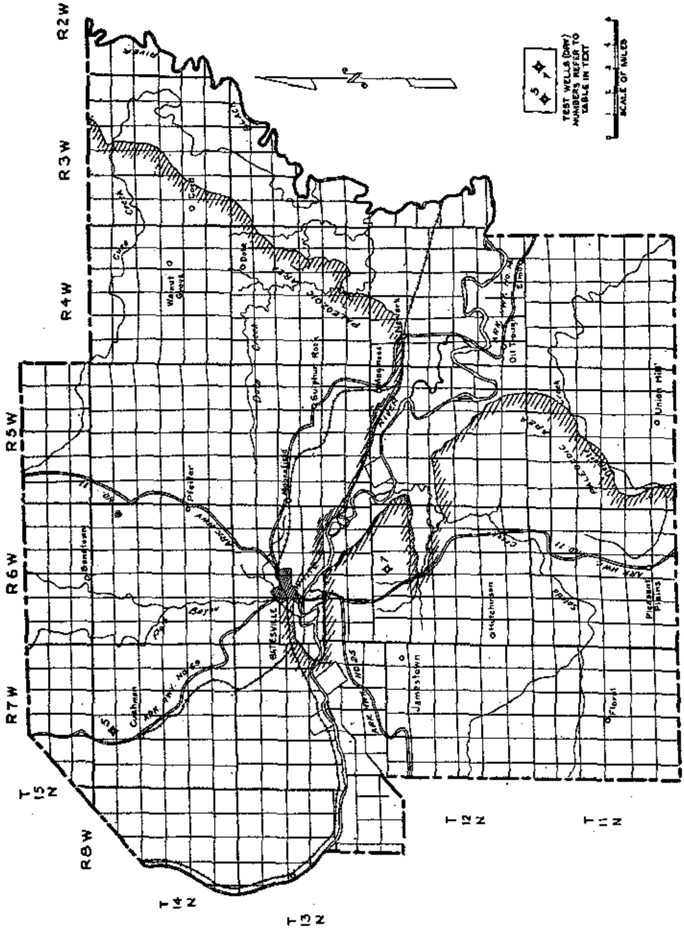


FIGURE 65.—Map of Independence County.

rocks underlie the Coastal Plain area but nowhere at greater depth than 500 feet below sea level.

The older Coastal Plain strata that crop out in this area are glauconitic sands interbedded with laminated clays and subordinate lenses of shale and marl of Upper Cretaceous age and are probably referable to the Nacatoch formation. Limestones of

Eocene age belonging to the Midway formation appear in the Grandglaise terrace along the margin of the Ozark province. Undifferentiated Eocene and Cretaceous strata underlie the remainder of the Coastal Plain area in Independence County beneath alluvial deposits, which are estimated to be 100 to 150 feet thick. The maximum thickness of the Cretaceous is estimated to be 100 feet or less in the southeastern corner of Independence County where the top of the Nacatoch lies approximately at sea level.

Map showing test wells drilled in Independence County is given in Figure 65.

List of wells drilled in Independence County

No.,	Company Farm & Number	Location Sec.	Twp.	R.	T. D.	Elev.*	Depth to Nacatoch feet	Depth to red shale feet	Oldest formation penetrated
1	Butler et al, Butler No. 1	20	13N	7W	372	-------	------	------	------------
2	Davis O. & G. Co., J. P. Montgomery No. 1	31	15N	6W	-------	-------	------	------	------------
3	Fulk & Riffel, Adams No. 1	14	13N	7W	1600	-------	------	------	------------
4	Hinkle, ------------	17	13N	6W	-------	-------	------	------	------------
5	Southern Mine. Co., ------------	8	14N	7W	-------	-------	------	------	------------
6	Sulphur Rock O. Co., Jameson No. 1	13	13N	5W	1260	-------	------	------	------------
7	Walbert Oil Co., Grigsby No. 1	3	12N	6W	2600	-------	------	------	------------
8	White River O. & G. Co., Earnharts No. 1	20	13N	7W	1100	-------	------	------	------------

* Letters refer to key to datum for elevation on page 261.

JACKSON COUNTY

LOCATION

Jackson County, situated in northeastern Arkansas, is bounded on the south by Woodruff County, on the west by White and Independence counties, on the north by Lawrence County, and on the east by Poinsett and Craighead counties.

GENERAL FEATURES

A small area in the southwestern part of the county is included in the Ozark province; the remainder of the county lies within the Gulf Coastal Plain. The Grandglaise terrace is a narrow ridge, or dissected terrace, bordering the Ozark province just west of the St. Louis, Iron Mountain, and Southern Railway, the crest of which is about 300 feet above sea level. The Advance lowland is a plain lying 200 to 300 feet above sea level and sloping slightly to the south. In the interstream areas the surface is gently undulating and partly timbered. The broad flood plains of the streams are a few feet lower than the interstream areas, are in part swampy, and are traversed by numerous bayous. Between the swamps and bayous are heavily tmbered ridges of sand or sandy loam, some rising a few feet higher than the general level of the lowlands.

STRATIGRAPHY

The Midway formation is represented by pebbly fossiliferous limestone interbedded with gray to yellowish sands which crop out in the basal 20 to 25 feet of the east-facing escarpment of the Grandglaise terrace. The Midway is overlain by reddish, pebbly sand, probably of the same age as the similar sands (Lafayette formation) overlying the Eocene strata of Crowley's Ridge; the red sands are overlain by dark and light, more or less sandy loams resembling certain facies of the loess of Crowley's Ridge. The Midway is separated from the alluvial deposits of the Advance lowlands to the east by an abrupt erosion escarpment. The alluvial deposits which underlie the Advance lowland to an estimated depth of 100 to 150 feet consist of loams, clays, sands, and gravels of Pleistocene and Recent age. The few wells drilled in Jackson County have furnished only a meager record of the thickness and the character of the sediments which underlie the surface of this area. A generalized section of formation is given in Table 42. (See Fig. 13.)

BASEMENT ROCKS

In the Ozark province in the southwestern part of the county the surface is formed by Paleozoic rocks of Pennsylvanian age.

TABLE 42.—*Generalized section of formations in Jackson County*

System	Series	Formation	Thickness in feet	Character
Quaternary	Pleistocene and Recent	Terrace and river deposits	100-150	Alluvial sand, gravel, clay, and loam.
		Unconformity		
Tertiary	Eocene	Undifferentiated	0-700	Sand and clay.
		Midway	25-275	Gray, noncalcareous clay; limestone sand and shale in lower part.
		Unconformity		
Cretaceous	Gulf	Arkadelphia marl Nacatoch and older	0-300	Calcareous, sands, sandy clays, and shales.
		Unconformity		
Paleozoic		Undifferentiated		

At their eastern border the Paleozoic rocks are separated from the materials of the Coastal Plain by an abrupt erosion escarpment along which their eroded surface passes beneath the Coastal Plain deposits. The basement rocks extend eastward to increasing depths estimated to be about 1,500 feet below sea level in the southeastern part of the county.

CRETACEOUS

GULF SERIES

The Gulf series increases in thickness from a few feet in the northwestern part to an estimated thickness of 300 feet in the southeastern part of Jackson County. The age of the basal beds in the southeastern part of the county is not definitely known, but it is probably the equivalent of the Marlbrook marl. To the west these beds are overlapped by the Saratoga chalk and the Nacatoch formation. The Arkadelphia has not been recognized in the western part of the county where it is either absent or changes to sands and, therefore, cannot be separated from the underlying Nacatoch.

TERTIARY

EOCENE SERIES

The Midway formation consists chiefly of gray noncalcareous clays and sandy clay in the upper part, and of limestone, calcareous shale, and sand in the lower 25 to 50 feet of beds. It is estimated to be about 275 feet thick in the southwestern part of the county.

The Midway formation, except in the western part, is overlain by sands and clays which reach a maximum thickness of 650 to 700 feet in the southeastern part of the county. The age of these beds has not been determined but they probably belong in the Wilcox formation and may include some beds of Claiborne age.

QUATERNARY

PLEISTOCENE AND RECENT SERIES

The Advance lowland is underlain by alluvial deposits of Pleistocene and Recent age to an estimated depth of 100 to 150 feet.

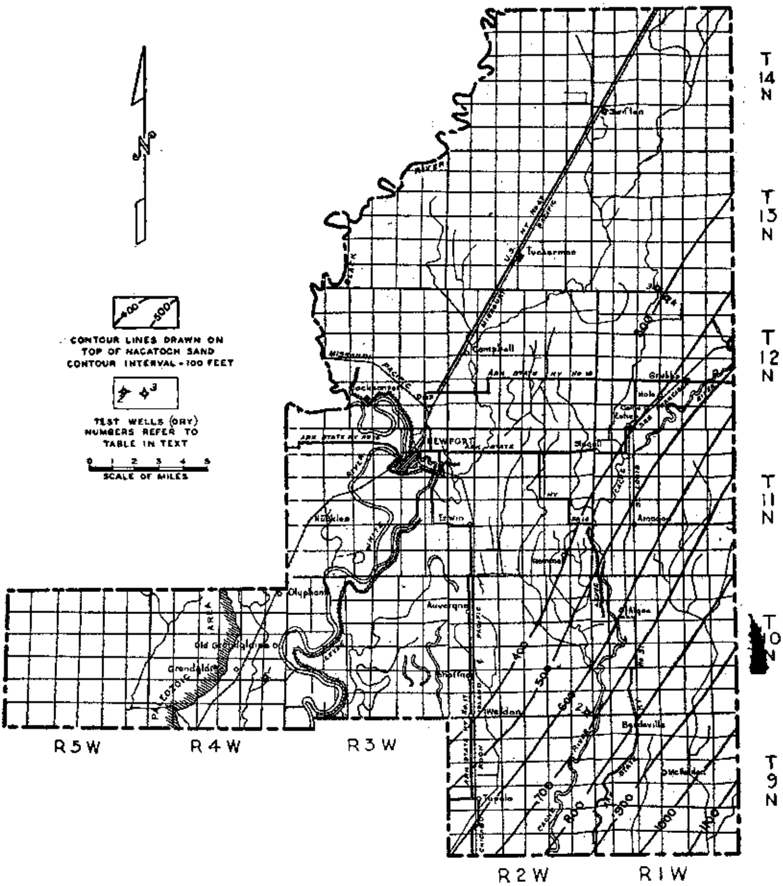


FIGURE 66.—Structure contour map of Jackson County. Figures give depth below sea level in feet.

STRUCTURE

The available data indicate that the Cretaceous dip to the east and southeast. The top of the Nacatoch formation lies at sea level in the northwestern part and at a depth of about 1,000 feet below sea level in the southeastern part of the county. (See Fig. 66.)

List of wells drilled in Jackson County

No., Company, Farm & Number	Location Sec.	Twp.	R.	T. D.	Elev.*	Depth to Nacatoch feet	Depth to red shale feet	Oldest formation penetrated
1 Fullmoon Petrol. Co., Hague No. 1	24	10N	4W	-------	-------	-------	-------	Paleozoic
2 A. N. Sutton, Johnson & Perger No. 1	31	10N	1W	1269	210	905	-------	Paleozoic
3 Village Creek Dev. Co., Bowen No. 1	33	13N	1W	584	230	518	-------	Paleozoic
4 J. F. Page, Page No. 1	3	12N	1W	910	230[b]	595	-------	Paleozoic

* Letters refer to key to datum for elevation on page 261.

JEFFERSON COUNTY

LOCATION

Jefferson County is bounded on the south by Lincoln and Cleveland counties, on the west by Grant County, on the north by Pulaski and Lonoke counties, and on the east by Arkansas County.

GENERAL FEATURES

The well defined topographic division of the Gulf Coastal Plain is represented in Jefferson County. In the west an area, varying in width from 5 miles in the north to 16 miles in the south, forms part of an upland which is extensively developed in the interstream areas of southwestern Arkansas, which in this county lies 300 to 350 feet above sea level. The remainder of the county is included within the Advance lowland, the general surface of which is a plain 190 to 235 feet above sea level, sloping slightly to the south. Arkansas River traverses the lowland from northwest to southeast. Nearly all of the land northeast of the river is included within the gently undulating flood plain of Arkansas River; it is in part swampy and is traversed by numerous bayous and abandoned stream channels.

STRATIGRAPHY

The Jackson formation of the Eocene age crops out in the upland area west of Arkansas River; Eocene deposits underlie the remainder of the county beneath 100 to 150 feet of Quaternary alluvium. The Eocene, which includes the Jackson, Claiborne, Wilcox, and Midway formations, ranges in thickness from about 2,000 feet in the northwestern, to about 3,800 feet in the southeastern part of the county. The Cretaceous strata, which unconformably underlie the Eocene, increase from about 200 feet in the northern to about 800 feet in thickness in the southeastern part of the county.

A generalized section of formations is given in Table 43.

BASEMENT ROCKS

The basement rocks have not been penetrated in wells drilled in Jefferson County but from the attitude of the Nacatoch sand and the regional thickness of the Cretaceous beds, it is estimated that these rocks lie at depths ranging from about 2,000 feet below sea level in the northwestern corner, to about 4,600 feet below sea level in the southeastern corner of the county.

CRETACEOUS

GULF SERIES

The data concerning the Gulf series are meager, as the deep-

TABLE 43.—*Generalized section of formations in Jefferson County*

System	Series	Formation	Thickness in feet	Character
Quaternary	Pleistocene and Recent		0-150	Alluvial sands, gravels, clays, and loams.
		Unconformity		
Tertiary	Eocene	Jackson Claiborne Wilcox	1500-3300	Chiefly sand, sandy clays, and clays, in part lignitic. Glauconitic sand and clay principally in the basal Claiborne and in the Jackson formation.
		Midway clays	460-500	Gray and bluish-gray clay, abundant siderite concretions.
		Unconformity		
Cretaceous	Gulf	Arkadelphia marl	65-100	Gray to dark-gray calcareous shale.
		Nacatoch sand and Saratoga chalk	175-300	Generally fine-textured, in part glauconitic and calcareous sand and sandstone; subordinate beds of shale and limestone.
		Marlbrook marl and older	0-350	Marls, chalks, and sand.

est well drilled, located in the northwestern part of the county, penetrated only the Nacatoch sand. From original studies it is estimated that the Gulf series is about 200 feet thick in the northwestern part and more than 800 feet thick in the southeastern part of the county. The northwestward thinning of the strata is the result of the thinning of individual members and of overlap.

The Arkadelphia marl, estimated to be from 65 to 100 feet thick, consists of gray, calcareous shale, characteristic of this formation over most of Arkansas.

The Nacatoch and Saratoga chalks are estimated to be from 175 to 300 feet thick, and probably consist chiefly of fine-textured sand and sandstone, in part glauconitic, with subordinate beds of shale and chalk in the lower part.

The Marlbrook marl and older strata are estimated to attain a maximum thickness of 350 feet in the southeastern corner of the county, where the beds of the Tokio-Woodbine age may be present.

TERTIARY

EOCENE SERIES

The Jackson formation of Eocene age is exposed in a belt 5 miles wide in the north and 16 miles in the south, lying west of Arkansas River. These beds are perhaps best exposed in White Bluff in sec. 19, T. 3 S., R. 10 W., where Harris[9] measured the following section:

[9]Harris, G. D., The Tertiary geology of southern Arkansas: Arkansas Geol. Survey Ann. Rept. 1892, pp. 88-91.

Section of White Bluff, Jefferson County, Arkansas

Bed		Thickness in feet
(c)	Soil and sand	8
(d)	Light-grayish sandy clay	9
(e)	Very light pinkish-colored clay containing numerous well preserved dicotyledonous leaves	8
(f)	Evenly laminated dark lignitic and more or less sulphurous shaly clay	9
(g)	Dark lignitic clay resting unconformably on and containing two beds of lignite, separated from the overlying bed by a seam of lignite, separated from the overlying bed by a seam of lignite 3 to 6 inches thick	5-9
(h)	White sand, sometimes stained yellowish	4-8
(i)	Evenly laminated dark lignitic, more or less sulphurous shaly clay. Between this bed and the bed below are occasional ferruginous concretions	11
(j)	Dark bluish sandy marl, containing in its lower portion an abundant nolluscan fauna	28

In the remainder of the county, the surface materials are Quaternary alluvial deposits.

The Eocene strata in this area are estimated to aggregate about 2,000 feet in the northwestern part and about 3,800 feet in the southeastern part of the county. The Eocene includes the Jackson, Claiborne, Wilcox, and Midway formations, but, owing to lack of data, these formations cannot be accurately differentiated.

The Midway, 460 to 500 feet thick, consists of gray and bluish-gray, generally concalcareous clays but is calcareous and fossilifereous in its lower part.

The Wilcox formation is made up principally of sands, sandy clays, and clays and is in a large part lignitic.

The Claiborne formation consists chiefly of sands and clays in the upper part and of glauconitic sand and clays in the lower part.

QUATERNARY

The alluvial deposits in the Advance lowland northeast of Arkansas River have an estimated thickness of 125 to 150 feet, consisting of alluvial loams, clays, sands, and gravels. The surface materials are, probably, for the most part of Recent age, but some of the higher interstream areas may be of Pleistocene age.

STRUCTURE

The generalized structure of Jefferson County drawn on top of the Nacatoch sand is shown in Plates I and XI, and Figure 67. The top of the Nacatoch sand lies at a depth of about 1,700 feet below sea level in the northwestern corner and is estimated to be about 3,800 feet below sea level in the southeastern corner of the county. The dip is towards the southeast at the rate of 60 to 90 feet per mile. The available data are insufficient to indicate local structural features which may be present in this area.

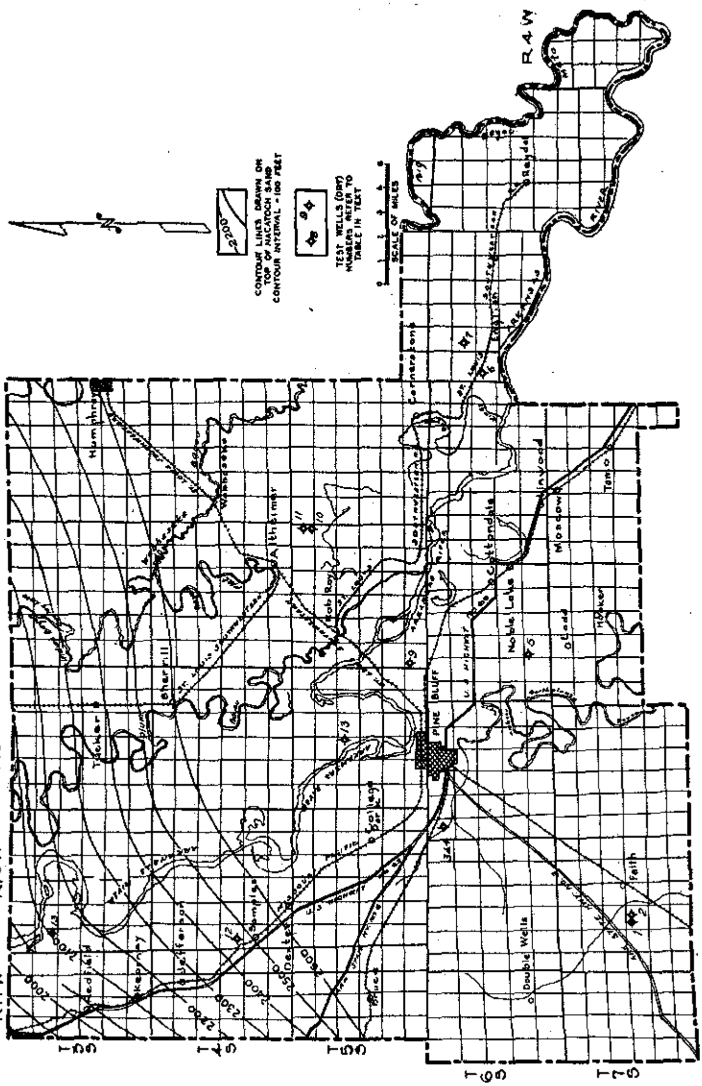


FIGURE 67.—Structure contour map of Jefferson County. Figures give depth below sea level in feet.

List of wells drilled in Jefferson County

No., Company, Farm & Number	Location Sec.	Twp.	R.	T. D.	Elev.*	Depth to Nacatoch feet	Depth to red shale feet	Oldest formation penetrated
1 Richardson et al, (Faith Oil Co.) Zangerle No. 1	21	7S	10W	2460	-------	-------	-------	Claiborne or Wilcox
2 D. C. Richardson,	27	7S	10W	-------	240[b]	-------	1800	Wilcox
3 St. L. S. W. Ry., Well at Pine Bluff No. 1	6	6S	9W	-------	-------	-------	-------	Claiborne
4 St. L. S. W. Ry., Water well at Pine Bluff No. 2	6	6S	9W	960	215[b]	-------	-------	Claiborne
5 Jefferson O. & G. Co., Rutherford No. 1	33	6S	8W	1565	-------	-------	-------	Claiborne or Wilcox
6 Richardson Oil Co., (R. N. Burke) Swan Lake (Louden) No. 1	18	6S	6W	1930	-------	-------	-------	Wilcox
7 Hall & Smith, Hicks No. 1	8	6S	6W	3008	-------	-------	-------	Midway
8 Brothers Oil Co., Crawford No. 1 (Townsite)	21	5S	11W	2485	334.2[a]	-------	-------	Wilcox
9 Fuller & Draiss, Trimble No. 1	31	5S	8W	2534	-------	-------	-------	Wilcox
10 Ark. Oil Corp., Phillips No. 1	2	5S	8W	-------	207[a]	-------	-------	Wilcox
11 Gladys-Belle O. Co., Phillips No. 1	2	5S	8W	2200	207	-------	-------	Wilcox
12 Jefferson O. & G. Co., Nevins No. 1	22	4S	10W	2522	-------	-------	-------	Wilcox
13 Decem Oil Co., (Peavy & Brett) McIntosh-Misbey (Tensley) No. 1	7	3S	10W	2532	306[a]	-------	-------	Nacatoch
14 L. A. Schumacher, M. & P. Danaher No. 1	16	5S	9W	3286	219	-------	-------	Paleozoic

* Letters refer to key to datum for elevation on page 261.

LAFAYETTE COUNTY

LOCATION

Lafayette County is bounded on the south by the State of Louisiana, on the west by Miller County, on the north by Nevada and Ouachita counties, and on the east by Columbia County.

STRATIGRAPHY

The rocks at the surface in Lafayette County range in age from Recent to Tertiary, but deep wells have penetrated all of the Gulf series and more than 1,500 feet of the Trinity. A generalized section of formations encountered in drilling is given in Table 44.

CRETACEOUS

COMANCHE SERIES

The character and thickness of the Comanche series underlying Lafayette County are estimated from deep wells drilled in Miller, Nevada, and Columbia counties. The greatest thickness of these rocks is in the southwestern part and the least thickness in the northeastern part of the county.

GULF SERIES

WOODBINE SAND AND TOKIO FORMATION

The Woodbine sand and the Tokio formation in Lafayette County, as in Miller County, are not separable in distinct formations. Their combined thickness is 550 feet in the southern part and 400 feet in the northern part of the county, consisting of generally thin-bedded sand, sandy shale, and shale, lignitic in the upper part. The lower part is dominantly tuffaceous and, locally, contains lenses of conglomeratic tuffaceous sandstone; locally, red clays are present at the base.

OZAN FORMATION

The Ozan formation is 125 to 160 feet thick, consisting of micaceous gray and greenish-gray marl and shale. The basal member, the Buckrange sand, is best developed in the southern half of the county, where it is 15 to 35 feet thick, made up of sand and sandy shale. In the northern half of the county the Buckrange sand is absent in local areas.

OTHER FORMATIONS

The formations above the Ozan show only slight changes in character and thickness within this area. A typical well section of the basal formations is shown in the following section and in Figure 67.

TABLE 44.—*Generalized section of formations in Lafayette County*

System	Series	Formation	Thickness in feet	Character
Quaternary	Pleistocene and Recent	Terrace and river deposits		Sand, silt, and gravel.
		Unconformity		
Tertiary	Eocene	Claiborne	500-700	Chiefly sand and clay, thin beds of glauconitic sand and ferrginous sandstone.
		Wilcox	500-600	Lignitic sand and clay.
		Midway clays	500-550	Gray to bluish-gray clay siderite concretions.
		Unconformity		
Cretaceous	Gulf	Arkadelphia marl	80-110	Dark-gray shales.
		Nacatoch sand	400-480	Sand, sandstone, sandy limestone and sandy shale in alternating beds, and a gray shale member at the base.
		Saratoga chalk Marlbrook marl Annona chalk	330-340	Gray to white chalk and chalky marl and shale.
		Ozan (Buckrange sand at the base)	125-160	Micaceous marl and shale with the Buckrange sand member at the base.
		Brownstown marl	125-200	Chiefly gray clay and shale.
		Tokio and Woodbine sand	400-550	Sand and sandy shale, in part lignitic, in the upper part; sand, sandy shale and shale, in part tuffaceous and conglomerate in lower part. Locally, red shale at the base.
		Unconformity		
	Comanche (Washita and Fredericksburg group)	Undifferentiated	0-300	Gray limestone and shale.
	(Trinity group)	Paluxy Upper Glen Rose	200-1650	Red sand and shale in upper part; marine shale and impure limestone with some interbedded red shale in the lower part.
		Anhydrite zone	175-500	Anhydrite with interbedded limestone and shale.
		Lower Glen Rose	700-900	Marine shale and impure limestone with subordinate beds of sand. Thin beds of red shale in northern part.
		Travis Peak	0-500+	Dominantly red shale and sand in upper part. Gray to brown shale and sand in lower part.

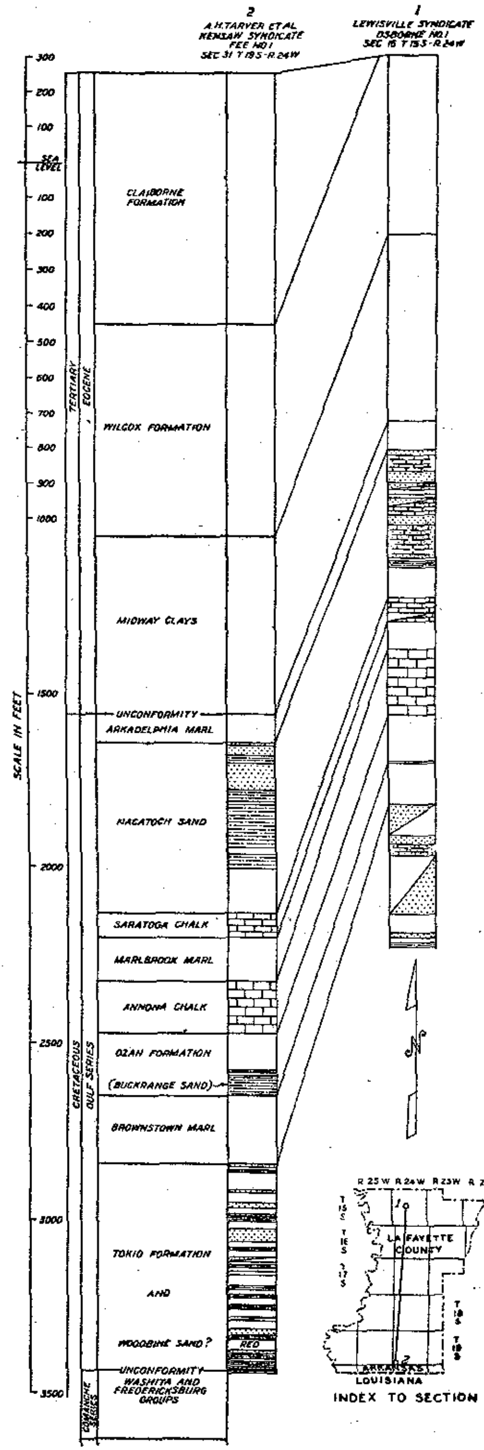


FIGURE 68.—North-south cross section through Lafayette County showing correlation of Cretaceous and Tertiary.

Section of Brownstown marl, Tokio formation, and Woodbine sand in Arkansas Fuel Oil Company's Red River Lumber Company No. 1 well sec. 18, T. 19 S., R. 24 W.

Geologic age	Depth in feet
Cretaceous	
Gulf series	
Ozan formation, Buckrange sand	
Hard sand rock	2813-2815
Sandy shale	2832
Brownstown marl	
Shale	2878
Shale with streaks of lime	2910
Sticky lime	2925
Shale	2959
Lime	2960
Hard lime	2961
Gummy lime	2969
Shale	3003
Tokio formation and Woodbine sand	
Sand and shale	3004
Sandy shale	3006
Hard shale	3026
Lime rock	3027
Hard shale and sand	3029
Hard shale	3043
Shale and sandy limestone	3046
Sandy lime	3051
Shale and sand	3053
Sandy lime	3057
Sandy shale	3069
Shale	3084
Sand	3085
Shale	3129
Sandy shale	3145
Sand	3146
Sandy shale	3153
Sand; salt water	3156
Sand and lime	3160
Sandy shale	3167
Sticky lime	3171
Sand	3175
Shale	3177
Sand	3180
Sticky lime	3184
Gravel and shale	3186
Sandy lime	3188
Shale and boulders	3195
Sand and gravel	3200
Sand	3207
Sandy shale	3211
Sand	3217
Sticky lime	3219
Sand	3230
Shale	3237
Sand	3238
Sand and shale	3260

Geologic age	Depth in feet
Shale	3268
Sand	3272
Shale	3280
Sand and sandy shale; salt water	3292
Shale	3300
Sand and shale	3311
Sand	3322
Sandy shale	3335
Gummy lime	3342
Sandy shale	3394
Gummy lime	3406
Sandy shale	3418
Sand	3420
Shale	3425
Sandy shale	3447
Shale	3520
Upper Cretaceous red beds	
Red shale	3545
Shale	3549
Hard sand	3551
Unconformity	
Trinity group	
Red shale with streaks of hard limestone (cored)	3552

OIL AND GAS-PRODUCING HORIZONS

The Nacatoch sand, the uppermost producing horizon of the Cretaceous system, is present, and finely developed as a reservoir sand throughout Lafayette County.

The Buckrange sand at the base of the Ozan formation, is generally thin and not a very satisfactory oil and gas reservoir. It is best developed in the southern part of the county, where it is the oil-producing horizon in the Bradley district. A typical well section of the Buckrange sand is given below:

Section of Buckrange sand in Arkansas Fuel Oil Company's Red River Lumber Company No. 3 well, sec. 7, T. 19 S., R. 24 W.

Geologic age	Depth in feet
Buckrange sand	
Hard coarse sand and lime	2805
Hard sand and lime	2807
Sandy shale	2812
Shale	2813
Sand	2815
Shale	2816
Sand	2819
Sandy shale with streaks of sand	2823
Shale with streaks of sand	2825

The Tokio-Woodbine section contains several excellent reservoir sands. The Upper Glen Rose (Trinity group) has yielded a small amount of oil in T. 15 S., R. 26 W., just across the line in Miller County, and this horizon, with the beds immediately below the anhydrite zone of the Glen Rose formation, should be tested for oil and gas in deep wells drilled in Lafayette County.

STRUCTURE

The structure of Lafayette County, represented by contour lines on top of the Nacatóch sand, as recorded in deep wells, is shown in Plate I and Figure 69.

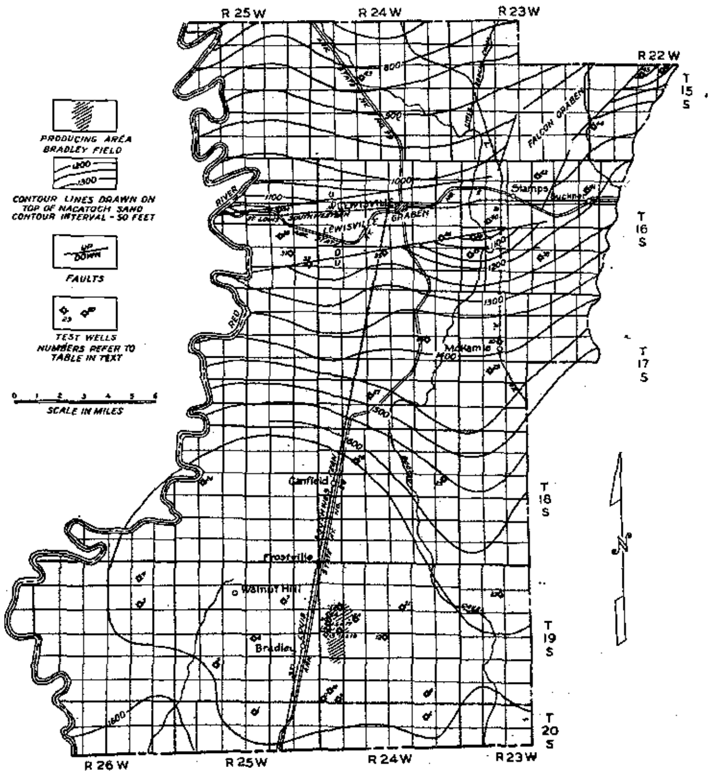


FIGURE 69.—Structure contour map of Lafayette County. Figures give depth below sea level in feet.

The principal structural features from north to south are: (1) A southward dipping monocline in T. 15 S., Rs. 23, 24 and 25 W.; (2) the Lewisville and Falcon grabens which extend from Red River through Lewisville and Stamps into Nevada County; (3) a southward dipping structural nose through Tps. 17, 18, and 19 S., Rs. 24 and 25 W., and (4) a broad structural terrace in T. 18 and 19 S., R. 24, 25 and 26 W.

The strike of the Nacatoch sand in the northern part of Lafayette County is nearly east-west and the dip to the south at the rate of 25 to 50 feet per mile. There are no determinable local structural features in this part of the county.

The Lewisville and Falcon grabens, described more in detail on page 136, are downfaulted wedges from half a mile to 2½ miles wide, in which the top of the Nacatoch sand lies 350 to 400 feet lower than normal. The Lewisville graben trends slightly north of east from T. 16 S., R. 25 W., to the vicinity of Stamps, where it changes abruptly in direction and continues as the Falcon graben to the northeast.

A closure of between 50 and 100 feet against the Falcon graben is present in T. 15 S., R. 22 W., on which a number of wells were drilled for oil and gas, yielding shows, but no commercial production.

Another and larger closure is present on the southside of the Lewisville graben at the town of Stamps. This area shows a closure of between 100 and 150 feet on the top of the Nacatoch sand. See Plates I and XIII.

A suggestion of a small closure against the southside of the Lewisville graben is found in secs. 25 and 36, T. 16 S., R. 25 W., and secs. 28, 29, 30, 31 and 32, T. 16 S., R. 24 W.

The southward-dipping structural nose extends from the center of T. 17 S., R. 23 and 24 W., into T. 19 S., R. 23 W. As interpreted in Plate I, there is a marked decrease in the rate of dip in the southeast corner of T. 17 S., R. 24 W., and the southwest corner of T. 17 S., R. 23 W., forming a structural terrace superimposed on this general structural feature.

The southern part of Lafayette County is a broad flat area that extends from Canfield on the north, to the Louisiana line on the south, and from the eastern line of T. 19 S., R. 24 W., into T. 19 S., R. 26 W. The producing area, known as the "Bradley district" is situated upon this structural terrace.

STRUCTURE OF THE COMANCHE SERIES

The structure of the Comanche series is not known, owing to lack of data; but a generalized picture may be obtained from Plate XII, which shows the general structural feature of the Trinity, based on records of deep wells.

SUMMARY

The Nacatoch sand is present throughout Lafayette County, where locally it has yielded slight shows of oil and gas.

The Buckrange sand, although present in most of the wells drilled in the county, is thin. It is the producing sand in the Bradley district.

The several sands in the Tokio formation and the basal beds of the Gulf series are present throughout the county, as are the Upper Trinity sands and the sands at the base of the anhydrite zone of the Glen Rose formation.

The geologic structure of Lafayette County, so far as determinable on the basis of available data, suggests that the following areas are the most favorable for oil and gas production: The closure against the Lewisville graben at Stamps in T. 16 S., R. 24 W., and T. 16 S., R. 23 W.; the area which includes secs. 29, 30, 31 and 32, T. 16 S., R. 24 W., and secs. 25 and 36, T. 16 S., R. 25 W.; the structural terrace, including secs. 25 and 36, T. 17 S., R. 24 W., and secs. 30 and 31, T. 17 S., R. 23 W., and the structural terrace in the southern part of the county.

DEVELOPMENT

The Bradley district in T. 19 S., R. 24 W., has produced 84,223 barrels of oil from 4 wells, all in sec. 18, T. 19 S., 24 W. The production is from the Buckrange sand at an average depth of 2,780 feet below the surface. A number of dry holes have been drilled in the immediate vicinity of these wells. The deep wells drilled for oil and gas in Lafayette County are shown listed below:

List of wells drilled in Lafayette County

No., Company, Farm & Number	Location Sec.	Twp.	R.	T. D.	Elev.*	Depth to Nacatoch feet	Depth to red shale feet	Oldest formation penetrated
1 Cotton Belt Land & Dev. Co., Fee No. 1	2	20S	25W	2620	246.8[f] 252[d] 250[b]	1850	-------	Annona
2 Ken-Saw Petrol. Co., Red River Ld. Co.	3	20S	24W	2440	245[a] 239.07[f]	1870	-------	Annona
3 Dixie Oil Co., Meyer Stove Mfg. Co. No. 1	11	19S	26W	3379	204[d] 215[a] 222[c]	1878	-------	Tokio-Woodbine
4 Jack Doyle et al, John Murphy No. 1	2	19S	26W	2900	261[b]	1880	-------	Annona
5 Walnut Hill Gas Co., Carl (Federal Ld. Book) No. 1	29	19S	25W	2515	227[d] 225.53[f]	1875	-------	Marlbrook
6 Jack Doyle, Tr., Crabtree No. 1	22	19S	25W	2870	255[a] 261[b] 261[d] 270[a] 260.58[f]	1868	-------	Annona
7 Ark. Fuel O. Co., R. H. Duty No. 1	11	19S	25W	2842	262.68[a]	1868	-------	Buckrange sand
8 Ken-Saw Petrol. Co., Red River Ld. Co.	34	19S	24W	2780	240[a]	1848	-------	Buckrange sand
9 Ken-Saw Petrol Co., Red River Lbr. Co. No. 1	31	19S	24W	3175	258[a]	1850	-------	Tokio-Woodbine
10 Bertram Dev. Co., Ken-Saw No. 1	31	19S	24W	1900	-------	1820	-------	Nacatoch sand
11 A. H. Tarver, Ken-Saw Synd. No. 1 (Fee No. 4)	31	19S	24W	3620	251.45[g]	1854	3517	Trinity group.
12 Keen-Woolf O. Co., Red River Lbr. Co. No. 1	21	19S	24W	3016	234[a] 232[d]	1866	-------	Brownstown marl

No.,	Company, Farm & Number	Location Sec.	Twp.	R.	T. D.	Elev.*	Depth to Nacatoch feet	Depth to red shale feet	Oldest formation penetrated
13	Ark. Fuel Oil Co., P. M. Allen No. 2	19	19S	24W	2797	253[d] 259.47[a]	1855	———	Buck-range sand
14	Ark. Fuel Oil Co., Allen No. 1	18	19S	24W	3088	254.9[a]	1845	———	Tokio
15	Ark. Fuel Oil Co., P. M. Allen No. 3	18	19S	24W	2783	251.7[a]	1847	———	Buck-range sand
16	Ark. Fuel Oil Co., P. M. Allen No. 4	18	19S	24W	2802	253.52[a]	1845	———	Buck-range sand
17	Ark. Fuel Oil Co., P. M. Allen No. 5	18	19S	24W	2787	253.42[f]	1844	———	Buck-range sand
18	Ark. Fuel Oil Co., Red River Lbr. Co. No. 1	18	19S	24W	2790	252.53[a]	1847	———	Buck-range sand
19	Ark. Fuel Oil Co., Red River Lbr. Co. No. 2	18	19S	24W	2811	253.10[a]	1843	———	Buck range sand
20	Ark. Fuel Oil Co., Red River Lbr. Co. No. 4	18	19S	24W	3552	252.2[a]	1845	3520	———
21	Gulf Refg. Co. of La., Red River Lbr. Co. No. E-1	10	19S	24W	2843	252[d]	1875	———	Buck-range sand
22	Ark. Fuel Oil Co., Red River Lbr. Co. No. 3	7	19S	24W	2825	251.01[d]	1863	———	Buck-range sand
23	Geo. Wetherbee, Jeffus No. 1	8	19S	23W	3158	229[d] 228[a]	1858	———	Tokio-Woodbine
24	A. D. Morris et al, Casey No. 1	17	18S	25W	2614	217.85[f] 223[d]	1902	———	Marlbrook
25	Oliver and Estes, Bodcaw No. 1	13	18S	24W	2799	262.5[a]	1870	———	Buck-range sand
26	M. H. Bostick et al, Frazier No. 1	8	18S	24W	3022	255[d]	1830	———	Tokio-Woodbine
27	Caddo O. & G. Co., Moore No. 1	28	17S	24W	2422	249[d] 260[a]	1616	———	Annona chalk
28	The Texas Co., Colvin No. 1	14	17S	24W	2800	234[d] 229.3[a]	1644.	———	Tokio-Woodbine
29	Ark. Tex. Leasing Co., Buchanan et al No. 2	20	17S	23W	2990	269[d] 275[a]	1640	———	Tokio-Woodbine
30	Ark. Tex. Leasing Co., Buchanan et al No. 1	17	17S	23W	3200	281[a] 279[d]	1612	———	Buck-range sand
31	Humble O. & R. Co., Bradshaw No. 1	26	16S	26W	1422	220[a]	———	———	Arkadel-phia marl
32	Wilcox O. & G. Co., Renick No. 1	25	16S	25W	2820	224.8[d]	1505	———	Tokio-Woodbine
33	Humble O. & R. Co., Johnson No. 1	23	16S	25W	1114	220.5[c]	———	———	Midway
34	Caddo O. & G. Co., Moore No. 2	14	16S	25W	2465	163[c] 220[a]	1985 ?	———	Browns-town marl
35	Humble O. & R. Co., Ford No. 1	28	16S	24W	1513	278.83[a]	1507	———	Nacatoch
36	Humble O. & R. Co., Massie No. 1	24	16S	24W	1380	240.3[c]	1341	———	Nacatoch
37	Robert Buchanan, King & Kimball	30	16S	23W	2900	263.4[f]	1400	———	Tokio-Woodbine

No., Company, Farm & Number	Location Sec.	Twp.	R.	T. D.	Elev.*	Depth to Nacatoch feet	Depth to red shale feet	Oldest formation penetrated
38 A. P. Beasley, Roper No. 1	27	16S	23W	2565	348[a] 248[d]	1570	-------	Tokio Woodbine
39 Humble O. & R. Co., Bodcaw Fee No. 3	19	16S	23W	-------	246[1]	1291	-------	Nacatoch
40 Humble O. & R. Co., Bodcaw Fee No. 1	17	16S	23W	1460	253[1]	-------	-------	Midway
41 Gaier and Cadman, Riley No. 1	12	16S	23W	3030	329[d]	1515 -------	2824 2995	Glen Rose -------
42 Humble O. & R. Co., Shirtleff No. 1	3	16S	23W	1465	304.8[a]	-------	-------	Midway
43 Lewisville Synd., Osborne No. 1	16	15S	24W	2524	303[a] 305[d]	1115	-------	Tokio-Woodbine
44 Humble O. & R. Co., Riggens No. 2	30	15S	22W	1408	275.7[a]	1403	-------	Nacatoch
45 Humble O. & R. Co., Reed-Bodcaw No. 1	16	15S	22W	2368	289.45[a]	1208	-------	Ozan
46 Humble O. & R. Co., Bodcaw Warren No. 1	15	15S	22W	1289	277.55[a]	1245	-------	Nacatoch

* Letters refer to key to datum for elevation on page 261.

LAWRENCE COUNTY

The western half of Lawrence County lies within the Ozark province and the eastern half within the Gulf Coastal Plain. The Paleozoic rocks which crop out in the Ozark province pass beneath the Coastal Plain sediments, slope to the southeast and lie at estimated depths of 700 feet below sea level in the southeastern corner of the county.

The Grandglaise terrace, which extends from Independence County for a short distance into Lawrence County, is composed chiefly of stratified sands and clays probably belonging to the Nacatoch formation of the Upper Cretaceous. These beds are capped by 3 to 10 feet of pebbly sands and loams, probably corresponding in part to the Lafayette formation (Pliocene?) and in part to the loess of Crowley's Ridge. The remainder of the Coastal Plain is mantled by 150 to 180 feet of alluvial deposits resting unconformably on strata of Cretaceous and Eocene age.

The Cretaceous strata, represented by the Arkadelphia marl and a part of the Nacatoch formation, thickens to the southeast and is estimated to lie less than 200 feet thick in the southeastern corner of Lawrence County. The top of the Nacatoch lies approximately at sea level in the southeastern part of the county.

A map of Lawrence County is shown in Figure 70.

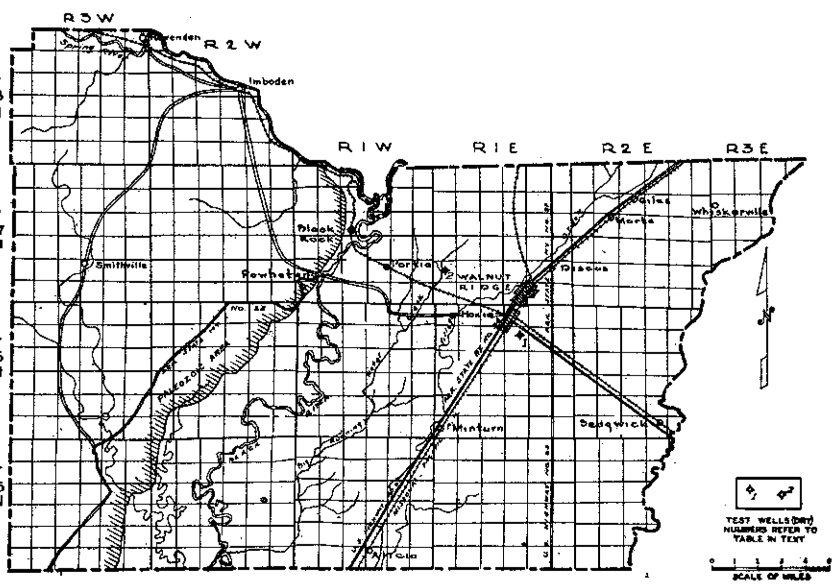


FIGURE 70.—Map of Lawrence County.

List of wells drilled in Lawrence County

No., Company, Farm & Number	Location Sec.	Twp.	R.	T. D.	Elev.*	Depth to Nacatoch feet	Depth to red shale feet	Oldest formation penetrated
1 Home Oil Co., Long No. 1	11	16N	1E	411	280	-------	-------	Paleozoic
2 Ark. Drlg. & Lease Co., Hatcher No. 1	30	17N	1E	200	-------			

* Letters refer to key to datum for elevation on page 261.

LEE COUNTY

LOCATION

Lee County is bounded on the south by Phillips County, on the west by Monroe County, on the north by St. Francis County, and on the east by Mississippi River.

GENERAL FEATURES

The principal topographic feature in Lee County is Crowley's Ridge, which trends north and south a little east of the center of the county. The ridge is interrupted by a gap 6 to 8 miles wide, through which L'Anguitte River flows from northwest to southeast. Only the extreme southern part of the main Crowleys' Ridge, which extends northward beyond the state line, appears in Lee County. The part of the ridge south of the gap is a hilly, wooded area, 3 to 5 miles wide, extending from Marianna to the southern boundary of the county—a distance of 6 miles. The maximum elevation of the ridge is between 300 and 350 feet above sea level, or 100 to 125 feet above the lowlands to the east and west. The Advance lowland, which includes the part of the county west of Crowley's Ridge, is in general a plain 200 to 230 feet above sea level. The Mississippi lowlands include the part of the county east of Crowley's Ridge, and is a poorly drained, heavily timbered plain 200 to 220 feet above sea level, on which swamps, bayous, and abandoned stream channels are numerous.

STRATIGRAPHY

Crowley's Ridge to a height of 50 to 80 feet above its base, is composed of irregularly bedded sands and clays, in part lignitic, belonging to the Jackson formation of Eocene age. The surface materials to the west and east of Crowley's Ridge consist of loams, clays, sands, and gravels of Pleistocene and Recent age. The Tertiary sediments are estimated to range in thickness from 2,100 feet in the northwestern part to 3,500 feet in the southeastern part of the county and the Cretaceous from 600 feet to about 1,000 feet. A generalized section of formations is given in Table 45. (See Fig. 14.)

BASEMENT ROCKS

The Coastal Plain sediments (Cretaceous and younger in age) were deposited upon a nearly level floor of folded and truncated Paleozoic rocks. This floor was subsequently downwarped toward the southeast and now lies at a depth of about 2,700 feet below sea level in the northwestern corner, and about 4,500 feet below sea level in the southeastern corner of the county. The

TABLE 45.—*Generalized section of formations in Lee County*

System	Series	Formation	Thickness in feet	Character
Quaternary	Pleistocene and Recent		50-200	Alluvial sands, gravels, clays, and loess.
		Unconformity		
Tertiary	Pliocene?	Lafayette	0-15	Coarse sands and gravel.
		Unconformity		
	Eocene	Undifferentiated	1500-2900	Chiefly sands, clays, and sandy clays, in part lignitic, and subordinate beds of glauconitic sands and clays.
		Midway clays	500-600	Gray and bluish-gray shale, and clay, and siderite concretions.
		Unconformity		
Cretaceous	Gulf	Arkadelphia marl	75-100	Gray to dark-gray shale.
		Nacatoch sand and Saratoga chalk	275-375	Gray sands, sandstone, sandy limestone, shale and chalk, in part glauconitic.
		Marlbrook marl and older	250-525	Chalky limestone marls and sands.
		Unconformity		
		Basement rocks		

character of the basement rocks is not known but probably consists of sandstones, shales, and limestones of Pennsylvanian and Mississippian age.

CRETACEOUS

GULF SERIES

The Cretaceous rocks have not been penetrated in deep wells drilled in Lee County, but from regional studies there are reasons for assumnig that they are similar in essential details to the equivalent rocks in St. Francis County to the north. The Cretaceous is estimated to be about 600 feet thick in the northwestern part and about 1,000 feet thick in the southeastern part of the county. The following formations should be represented in this area: Arkadelphia marl, Nacatoch sand, Saratoga chalk, Marlbrook marl and the Tokio formation. The Tokio formation, or its equivalent (the Tuscaloosa formation of Mississippian age) is believed to be present in the southeastern part, but may be absent in the northeastern part of the county.

The Arkadelphia marl consists of gray to dark-gray shales. The Nacatoch sand consists principally of fine and medium-textured sand, sandstone, and sandy limestone, in part glauconitic, and subordinate beds of shale. The Saratoga chalk and Marlbrook marl are believed to be made up chiefly of chalks and marls with, perhaps, sand and sandy marls in the northwestern part. The Tokio formation probably consists principally of sands and clays.

TERTIARY

EOCENE SERIES

The Eocene series, which comprises the Jackson, Claiborne, Wilcox, and Midway formations, has an estimated thickness of about 2,000 feet in the northwestern part and about 3,500 feet in the southeastern part.

The Midway clays, estimated to be 500 to 600 feet thick, rest unconformably upon the Arkadelphia marl of Cretaceous age. It consists of gray and bluish-gray generally noncalcareous clays, characterized by an abundance of siderite concretions.

The Jackson, Claiborne, and Wilcox formations cannot be differentiated in this area. They have a combined thickness of 1,500 to 2,900 feet with the greater thickness in the southeastern part of the county. These formations are made up chiefly of sand, clays, and sandy clay, but contain beds of glauconitic sands and clays, especially in the basal part of the Claiborne formation and in the Jackson formation.

PLIOCENE SERIES

The Jackson formation on Crowley's Ridge is overlain by from 10 to 15 feet of coarse sands and gravels of the Lafayette formation, provisionally assigned to Pliocene age.

QUATERNARY

PLEISTOCENE AND RECENT SERIES

The Advance lowland, west of Crowley's Ridge, is underlain to a depth of 125 to 200 feet by loams, clays, sands, and gravels of Pleistocene age. Although irregularly bedded, in general they grade downward from silty clays, loans, and fine sands at the surface through fine sand to coarse sands and gravels at the base. The Mississippi lowland, east of Crowley's Ridge, is underlain to an estimated depth of 150 to 200 feet by Quaternary alluvial loams, clays, sands, and gravels.

STRUCTURE

The structure of a part of Lee County is shown in Plates I, XV, and Figure 71, by means of contour lines drawn on the top of the Nacatoch sand. As the structure contours are based on deep well records, it is necessarily very much generalized in this area.

The top of the Nacatoch sand lies at a depth of about 2,100 feet below sea level in the northwest corner and probably at a depth of not less than 3,500 feet in the southeast part of the county. The dip is to the southeast at the rate of 35 to 50 feet per mile. The presence or absence of local anticlinal structure is not determinable from the available data.

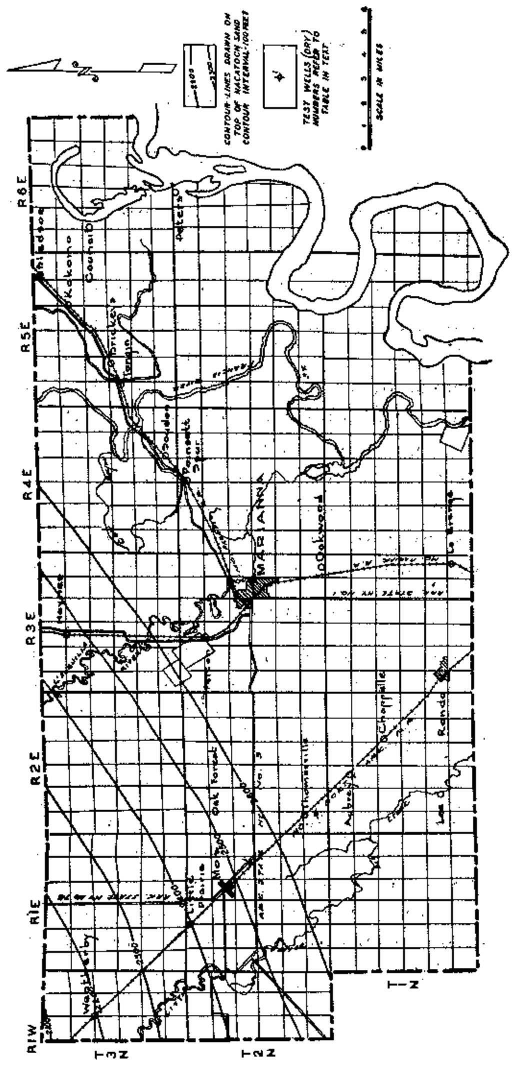


FIGURE 71.—Structure contour map of Lee County. Figures give depth below sea level in feet.

List of wells drilled in Lee County

No., Company, Farm & Number	Location Sec.	Twp.	R.	T. D.	Elev.*	Depth to Nacatoch feet	Depth to red shale feet	Oldest formation penetrated
1 Moro Dev. Co., National Security Co. No. 1	14	2N	1E	2012	196.2[a]	....	....	Wilcox

* Letters refer to key to datum for elevation on page 261.

LINCOLN COUNTY

LOCATION

Lincoln County, situated in southeastern Arkansas, is bounded on the south by Drew County, on the west by Cleveland County, on the north by Jefferson County, and on the east by Arkansas and Desha counties.

GENERAL FEATURES

Bartholomew Bayou, which traverses Lincoln County from the northwest to the southeast corners, divides the county into two distinct topographic provinces. To the east is the wide alluvial flood plain of Bartholomew Bayou and Arkansas River which slopes gently from an elevation of 185 feet in the north to 155 feet above sea level in the south. To the west a narrow terrace, a northwestward continuation of the Hamburg terrace, separates the flood plain from Monticello Ridge. In the vicinity of Star City the ridge is more than 300 feet above sea level.

STRATIGRAPHY

Rocks of Jackson age crop out along Monticello Ridge, but elsewhere alluvial deposits of Pleistocene and Recent age form the surface in Lincoln County. A generalized section of formations is given in Table 46.

BASEMENT ROCKS

The basement rocks have not been penetrated in deep wells drilled in Lincoln County, but, based on a regional study, the floor upon which the Cretaceous sediments accumulated slopes towards the east and is estimated to lie about 4,100 feet below sea level in the western part and about 5,000 feet below sea level in the eastern part of the county.

CRETACEOUS

COMANCHE SERIES

Rocks of Comanche age are not believed to be present in this area but are absent either by nondeposition or by truncation.

GULF SERIES

The Gulf series is estimated to range in thickness from about 400 feet in the western part to about 900 feet in the eastern part of Lincoln County.

TERTIARY

EOCENE SERIES

The available well records do not permit accurate differentiation of the Eocene sediments. Like the Cretaceous, the Eocene sediments increase in thickness from west to east.

TABLE 46.—*Generalized section of formations in Lincoln County*

System	Series	Formation	Thickness in feet	Character
Quaternary	Pleistocene and Recent	Terrace and river deposits	0-200	Alluvial sands, gravels, clays, and loams.
		Unconformity		
Tertiary	Eocene	Jackson	250-400 Est.	Sands and clays, in part fossiliferous and glauconitic.
		Claiborne	1200-1400	Sands, and clays in upper part; glauconitic sands and clays, in part lignitic, in lower part.
		Wilcox	1250-1750	Sands and clays, in part lignitic.
		Midway	450-550	Gray and dark-gray clay and shale; fossiliferous in lower part.
		Unconformity		
Cretaceous	Gulf	Arkadelphia marl Nacatoch Marlbrook marl	400-900	Not penetrated in Lincoln County.

QUATERNARY

PLEISTOCENE AND RECENT SERIES

Alluvial deposits, consisting of sands, gravels, silts, and loams of Pleistocene and Recent age underlie the surface, except over Monticello Ridge in the southwestern part of the county, to a depth of 200 feet.

STRUCTURE

A generalized picture of the structure of Lincoln County, drawn on top of the Cretaceous is given in Plate XIV, indicating that the top of the Cretaceous lies about 3,300 feet below sea level in the western part, and more than 4,000 feet below sea level in the eastern part of the county. (See also Fig. 72.)

List of wells drilled in Lincoln County

No., Company, Farm & Number	Location Sec.	Twp.	R.	T. D.	Elev.*	Depth to Nacatoch feet	Depth to red shale feet	Oldest formation penetrated
1 Lincoln Drew O. Co., Carter No. 1	33	10S	6W	2124	-------	------	------	Wilcox
2 Cambrian Tr. Co., Cambrian No. 1	3	9S	8W	2914	290	------	------	Wilcox
3 Lincoln Co. O. & G. Co., Touchstone No. 1	29	9S	7W	2950	300+	------	------	Wilcox

* Letters refer to key to datum for elevation on page 261.

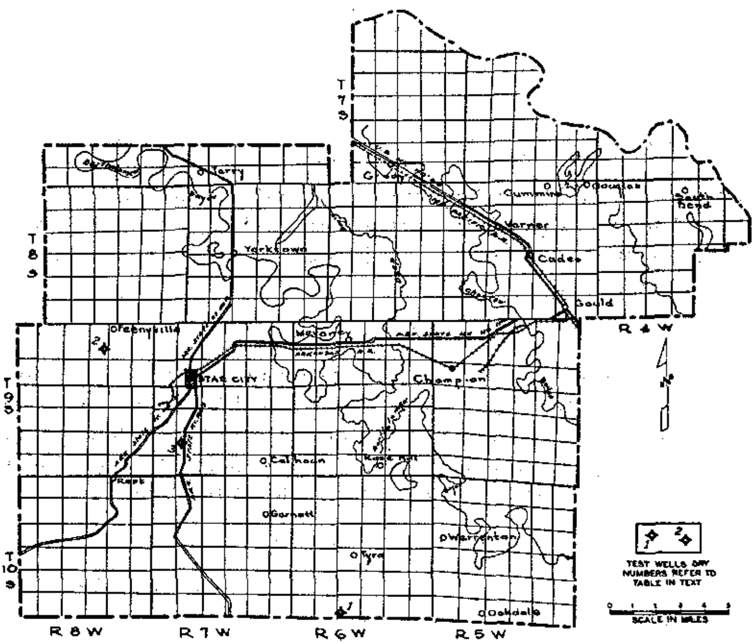


FIGURE 72.—Map of Lincoln County.

LITTLF RIVER COUNTY

LOCATION

The southern boundary of Little River County is formed by Red River, the western boundary by the Oklahoma state line, the northern and eastern boundaries by Little River. It adjoins Sevier County on the north and Hempstead County on the west.

STRATIGRAPHY

Little River County, except for a small area in the southwestern part, is mantled by terrace and river deposits of Pleistocene and Recent age which lie unconformably upon the truncated edges of Upper Cretaceous strata ranging in age from Arkadelphia to Brownstown. The Marlbrook marl, Nacatoch formation, Annona chalk, Ozan formation, and Brownstown marl appear at the surface in a small area in the southwestern part of the county. The Upper Cretaceous sediments of this area have been described by Dane. The Upper Cretaceous strata dip to the southeast.

CRETACEOUS

COMANCHE SERIES

Strata of Comanche age underlie the Gulf series throughout Little River County. Limestone and shale of Washita-Fredericksburg age are in contact with the base of the Gulf series in the western and the southwestern parts, but elsewhere in the county the upper part of the Trinity group occupies the same stratigraphic position. The Comanche sediments increase in thickness from north to south. The Grote et al Arden No. 1 well, sec. 2, T. 13 S., R. 31 W., in the southern part of the county recorded 130 feet of limestone and shale of Fredericksburg and Washita age and 1,380 feet of the Glen Rose, including the Paluxy sand at the top. The Glen Rose consists chiefly of red clays and sands in the upper part and of marine shale, impure limestone, and sand with interbedded red clays in the lower part. The anhydrite zone ranges from a few feet to about 50 feet in thickness. The thickness of the Travis Peak formation is not known, but it is estimated to be not less than 1,000 feet in the southern part of the county.

STRUCTURE

A very generalized interpretation of the structure of this area drawn on the base of the anhydrite zone of the Glen Rose is given in Plate XII. According to this interpreation, the Glen Rose strata slope to the south from a depth of about 500 feet below sea level in the northwestern part to a depth of about 3,000 feet below sea level in the southern part of the county.

A map showing Little River County is shown in Figure 73.

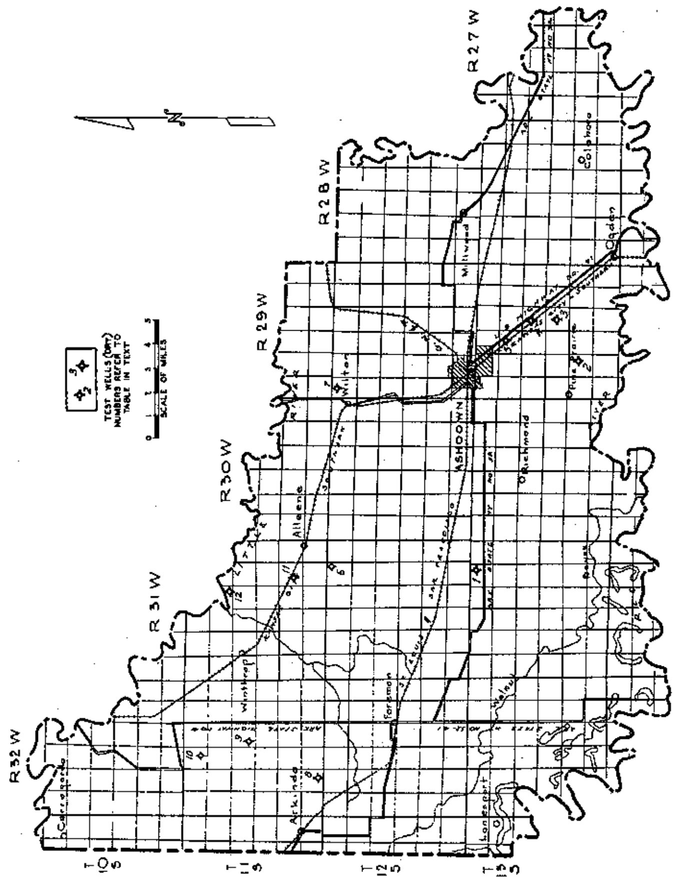


FIGURE 73.—Map of Little River County.

List of wells drilled in Little River County

No., Company, Farm & Number	Location Sec.	Twp.	R.	T. D.	Elev.*	Depth to Nacatoch feet	Depth to red shale feet	Oldest formation penetrated
1 Herman L. Grote, Allen or Arden No. 1	2	13S	31W	3406	350ᵈ	....	1145	Travis Peak
2 Red River Valley Oil & Gas Co., Leasing & Drlg. Co., Toland & Gaylor No. 1	29	13S	29W	2677	340ᵈ	....	1562	Travis Peak
3 Roberts et al, Hale No. 1	22	13S	29W	2052	....	....	1058	Trinity
4 D. F. Gaines, Goodrum No. 1	15	13S	29W	3895	322ᵈ	....	1345	Travis Peak

No.,	Company Farm & Number	Location Sec.	Twp.	R.	T. D.	Elev.*	Depth to Nacatoch feet	Depth to red shale feet	Oldest formation penetrated
5	Boone et al, Boone No. 1	9	13S	29W	858	------	------	------	Brownstown
6	W. F. Brookshire et al, Tootle No. 1	2	12S	31W	2180	------	------	720	Upver part of Trinity
7	McDonald et al, Wilton (Fosse) No. 1		12E	29W	884	------	------	765	Trinity
8	Sullivan Oil Synd., Ludlow No. 1	32	11S	32W	2163	400[b]	------	780	------
9	Sullivan Oil Synd., Ellis No. 1	15	11S	32W	------	410[a]	------	1130	Lower pt. of Trinity
10	Sullivan Oil Synd., Ludlow No. 2	4	11S	32W	------	410[a]	------	792	Basal Trinity or Paleozoic
11	Le Page, Lipton No. 1	26	11S	31W	------	------	------	------	Lower part of Trinity or Paleozoic
12	Mellick Oil Co., Hawkins No. 1	10	11S	31W	1600	------	------	------	Lower part of Trinity

* Letters refer to key to datum for elevation on page 261.

LONOKE COUNTY

LOCATION

Lonoke County is bounded on the south by Jefferson County, on the west by Pulaski County, on the north by White County, and on the east by Prairie County.

GENERAL FEATURES

The Ozark province is represented by a few square miles in the northwestern part; the remainder of the county is included in the Gulf Coastal Plain, which is here separable into Chinquapin Ridge and the Advance lowland.

The area included in the Ozark province coincides with the outcrop of Paleozoic rocks forming hill lands, in which the tops of the hills and ridges rise to a height of 400 to 600 feet above sea level.

Chinquapin Ridge, or the "sandhills" lying just east of the Ozark province and east of Austin and Cabot, is a sandy ridge, several miles wide and extending north and south for a distance of about 12 miles. The ridge is 375 to 400 feet above sea level. The Advance lowland is a nearly level or gently rolling plain 200 to 250 feet above sea level and slopes slightly to the south. The interstream areas present numerous tracts of open, grass-covered prairies, separated by slightly lower timbered lands. Grand prairie, an irregular but in general continuous tract of prairie, lies northeast of Bayou Two prairie and extends from a point 6 miles northwest of Lonoke southeastward through Lonoke, Prairie, and Arkansas counties. Prairie Longue, a similar prairie, extends southeastward through Lonoke County south of Bayou Two prairie, and parallel to Grand prairie. The broad flood plains of the streams, formed for the most part of swampy and heavily timbered land, are characterized by numerous ponds, abandoned stream channels, and bayous. The southwestern part of the county falls within the flood plain of Arkansas River and supports a vigorous growth of timber.

STRATIGRAPHY

Paleozoic rocks belonging to the Atoka formation of Pennsylvanian age, crop out in the Ozark province in the northwestern part of the county. They are separated from the Coastal Plain sediments by a relatively steep southeastward-facing erosion escarpment along the line of which the Paleozoic rock passes under the deposits of the Coastal Plain. A small outcrop of the Midway formation overlies the Paleozoic between Cabot and Austin, which, in turn is overlain by sands of the Wilcox formation forming Chinquapin Ridge. Throughout the reemainder of the county the Eocene is overlain by Quaternary luvial loams, clays, sands, and gravels of the Pleistocene and ecent age.

A generalized section of formations is given in Table 47.

TABLE 47.—*Generalized section of formations in Lonoke County*

ystem	Series	Formation	Thickness in feet	Character
Qua-ter-nary	Pleisto-cene and Recent		0-175	Alluvial loams, clays, sands, and gravels.
rtiary	Eocene	Unconformity Jackson ? Claiborne Wilcox	0-2000	Chiefly sand, clay, and sandy clays, in part lignitic; glauconitic sand in southern part especially in Jackson formation and in the basal part of the Claiborne.
		Midway clays	0-500	Gray and bluish-gray clays and siderite concretions; contains sand and glauconitic sand in western part.
reta-ceous	Gulf	Unconformity Arkadelphia marl	0-75	Gray and dark-gray, calcareous shale.
		Nacatoch sand and Saratoga chalk	0-250	Chiefly fine-textured sand, sandstone, and sandy limestone; thin beds of shale and chalk in lower part.
		Marlbrook marl and older	0-100	Shale, chalk, sandy shale, and sands.
Basement rocks—Paleozoic				

BASEMENT ROCKS

The Coastal Plain sediments were deposited on a nearly level loor of folded and truncated Paleozoic rocks and, in part of he area, is similar in character to the sandstones and shales of he Atoka formation of Pennsylvanian age, which crop out in the orthwestern part of the county. Subsequent warping has lowred the floor which now slopes toward the southeast and lies t an estimated depth of about 3,000 feet in the southeastern corer of the county.

CRETACEOUS

GULF SERIES

Strata of Cretaceous age are not known to crop out but re present beneath the Tertiary sediments throughout the ounty. A well at Cabot obtained calcareous sandstone containng Upper Cretaceous fossils at a depth of 15 or 20 feet below the urface, and deep wells drilled elsewhere in the county have enetrated more than 300 feet of the Cretaceous strata, repreented by the Arkadelphia marl, Nacatoch sand, and Saratoga halk.

The Cretaceous strata decreases in thickness from southeast to northwest, in part the result of actual thinning of individual members of the strata and in part the result of overlap. The Cretaceous is estimated to be about 400 feet thick in the southeastern part of the county where the Marlbrook marl is believed to be represented in the basal part of the section.

The Arkadelphia marl, ranging from less than a foot to 75 feet thick, consists chiefly of gray and dark-gray calcareous shale, but is probably represented in part by sand and sandstone in the northwestern part of the county.

The Nacatoch sand and Saratoga chalk are made up principally of fine-textured sand and sandstone, in part calcareous and glauconitic, and sandy shales, and some chalk in the lower part in the southeastern part of the county.

The Marlbrook marl, when present, probably consists of marl, shale, and chalky marl and sand at the base.

TERTIARY

EOCENE SERIES

The outcrop of the Tertiary strata is confined to a small area in the northwestern part of the county. The Midway crops out in a small area less than half a mile wide and 3 miles long at Cabot, where it lies directly on the Paleozoic rocks, and is overlain by the sands and sandy clays, probably belonging to the Wilcox formation, which composes Chinquapin Ridge. In the remainder of the county the Eocene deposits are overlain by Quaternary alluvial deposits.

The Tertiary strata increase in thickness from northwest to southwest, where they attain their maximum thickness, estimated to be 2,500 feet. Here the Jackson, Claiborne, Wilcox, and Midway formations are represented.

QUATERNARY

PLEISTOCENE AND RECENT SERIES

Throughout the Advance lowland the Eocene deposits are overlain by 100 to 175 feet of alluvial loams, clays, sands, and gravels of Pleistocene and Recent age. The Pleistocene series, which crops out in the interstream areas, through irregularly bedded, grades downward from gray compact, silty clays at the surface, through fine sands to coarse water-bearing sands and gravels at the base. The Recent alluvium immediately underlies the flood plains of the present streams.

STRUCTURE

The generalized structure of Lonoke County, drawn on top of the Nacatoch sand, is shown in Plates I and XV and Figure 74. The strata slope toward the southeast, carrying the top of the Nacatoch sand from above sea level in the northwestern to about 2,500 feet below sea level in the southeastern corner of the county. The rate of dip is from 50 to 75 feet per mile.

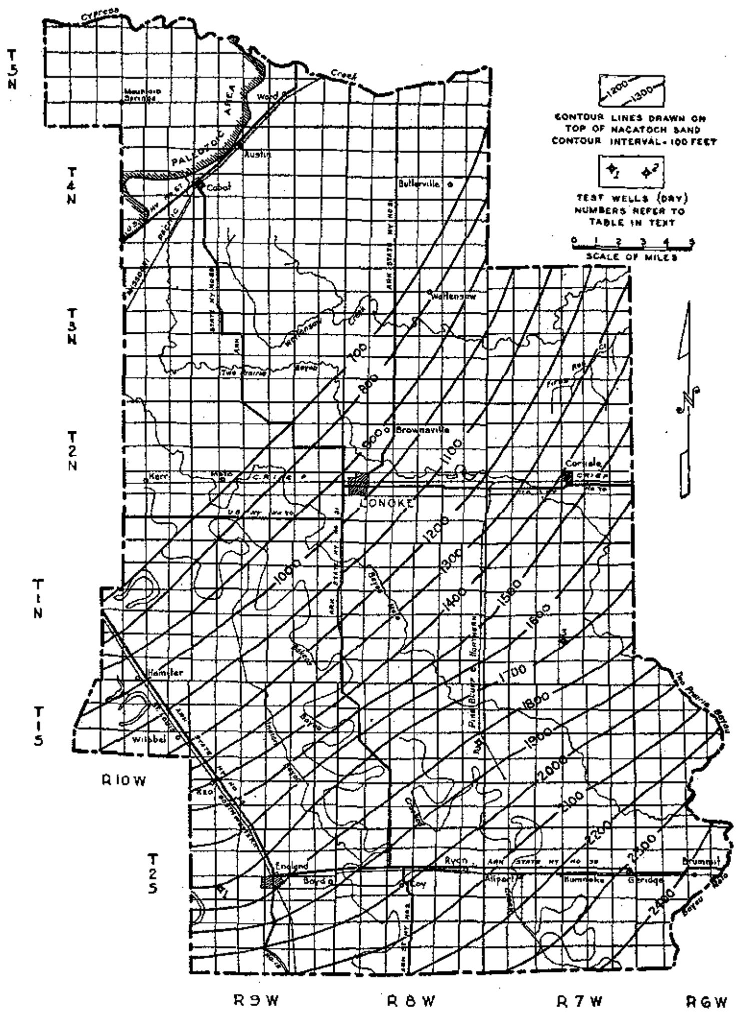


FIGURE 74.—Structure contour map of Lonoke County. Figures give depth below sea level in feet.

List of wells drilled in Lonoke County

No., Company, Farm & Number	Location Sec.	Twp.	R.	T. D.	Elev.*	Depth to Nacatoch feet	Depth to red shale feet	Oldest formation penetrated
1 Arkansas Oil Corp., Scroggins No. 1	17	2S	9W	2163	257	1975	....	Paleozoic
2 Fletcher-Gates Dev. Co., Fletcher No. 1	13	1S	8W	2265	217a	2010	....	Paleozoic
3 Fletcher, Gates Dev. Co., Fletcher No. 2	27	1N	7W	2040	227	1905	....	Paleozoic

* ... datum for elevation on page 261.

MILLER COUNTY

Miller County is situated in the southwestern corner of Arkansas. It is bounded on the south by the State of Louisiana, on the west by the State of Texas, on the north by Little River and Hempstead counties, and on the east by Lafayette County.

STRATIGRAPHY

The rocks at the surface in Miller County range in age from Recent to Tertiary, but deep wells have penetrated all of the Gulf series and more than 1,500 feet of the Comanche series. A generalized section of formations is given in Table 48.

CRETACEOUS

COMANCHE SERIES

The oldest Comanche sediments recognized in this region is a series of shale, limestone, and sand of Trinity age. These beds have not been reached in any of the deep wells drilled in Miller County, but were penetrated in deep wells in Louisiana, a few miles to the south, and no doubt are present in the southern part of this area.

The Trinity group increases in thickness from north to south, and becomes more characteristically marine in that direction. The decrease in thickness (See Fig. 75) is in part the result of depositional conditions, and in part the result of erosion in the interval between Lower and Upper Cretaceous time.

The Washita and Fredericksburg groups have not been recognized in deep wells in the northern part, but are present in the southern part of Miller County as indicated in Figure 75.

GULF SERIES

WOODBINE SAND AND TOKIO FORMATION

The Woodbine sand and the Tokio formation are inseparable in the well records of this area. Their combined thickness ranges from 400 feet in the northern part to 600 feet in the southern part of Miller County. The upper part consists of light-colored sands and gray to dark-gray shale and clay, and the lower part consists of tuffaceous sands interbedded with shale and glauconitic sands. Locally, thin beds of red clay are present in the basal part of the section.

The lower part of the section, although it represents the basal beds of the Gulf series, is younger than the Woodbine sand of Texas.

TABLE 48.—*Generalized section of formations in Miller County*

System	Series	Formation	Thickness in feet	Character
Quaternary		Recent sand and gravel	0-50	Sand, silt and gravels principally in flood plains of major streams.
		Unconformity		
Tertiary	Eocene	Claiborne formation	500-550	Chiefly sand and sandstone; thin beds of glauconitic and ferruginous sand and clay.
		Wilcox	500-600	Lignitic sand and clay.
		Midway clays	500	Gray to bluish-gray clays, containing an abundance of siderite concretions.
		Unconformity		
Cretaceous	Gulf	Arkadelphia marl	90-120	Dark-gray shales.
		Nacatoch sand	400-535	Sand sandy limestone and sandy shale; gray in the lower part.
		Saratoga chalk Marlbrook marl Annona chalk	450	Gray and white chalk and chalky shale.
		Ozan formation (Buckrange sand at the base)	125-150	Micaceous sandy marls and glauconitic sands.
		Brownstown marl	100-200	Chiefly gray clays, shale, and marl.
		Tokio formation and Woodbine sand	400-600	Sand, sandy shale and shale, in part lignitic, and interbedded tuffaceous sand; locally red clays in basal part.
		Unconformity		
	Comanche (Washita and Fredericksburg group)	Undifferentiated	0-400	Gray limestone and calcareous shales .
		Upper Glen Rose	700-1650	Dominantly red shale and sand in the upper part; red and blue shale and interbedded sand, shale and impure limestone in the lower part.
	Comanche (Trinity group)	Anhydrite zone	200-550	Interbedded anhydrite, limestone, and shale.
		Lower Glen Rose	1000	Chiefly gray and blue shale and interbedded, generally impure limestone, in the southern part; becomes increasingly sandy and interbedded with red shale in northern part.
		Travis Peak	2000	Red, brown, purple, and gray shale and gray to white and brown sands.
		Neocomian ?	0-500	Gray limestone, shale, and sands; not penetrated in Miller County, and probably present only in southern part of the county.
		Unconformity		

Basement rocks

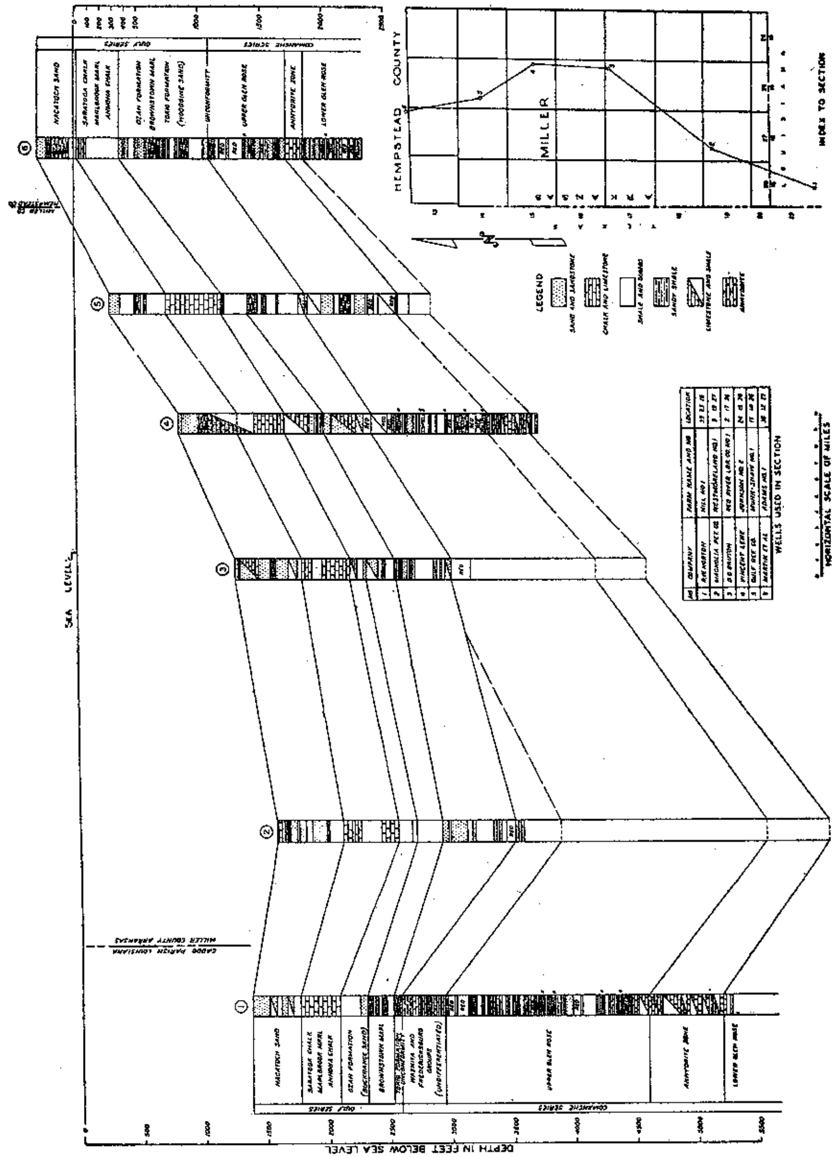


FIGURE 75.—North-south cross section through Miller County showing correlation of Upper and Lower Cretaceous.

OZAN FORMATION

The Ozan formation is from 125 to 150 feet thick, made up of micaceous clay and marl, and with a persistent sand member (the Buckrange sand) at the base. This member is best developed in the southern half, but is either thin or represented by sandy shale in the northern part of the county. A glauconitic sand or sandy shale is generally present in the upper part of the Ozan formation in northern Miller County.

OTHER FORMATIONS

The Cretaceous formations above the Ozan formation show only slight changes in thickness and character within the boundaries of Miller County.

OIL AND GAS-PRODUCING HORIZONS

The oil and gas-producing horizons of southern Arkansas are listed in Table 6A. Of these horizons, the Nacatoch sand is present and well developed throughout the county.

In the northern part the Ozan formation contains a sand member that is approximately equivalent to the Meakin sand in Union County. The Buckrange sand is present over most of the county, although best developed in the southern half of Miller County.

The Tokio-Woodbine section contains a number of excellent reservoir sands.

The upper part of the Glen Rose (Trinity group) has yielded a small amount of oil in T. 15 S., R. 36 W., from a sand member at a depth of 2,850 feet. This sand horizon is present in the northern part of the county. The beds immediately below the anhydrite zone of the Glen Rose formation contain sand members capable of serving as reservoirs for oil and gas.

The horizons listed above should be tested for oil and gas in all drilling wells.

STRUCTURE

The structure of Miller County, represented by structure contour lines drawn on top of the Nacatoch sand as recorded in deep wells, is shown in Plates I and XI and Figure 76. The principal structural features shown are: (1) A generally southward-dipping monocline in the northern half; (2) a generally southwest-trending series of grabens in the central and south central part; (3) and a structural terrace in the southern part of the county.

In the northern half of the county the Nacatoch sand strikes slightly north of east and dips south 20 to 30 degrees east at the rate of 40 to 65 feet per mile. The top of the Nacatoch sand lies at sea level in T. 16 S. The available data show no local structural features of importance in relation to oil and gas accumulations.

The grabens, described in more detail on pages 135 and 136 are down-faulted wedges 2½ to 3 miles wide, in which the Nacatoch sand lies 350 to 400 feet lower than normal. The Lewisville graben trends slightly south of west through T. 16 S., R. 25 and 26 W.; the Fouke graben trends southwest through T. 17 S., R. 27 W., into T. 18 S., Rs. 27 and 28 W.

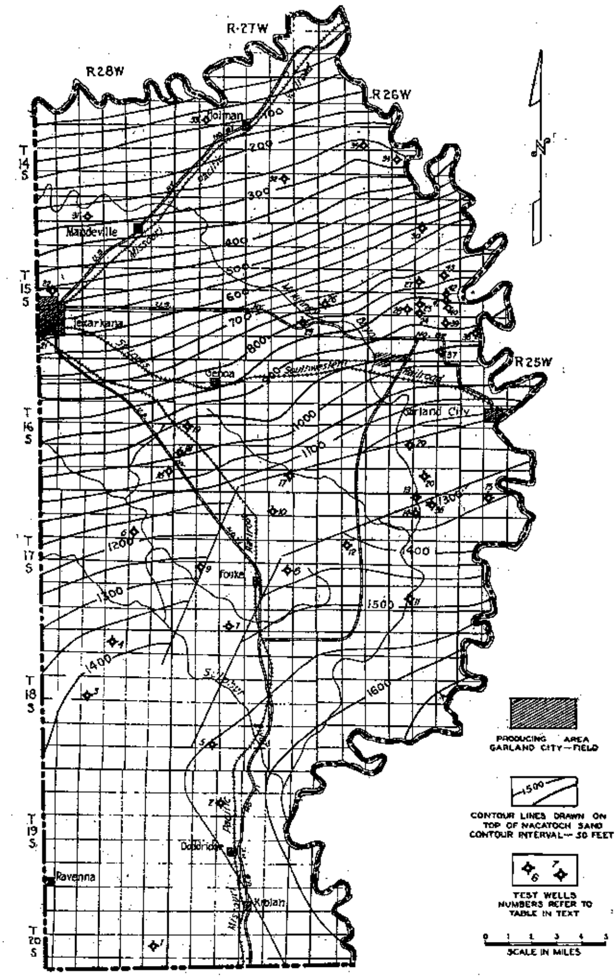


FIGURE 76.—Structure contour map of Miller County. Figures give depth below sea level in feet.

A closure of slightly less than 50 feet against the Lewisville graben in the northeastern corner of T. 17 S., R. 26 W., is indicated by the record of the D. D. Bruton's Red River Lumber Company No. 1 well, sec. 2, T. 17 S., R. 26 W. This well penetrated the upper part of the Trinity group but did not reach the anhydrite zone. The character of the local structure along the Fouke graben is not determinable from the available data.

The structural terrace, or perhaps more properly structural saddle, in the southern part of Miller County separates the principal east Texas syncline from a similar syncline which trends southeastward into Louisiana. The available data are insufficient to determine the structure in detail.

STRUCTURE OF THE COMANCHE SERIES

The structure of the Comanche strata, owing to the pronounced unconformity which separates these strata from the overlying Gulf series, will differ considerably from the structure drawn on top of the Nacatoch sand. A generalized structure contour map drawn on the base of the anhydrite zone of the Glen Rose is shown in Plate XII. The principal feature is a pronounced syncline entering southern Miller County from the west, in which the top of the anhydrite is 5,500 feet below sea level. The central and northern parts of the county, as indicated by the meager data available, is represented by a south and southwest-dipping monocline, dipping at the rate of 75 to 100 feet per mile. The subsurface distribution of the Comanche series (See Fig.5) indicates the presence of a generally west-trending structural nose through northern Miller county, but, owing to the subsequent Cretaceous and Tertiary deformation, it is not possible to evaluate the importance of this feature on account of insufficient data.

SUMMARY

The Nacatoch sand, Buckrange sand, the several sands in the Tokio formation, and the basal beds of the Upper Cretaceous and the Trinity group of the Lower Cretaceous, which produce oil and gas in other parts of southern Arkansas and northern Louisiana, are present over most of Miller County.

The geological structure is generalized, owing to lack of adequate data to show structural details, and local structural features, which may have an important bearing upon oil and gas accumulations, are not determinable or at the best are only suggested. The structure shows particularly favorable areas, but a local anticlinal structure in the Trinity strata may be present in T. 15 S., Rs. 26 and 27 W.

A small closure against the Lewisville graben in the northeast corner of T. 17 S., R. 26 W., has been tested only in the upper part of the Trinity group. In order to test this structural feature adequately, it should be drilled at least 100 feet below the anhydrite zone.

The area adjacent to the east side of the Fouke area has been drilled; however, favorable structural conditions may exist.

DEVELOPMENT

There is one oil and gas-producing area in Miller County in secs. 33 and 34, T. 16 S., R. 26 W., and secs. 3 and 4, T. 16 S., R. 14 W. The Lenz Johnson No. 1 well, sec. 24, T. 15 S., R. 26 W., made oil from the upper part of the Trinity group at a depth of 2,850 feet below the surface. The production for 1933 was 87,-265 barrels. The deep wells drilled in Miller County, together with essential data, are listed below:

List of wells drilled in Miller County

No., Company, Farm & Number	Location Sec.	Twp.	R.	T. D.	Elev.*	Depth to Nacatoch feet	Depth to red shale feet	Oldest formation penetrated
1 Nigh et al, Thomas No. 1	12	20S	28W	3003	313[g] 329[h]	1720	-------	Tokio
2 Magnolia Petrol. Co., Westmoreland No. 1	9	19S	27W	3852	261[d] 238[a]	1832	3690	Washita
3 Welsh D. & G. Co., Steed No. 1	16	18S	28W	3050	261.16[d] 275[g]	1635	-------	-------
4 Humble O. & R. Co., Miller Land & Lbr. Co. No. 1	3	18S	28W	1614	216[a]	1580	-------	Nacatoch
5 Dodwell et al, Miller Land & Dev. Co. No. 1	29	18S	27W	-------	200[a] 229[d]	1785	-------	Ozan
6 Humble O. & R. Co., Dickerman No. 1	11	17S	28W	1402	231[a]	1390	-------	Nacatoch
7 Humble O. & R. Co., Big Pine Lbr. Co. No. 1	33	17S	27W	1715	250[a]	-------	-------	Arkadelphia
8 Ark. Nat Gas Co., J. E. Ferguson No. 1	23	17S	27W	2218	318[d] 310[h]	1600	-------	Ozan
9 Davidson et al, Fouke No. 1	20	17S	27W	2600	255[d] 249[a] 253[a]	1830	-------	Ozan
10 Humble O. & R. Co., Fouke Estate No. 1	2	17S	27W	1735	315.8[a]	-------	-------	Arkadelphia
11 Gulf Refg. Co., Dorsey et al No. 1	27	17S	26W	2978	215.84[a] 220[d]	1740	-------	Tokio-Woodbine
12 Humble O. & R. Co., McKnight No. 1	17	17S	26W	1559	304[a]	-------	-------	Nacatoch
13 Humble O. & R. Co., Red River No. 1	2	17S	26W	1592	220	-------	-------	Arkadelphia
14 Humble O. & R. Co., Red River No. 2	2	17S	26W	1570	220[a]	-------	-------	Wilcox
15 Humble O. & R. Co., J. W. Crank No. 1	5	17S	25W	1570	215[a]	1566	-------	Nacatoch
16 Humble O. & R. Co., Vann No. 1	36	16S	28W	1360	266.64[a]	1300	-------	Nacatoch
17 Humble O. & R. Co., Fouke No. 1	35	16S	27W	1760	257.17[a]	1752	-------	Nacatoch
18 Humble O. & R. Co., Goodson No. 1	30	16S	27W	1320	314.74[a]	1295	-------	Nacatoch
19 Humble O. & R. Co., Bishop No. 1	19	16S	27W	1420	371[d]	1350	-------	Nacatoch
20 Humble O. & R. Co., Dale No. 3	35	16S	26W	1485	220[d] 230[a]	-------	-------	Midway

No., Company, Farm & Number	Location Sec.	Twp.	R.	T. D.	Elev.*	Depth to Nacatoch feet	Depth to red shale feet	Oldest formation penetrated
21 Heilbron & Conway, Bronway No. 1	31	15S	28W	3000	289[d] 298[a]	855	2710	Upper Glen Rose
22 Texarkana Oil Prospecting Co., Kirby No. 1	30	15S	28W	2305	300[b] 292[a]	842	....	Tokio-Woodbine
23 Coples et al, Wiseman No. 1	36	15S	27W	2710	360[a]	1240	....	Tokio-Woodbine
24 Central Coast, Mann No. 1	23	15S	26W	3357	230[d]	1040	2710	Upper Glen Rose
25 Edgar A. Martin, Tr., May B. Dale No. 2	23	15S	26W	3005	250[a]	1110	2610	Upper Glen Rose
26 E. B. Guest, Merchants & Planters Bank No. 1	30	15S	26W	3012	245	1085	2646	Upper Glen Rose
27 E. B. Guest et al, Sanderson No. 1	14	15S	26W	....	247	1011	....	....
28 Edgar A. Martin, Tr., Mann No. 1	22	15S	26W	3055	240[b]	1110	2616	Upper Glen Rose
29 Humble O. & R. Co., Dale No. 2	22	16S	26W	1045	232[a]	....	....	Midway
30 Nash Clifford & Son, Hervey No. 1	2	15S	26W	2506	246.7[d]	875	2328	Upper Glen Rose
31 J. K. Wadley (Kingsley) Thompson No. 1	33	14S	28W	1790	344[a]	615	....	Tokio Woodbine
32 W. D. Nash, Priest No. 1	26	14S	27W	3876	276[a] 271[a]	559	2115	Lower Glen Rose
33 Cochran & Graham, Adams No. 1	8	14S	27W	3001	278[d] 230[b]	310	1906	Lower Glen Rose
34 Buzzard Bluff O. Co., Munn (Gillespie) No. 1	22	14S	26W	2512	256[d] 255[a]	652	2128	Upper Glen Rose
35 Atlas Oil Co. and Gulf Refg. Co., Munn-Shaw No. 1	17	14S	26W	3014	296.7[a]	570	2160	Glen Rose
36 D. D. Bruton, Red River Lbr. Co. No. 1	2	17S	26W	3409	220	1499	3245	Upper Glen Rose
37 E. & F. Oil Co., Beck No. 1	36	15S	26W	2804	232	1220	2799	Upper Glen Rose
38 Big Bill Oil Co., Arthur Dean No. 1	30	15S	25W	3102	....	1190	2685	Upper Glen Rose
39 V. Lenz et al, Dale No. 1	25	15S	26W	2843	250[a]	1146	....	Upper Glen Rose
40 V. Lenz et al, Johnson No. 1	24	15S	26W	2856	261	1121	2585	Upper Glen Rose
41 V. Lenz et al, Johnson No. 2	24	15S	26W	4015	262	1096	2592	Lower Glen Rose
42 . Lenz et al, Johnson No. 3	24	15S	26W	....	261	....	....	....
43 V. Lenz et al, Pierson No. 1	13	15S	26W	3366	256	....	....	....

* Letters refer to key to datum for elevation on page 261.

MISSISSIPPI COUNTY

LOCATION

Mississippi County is bounded on the south by Crittenden County, on the west by Poinsett and Craighead counties, on the north by the State of Missouri, and on the east by Mississippi River.

GENERAL FEATURES

Mississippi County is entirely within the Mississippi lowlands. It is a gently rolling plain lying 235 to 260 feet above sea level and sloping gently to the south and west. The highest land in the county, with the exception of Big Lake highlands, a tract of slightly elevated land 2 to 3 miles wide, lying west of Big Lake and extending northward into Missouri, is immediately west of Mississippi River. Swamps, bayous, and abandoned stream channels are numerous and much of the area is subject to overflow. The western half of the county, with the exception of Big Lake highlands, is included in the area known as the St. Francis "sunk lands", where bayous and swamps are separated by low ridges of sandy loam, dotted with the so-called "sand blows" of the region.

STRATIGRAPHY

The materials at the surface and down to an estimated depth of 150 to 225 feet are Quaternary alluvial loams, clays, sands, and gravels. The Cretaceous strata have not been reached in any of the deep wells drilled in the county. On the basis of available data from the adjacent counties, the following stratigraphic section (Table 49) is believed present in Mississippi County.

TABLE 49.—*Generalized section of formations in Mississippi County*

System	Series	Formation	Thickness in feet	Character
Quaternary	Pleistocene and Recent		150-225	Alluvium, sands, gravels, and clays
		Unconformity		
Tertiary	Eocene	Undifferentiated	1000-1800	Sand and clays, in part lignitic.
		Midway clays	400-500	Gray clays, and siderite concretions.
		Unconformity		
Cretaceous	Gulf	Arkadelphia marl Nacatoch sand and older	400-800	Sand, clay, and chalk.
		Unconformity		

Basement rocks—Paleozoic or older

BASEMENT ROCKS

The basement floor, believed to consist of folded Paleozoic strata, slopes toward the east from about 1,700 feet below sea level in the northwestern corner to about 3,200 feet below sea level in the southeastern corner of Mississippi County.

CRETACEOUS

GULF SERIES

The Cretaceous strata have not been penetrated in deep wells drilled in Mississippi County, but are believed to be essentially of the same character as those found in Greene and Poinsett counties to the west. The Cretaceous is estimated to total about 400 feet in the northwestern corner and 800 feet in the southwestern corner of the county (See Pl. XIV). The following formations are believed to be in the Cretaceous strata: Arkadelphia marl, Nacatoch sand, Saratoga chalk, and Marlbrook marl.

TERTIARY

EOCENE SERIES

The Tertiary is represented by 1,400 to 2,300 feet of strata with the greatest thickness in the southeastern corner of the county. The lower 400 to 500 feet of beds, consisting chiefly of gray clays, belongs to the Midway formation (basal Eocene). Above the Midway formation is 1,000 to 1,800 feet of sands and clays which are in part lignitic, belonging to the Wilcox formation, but in part, perhaps, to younger formations of the Eocene age.

QUATERNARY

PLEISTOCENE AND RECENT SERIES

The materials underlying the surface to depths of 150 to 225 feet are, according to Stephenson and Crider[10], Quaternary alluvial loams, clays, sands, and gravels. The immediate surface materials are probably all of Recent age, though in some of the higher swells, such as Big Lake highlands west of Big Lake, deposits of Pleistocene age may come to the surface.

STRUCTURE

The structure of Mississippi County is shown in Plate XV and Figure 77, by means of contour lines drawn on the top of Nacatoch sand, at intervals of 100 feet. Owing to the scarcity of data in this area, the structure is generalized, showing only the regional features. The normal dip is to the southeast at the rate of 30 to 40 feet per mile. The top of the Nacatoch sand lies at a depth of about 1,200 feet below sea level in the northwestern corner and about 2,400 feet below sea level in the southeastern corner of the

[10] Stephen, L. W., and Crider, A. F., Geology and ground-waters of northeastern Arkansas: U. S. Geol. Survey Water-Supply Paper 399, p. 224, 1916.

county. The presence or absence of local structural features is not determinable with the available data.

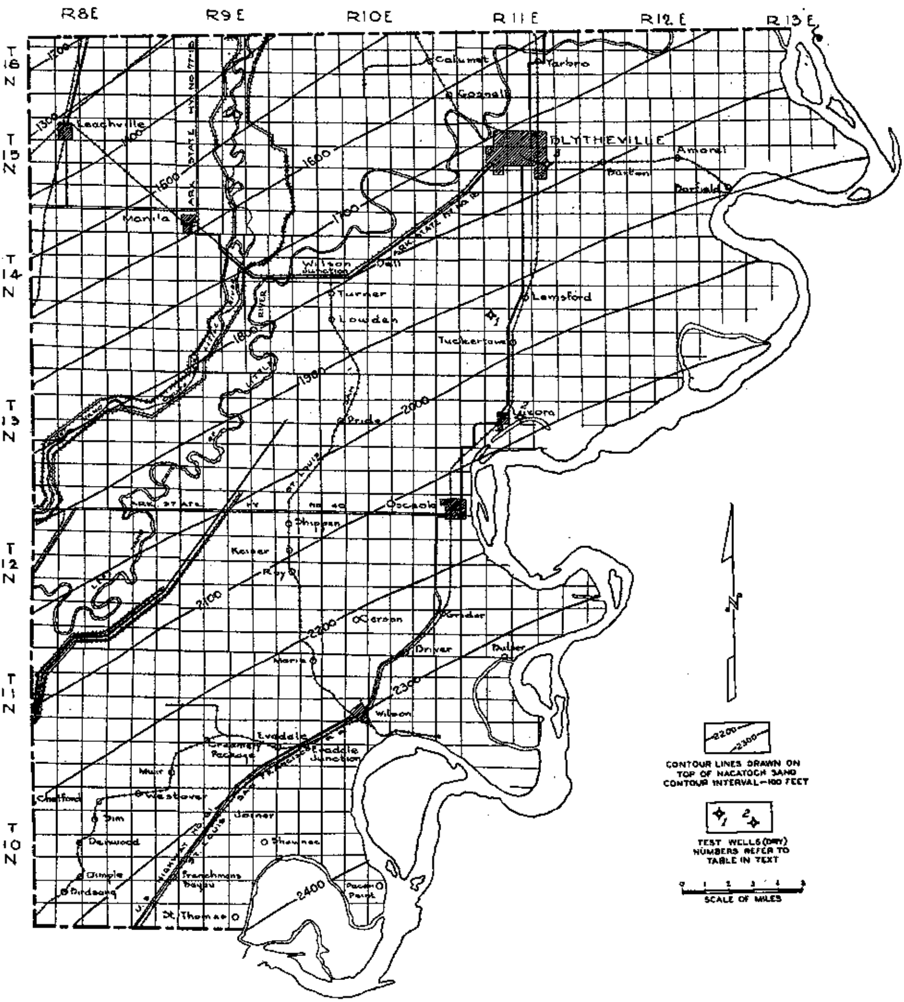


FIGURE 77.—Structure contour map of Mississippi County. Figures give depth below sea level in feet.

List of wells drilled in Mississippi County

No., Company, Farm & Number	Location Sec.	Twp.	R.	T. D.	Elev.*.	Depth to Nacatoch feet	Depth to red shale feet	Oldest formation penetrated
1 Burdett	20	14N	11E	1544	------	------	------	Eocene
2 Luxoria	9	13N	11E	1544	------	------	------	Eocene
3 Blytheville	15	15N	11E	1450	------	------	------	Eocene

* Letters refer to key to datum for elevation on page 261.

MONROE COUNTY

LOCATION

Monroe County is bounded on the south by Arkansas County, on the west by Arkansas and Prairie counties, on the north by Woodruff County, and on the east by Lee and Phillips counties.

GENERAL FEATURES

Monroe County lies within the Advance lowland, one of the topographic subdivisions of the Coastal Plain. The surface is, in general, a gently undulating plain 175 to 210 feet above sea level. In most of the county east of White River are numerous swamps, bayous, and abandoned stream channels, separated by low, rolling ridges of sand, or sandy loam. Much of the surface is poorly drained, and the greater part of the area is wooded; however, there are a few small tracts of prairie-like land in the northeastern part. A relatively small area in the west-central part of the county lies west of White River, and about 15 square miles of this section is open, grass-covered prairie, forming a part of Grand prairie.

STRATIGRAPHY

Throughout the county the materials underlying the surface to estimated depths of 125 to 175 feet, are Quaternary alluvial loams, sand, and gravels of Recent and Pleistocene age, which rest unconformably on strata of Eocene age.

The Eocene strata have an estimated thickness of about 1,700 feet in the northwestern part and about 4,000 feet in the southeastern part of the county. The Cretaceous is estimated to range from 400 feet to nearly 1,000 feet in thickness, with the greater thickness in the southeastern part of the county. A generalized section of formations is given in Table 50.

BASEMENT ROCKS

The Cretaceous sediments in this area were deposited on a nearly level floor of folded and truncated rocks of Paleozoic age. Warping has modified the attitude of the floor which now lies at a depth of about 2,100 feet below sea level in the northwestern corner and about 5,000 feet in the southeastern corner of the county.

CRETACEOUS

GULF SERIES

The Cretaceous strata have been penetrated in but two deep wells, both located in the northwestern part of the county. The

TABLE 50.—*Generalized section of formations in Monroe County*

System	Series	Formation	Thickness in feet	Character
Quaternary	Pleistocene and Recent		125-175	Alluvial, loams, clays, sands, and gravels.
		Unconformity		
Tertiary	Eocene	Undifferentiated	1200-3600	Sands, clays, and sandy clays, in part lignitic; glauconitic sand and clays.
		Midway clays	500-600	Gray and bluish-gray clay and shale, abundant siderite concretions.
		Unconformity		
Cretaceous	Gulf	Arkadelphia marl	75-100	Gray to dark-gray shale.
		Nacatoch sand and Saratoga chalk	230-350	Generally fine - textured sands, sandstone and sandy limestones; in part glauconitic and subordinate beds of shale, chalk, and limestone.
		Marlbrook and older formations	100-500	Marl and chalk; sand and sandy clays in the lower part of the section.
		Unconformity		
		Basement rocks		

Cretaceous is estimated to be about 400 feet thick in the northwestern corner, and about 1,000 feet thick in the southeastern corner of the county. The following formations are believed to be represented in this section: Arkadelphia marl, Nacatoch sand, Saratoga chalk, Marlbrook marl, and Tokio formation (present only in the southeastern part of the county).

The Cretaceous sediments not only increase in thickness toward the southeast, but also change laterally, showing increasingly greater amounts of shale, marl, chalks, and limestones in the same direction.

The Arkadelphia marl, 75 to 100 feet thick, consists of gray to dark-gray Cretaceous shale.

The Nacatoch sand and Saratoga chalk are made up of generally fine-textured sand and sandstone, in part glauconitic, and subordinate beds of shale, chalk, and limestone, which increase in thickness toward the southeast.

The Marlbrook marl consists of marls, chalk, and limestone; sand and sandy clays in the lower part.

The Tokio formation or its equivalent (the Tuscaloosa formation of Mississippi) made up principally of sands and clays, is believed to be present in the southeastern part of the county.

TERTIARY

EOCENE SERIES

The Eocene sediments have an estimated thickness ranging from 1,700 feet in the northwestern part to 4,200 feet in the southeastern part of the county. The following formations are represented: Jackson formation, Claiborne formation, Wilcox formation, and Midway clays.

The Midway clays have an estimated thickness of 500 to 600 feet, consisting of gray and bluish-gray generally noncalcareous clays, characterized by an abundance of siderite concretions.

On the basis of available information it is not possible to differentiate accurately the formations above the Midway, which have an aggregate thickness ranging from 1,200 feet in the northwestern corner to 3,600 feet in the southeastern corner of the county. These strata are made up chiefly of sands, clays, and sandy clays, in part lignitic with subordinate beds of glauconitic sand and marls, most abundant in the basal Claiborne and in the Jackson formations.

QUATERNARY

PLEISTOCENE AND RECENT SERIES

Throughout the county the materials underlying the surface to an estimated depth of 125 to 175 feet, are Quaternary alluvial loams, clays, sands, and gravels of Pleistocene and Recent age. The Pleistocene deposits crop out in the prairies west of White River and probably in the higher areas east of White River, and underlie the remainder of the county beneath Recent deposits. Although irregularly bedded in general, they grade downward from loams, or fine silty clays at the surface, through fine sands to coarse sands and gravels at the base.

A typical record of a deep well in the northwestern part of the county is given below:

F. T. Whitted, Tr., Whitted No. 2 well, sec. 28, T. 4 N., R. 1 W.

Geologic age	Depth in feet
Quaternary	
Pleistocene and Recent series	
Sand and clay	20
Sand and gumbo	140
Unconformity	
Tertiary	
Eocene series	
Jackson, Claiborne, and Wilcox formations	
Sand	202
Gumbo	212
Sand and boulders	649
Hard sand	700
Gumbo	720
Sand and boulders	751
Gumbo	773
Sand and boulders	779
Shale and boulders	1083

Geologic age	Depth in feet
Sand	1133
Shale and gumbo	1348
Sand and boulders	1360
Gumbo	1423
Sand and shale	1449
Hard sand (show of oil ?)	1454
Sandy shale	1470
Gumbo	1507
Sandy shale	1524
Rock	1525
Shale and gumbo	1565
Shale and boulders	1589
Rock	1593
Gumbo	1595
Sandy shale	1615
Gumbo	1633
Shale	1638
Midway clay	
Gumbo and boulders	1802
Shale and gumbo	1897
Shale and boulders	1929
Gumbo	1935
Shale and boulders	2012
Limestone	2014
Shale and boulders	2058
Shale and gumbo	2171
Unconformity	
Cretaceous	
Gulf series	
Nacatoch sand	
Rock	2274
Sand	2316
Rock; gas show	2312
Sand; carrying salt water	2325
T. D.	2325

STRUCTURE

The structure of Monroe County is shown in Plates I and XV and Figure 78, by means of contour lines drawn on top of the Nacatoch sand at intervals of 100 feet and 500 feet. Inasmuch as only a few wells have penetrated the Nacatoch sand in this area, the structure is generalized and does not show any local structural features which may be present.

The Nacatoch sand lies at a depth of about 1,700 feet below sea level in the extreme northwestern corner and is estimated to be more than 4,000 feet below sea level in the southeastern corner of the county. The dip is to the southeast at the rate of 35 to 50 feet per mile.

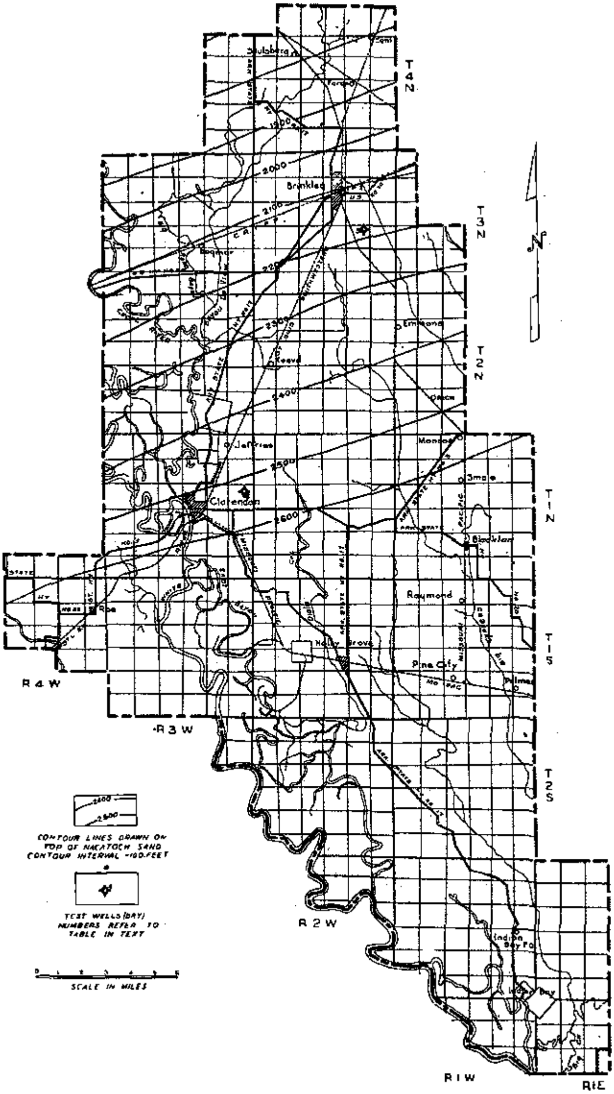


FIGURE 78.—Structure contour map of Monroe County. Figures give depth below sea level in feet.

List of wells drilled in Monroe County

No., Company, Farm & Number	Location Sec.	Twp.	R.	T. D.	Elev.*	Depth to Nacatoch feet	Depth to red shale feet	Oldest formation penetrated
1 Brinkley Water & Light Co., Brinkley, Ark.	10	3N	2W	1200	....	....	....	Claiborne
2 Ferrell Light, Heat & Water Co., Brinkley, Ark.	10	3N	2W	580	....	....	....	Claiborne

No., Company, Farm & Number	Location Sec.	Twp.	R.	T. D.	Elev.*	Depth to Nacatoch feet	Depth to red shale feet	Oldest formation penetrated
3 Traffic Oil Co., Clark No. 1	23	3N	2W	2498	188.2[a]	2345	....	Nacatoch
4 Prairie O. & G. Co., (Cowhan et al) Jefferies No. 1	13	1N	3W	3008	175[b]	2675	....	Saratoga or Marlbrook

* Letters refer to key to datum for elevation on page 261.

NEVADA COUNTY

LOCATION

Nevada County adjoins Columbia County on the south, Hempstead County on the west, Clark County on the north, and Ouachita County on the east.

GENERAL FEATURES

Nevada County is a dissected upland area; the higher ridges in the interstream area stand at altitudes of 350 to more than 400 feet above sea level. Ouachita River, forming the northern boundary and Terre Range Creek emptying into Ouachita River in the northeastern part, are the principal streams in the county. Both of these streams flow through wide flood plains with altitudes of 175 to 225 feet above sea level.

STRATIGRAPHY

Rocks of Upper Cretaceous age are exposed in the northwestern part of Nevada County. In the central and southern parts of the county the Midway, Wilcox, and Claiborne strata of Tertiary age form the surface rocks. A generalized section of formations in Nevada County follows in Table 51.

BASEMENT ROCKS

The basement floor on which the Cretaceous sediments accumulated slopes from a depth of 500 feet below sea level in the extreme northern part to about 2,500 feet below sea level in the central part of Nevada County. South of the line represented by the 2,500-foot contour line, the basement floor is sharply flexed and lies at depths greater than the depths of the deep wells drilled in this area (See Plate III).

CRETACEOUS

COMANCHE SERIES

The Comanche sediments, as originally deposited in this area, decreased in thickness and changed laterally in character to the north and northeast until in the northern part they were comparable in thickness and character to the sediments now exposed in Pike County. The changes in thickness and in lithology appear to have been most pronounced in the vicinity of, and to the north of the flexure in the basement rocks. The Comanche strata were tilted and truncated before the beginning of Upper Cretaceous deposition and the basal beds of the Gulf series lie unconformably on strata ranging in age from Upper Glen Rose to Travis Peak. The Upper Glen Rose and the anhydrite zone of the Glen Rose are present only in the extreme southern and

TABLE 51.—*Generalized section of formations in southern Nevada County*

System	Series	Formation	Thickness in feet	Character
Quaternary	Pleistocene and Recent	Terrace and river deposits	0-40	Alluvial sand, gravel, clay, and loam.
		Unconformity		
Tertiary	Eocene	Claiborne	0	Sands, clays, and glauconitic sand and marl.
		Wilcox	0	Lignitic sand and clay.
		Midway	475-500	Gray to blue noncalcareous clays with siderite concretions. Calcareous clay in lower 25 to 50 feet of beds.
		Unconformity		
Cretaceous	Gulf	Arkadelphia marl	90-100	Gray to black calcareous marls and shales.
		Nacatoch	260-370	Sand, calcareous sandstone, and shale.
		Saratoga chalk	25-60	Gray and grayish-white chalk.
		Marlbrook marl	175-225	Light-colored marls and chalky marl.
		Annona chalk	0-50	White chalk.
		Ozan Buckrange sand member at the base	100-150	Greenish-gray micaceous and glauconitic marl with sand at the base.
		Brownstown marl	125-180	Chiefly gray clay and shale.
		Tokio-Woodbine	150-375	Gray shale and sandy shale in upper part. Tuffaceous sand and clay in lower part.
		Unconformity		
	Comanche (Trinity group)	Upper Glen Rose	0-75	Impure limestone, shale, thin beds of sand and red clay.
		Anhydrite zone	0-70	Gray to white thin-bedded and marine anhydrite.
		Lower Glen Rose	0-900	Interbedded impure limestone and shale with subordinate beds of sand and red shale.
		Travis Peak	100-2000	Red clays and sands.
	Neocomian		0-700+	Marine limestone, shale, and sand.

western part where they have a combined thickness of about 150 feet. The Lower Glen Rose underlies all except the northeastern part of Nevada County. Its maximum thickness is about 900 feet. In the northeastern part the basal Upper Cretaceous beds are in contact with red shale and sands of the Travis Peak formation. The Travis Peak formation is estimated to be about 2,000 feet thick in the southern part of the county. To the south of the flexure the Travis Peak formation is probably underlain by marine beds of Neocomian age of unknown thickness.

GULF SERIES

The Gulf series increases in thickness to the southwest from about 800 feet in the northeastern part to about 1,500 feet in the southwestern part of the county. The sediments down to, and including the Ozan formation are exposed at the surface in northwestern Nevada and have been described in detail by Dane[10]. The Tokio-Woodbine section ranges in thickness from 150 feet in the northeastern part to 375 feet in the southern part of the county. It consists of gray shale, sand and sandy shale in the upper part, which becomes increasingly sandy to the northeast. The lower part consists chiefly of tuffaceous sand with subordinate beds of clays and locally contains red beds at the base. The Brownstown marl and the Ozan formation decrease in thickness and become increasingly sandy to the north and east. The Annona chalk as a lithologic unit is recognizable only in the southwestern part of the county. The Saratoga chalk and the Nacatoch formation thin out to the north and east. The Arkadelphia marl maintains its regional character throughout Nevada County and a nearly constant thickness of 90 to 100 feet.

TERTIARY

EOCENE SERIES

The Midway formation maintains its regular character throughout this area and a nearly constant thickness of 475 to 500 feet. The Wilcox formation in southern Nevada County is between 600 and 650 feet thick. The Claiborne of which only the lower part is present has a maximum thickness of 200 to 250 feet in the southeastern part of the county.

QUATERNARY

PLEISTOCENE AND RECENT SERIES

Alluvial deposits of Pleistocene and Recent age underlie the flood plain of Ouachita River and Terre Range Creek to an estimated depth of 40 feet.

STRUCTURE

The present available data are inadequate for determining the structure of the Comanche strata. They dip to the southwest at estimated rates of 100 to 150 feet per mile. (See Plate XII).

The structure of Nevada County, drawn on top of the Nacatoch formation, is shown in Figure 79. The Nacatoch, which crops out in the northwestern part, slopes to the southeast and lies at a depth of 1,100 1,150 feet below sea level in the southeastern part of the county. The rate of dip varies from 25 feet to 100 feet per mile with the prevailing dip about 50 feet per mile. The principal structural features are the Falcon and Irma grabens. The Falcon graben enters Nevada County, in the northeastern part of T. 15 S., R. 22 W., and continues in a northeasterly trend to the east side of T. 14 S., R. 22 W. It is 1½ to nearly 2 miles wide and the maximum displacement is about 500

[10] Dane, C. H., Upper Cretaceous formation of southwestern Arkansas: Arkansas Geol. Survey Bull. 1, 1929.

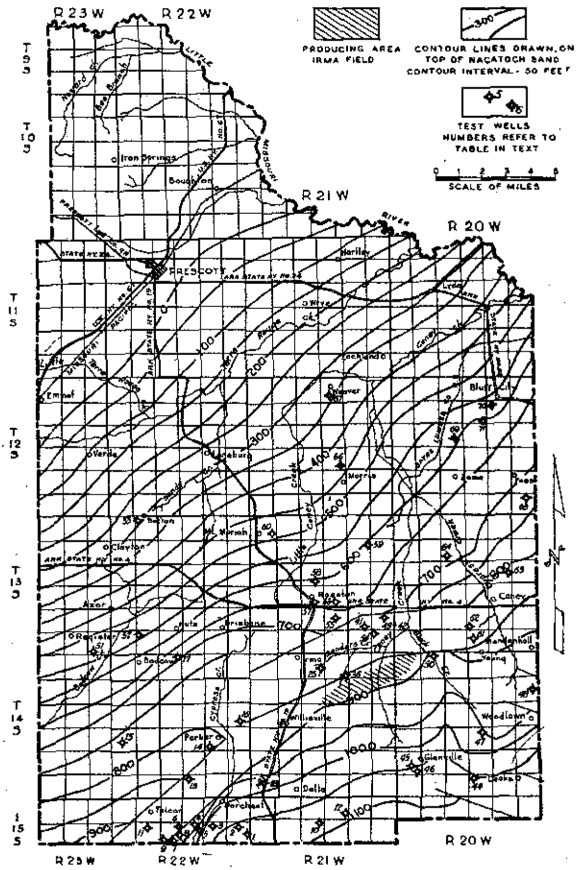


FIGURE 79.—Structure contour map of Nevada County. Figures give depth below sea level in feet.

feet. The 950-foot contour line closes against the southeast side of the graben. The Irma graben is offset to the north from the Falcon graben; it is first recognized in the northeastern part of T. 14 S., R. 21 W., and trends northeast into the southeast corner of T. 13 S., R. 21 W., where it changes direction and trends east-west to the center of T. 13 S., R. 20 W. It is from 1½ to 2 miles wide and the maximum displacement, as in the Falcon graben, is about 500 feet. The contours close against the south side of the fault, and this closure outlines the productive area of the Irma field described in detail in Part II. Aside from minor irregularities in the strike and dip the available data do not reveal the presence of anticlinal structure except as mentioned above.

List of wells drilled in Nevada County

No.,	Company, Farm & Number	Location Sec.	Twp.	R.	T. D.	Elev.*	Depth to Nacatoch feet	Depth to red shale feet	Oldest formation penetrated
1	Burnham et al, Perry No. 1	12	15S	22W	1394	325.3[a] 305.5[a] 306[d]	1118	—	Marlbrook
2	J. M. Burnham et al, W. M. Miller No. 1	12	15S	22W	1348	327[a]	1122	—	Marlbrook
3	Humble O. & R. Co., Traylor No. 1	11	15S	22W	1330	276[a]	1290	—	Nacatoch
4	Humble O. & R. Co., Calloway No. 1	10	15S	22W	1317	269.5[l]	1317	—	Nacatoch
5	Humble O. & R. Co., Calloway No. 2	10	15S	22W	1233	268.3[l] 325.3[a]	1225	—	Nacatoch
6	Chas. F. Steele, F. D. Fincher No. 1	9	15S	22W	1394	305.9[a]	1120	—	Nacatoch
7	Humble O. & R. Co., Bodcaw Fee No. 2	9	15S	22W	1247	304.5[l]	1215	—	Nacatoch
8	Humble O. & R. Co., Bodcaw No. 4	9	15S	22W	3888	285.35[l]	1195	2690	Travis Peak
9	McDonald et al, Pelt No. 1	9	15S	22W	—	306.3[a]	—	—	Marlbrook
10	Waldo O. & G. Co., Johnson No. 1	9	15S	21W	3140	373.4[h] 377.7[c]	1445	2627	Glen Rose
11	Humble O. & R. Co., Pelt No. 1	8	15S	22W	1672	337.45[c]	1665	—	Nacatoch
12	Magnolia Petrol. Co., B. F. Johnston No. 1	3	15S	21W	4600	391.25[a] 380[g]	1490	2940	Travis Peak
13	Ark. Drlg. Co., Hamilton No. 1	34	14S	22W	2515	372[d] 360.7[g]	In Graben	—	Glen Rose
14	Dudney-Thompson, May No. 1	23	14S	22W	1087	318[d]	—	—	Midway
15	M. G. Haskell, McKamie No. 1	19	14S	22W	—	374[d] 379[a]	1145	2418	Glen Rose
16	Steel & Sandlin, B. Martin No. 1	13	14S	22W	2450	341[d]	—	2440	Tokio-Woodbine
17	John Woodley, Munn No. 1	4	14S	22W	1748	370[a]	1075	2205	Glen Rose
18	Kimbrough et al, Page No. 1	31	14S	21W	1960	267[d] 356[g]	1278	—	Tokio Woodbine
19	Ames & Zingg, Waters No. 1	11	14S	21W	1191	312.97[a] 311[a]	1192	—	Nacatoch
20	Ames & Zingg, Waters No. 2	10	14S	21W	1183	301.4[a]	1180	—	Nacatoch
21	Smitherman & McDonald, Drake No. 1	10	14S	21W	1187	283[a]	1143	—	Nacatoch
22	Smitherman & McDonald, P. J. Drake No. 3	10	14S	21W	1178	—	1165	—	Nacatoch
23	Autrey Oil Co., E. E. Warmack No. 1	10	14S	21W	1199	321[a]	1183	—	Nacatoch
24	Autrey Oil Co., E. E. Warmack No. 5	10	14S	21W	1213	321[a]	1200	—	Nacatoch
25	Geo. J. Ames, E. E. Warmack No. 2	10	14S	21W	—	310[a]	—	—	Nacatoch
26	Geo. J. Ames, E. E. Warmack No. 3	10	14S	21W	1201	315[a]	1190	—	Nacatoch

No., Company, Farm & Number	Location Sec.	Twp.	R.	T. D.	Elev.*	Depth to Nacatoch feet	Depth to red shale feet	Oldest formation penetrated
27 Autrey Oil Co., P. J. Drake No. 1	10	14S	21W	1171	300.1[a]	1160	......	Nacatoch
28 Autrey Oil Co., P. J. Drake No. 2	10	14S	21W	1179	285.8[a]	1168	......	Nacatoch
29 Dixie Oil Co., P. R. Warmack No. 1	10	14S	21W	1200	295[a]	1180	......	Nacatoch
30 Dixie Oil Co., P. R. Warmack No. 2	10	14S	21W	1198	309.5[a] 298.6[a]	1193	......	Nacatoch
31 Smitherman & McDonald, T. P. Waters No. 2	10	14S	21W	2320	277[a]	......	2300	Tokio-Woodbine
32 Smitherman & McDonald, McKinney No. 1	10	14S	21W	1218	......	1207	......	Nacatoch
33 Smitherman & McDonald, E. E. Warmack No. 3	10	14S	21W	......	......	1195	......	Glen Rose
34 Dixie Oil Co., Warmack No. 1	10	14S	21W	1215	334[a]	......	......	Nacatoch
35 Danciger Dev. Synd., Waters No. 1	4	14S	21W	2400	341[a]	1720	......	Ozan
36 Owens et al, Waters No. 1	3	14S	21W	1260	293.6[a]	......	......	Midway or Arkadelphia
37 W. N. Bemis et al, J. B. Ellis No. 1	2	14S	21W	1042	274.5[a]	1042	......	Nacatoch
38 Smitherman & McDonald, C. W. Waters No. 1	2	14S	21W	1144	268.5[a]	1140	......	Nacatoch
39 Smitherman & McDonald, C. W. Waters No. 3	2	14S	21W	1167	......	1157	......	Nacatoch
40 Smitherman & McDonald, C. W. Waters No. 4	2	14S	21W	1090	......	1080	......	Nacatoch
41 Smitherman & McDonald, C. W. Waters No. 5	2	14S	21W	1176	......	1176	......	Nacatoch
42 C. F. Steele et al, Horso No. 1	1	14S	21W	1037	256[a]	1020	......	Nacatoch
43 Steele et al, Haynie No. 1	1	14S	21W	1125	252[a]	1120	......	Nacatoch
44 Gulf Refining Co., Graves No. 1	34	14S	20W	2548	267[d] 264[a]	1320	......	Glen Rose
45 Ouachita Valley O. Co., Phillips No. 2	30	14S	20W	2250	363.8[a]	1420	......	Glen Rose
46 E. S. White et al, (Haskell) Phillips No. 1	30	14S	20W	2506	363.8[a]	1410	......	Glen Rose
47 W. G. Gray et al, Lester & Holton No. 1	22	14S	20W	2526	279[d] 379.3[a]	1325	2500	Glen Rose
48 Danciger et al, Williams No. 1	12	14S	20W	2931	309.2[a]	1428	......	Tokio-Woodbine
49 Southern Oil, (Keystone) Billie Moss No. 1	7	14S	20W	1333	371[a]	1290	......	Nacatoch
50 Chas. F. Steele, Howell & Calloway No. 1	5	14S	20W	1250	250[d]	1180	......	Nacatoch

No., Company, Farm & Number	Location Sec.	Twp.	R.	T. D.	Elev.*	Depth to Nacatoch feet	Depth to red shale feet	Oldest formation penetrated
51 Shaw & Shaw, Russell No. 1	36	13S	23W	2600	350d 309.6h	835	2052	Travis Peak
52 T. G. Phillips, Buchanan or Bodcaw No. 1	32	13S	22W	2208	325a 280a	865	1885	Travis Peak
53 Home Rust Joint Venture (Straughn & Crawford) Anders (Sutton) No. 1	4	13S	22W	2640	319d	670	1808	Travis Peak
54 Houston Oil Co., Graves No. 1	36	13S	21W	2510	298.81d 296g	1465	2417	Glen Rose
55 Fruen & Booth, T. H. Whitehead No. 1	27	13S	21W	1209	308.5d	1080	......	Nacatoch
56 Greason et al, Tidwell No. 1	22	13S	21W	1200	370b	1012	......	Nacatoch
57 Ken-Ark. Oil Co., Bremberry (Phillips) No. 1	21	13S	21W	3225	355d 253.78l 350a	965	2175	Paleozoic
58 Ken-Ark. Oil Co., Luck No. 1	16	13S	21W	3110	291.5l 378a	915	2125	Travis Peak
59 Ken-Ark. Oil Co., B. M. White No. 1	11	13S	21W	2066	300d	912	1975	Tokio-Woodbine
60 Sundby Fruen & Booth, Fuller No. 1	6	13S	21W	......	......	755	......	Tokio-Woodbine
61 Bob Harrelson, Ritchie (Young) No.1	34	13S	20W	1265	325a	1215	......	Nacatoch
62 R. M. Zingg, Blakely No. 1	27	13S	20W	1228	312h	1155	......	Nacatoch
63 Transcont. Oil Co., I. H. Blakely No. 1	14	13S	20W	2780	311d	1146	2730	Travis Peak
64 Wooten et al, Moore & Martin No. 1	9	13S	20W	1225	318a	1200	......	Nacatoch
65 Edwards & Anderson, (T. W. Murray) Eaves No. 1	11	12S	23W	1420	290d	1020	......	Ozan or Brownstown
66 Sundby, Fruen & Booth, B. F. Rhodes No. 1	22	12S	21W	2344	246.3a	690	1726	Travis Peak
67 Morefield & Tanner, Westmoreland No. 1	10	12S	21W	2519	250b 253d	605	1690	Travis Peak or older
68 Millie Dee, Tr., Stone No. 1	36	12S	20W	2560	226a 225d	945	2045	Travis Peak
69 Merritt O. & G. Co., (Home Rust Joint Venture) Gothright & Barlow No. 1	16	12S	20W	3011	356h 360	935	1887	Travis Peak or older
70 El Dorado Union O. Co., Adams No. 1	11	12S	20W	1900	356.85a	915	1870	Tokio-Woodbine
71 Prescott Oil Co., (John P. Beck) C. D. Henry No. 1	10	12S	20W	2685	245a	885	......	Tokio-Woodbine
72 Phillips Petrol. Co., Gleason No. 1	10	11S	22W	2355	280a 312a	194	1120	Travis Peak or Paleozoic

No., Company, Farm & Number	Location Sec.	Twp.	R.	T. D.	Elev.*	Depth to Nacatoch feet	Depth to red shale feet	Oldest formation penetrated
73 British Allied Est., J. G. Benton No. 1	31	11S	20W	2101	187.9	610	1580	Travis Peak or older
74 R. M. Zingg, Graves Land & Timber Co. No. 1	22	10S	23W	1260	-------	------	1028	Paleozoic
75 Humble O. & R. Co., Hein No. 2	1	14S	21W	3738	252	1180	2378	Travis Peak

* Letters refer to key to datum for elevation on page 261.

OUACHITA COUNTY

LOCATION

Ouachita County is bounded on the south by Union and Columbia counties, on the west by Nevada County, on the north by Clark and Dallas counties, and on the east by Calhoun County.

GENERAL FEATURES

Ouachita County is a dissected upland. The higher ridges in the interstream areas stand 200 to more than 300 feet above sea level in the western part but slope eastward to about 200 feet in the bluff along Ouachita River.

STRATIGRAPHY

Rocks of Wilcox age are exposed in the northern part and rocks of Claiborne age form the surface in the central and southern parts of Ouachita County. Deep wells have penetrated all of the Cretaceous strata in this area. A generalized section of formations is given in Table 52.

BASEMENT ROCKS

The basement rocks have been reached in a number of deep wells in the northern half of Ouachita County where these rocks lie at depths of 2,000 to 2,500 feet below sea level. The northern part is separated from the southern part of the county by faulting or sharp flexing of the basement floor which carries these rocks to undetermined depths in that area.

CRETACEOUS

COMANCHE SERIES

The Comanche sediments increase in thickness to the southwest. The youngest known Comanche sediments are represented by the Lower Glen Rose formation which underlies the surface in the southwestern part of the county. It is 800 feet thick in the southwestern corner of the county. The Travis Peak formation underlies most of Ouachita County. It is about 2,000 feet thick where overlain by the Glen Rose formation but decreases in thickness to the northeast as the result of truncation and is probably absent in the extreme northeast part of the county. The Travis Peak formation is probably underlain by marine beds of Neocomian age in the southern half of the county.

GULF SERIES

The Gulf series increases in thickness to the southwest from about 700 feet in the northeast corner to slightly more than 1,200 feet in the southwest corner of the county. The Tokio-

TABLE 52.—*Generalized section of formations in Ouachita County*

System	Series	Formation	Thickness in feet	Character
Quaternary	Pleistocene and Recent	Terrace and river deposits	0-50	Alluvial sand, gravel, clay, and loam.
Tertiary	Eocene	Unconformity Claiborne	0-700	Lignitic sand and clay in upper part; sands, and clay and glauconitic sand and marl.
		Wilcox	150-650	Lignitic sand and clay.
		Midway Unconformity	450-500	Gray to blue noncalcareous clays with siderite concretions, fossiliferous, calcareous clay and shale in lower 50 feet of beds.
Cretaceous	Gulf	Arkadelphia marl	70-100	Gray to black calcareous marl and shale.
		Nacatoch	250-280	Calcareous sand and sandstone with shale in lower part.
		Saratoga chalk	20-60	Sandy chalk and chalk.
		Marlbrook marl Annona chalk	85-240	Light-colored marl, sandy marl, and chalk. Gray to white chalk.
		Ozan	100-180	Greenish-gray micaceous marl and sand.
		Brownstown marl	0-135	
		Tokio-Woodbine Unconformity	175-400	Sands and shale in part tuffaceous; red beds at the base in part of area.
	Comanche (Trinity group)	Lower Glen Rose	0-800	Marine limestone and shales with interbedded sand and red clays.
		Travis Peak	0-2000+	Red clays and sands.
	Comanche Neocomian ?		0-700+	Marine limestone, shale, and sand.

Woodbine sediments range in thickness from 175 to 400 feet with the greater thickness in the southwestern part. These sediments consist of clays, sands, and sandstone and contain volcanic materials which are especially abundant in the lower half of the section. The sediments vary from light-gray to green but contain red beds in the basal part in the southeastern part of the county. The Brownstown marl is 135 feet thick in the southwestern part but thins eastward and becomes increasingly sandy and is not recognized in the eastern part of the county. The Ozan formation ranges in thickness from 100 to 180 feet with the greater thickness in the western part. In the eastern part it consists chiefly of sands with the Meakin sand at the top and the Buckrange, or Graves sand, at the base with the intervening sediments made up of sandy marls and thin beds of marls. The Annona chalk as a lithologic unit is recognizable only in the western part of the county, elsewhere the Annona and Marlbrook are grouped together. These sediments increase in thickness from 85 feet in the northeastern part to 240 feet in the southwestern part of the county. The Saratoga chalk and Nacatoch formation have a combined thickness ranging from 270 to 340 feet. The Arkadelphia marl is from 70 to 100 feet thick in Ouachita County.

TERTIARY

EOCENE SERIES

The Midway formation underlying Ouachita County maintains its regional characteristics and is 450 to 500 feet thick. In the northwestern part of the county a part of the Wilcox formation has been removed by erosion, but, where the complete section is present, it is from 600 to 650 feet thick. The maximum thickness of the Claiborne is about 700 feet in the southeastern part of Ouachita County.

QUATERNARY

PLEISTOCENE AND RECENT

Alluvial deposits of Pleistocene and Recene age underlie the flood plain of Ouachita River to an estimated depth of 50 feet.

STRUCTURE

The structure of the Comanche strata is not determinable. The regional dip is to the southwest at the rate of 50 to 100 feet or more per mile.

The structure of Ouachita County drawn on the top of the Nacatoch formation is shown in Figure 80. The prevailing dip is to the southeast at the rate of 15 to 75 feet per mile. The top of the Nacatoch lies at depths ranging from about 500 feet below sea level in the northeastern part to 1,850 feet below sea level in the southeastern part of the county.

The most conspicuous structural features are the grabens in the southern part of the county. The Buena Vista graben enters the county in the northwestern part of T. 14 S., R. 19 W., and continues in a southeasterly trend to the south-central part of the same township. The Stephens graben enters the county in the northeast corner of T. 15 S., R. 19 W., and continues southeastward to the southeast corner of T. 15 S., R. 18 W. The Smackover graben trends in a general east-west direction from the center of T. 15 S., R. 18 W., to the eastern boundary of the county. The grabens vary from 1½ to 2 miles wide; the maximum displacement is about 500 feet. The structure of the Smackover and Stephens fields in the southern part of Ouachita County has been described in Part II.

In the central and northern parts of the county are several irregularities in the attitude of the strata which may be classed as structural terraces and structural noses. These structural features are situated in the northeastern part of T. 12 S., R.

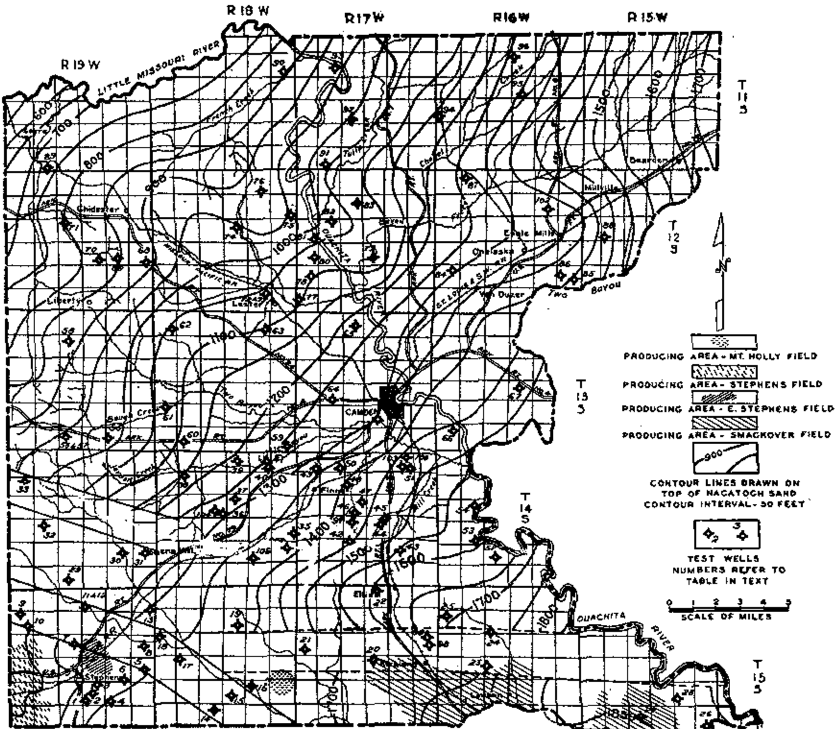


FIGURE 80.—Structure contour map of Ouachita County. Figures give depth below sea level in feet.

18 W., marked by the southeast swing in the 950-foot contour line; in the central part of T. 12 S., R. 17 W., marked by the southeast swing in the 1,100-foot contour line; in east-central part of T. 12 S., R. 16 W., marked by the swing in the contours and the decrease in the rate of dip; and in the central part of T. 13 S., R. 17 W. If the available data permitted contouring on a lesser interval than the 50-foot interval used in Figure 80 it is possible that any of the above areas might show a small amount of closure.

List of wells drilled in Ouachita County

No., Company, Farm & Number	Location Sec.	Twp.	R.	T. D.	Elev.*	Depth to Nacatoch feet	Depth to red shale feet	Oldest formation penetrated
1 Hoosier Trust, J. E. Morgan No. 1	27	15S	19W	2165	187[d]	1467	......	Ozan
2 Stephens O. & G. Co., Brewer No. 1	27	15S	19W	2230	197[a]	1500	......	Ozan
3 Sunny Jim O. Co., Wallace No. 1	27	15S	19W	2196	......	1520	......	Ozan
4 M. J. Gossett, M. Davis No. 1	26	15S	19W	1576	123[d]	1490	......	Nacatoch

No., Company Farm & Number	Location Sec.	Twp.	R.	T. D.	Elev.*	Depth to Nacatoch feet	Depth to red shale feet	Oldest formation penetrated
5 S. S. Hunter, Wesson No. 1	24	15S	19W	2840	278.5d	1418	----	Tokio-Woodbine
6 Stephens O. & G. Co., Davis No. 2	23	15S	19W	2254	254d 250a	1530	----	Ozan
7 C. W. Robinson, Polk No. 1	16	15S	19W	2356	262.8d	1570	----	Ozan
8 Transcont. O. Co., Lester & Holton No. 1	13	15S	19W	2516	169.19d	1700	----	Tokio-Woodbine
9 R. W. Williams, Gilbert No. 1	7	15S	19W	2210	267.9a	1568	----	Ozan
10 Magnolia Petrol. Co., J. E. Morgan No. 1	7	15S	19W	3050	295a	1600	2700	Glen Rose
11 Ark. Drlg. Co., Earl Morgan No. 1	3	15S	19W	2265	198d	1685	----	Ozan
12 Ark. Drlg. Co., Earl Morgan No. 2	3	15S	19W	1260	198d	----	----	Midway
13 Standard O. Co. of La., J. Cole No. 1	1	15S	19W	2406	193.75d	----	----	Tokio-Woodbine
14 Ark. Invisible, Poindexter No. 1	33	15S	18W	2617	224.25a 225d	1594	----	Tokio-Woodbine
15 Pure Oil Co., Stout Lbr. Co. No. 1	27	15S	18W	2801	143d	----	----	Tokio-Woodbine
16 E. M. Jones, Wilson No. 1	26	15S	18W	2510	155d	1750	----	Tokio-Woodbine
17 S. S. Hunter, Norman No. 1	20	15S	18W	2814	166d 160a	----	2652	Tokio-Woodbine or Glen Rose
18 Standard Oil Co., Lester & Holton No. 2	18	15S	18W	2606	166d 170a	1250 ?	2538	Glen Rose
19 Gulf Refg. Co., J. H. Dawson No. 1	10	15S	18W	----	272.90a 272d	1500	2903	Glen Rose
20 Hammann et al, Riley No. 1	22	15S	17W	2647	188.1g	1370	----	Ozan
21 Marr Oil Co., Myar No. 1	18	15S	17W	2210	165d	2095 ?	----	Nacatoch
22 Rebel Oakes O. Co., Cook No. 1	3	15S	17W	2422	228d 228g	1768	----	Nacatoch
23 Sakaba Oil Corp., Hays No. 1	21	15S	16W	2905	171a	2036	2866	Basal Upper Cretaceous red beds
24 McPhail Oil Co., Berg No. 1	9	15S	16W	2213	195d	----	----	Marlbrook
25 Gulf Refg. Co., Burkett No. 1	7	15S	16W	2918	181.18	1796	2715	Travis Peak
26 Baker, Tr., Ursey No. 1	36	15S	15W	2510	81.04g 85.37f 90d	----	----	Tokio-Woodbine
27 Crosbie et al, (Sunny Jim) Berry No. 12	33	15S	15W	4570	98a	1962	2832	Travis Peak
28 C. W. White, Watts No. 1	26	15S	15W	2699	132a 135d	1896	----	Ozan
29 S. P. Hopkins, Tr., Allen & Curry No. 1	33	14S	19W	2050	239.8a	1420	----	Ozan
30 K. C. Lumbermen's O. Co., Crutcher No. 1	0 27	14S	19W	2300	250g	1390	----	Tokio-Woodbine

No., Company Farm & Number	Location Sec.	Twp.	R.	T. D.	Elev.*	Depth to Nacatoch feet	Depth to red shale feet	Oldest formation penetrated
31 Layner-Langston, Alley No. 1	25	14S	19W	2502	243.5[d]	1428	2390	Glen Rose
32 Humble O. & R. Co., Tribble No. 1	20	14S	19W	......	297[1]	1370	......	Nacatoch
33 Humble O. & R. Co., Smith Bros. No. 1	7	14S	19W	1353	293.5[1]	......	......	Midway
34 Carter Oil Co., Hodnett (or Eubank) No. 1	28	14S	18W	3240	286.65[f] 287[a] 189[d]	1430	2645	Travis Peak
35 Sutton et al, Sutton (Graves) No. 1	24	14S	18W	2200	190[a] 191[a] 188.69[f] 159[d]	1410	......	Tokio-Woodbine
36 Thompson et al, (A. J. M. Oil Co.), Graves No. 1	16	14S	18W	2502	221.6[d]	1352	2427	Travis Peak
37 J. D. Reynolds, Howell No. 1	15	14S	18W	2262	161[d]	1417	......	Tokio-Woodbine
38 Smackover Petrol. Co., (Roy et al) Graves No. 1	8	14S	18W	2400	175.6[d] 180[a]	1370	......	Tokio-Woodbine
39 J. D. Reynolds, Chandler No. 1	3	14S	18W	......	155.9[a]	1370	......	Nacatoch
40 J. D. Reynolds, Rath & Cartier No. 1	2	14S	18W	2510	165[g]	1472	2340	Travis Peak
41 Reynolds et al, Rath & Cartier No. 3	2	14S	18W	1900	163[a]	1450	......	Ozan
42 Morefield & White, Daniels No. 1	28	14S	17W	2700	291[d]	1840	2690	Travis Peak
43 Sid Umsted, Reynolds No. 1	26	14S	17W	2527	253[d] 241[a]	1735	......	Tokio-Woodbine
44 Vandiver et al, Yarbrough No. 1	22	14S	17W	1720	155[b] 158[d]	1600	......	Nacatoch
45 C. E. Vandiver, Yarbrough No. 2	22	14S	17W	1720	171 158[d]	1623	......	Nacatoch
46 Walker et al, Venerable No. 1	16	14S	17W	3202	170[a] 223[f]	1670	2570	Travis Peak
47 Walker Consolidated Petrol. Co., Hickman No. 1	16	14S	17W	......	170[d] 172.83[f]	1730	......	Nacatoch
48 Phillips Petrol. Co., W. F. Tate No. 1	9	14S	17W	3132	197[d] 199[h]	1624	2510	Paleozoic
49 Sutton et al, Hooper No. 1	6	14S	17W	2345	156.07[f] 159[c]	1460	......	Ozan
50 Phillips Petrol. Co., W. H. Gregory No. 1	5	14S	17W	1627	191.83[d]	1550	......	Nacatoch
51 Dickson et al, Hecker (Dorothy) No. 1	2	14S	17W	......	172[d] 181.64[f]	1665	......	Tokio-Woodbine
52 Magnolia Petrol. Co., Stout No. 1	28	14S	17W	3418	104[a]	2082	2623	Travis Peak
53 Bray-Hawthorne, Halford No. 1	20	14S	16W	2546	191[d]	1701	......	Tokio-Woodbine
54 Kelly Drlg. Co., Reynolds No. 1	17	14S	16W	3093	100[d] 99.2[a]	1665	2600	Travis Peak
55 Humble O. & R. Co., Warren No. 1	35	13S	19W	1264	212[1]	1205	......	Nacatoch

No.	Company Farm & Number	Location Sec.	Twp.	R.	T. D.	Elev.*	Depth to Nacatoch feet	Depth to red shale feet	Oldest formation penetrated
56	Humble O. & R. Co., Myar No. 1	33	13S	19W	1249	244[j]	1232	-------	Nacatoch
58	Amerada Petrol. Co., Lester Mill No. 1	9	13S	19W	2674	279[d]	1169	2152	Travis Peak
59	J. D. Reynolds et al, Rath & Cartier No. 2	36	13S	18W	1885	124.3[d]	1450	-------	Ozan
60	Okla. Prod. & Refg. Co., Graves No. 1	32	13S	18W	3002	252[d] 247[a]	1347	2272	Travis Peak
61	Roy Berry et al, Adams (Smith) No. 1	30	13S	18W	2300	156[g]	1240	2250	Travis Peak
62	British Allied Est., Fee (Lampkin) No. 1	6	13S	18W	2120	175[a]	1235	-------	Tokio-Woodbine
63	Brown & Sheppard, Monalithic Carbon & Paint Co. No. 1	2	13S	18W	2296	144.3[d]	1251	2191	Travis Peak
64	The Sun Co., (Gaines et al) Scott No. 1	20	13S	17W	2507	170.24[f] 171.8[d]	1440	2335	Travis Peak
65	Scalpino et al, Higgins No. 1	4	13S	17W	1345	107.62[d]	1328	-------	Nacatoch
66	Marr Drlg. Co., Mike Berg No. 1	31	13S	16W	-------	129.6[d] 134.58[a]	1604	-------	Nacatoch
67	Crusader Oil Co., W. F. Snow No. 1	23	13S	16W	2502	123[a] 121[d]	1608	-------	---------------
68	Dickenson et al, (Dickson) Benton Heirs No. 1	24	12S	19W	3550	247.50[f]	1150	2000	Paleozoic
69	Humphreys Petrol. Co., Reid (Boyde) No. 1	23	12S	19W	2940	----------	-------	2030	Travis Peak or Paleozoic
70	So. Producing Co., Patterson No. 1	22	12S	19W	2819	241.50[j] 242.33[a]	1060	2089	Travis Peak
71	Oregon O. & Refg. Co., Jackson No. 1	16	12S	19W	2120	200[d] 240[a]	1048	1880	---------------
72	W. H. Littlejohn, ----------------	35	12S	18W	-------	160	1235	2145	Travis Peak
73	Caddo O. & G. Co., Lester No. 2	35	12S	18W	2150	162.31[f]	-------	-------	Tokio-Woodbine
74	Straughn Petrol. Co., Garnett No. 2	15	12S	18W	3270	242[d]	1160	2108	Paleozoic
75	La. Petrol. Co., Camden Coal & Clay Co. No. 1	12	12S	18W	2105	243[a]	1185	2100	Tokio-Woodbine
76	C. E. Woods et al, Garnett No. 1	1	12S	18W	2700	134.5[d]	1085	2173	Travis Peak
77	Caddo O. & G. Co., Lester Mills No. 3	31	12S	17W	-------	108.61[f] 110[a] 113	1295	-------	Tokio-Woodbine
78	Caddo O. & G. Co., Lester Mills No. 1	30	12S	17W	2305	116[f] 160[a]	1320	2097	Travis Peak
79	Standard Oil Co., Moline Lbr. Co. No. 1	22	12S	17W	2591	109.59[f]	1192	2206	Travis Peak
80	H. M. Harrell, Tr., Ponder No. 1	19	12S	17W	-------	147.35[a] 145[d]	1257	-------	Ozan
81	H. M. Harrell, Tr., Ponder No. A-1	18	12S	17W	1638	113[a]	1176	-------	Ozan

No., Company Farm & Number	Location Sec.	Twp.	R.	T. D.	Elev.*	Depth to Nacatoch feet	Depth to red shale feet	Oldest formation penetrated
82 H. M. Harrell, Moline Lbr. Co. No. 2	17	12S	17W	1890	112[d]	1157	......	Tokio-Woodbine
83 H. M. Harrell, Moline Lbr. Co. No. 3	9	12S	17W	1682	116.85[d]	1202	......	Ozan
84 Dr. Newton's Exploration Synd., Martin No. 1	30	12S	16W	2507	121[g] 122.9[f]	1440	......	Tokio-Woodbine
85 Peltier Oil Co., Eagle Lbr. Co. No. 1	25	12S	16W	2310	139.84[f]	1430 ?	......	Tokio-Woodbine
86 Peltier Oil Co., Eagle Lbr. Co. No. 2	25	12S	16W	2693	134[d] 138[a]	1495	2660	Travis Peak or older
87 Arkansas Traveler, McLeod No. 1	5	12S	16W	......	116 141	......	......	Travis Peak or older
88 El Dorado Union O. Co., Eagle Lbr. Co. No. 1	17	12S	15W	2832	154[d] 156.9[a]	1565	2506	Travis Peak
89 Broderick & Calvert, Harvey No. 1	32	11S	19W	1965	212.9[d]	935	1745	Travis Peak
90 Moody Corp. Bacon No. 1	12	11S	18W	1604	110 150	960	......	Nacatoch
91 H. M. Harrell, Moline Lbr. Co. No. 1	32	11S	17W	1168	117.57[d]	1160	......	Nacatoch
92 Pure Oil Co., Moline Lbr. Co. No. 1	21	11S	17W	2885	126.9[a] 130[d]	1120	2055	Paleozoic
93 Moody-Seagraves, Moline Lbr. Co. No. 1	8	11S	17W	2002	110[b] 110[d]	1055	1888	Travis Peak
94 W. S. Hall, Goodgame No. 1	19	11S	16W	2288	151[a] 147[g]	1310	2123	Paleozoic
95 Cameron & Anderson, Henry No. 1	15	11S	16W	......	151[a] 146[a]	1475	2458	Paleozoic
96 Reilly, Trustee, (Trapshooter Dev. Co.) H. H. Henry No. 1	10	11S	16W	......	162.4[d]	1440	......	......
97 J. D. Reynolds, Venerable No. A-1	21	14S	17W	2296	267[a]	1703	......	......
98 Bray-Hawthorne, Berg No. 1	13	15S	17W	2530	171	Graben		
99 Coperhoven-Belmont, Berg No. 3	13	15S	17W	2210	182	Graben		
100 Reynolds et al, J. W. Reynolds No. 1	2	14S	17W	2283	267	......	......	......
101 Timber Lake, Curnes No. 1	27	12S	17W	2612	120	1400	2482	Travis Peak
102 Amerada Petrol. Co., Eagle Mills No. 1	11	12S	16W	3600	144	1576	2410	Travis Peak or Paleozoic
103 Dickinson et al, Hecker No. 1	2	14S	17W	1814	172	1665	......	Nacatoch
104 Reynolds & Thompson, Graves No. 1	16	14S	18W	2502	221.6	1455	2376	Travis Peak
105 Timber Lake et al, Wright No. 1	25	14S	18W	2905	297	1697	2596	Travis Peak
106 Timber Lake et al, Criner No. 1	26	14S	18W	2900	282	1647	2544	Travis Peak

* Letters refer to key to datum for elevation on page 261.

PHILLIPS COUNTY

LOCATION

Phillips County is bounded on the south by Desha County, on the west by Arkansas and Monroe counties, on the north by Lee County, and on the east by Mississippi River.

GENERAL FEATURES

The three topographic subdivisions of the upper Mississippi embayment (Crowley's Ridge, the Advance lowland and the Mississippi lowland) are represented in Phillips County.

Crowley's Ridge includes a small tract of hilly, partly wooded, partly cultivated land, in the northeastern part of the county. It's maximum elevation is about 400 feet or about 200 feet above the surrounding lowland.

The Advance lowland includes the area between Crowley's Ridge and the western boundary, and extends southward to a maximum of 14 miles from the northern boundary. The surface is a rolling plain 170 to 240 feet above sea level with a gentle slope to the south. The creeks and bayous flow through poorly drained, shallow valleys and are separated by low ridges of light to dark loam. One of the more prominent ridges, known as Hickory Ridge, is 20 to 30 feet higher than the surface to the west, which extends from a short distance south of Marvel to the northern boundary of the county. Along the western side of Crowley's Ridge is a well-defined terrace, 1 to 3 miles wide, lying 30 to 40 feet above the lowland immediately to the west, from which it is separated by an abrupt escarpment; it is also separated from Crowley's Ridge on the east by a plainly defined escarpment.

The Mississippi lowland is an area 1 to 12 miles wide, bordering Mississippi River along the entire southeastern side of the county; a few square miles of the area lie east of the southern part of Crowley's Ridge and north of Helena. The lowland slopes from about 200 feet above sea level in the western part to about 170 feet above sea level in the southern part of the county. Swamps, lakes, abandoned stream channels, and bayous, are numerous, and much of the surface is heavily timbered.

STRATIGRAPHY

The Jackson formation of the Eocene age forms the core of Crowley's Ridge. It is unconformably overlain by sands and gravels with a maximum thickness of 80 feet, belonging to the Lafayette formation of Pleiocene age, which, in turn, is overlain by Pleistocene loess, having a maximum measurable thickness of about 140 feet. The Advance lowlands west of Crowley's Ridge is underlain to estimated depths of 125 to 200 feet by Quaternary alluvial loams, clays, sands, and gravels of Pleistócene and Recent age, and the Mississippi lowland is underlain by similar materials to estimated depths of 150 to 200 feet.

The Eocene series, represented by the Jackson, Claiborne, Wilcox, and Midway formations, is estimated to range in thickness from about 3,000 feet in the north to about 4,600 feet or more in the south.

The Cretaceous underlying the Eocene is estimated to be about 700 feet thick in the northern part and about 1,100 feet thick in the southern part of the county. These rocks have not been penetrated in deep wells.

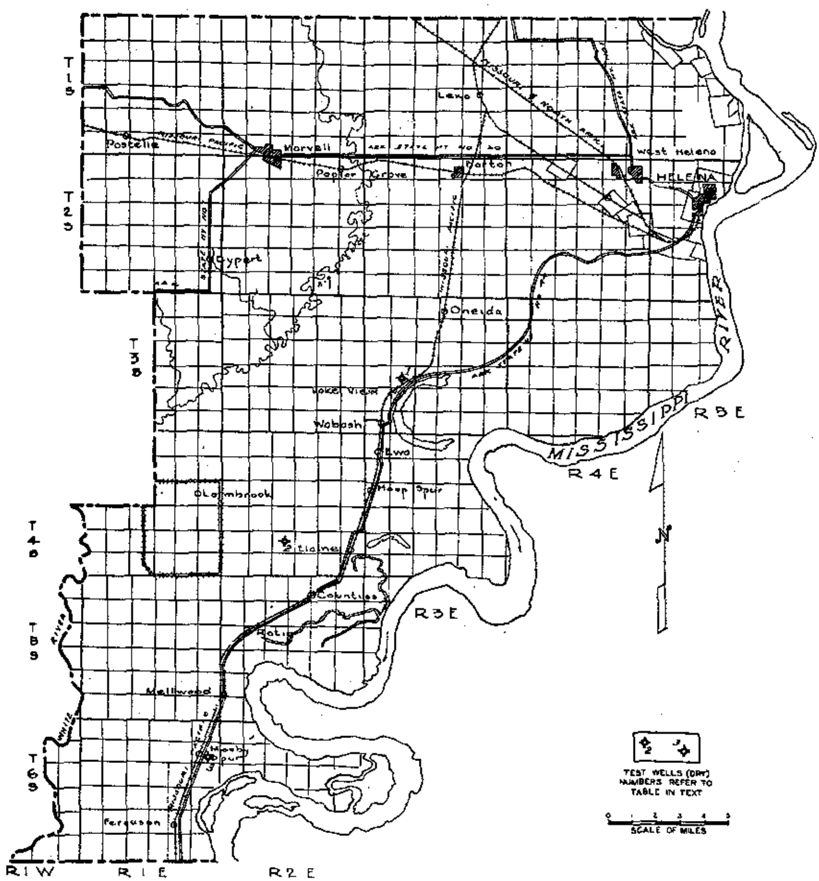


FIGURE 81.—Map of Phillips County.

STRUCTURE

The generalized structure of Phillips County is shown in Plate XIV, generalized structure of the upper Mississippi embayment. No wells in this area have penetrated the Cretaceous strata, and the structure is necessarily very much generalized. The top of the Cretaceous lies at an estimated depth of about 3,000 feet below sea level in the northwestern corner and about 4,500 feet or more below sea level in the southeastern part of the county.

A map of Phillips County showing test well locations is given in Figure 81.

List of wells drilled in Phillips County

No., Company, Farm & Number	Location Sec.	Twp.	R.	T. D.	Elev.*	Depth to Nacatoch feet	Depth to red shale feet	Oldest formation penetrated
1 Eastern Ark. O. Co., Richardson No. 1	20	3S	3E	2780	----	----	----	Wilcox
2 Eastern Ark. O. & G. Co., Richardson No. 1	28	4S	2E	1508	----	----	----	Claiborne
3 Lundell L. & Lbr. Co., Fee No. 1	12	6S	1E	1787	----	----	----	Claiborne

* Letters refer to key to datum for elevation on page 261.

PIKE COUNTY

The north and central parts of Pike County lie in the Ozark province and the southern part in the Gulf Coastal Plain. The rocks at the surface in the Ozark province consist of sandstone and shales belonging to the Atoka formation, Jackford sandstone and Stanley shale of Paleozoic age. The surface of the Paleozoic rocks dip under the Coastal Plain sediments and is estimated to lie at depths of about 500 feet below sea level in the southern part of Pike County.

The Comanche series is represented in Pike County by the Trinity group. These strata are exposed in a generally east-west trending belt in the southern part of the county, extending with decreasing width from the western boundary into the eastern part where they are overlapped by the Gulf series. The uppermost sand member and the De Queen limestone member diminish in thickness and lense out in the southwestern part of the county. The shale member intervening between the De Queen and Dierks limestone member decreases in thickness and and is represented by only a few feet of beds in the eastern part. The Dierks limestone and the underlying sands including the Pike gravel member likewise decrease in thickness to the east. The total thickness of the Trinity group in the eastern part of Pike County is about 70 feet.

Deposits of asphalt impregnated sand occur in the basal part of the Dierks limestone lentil and in the sand beneath, and at least in one locality the Pike gravel member contains asphalt. The asphalt impregnated beds range in thickness from an inch to 12 feet.

The lower part of the Gulf series is exposed at the surface in the southern part of Pike County. The Woodbine sand appears only in the southwestern part, elsewhere in the county it is overlapped by the Tokio formation. The Brownstown marl and the Ozan formation are at the surface in the extreme southeastern part of Pike County.

Igneous rocks occur in four localities in Pike County which have been described by Miser and Purdue.

These rocks are peridotite and in three of the localities have yielded diamonds.

A map of Pike County is shown in Figure 82.

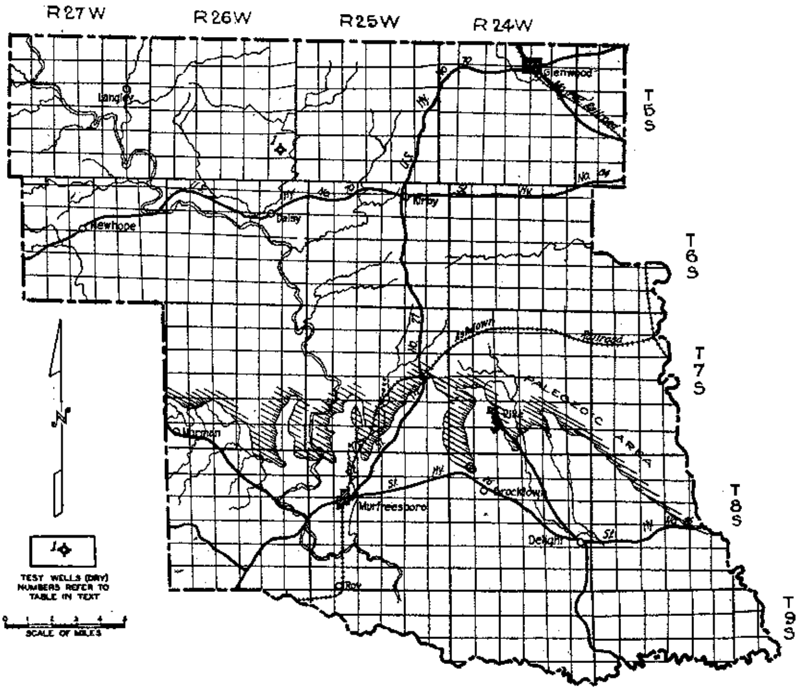


FIGURE 82.—Map of Pike County.

POINSETT COUNTY

LOCATION

Poinsett County is bounded on the south by Cross and Crittenden counties, on the west by Jackson County, on the north by Craighead County, and on the east by Mississippi County.

GENERAL FEATURES

The three principal topographic divisions of northeastern Arkansas are represented in Poinsett County: Crowley's Ridge, the Advance lowland, and the Mississippi lowland.

Crowley's Ridge is a belt of hilly land 1 to 3 miles wide, extending north-south, slightly west of the center of the county, and separated from the adjacent plains by sharply defined escarpments. The top of the ridge is 350 to 400 feet above sea level or 100 to 150 feet above the lowlands on either side.

West of Crowley's Ridge is a nearly level or gently rolling plain 230 to 290 feet above sea level, which forms a part of the Advance lowland.

East of Crowley's Ridge is the gently undulating plain of the Mississippi lowland, lying 225 to 240 feet above sea level. Much of the surface is swampy, and bayous and ponds are common.

STRATIGRAPHY

The surface rock in Poinsett County, for the most part, are alluvial sand, gravels, and clays of Pleistocene and Recent age, but the Wilcox formation of Eocene age, and the Lafayette formation of Pliocene age, crop out in narrow bands on the flanks of Crowley's Ridge. Deep wells drilled in the county have penetrated all of the Tertiary and the Cretaceous strata and entered the Paleozoic rock, which form the basement floor upon which the Coastal Plain sediments were deposited. A generalized section of formations encountered in the drilling of deep wells is given in Table 53.

BASEMENT ROCKS

The Coastal Plain sediments lie upon a floor of folded and truncated rocks of Paleozoic age and probably similar to the rocks which are at the surface in the adjacent part of the Arkansas Valley and the Ozark province to the west. The basement floor slopes southeastward in Poinsett County and lies at a depth of about 250 feet below sea level in the western part and at a depth of 3,100 to 3,200 feet below sea level in the southeastern part of the county.

TABLE 53.—*Generalized section of formations in Poinsett County*

System	Series	Formation	Thickness in feet	Character
Quaternary	Pleistocene and Recent		10-175	Alluvium, sand, gravel, clays, and loess.
		Unconformity		
Tertiary	Pliocene?	Lafayette	10-40	Sand and gravel
		Unconformity		
	Eocene	Claiborne and Wilcox	250-1700	Sand and clays, in part lignitic.
		Midway clays	100-450	Gray and bluish-gray clay and siderite concretions.
		Unconformity		
Cretaceous	Gulf	Arkadelphia marl	0-75	Dark-gray to black shale.
		Nacatoch sand and Saratoga chalk	100-450	Gray to green sand, calcareous sandstone, limestone, and shales; in part glauconitic.
		Marlbrook marl and older	0-250	Chalky shale and calcareous sandstone.
		Unconformity		
Basement rock—Paleozoic or older				

CRETACEOUS

GULF SERIES

The correlation of the Cretaceous system of Poinsett County is made chiefly on the basis of the lithologic character of the strata as recorded in the driller's logs, supplemented by a few cores, and samples from these wells. The Cretaceous strata increases in thickness from about 100 feet in the western part to about 800 feet in the eastern part of the county, where the Arkadelphia marl, Nacatoch sand, Saratoga chalk, and Marlbrook marl are represented. The Arkadelphia marl consists principally of dark-gray to nearly black calcareous shale; the Nacatoch is made up chiefly of glauconitic sand, calcareous sandstone, and gray to greenish-gray shale. The Saratoga and the Marlbrook consist of impure chalk, limestone, and shale, and subordinate beds of sand. The character and structure of the strata are shown in Figure 13.

TERTIARY

EOCENE SERIES

The Eocene series, represented by the Wilcox formation and the Midway clays, increases from about 350 feet in the western part to more than 2,100 feet in the southeastern corner of Poinsett County.

The Wilcox formation consists principally of sand with subordinate beds of clay in the upper part and of sandy clay and clay in the lower. The formation is in part lignitic.

The Midway is principally gray to bluish-gray clay, in which siderite concretions are abundant .

PLIOCENE?

LAFAYETTE FORMATION

The Eocene strata in Crowley's Ridge are overlain unconformably by a few feet to 40 feet of sands and gravels, locally

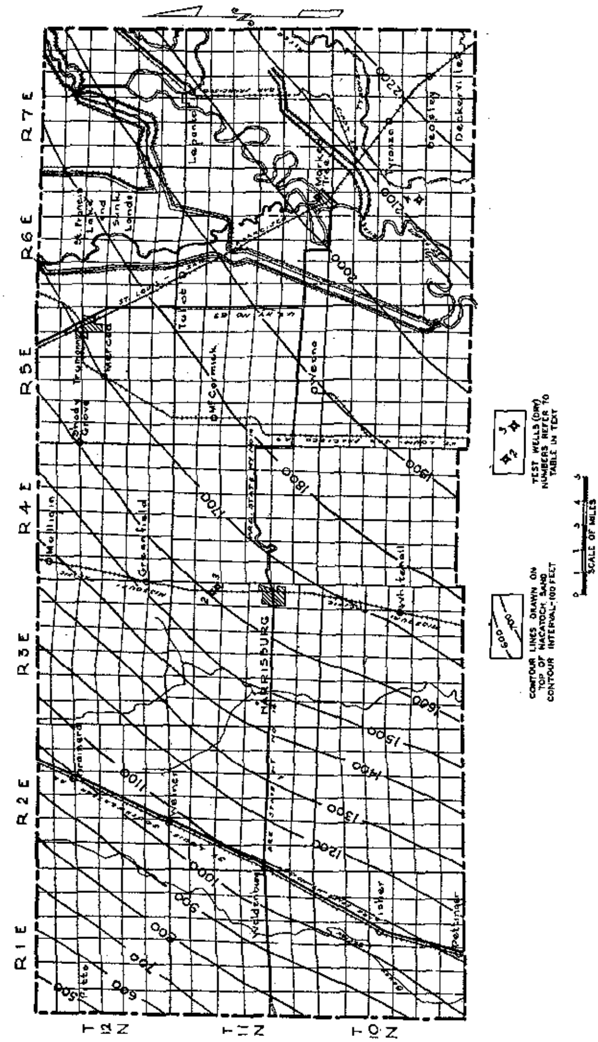


FIGURE 83.—Structure contour map of Poinsett County. Figures give depth below sea level in feet.

indurated to hard conglomerate, belonging to the Lafayette formation probably of the Pliocene age.

QUATERNARY

PLEISTOCENE AND RECENT SERIES

The Lafayette formation is overlain in places by loess, 20 feet or more in thickness, which, where present, forms the capping material of Crowly's Ridge.

In the Advance lowland, the Eocene strata are overlain by an estimated thickness of 125 to 175 feet of Quaternary alluvium of the Pleistocene and Recent age; and the Mississippi lowland is underlain by 150 to 225 feet of alluvial loams, clays, and water-bearing sands and gravels of Pleistocene and Recent age.

STRUCTURE

The generalized structure of the Nacatoch sand is shown by structure contours in Plate XV and Figure 83. The dip of the strata is to the east and southeast at the rate of 60 to 75 feet per mile. The top of the Nacatoch lies at a depth of 400 feet below sea level in the northwest corner and at a depth of 2,100 feet below sea level in the southeast corner of the county. The available data are inadequate to determine the presence or absence of local anticlinal folding.

List of wells drilled in Poinsett County

No.,	Company Farm & Number	Location Sec.	Twp.	R.	T. D.	Elev.*	Depth to Nacatoch feet	Depth to red shale feet	Oldest formation penetrated
1	City Water Works, Marked Tree, Ark.	35	11N	6E	2006	....	....	....	Midway
2	J. F. Scott, Tr., Nelson No. 1	12	11N	3E	2120	260	1860	....	Nacatoch or Saratoga
3	J. F. Scott, Tr., Nelson No. 2	12	11N	3E	2150	....	....	....	Nacatoch or Saratoga
4	Aarnes et al, Lemmon & Kahn No. 1	23	10N	6E	3005	210	2490	....	Paleozoic

* Letters refer to key to datum for elevation on page 261.

PRAIRIE COUNTY

LOCATION

Prairie County is bounded on the south by Arkansas County, on the west by Lonoke County, on the north by White County, and on the east by Woodruff and Monroe counties.

GENERAL FEATURES

Prairie County is included within the Advance lowland, the surface of which is, in general, a gently undulating or rolling plain 200 to 240 feet above sea level, and sloping slightly to the south. White River flows a little east of south across the county, and leaves it about 10 miles north of the southeastern corner. Cache River forms the eastern boundary for a few miles. The channel of White River is near the western edge of the flood plain. All the county east of the river is in the heavily timbered flood plain of White or Cache River, an area charactreized by numerous bayous, lakes, and abandoned stream channels. West of White River and north of the Chicago, Rock Island, and Pacific Railway, much of the surface is timbered land lying a few feet higher than the flood plains and slightly lower than the prairies. South of this railway and west of the wooded belt bordering White River are broad stretches of grass-covered prairie, separated by patches and belts of slightly lower timbered lands.

STRATIGRAPHY

Quaternary alluvial deposits of Pleistocene and Recent age cover the surface of Prairie County and extend to depths of 120 to 180 feet and rest unconformably on strata of Eocene age. The Eocene series is represented by the Jackson (probably present only in the southeastern part), the Claiborne, Wilcox, and Midway formations, having an aggregate thickness ranging from about 650 feet in the northwestern part to about 2,800 feet in the southeastern part of the county. The Cretaceous strata which unconformably underlie the Eocene increase in thickness from about 100 feet in the northwestern part to about 500 feet in the southeastern part of Prairie County. A generalized section of formations is given in Table 54.

BASEMENT ROCKS

The Cretaceous strata were deposited on a nearly level floor of folded and truncated Paleozoic rocks which was subsequently lowered and tilted to the southeast, and now lies at depths ranging from about 500 feet below sea level in the northwestern corner to about 2,100 feet below sea level in the southeastern corner of the county. The basement rocks probably are com-

TABLE 54.—*Generalized section of formations in Prairie County*

System	Series	Formation	Thickness in feet	Character
Quaternary	Pleistocene and Recent		100-175	Alluvial loams, clays, sands, and gravels.
		Unconforimty		
Tertiary	Eocene	Jackson Claiborne Wilcox	450-2250	Principally sands, clays, and sandy clays, in part lignitic; subordinate thin beds of glauconitic sands.
		Midway clays	200-500	Gray and bluish-gray clays, siderite concretions abundant.
		Unconformity		
Cretaceous	Gulf	Arkadelphia marl	50-75	Gray and dark-gray calcareous shales.
		Nacatoch sand and Saratoga chalk	50-300	Chiefly fine-textured sand, sandstone and sandy limestone, in part glauconitic; subordinate beds of shale and chalk.
		Marlbrook marl and older	0-150	Marls, chalks, shales and sands.
		Basement rocks		

posed of sandstones and shales of Pennsylvanian and Mississippian age.

CRETACEOUS

GULF SERIES

The Cretaceous strata underlying Prairie County range in thickness from about 100 feet in the northwestern part to about 500 feet in the southeastern part of the county. On the basis of the driller's records of deep wells, the Cretaceous is divided into the following formations: Arkadelphia marl, Nacatoch sand, Saratoga chalk, and Marlbrook marl.

The Marlbrook marl, 50 to 75 feet thick, is composed of gray to dark-gray calcareous shales.

The Nacatoch sand and the Saratoga chalk, not readily separable in the available records, range from 50 to 300 feet in thickness. In the northwestern part they are composed principally of fine-textured sand and sandstone, in part glauconitic and calcareous, and subordinate thin beds of shales and sandy shales. In the southeastern part of the county the upper part is composed chiefly of sand and sandstone, with shales, chalk, and chalky shales in the lower part of the section.

The Marlbrook marl is present only in the southeastern part of the county, where it is estimated to attain a maximum thickness of 150 feet. It is made up principally of shales and marls, with sand at the base.

TERTIARY

EOCENE SERIES

The Eocene strata of the area, unconformably overlain by Quaternary alluvial deposits, have been penetrated in a number of deep wells which have furnished an incomplete record of their

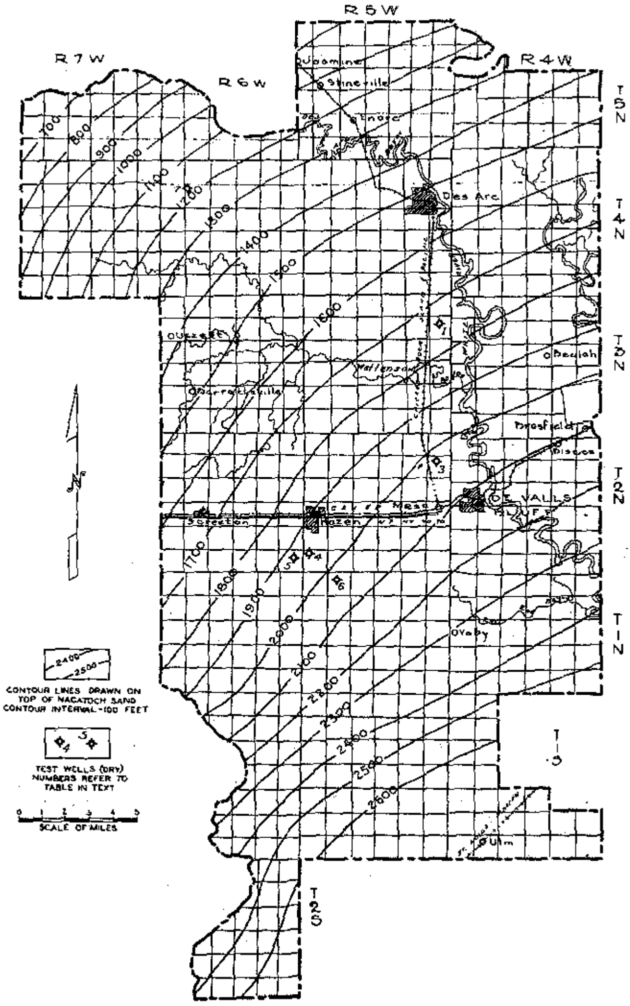


FIGURE 84.—Structure contour map of Prairie County. Figures give depth below sea level in feet.

character and thickness. The Eocene series, represented by the Jackson, Claiborne, Wilcox, and Midway formations, is estimated to be about 650 feet thick in the northwestern and about 2,800 feet thick in the southeastern part of the county. The difference in the thickness is in part the result of lateral thinning of the formations, and in part the result of erosion and truncation.

The Midway, made up of gray and bluish-gray, generally noncalcareous clay and shale, containing an abundance of siderite concretions, is estimated to be from 200 to 500 feet thick.

The strata above the Midway consist principally of sands, clays, and sandy clays, in part lignitic, with some glauconitic sand and clays in the basal Claiborne and Jackson formations. The Wilcox formation underlies all of the county, but the Claiborne formation probably does not extend west of the central part, and the Jackson formation is present only in the southeastern part of the county. The aggregate thickness of the formations is estimated to be about 2,250 feet in the southeastern corner of Prairie county.

QUATERNARY

PLEISTOCENE AND RECENT SERIES

Quaternary alluvial deposits of Pleistocene and Recent age immediately underlie the surface to depths of 100 to 175 feet, and rest unconformably on strata of Eocene age. The Pleistocene strata crop out in the interstream areas; they are irregularly bedded, but in general grade downward from fine silty loams and clays at the surface into coarse sand and gravels at the base. Loams, clays, sands, and gravels of Recent age constitute the flood plain materials of the present streams.

STRUCTURE

The generalizd structure of Prairie County, drawn on top of the Nacatoch sand at intervals of 100 feet, is shown in Plate XV. Also see Figure 84. The top of the Nacatoch sand lies at a depth of about 600 feet below sea level in the northwestern corner and at a depth of about 2,800 feet below sea level in the southeastern corner of the county. The dip is to the southeast at the rate of 70 to 90 feet per mile. The available data is not sufficient to determine local structural features.

List of wells drilled in Prairie County

No.,	Company Farm & Number	Location Sec.	Twp.	R.	T. D.	Elev.*	Depth to Nacatoch feet	Depth to red shale feet	Oldest formation penetrated
1	DeValls Bluff, Gates No. 1	12	3N	5W	2510	200+	2215	....	Paleozoic
2	Bowler Well & Const. Co., Hardkie No. 1 (at Screeton, Ark.)	20	2N	6W	3000	247	1918	....	Paleozoic
3	Ark. Grand Prairie, McClintock No. 1	12	2N	5W	2780	194	2290	....	Paleozoic
4	Bowler Well & Const. Co., John Sims, (Hazen well)	31	2N	5W	2356	232	2173	....	Paleozoic
5	Transcont. Oil Co., Louis Novak No. 1	36	2N	6W	2954	223	2170	....	Paleozoic
6	Harvey Dev. Co., Kancourek No. 1	5	1N	5W	2564	225	....	....	Paleozoic
7	A. J. Bellporte, Thomas No. 1	8	4N	6W	2072	240	1420	....	Paleozoic

* Letters refer to key to datum for elevation on page 261.

PULASKI COUNTY

Paleozoic rocks of Ordovician and Carboniferous age crop out in the Ozark province. These rocks pass under the Coastal Plain sediments and are estimated to lie at depths of about 2,000 feet in the southeastern corner of the county. Strata of Tertiary age, including the Midway and Wilcox formations, crop out in the Gulf Coastal Plain area in southeastern Pulaski County. The Midway formation, which consists of 25 feet or more of limestone, calcareous sandstones, sands, and clays, crops out in a narrow area along the northwestern margin of the Coastal Plain from Little Rock southwestward to the county line. The Wilcox sands and clays crop out in a small area southeast of the Midway area and also in a small area in the vicinity of Jacksonville, in the northeastern part of the county. The materials immediately underlying Arkansas River bottom to estimated depths of 100 to 200 feet consist of Quaternary alluvial loams, clays, sands, and gravels.

The Tertiary deposits are underlain by strata of Upper Cretaceous age belonging to the Arkadelphia marl and the Nacatoch formation. These sediments increase in thickness from a few feet along the margin of the Coastal Plain area to about 200 feet in the southeastern corner of Pulaski County. The strata dip to the southeast, and it is estimated that the top of the Nacatoch lies at depths of 1,800 to 1,900 feet below sea level in the southeastern corner of Pulaski County.

A map of Pulaski County showing test wells is shown in Figure 85.

List of wells drilled in Pulaski County

No., Company Farm & Number	Location Sec.	Twp.	R.	T. D.	Elev.*	Depth to Nacatoch feet	Depth to red shale feet	Oldest formation penetrated
1 The Stiles Interests, ----------	27	1S	11W	1005	225	------	------	Paleozoic
2 Fred Van Waggoner, Galloway No. 1 ----------	25	2S	11W	2070	250	------	------	Paleozoic
3 Protho & Zunt, Protho Gin No. 1 ----------	32	2S	11W	500	------	------	------	Paleozoic
4 Wonderstate Dev. Co., Wilson No. 1 ----------	21	2S	11W	1747	259	------	------	Paleozoic

* Letters refer to key to datum for elevation on page 261.

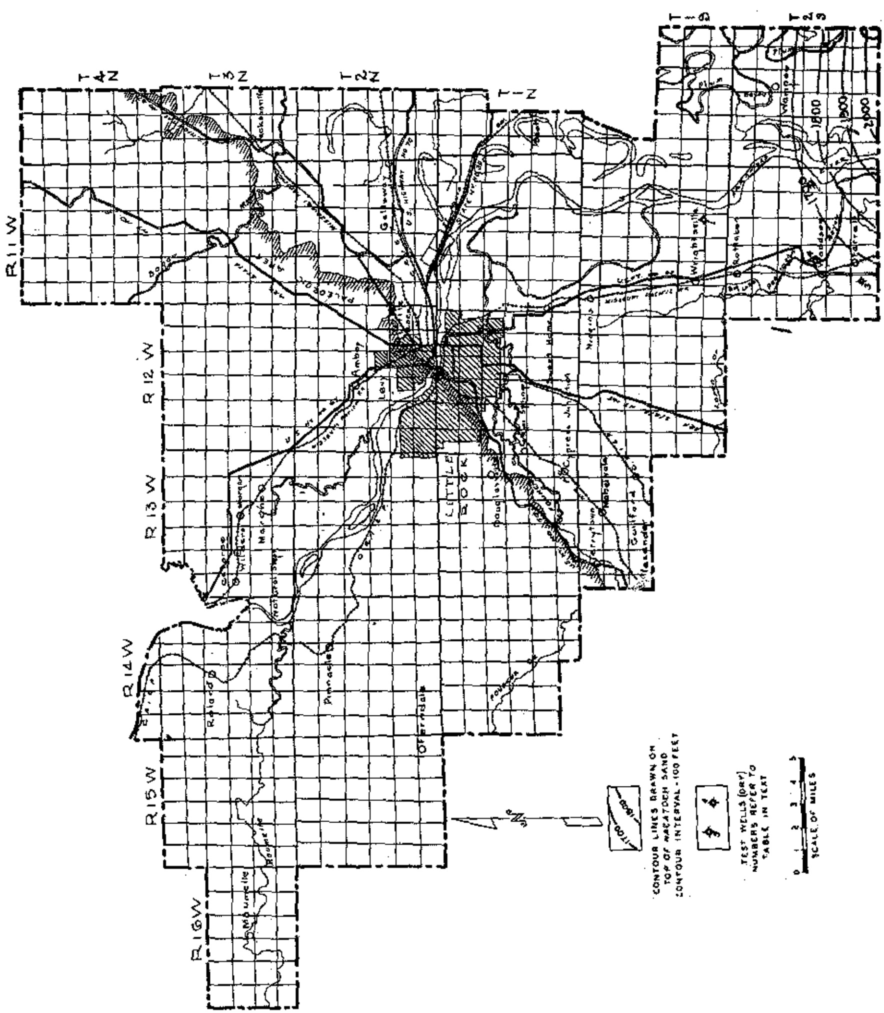


FIGURE 85.—Map of Pulaski County.

RANDOLPH COUNTY

About three quarters of the total area of the county is included in the Ozark province. A triangular area in the southeast, embracing about one-fourth of the county included, is in the Gulf Coastal Plain. The Paleozoic rocks of the Ozark province pass beneath the Coastal Plain sediments and lie at estimated depths of 500 to 750 feet below sea level in the southeastern corner of the county. The Coastal Plain area is under-

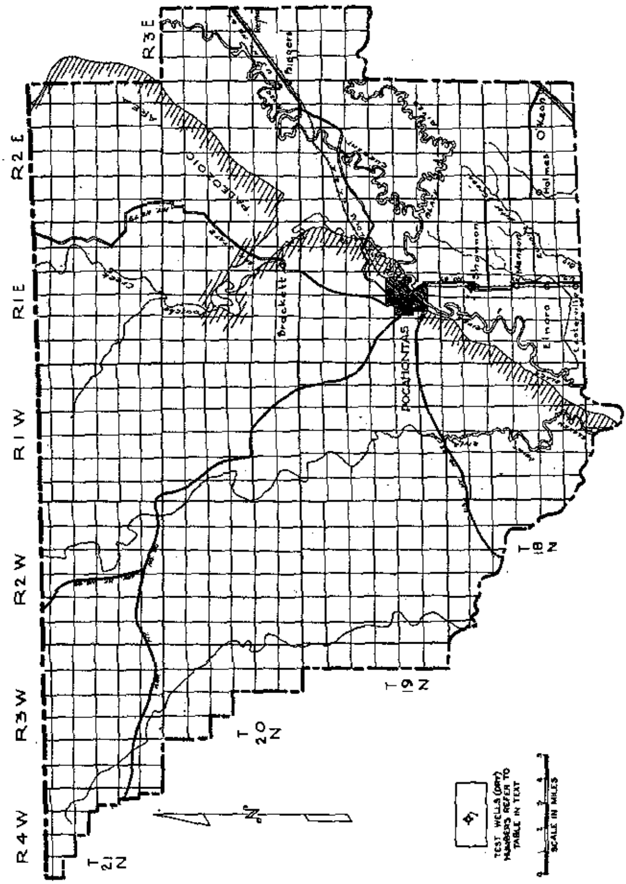


FIGURE 86.—Map of Randolph County

lain by an estimated thickness of 150 to 180 feet of Quaternary alluvial deposits of Pleistocene and Recent age which rest unconformably on strata of Eocene age and perhaps on Cretaceous or strata of Cretaceous age in the western part. The maximum thickness of Cretaceous strata underlying the area is estimated to be 100 feet or less and all of it is assigned to the Arkadelphia marl and the Nacatoch sand. The strata dip to the east and the top of the Nacatoch formation is estimated to lie at depths of 450 to 500 feet below sea level in the southeastern corner of Randolph County.

A map of Randolph County showing test wells is shown in Figure 86.

List of wells drilled in Randolph County

No.,	Company Farm & Number	Location Sec.	Twp.	R.	T. D.	Elev.*	Depth to Nacatoch feet	Depth to red shale feet	Oldest formation penetrated
1	Old River O. & G. Co., Holland No. 1	15	18N	1W	500	300	-------	-------	Paleozoic

* Letters refer to key to datum for elevation on page 261.

ST. FRANCIS COUNTY

LOCATION

St. Francis County is bounded on the south by Lee County, on the west by Monroe and Woodruff counties, on the north by Cross County, and on the east by Crittenden County.

GENERAL FEATURES

Crowley's Ridge is a belt of hilly land, 1½ to 6 miles wide, trending north and south, a little west of the center of the county. The crest of the ridge is about 350 feet above sea level or 140 to 160 feet above the lowlands to the east and west.

The part of the county west of Crowley's Ridge is included in the Advance lowland, a gently undulating plain 230 to 260 feet above sea level. The part of the county east of Crowley's Ridge is included in the Mississippi lowland, a heavily timbered, nearly level or gently undulating plain 220 to 230 feet above sea level. Swamps, lakes, bayous, and abandoned stream channels are numerous.

STRATIGRAPHY

The oldest formation appearing at the surface in St. Francis County is the Jackson, which crops out in a narrow band on the flanks of Crowley's Ridge. The Jackson is unconformably overlain by sands, and gravels of the Lafayette formation of Pliocene ? age. Over the remainder of the county the materials at the surface are alluvial loams, clays, sands, and gravels of Recent and Pleistocene age. The Tertiary strata range from 1,900 to 2,900 feet in thickness, and the Cretaceous from 400 to 900 feet or more in thickness. A generalized section of formations is given in Table 55.

BASEMENT ROCKS

The Coastal Plain sediments were deposited upon a nearly level floor of folded and truncated Paleozoic rocks. This floor, owing to subsequent warping, now slopes toward the southeast from about 2,100 feet below sea level in the northwestern part to about 3,900 feet below sea level in the southeastern part of St. Francis County. The characteristics of the basement rocks are not definitely known but are probably similar to the rocks present at the surface in the area west of the Coastal Plain.

CRETACEOUS

GULF SERIES

The Cretaceous strata underlying St. Francis County are composed of shales, sands, limestones, and chalks, which have

TABLE 55.—*Generalized section of formations in St. Francis County*

System	Series	Formation	Thickness in feet	Character
Quaternary	Pleistocene and Recent		10-200	Alluvial sands, gravels, clays, and loess.
		Unconformity		
Tertiary	Pliocene?		10-40	Sands and gravel.
		Unconformity		
	Eocene	Jackson Claiborne Wilcox	1200-2200	Sand, sandy clays and clay, in part lignitic; subordinate beds of glauconitic sand and marl.
		Midway clays	400-600	Gray clays and siderite concretions.
		Unconformity		
Cretaceous	Gulf	Arkadelphia marl	75-100	Dark-gray shale.
		Nacatoch sand and Saratoga chalk	250-350	Chiefly glauconitic sand and sandy limestone, chalk, and shale.
		Marlbrook and older	0-500	Chalk, marl, and sands.
		Unconformity		
Basement rocks				

an estimated thickness of about 400 feet in the northwestern part, and about 900 feet in the southeastern part of the county. The following formations are represented: Arkadelphia marl, Nacatoch sand, Saratoga chalk, and Marlbrook marl, and probably older formations in the extreme eastern part. The Marlbrook marl is probably absent in the western part, and the Tokio formation, or its Mississippian equivalent (the Tuscaloosa formation) is perhaps present in the eastern part of the county.

TERTIARY

EOCENE SERIES

The Eocene strata have an estimated thickness ranging from 1,800 feet in the northwestern to 2,800 feet in the southeastern part of the county. The basal Eocene (the Midway clays) are 400 to 600 feet thick, consisting principally of gray and bluish-gray clay, containing an abundance of siderite concretions. The larger part of the total thickness of the clay is noncalcareous.

The sediments overlying the Midway belong to the Jackson, Claiborne, and Wilcox formations, but owing to lack of detailed data, it has not been possible to differentiate accurately these formations in St. Francis County. Their thickness ranges from 1,200 feet in the western part to 2,200 feet in the eastern part of the county. These beds are made up principally of sands, clays, and sandy clays, in part lignitic, but they also contain beds of glauconite sand and clays, which are most abundant in the basal part of the Claiborne formation.

PLIOCENE

The Jackson formation of Crowley's Ridge is unconformably overlain by irregularly bedded gravels and sands reaching a thickness of about 40 feet or more. These sands and gravels are correlated with the Lafayette formation.

QUATERNARY

PLEISTOCENE AND RECENT SERIES

The Lafayette formation in Crowley's Ridge is overlain by loess of Pleistocene age, ranging in thickness from a few feet to 80 feet or more. The Quaternary alluvium which immediately underlies the surface in the Advance lowland west of Crowley's Ridge to a depth of 140 to 200 feet, is in part of the Pleistocene and in part of Recent age.

The Quaternary alluvium, which underlies the Mississippi lowland to a depth of 120 to 200 feet, consists of loams, clays, and gravels. The materials at the surface are entirely of Recent age, but Pleistocene beds probably are present between the Recent and the underlying Eocene strata.

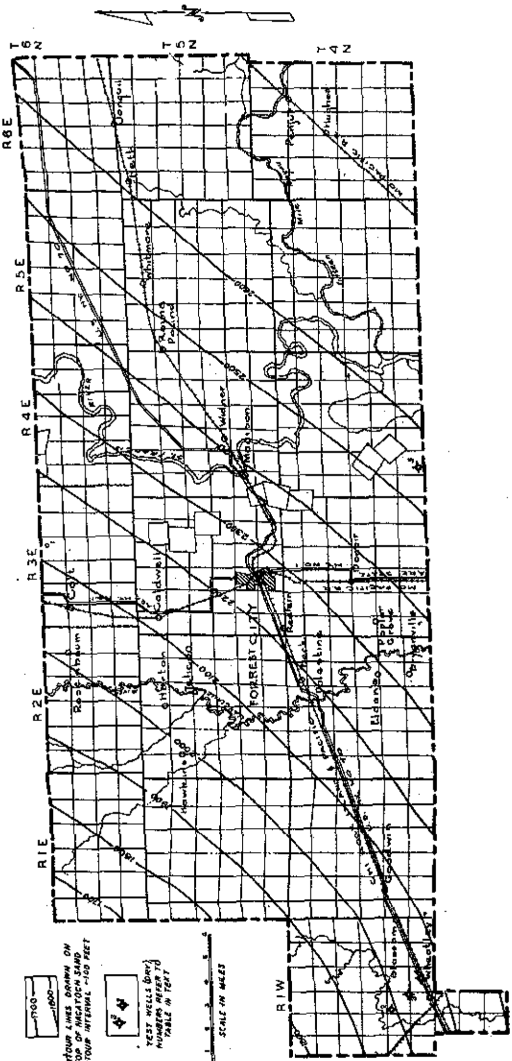


FIGURE 87.—Structure contour map of St. Francis County.

STRUCTURE

The structure of St. Francis County is shown in Plate XV and Figure 87, by means of contour lines drawn on the top of thethe Nacatoch sand at intervals of 100 feet. The data upon which the structure is based are obtained from the deep wells. Therefore, the structure is necessarily generalized, showing principally the regional structural features.

The Nacatoch sand lies at a depth of about 1,600 feet below sea level in the northwestern part and about 3,000 feet or more below sea level in the southeastern part of the county. The dip is to the southeast at the rate of 30 to 50 feet per mile.

The presence of local anticlinal folds is not determinable, owing to lack of detailed data.

Forrest Oil Company's Shirley No. 1 well, sec. 15, T. 6 N., R. 3 E., St. Francis County.

Geologic age	Depth in feet
Quaternary	
Pleistocene series	
Soft yellow surface material	20
Loose white sand	60
Unconformity	
Tertiary	
Eocene series	
Jackson, Claiborne, and Wilcox	
Soft gray gumbo	105
Soft white sand	200
Soft blue gumbo	225
Soft gray sand	238
Hard white gumbo	268
Soft gray sand	520
Gray gumbo	597
Gray sand	865
Brown gumbo	871
Gray and white shale and sand	972
Lignite	977
Hard blue gumbo	1090
Gray sandy shale	1040
Hard sand, broken with shale	1080
Hard gray sand	1190
Gray gummy shale	1220
Gray sand and sandstone	1255
Blue and black gumbo	1400
White water sand	1405
Gray, blue, and black gumbo and boulders	1465
Hard gray sand rock	1488
Hard chalky lime	1500
Hard lime rock	1560
Broken sand rock	1580
Gray gumbo	1700
Soft white water sand	1725
Gray gumbo and shale	1830
Soft white sand	1845
Midway clays	
Gray gumbo and shale	2145
Gumbo and boulders	2200
Hard gray shale and boulders	2245
Gray shale and gumbo	2340
Unconformity	

Geologic age	Depth in feet
Arkadelphia marl	
Very tough gray gumbo	2462
Cretaceous	
Gulf series	
Nacatoch sand	
Hard white rock	2467
White and gray sand (water)	2520
Hard gray sandy lime	2534
Soft and hard sand	2562
Soft gray shale	2602
White sand and sand rock	2750
Gray shale and gumbo	2770
Gray and white sand	2790
Saratoga chalk, Marlbrook marl, and older	
Gray to dark-gray shale and gumbo	2870
Dark-gray shale and sand	2885
Dark-gray gumbo	2900
Dark-gray gumbo and sand	2980
Dark-gray gumbo	3020
Hard gray sand rock	3022
Light-gray gyp rock	3050
Gray shale and sand	3072
Tough gray gypsum	3130
White and gray water sand	3172
Paleozoic ?	
Hard sandy shale	3180
Very hard sandstone	3191
Hard sandy shale	3196
Very hard dark-gray sandstone	3201
T. D.	3201

List of wells drilled in St. Francis County

No.	Company Farm & Number	Location Sec.	Twp.	R.	T. D.	Elev.*	Depth to Nacatoch feet	Depth to red shale feet	Oldest formation penetrated
1	Forest Oil Co., Shirley No. 1	14	6N	3E	3201	305	2460	......	Paleozoic
2	Brownlee Drlg. Co., Whitted No. 1	28	4N	1W	2810	224	2267	......	Paleozoic
3	F. T. Whitted, Tr., Whitted No. 2	28	4N	1W	2325	212a	2270	......	Nacatoch sand
4	Wheatley Co-operative Oil Co., Ewing No. 1	34	4N	1W	2378	209a	2376	......	Nacatoch
5	Ark. Nat. Gas Co., Swearingen No. 1	14	6N	1E	3043	215+	2035	......	Paleozoic

* Letters refer to key to datum for elevation on page 261.

SALINE COUNTY

The southeastern part of Saline County lies in the Gulf Coastal Plain; the remainder of the county lies in the Ozark province. The rocks at the surface in the western part consist of Paleozoic sandstones, shales, slates, and novaculites ranging in age from Pennsylvanian to Ordovician. The Paleozoic rocks dip under the Coastal Plain sediments and are estimated to lie at depths of 1,400 to 1,500 feet below sea level in the southeastern corner of the county.

The Comanche series is absent but strata of Upper Cretaceous age belonging to the Arkadelphia marl and the Nacatoch underlie most of the Coastal Plain area of Saline County. These strata increase in thickness from a few feet to between 100 and 200 feet in the southeast corner of the county. The strata dip to the southeast and the top of the Nacatoch is estimated to lie at depths of 1,400 to 1,500 feet below sea level in the southeastern corner of Saline County.

The Midway formation of Tertiary age crops out in a southwesterly trending belt 1 to 4 miles wide extending from the northeast corner of T. 1 S., R., 14 W., to the boundary of Hot Spring County in T. 3 S., R. 16 W. In the area to the east, the Midway sands and clays of Wilcox age are exposed at the surface.

A map showing test well locations in Saline County is shown in Figure 88.

List of wells drilled in Saline County

No.,	Company Farm & Number	Location Sec.	Twp.	R.	T. D.	Elev.*	Depth to Nacatoch feet	Depth to red shale feet	Oldest formation penetrated
1	Cal-Ark Oil Co., (W. W. Haley)	6	3S	14W	725	350[b]	......	......	Paleoozic
2	McRae & Jones (J. D. McRae) Bell No. 1	20	2S	15W	3750	....	......	......	Paleoozic
3	McRae et al, Moore No. 1	12	2S	15W	2165	....	......	......	Paleoozic
4	Wayman O. & G. Co., Wayman (I.P.O.G.Co.)	5	2S	12W	3410	270[a]	......	......	Paleoozic

* Letters refer to key to datum for elevation on page 261.

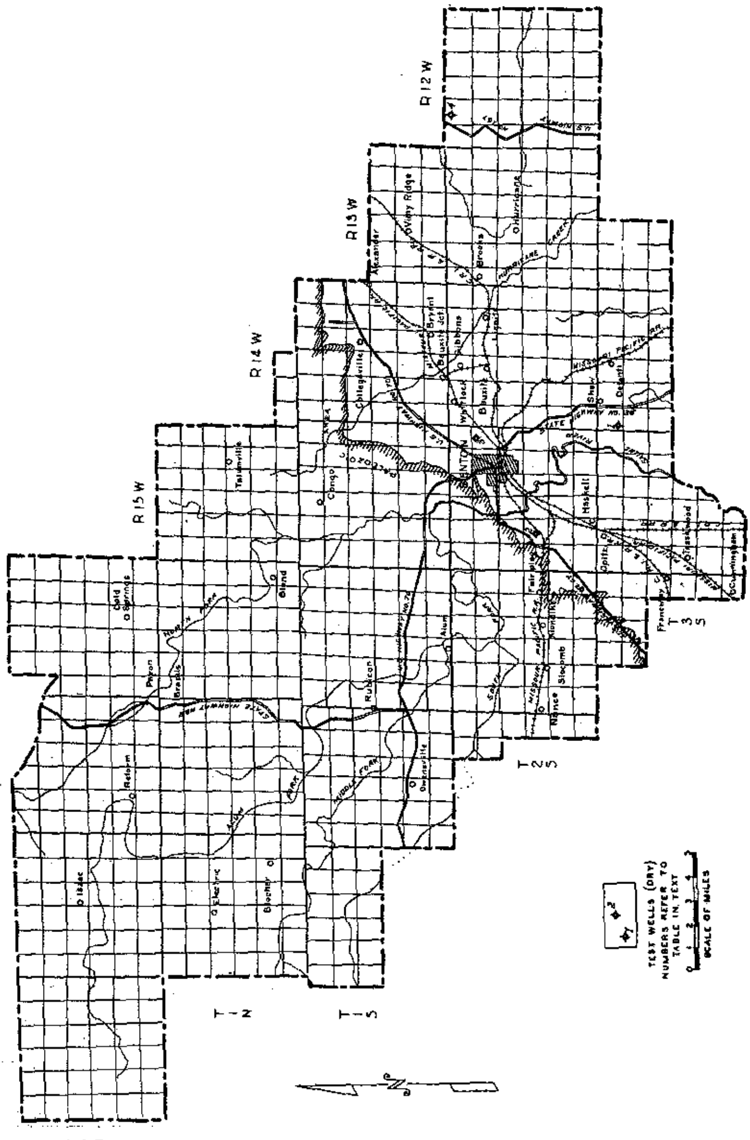


FIGURE 88.—Map of Saline County.

SEVIER COUNTY

The northern part lies in the Ozark province and the re-ainder of the county in the Gulf Coastal Plain. The rocks at e surface in the Ozark province are sandstones and shales be-nging to the Jackfork sandstone and Stanley shale of Paleozoic ge. The Comanche series, represented by the Trinity group, is the surface in the central part, and the Gulf series, up to and cluding the Annona chalk, is at the surface in the southern part Sevier County. The wide flood plains of Little River, Cossatat iver and Saline River, are underlain by sands, gravels, and ams of Pleistocene and Recent age.

The basement rocks on which the Cretaceous sediments ac-imulated slope southward to a depth of about 2,500 feet below a level in the southern part of the county. The rate of dip inges from 75 to 150 feet per mile.

The Trinity group of the Comanche series in Sevier County as been described by Miser and Purdue[11], who include these sedi-ents in the Trinity formation. They recognize several mem-ers beginning with a sand member at the top; the De Queen mestone member,. made up of limestone and green clay with ypsum and celestite near the base; variegated clays containing ie Ultima Thule gravel lentil; the Dierks limestone lentil con-sting fossiliferous limestone and small amounts of green ay; and a lower sand member with the Pike gravel member at ie base. The total thickness of the Trinity formation where xposed at the surface is from 600 to 900 feet.

The Trinity group increases in thickness to the south and is stimated to total about 2,000 feet in the southeastern corner of evier County where these sediments may be differentiated into ie Paluxy sand, Upper Glen Rose, anhydrite zone, Lower Glen ose, and Travis Peak formations.

The Trinity rocks contain deposits of asphalt in Sevier ounty where the asphalt impregnates nearly horizontal beds f loose sand in the basal part of the Dierks limestone lentil or till lower beds in the Trinity. The deposits consist of asphaltic and layers ranging from an inch to several feet in thickness.

The Trinity strata dip to the south at the rate of 75 to 100 eet per mile.

A map showing test wells in Sevier County is shown in 'igure 89.

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[11] Miser, H. D., and Purdue, A. H., Asphalt deposits and oil conditions in southwestern Arkansas: . S. Geol. Survey, Bull. 691-J, 1918.

———. Geology of the De Queen and Caddo Gap quadrangle, Arkansas: U. S. Geol. Survey

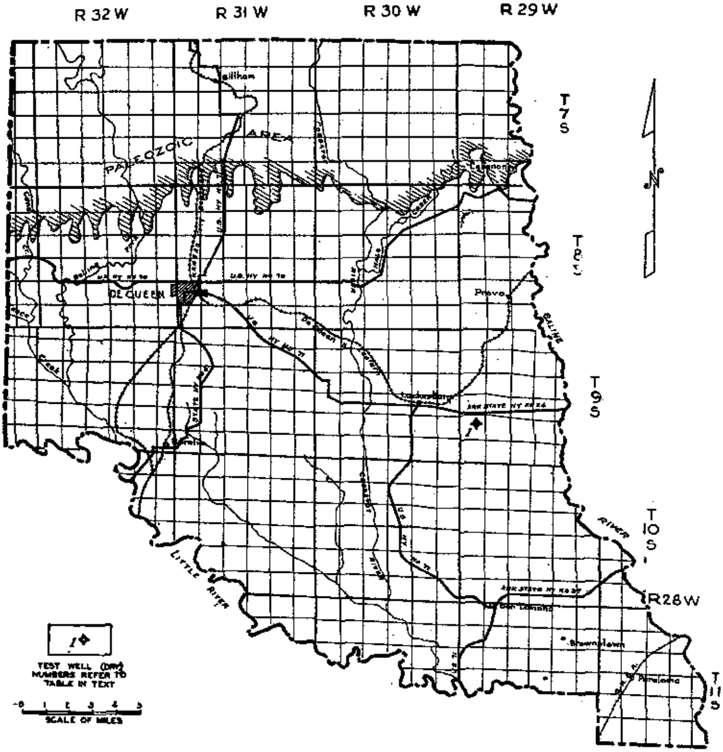

FIGURE 89.—Map of Sevier County.

List of wells drilled in Sevier County

No.,	Company Farm & Number	Location Sec.	Twp.	R.	T. D.	Elev.*	Depth to Nacatoch feet	Depth to red shale feet	Oldest formation penetrated
1	Sevier County O. & G. Co. (Moler et al), Jefferson Trust Co. No. 1	30	9S	29W	Inc	......	Complete log not available; probably slapped or Paleozoic rocks.		
2	......	18	10S	28W	......	......	No information.		

* Letters refer to key to datum for elevatioo on page 261.

UNION COUNTY

LOCATION

Union County adjoins the Louisiana line on the south, Columbia County on the west, Ouachita County on the north. Ouachita River, forming the eastern and northeastern boundary, separates Union County from Ashley, Bradley, and Calhoun counties.

GENERAL FEATURES

Union County is a dissected uplands area with altitudes ranging from 225 feet in the east-central part to 300 feet or more in the western part of the county. A wel-marked ridge forms the drainage divide between the north flowing streams emptying into Smackover Creek and the south and southeast flowing streams emptying into Ouachita River. East of Hillsboro and Urbana and north of El Dorado and Lisbon the surface decreases in elevation and gradually descends to the bottom lands along Ouachita River and Smackover Creek.

The principal oil-producing fields of the Coastal Plain of Arkansas lie within or in part within this area.

STRATIGRAPHY

The Cockfield formation, uppermost member of the Claiborne group of Tertiary age, forms the surface rocks over Union County except over the flood plain of Ouachita River and Smackover Creek where these strata are mantled with sands, gravels, and loams of Pleistocene and Recent age. Deep wells have penetrated all of the Tertiary and the Upper Cretaceous strata, and a considerable part of the Comanche strata. The Lion Oil and Refining Company's Hayes A-9 well in sec. 4, T. 16 S., R. 15 W., penetrated the Comanche strata and was abandoned in rock salt. A generalized section of formations in Union County is given in Table 56.

BASEMENT ROCKS

The basement rocks are not definitely known to have been reached in deep wells drilled in Union County, but it is probable that the rock salt penetrated in the Smackover field is older than Mesozoic and may be of Permian age.

CRETACEOUS

COMANCHE SERIES

The base of the Gulf series rests unconformably on the truncated edges of Comanche strata ranging in age from Upper Glen Rose in the southwestern part to early Travis Peak in the eastern part of the county. (See Figs. 90, 91, and 92).

TABLE 56.—*Generalized section of formations in Union County*

System	Series	Formation	Thickness in feet	Character
Quaternary	Pleistocene and Recent	Terrace and river deposits Unconformity	0-85	Alluvial sands, gravels, clays, and loams in the flood plains of the principal streams.
Tertiary	Eocene	Claiborne	850-1200	Lignitic sand and clay in upper part; glauconitic sand and marl; sand and clay.
		Wilcox	550-675	Lignitic sands and clays.
		Midway Unconformity	400-500	Gray and blue noncalcareous clays, calcareous clays and marls in lower 50 to 75 feet of beds.
Cretaceous	Gulf	Arkadelphia marl	0-120	Dark-gray to black calcareous shale and marls.
		Nacatoch and Saratoga chalk	230-275	Calcareous sand, sandy limestone, shale and chalk.
		Marlbrook marl	80-200	Light - colored to greenish - gray marls, chalky marls, and sandy marl.
		Ozan	0-125	Micaceous gray and greenish marl and sandy marls and light-colored micaceous sands.
		Brownstown marl	0-110	Dark gray clay and shale in western part; gray shale and sandy shale in eastern part.
		Tokio-Woodbine Unconformity	250-550	White to green sand, gray to green clays, in part lignitic and in part tuffaceous; red clays and sand in lower part.
	Comanche (Trinity group)	Upper Glen Rose	0-350	Earthy limestone, shales, thin beds of sands and red shale.
		Anhydrite zone	0-500	Massive and thin bedded anhydrite, limestone, and shale.
		Lower Glen Rose	0-900	Earthy limestone, gray and red shales and sand.
	Comanche	Travis Peak	500-2000	Red shale and sand.
Paleozoic	Neocomian ?	Unconformity	0-600+	Marine limestone, shale, and sand.

Most of Union County, except the eastern and southeastern parts, is believed to be underlain by a series of marine beds which have been provisionally assigned to the Neocomian. These rocks are believed to rest directly on pre-Cretaceous rocks and at the top are in contact with the Travis Peak formation of Trinity age. The Travis Peak formation consists of red clays and sands which in the western part are 2,000 feet or more thick and probably not more than 500 feet thick in the southeastern part of the county. The Lower Glen Rose formation is about 1,000 feet thick in the western part and is absent in the eastern part of the county. These strata change laterally to the east and northeast as evidenced in the thinning of the limestone members, in the appearance of sands and red clays interbedded with calcare-

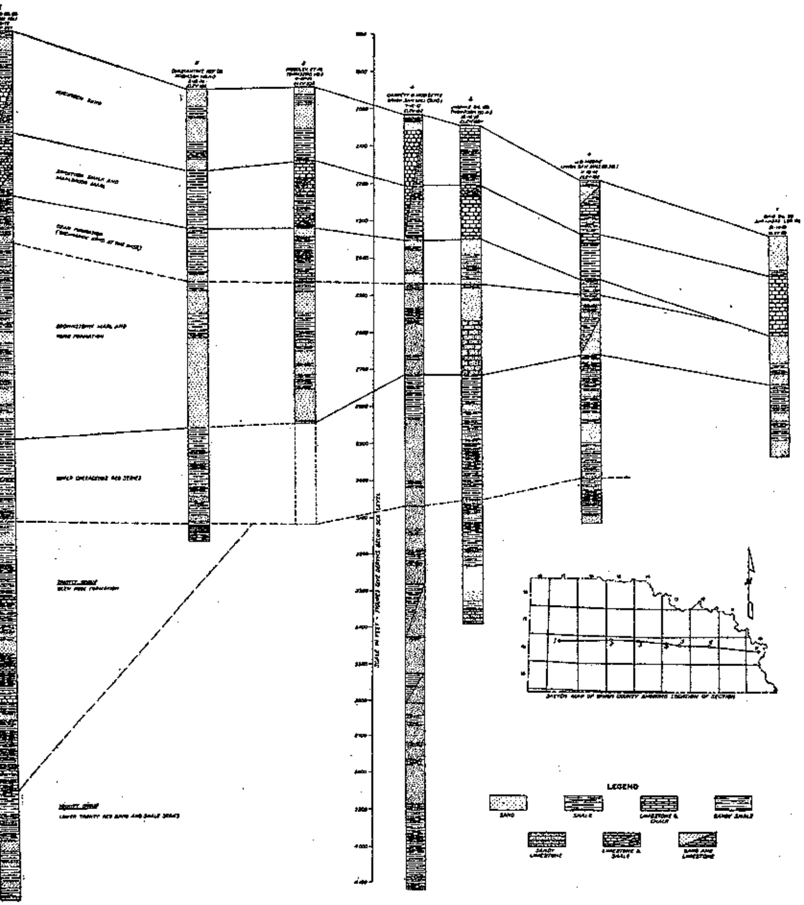

FIGURE 90.—East-west cross section through Union County showing rrelation of Cretaceous sediments.

is shale and impure limestones. The Upper Glen Rose and the nhydrite zone of the Glen Rose formation are present only in ne southwestern part of Union County where they have a maxi-ıum aggregate thickness of 500 to 600 feet. (See Pl. XII.)

GULF SERIES

The Gulf series increases in thickness from east to west. It less than 600 feet thick in the southeastern corner; 1,000 feet nick along Ouachita River in the northern part; and 1,350 to 400 feet thick in the southwestern corner of the county. There re corresponding variations in the distribution and the charac-er of the formational units included in the Gulf series.

The Tokio-Woodbine section is made up of an upper, non-red nember which ranges in thickness from 100 to 400 feet, with the reater thickness in the western part; and a lower member con-

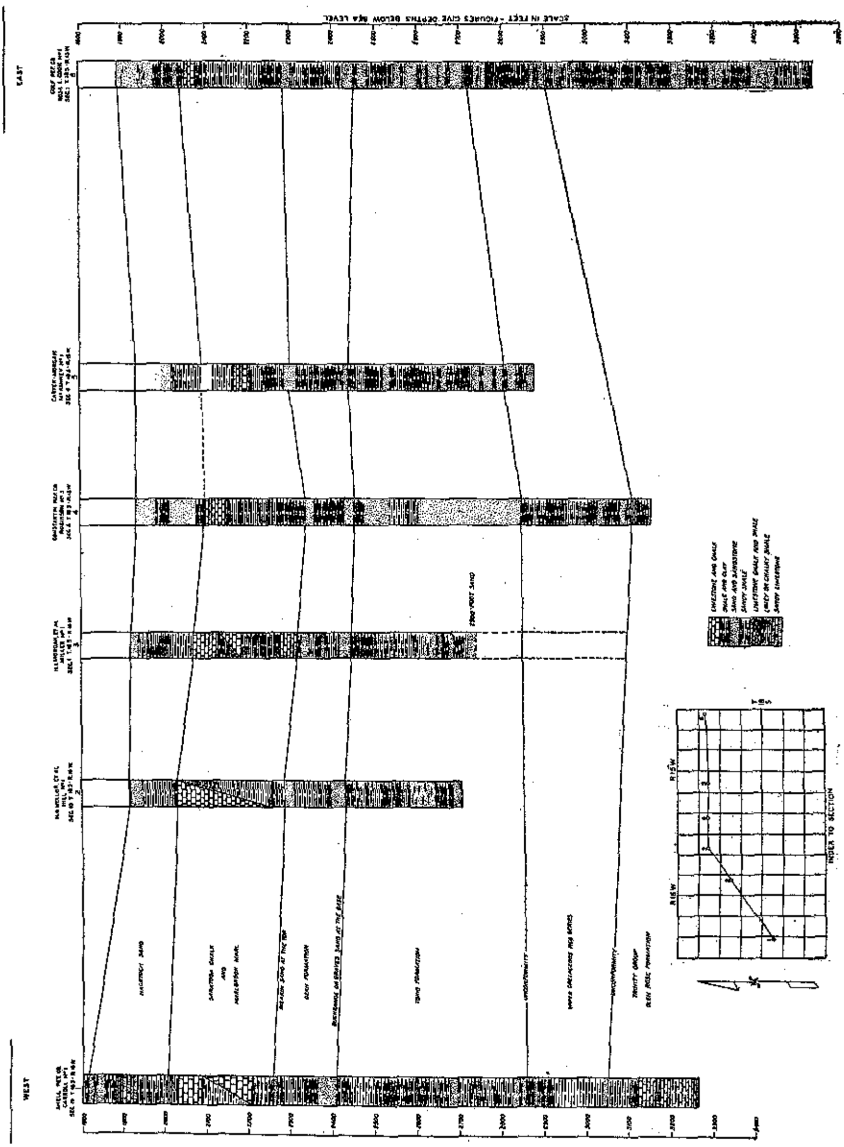

FIGURE 91.—Cross section through El Dorado field showing correlation of Cretaceous sediments.

sisting chiefly of red clays interbedded with sand. The lower member varies in thickness from about 50 feet in the northwestern part and 375 feet in the central part of Union County. The Brownstown marl is 100 to 110 feet thick in the western part, thins eastward, and is overlapped by the Ozan formation in the eastern part of the county. The Ozan formation is about

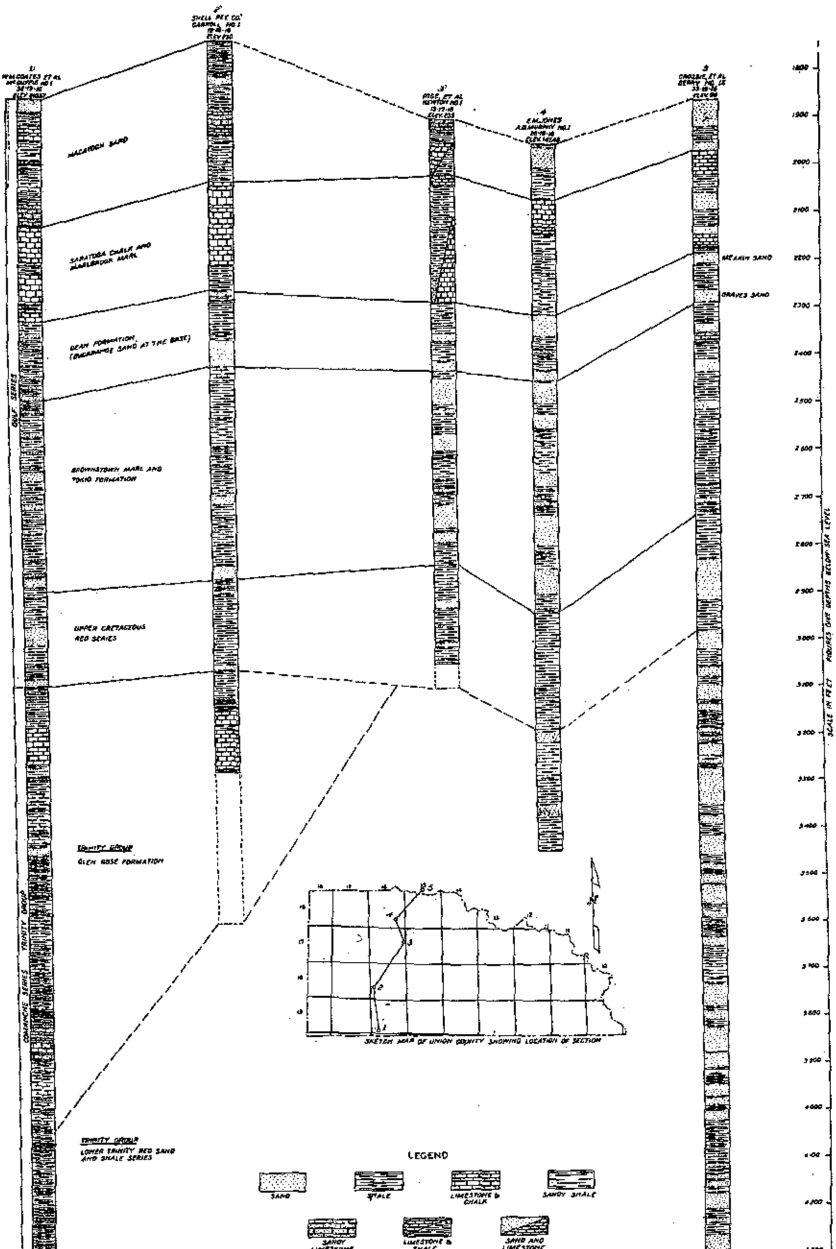

FIGURE 92.—North-south cross section through Union County showing correlation of Cretaceous sediments.

125 feet thick in the western part where it consists of marls with the Buckrange sand at the base. It decreases in thickness and becomes increasingly sandy to the east. The Marlbrook marl,

which probably includes beds of Annona age, ranges in thickness from 80 feet in the southeastern part to 200 feet in the western part of the county. The Nacatoch formation and the Saratoga chalk are not readily differentiated in the central and eastern parts of the area; their combined thickness ranges from 230 to 275 feet. The Arkadelphia marl thins to the southeast and is not recognized as a formational unit in the southeastern corner of the county.

TERTIARY

EOCENE SERIES

The Tertiary strata increase in thickness to the northeast. The Midway formation is from 400 to 500 feet thick. The Wilcox formation is about 550 feet thick in the western part and 600 to 675 feet thick in the eastern and northeastern parts of the county. The Claiborne sediments range in thickness from 850 feet in the northwestern to 1,200 feet in the northeastern part of Union County. The Cockfield formation of the Claiborne group is estimated to be 225 feet thick in the northeastern part of the county. The Cook Mountain is estimated to range in thickness from 150 to 200 feet. The Sparta sand is estimated to be about 375 feet thick in the western part and about 275 feet thick in the northeastern part. The Mount Selman is estimated to be about 350 feet thick in the western and about 400 feet thick in the eastern part of Union County.

QUATERNARY

PLEISTOCENE AND RECENT SERIES

Alluvial depsits of Pleistocene and Recent age underlie the flood plains of Ouachita River and Smackover Creek to estimated depths of 75 feet.

STRUCTURE

The strike of the Comanche strata is northwest-southeast and the dip is to the southwest. (See Plate XII). The rate of dip in the area southwest of a line drawn from Louann to near the southeast corner of T. 19 S., R. 12 W., is estimated to be from 75 to 110 feet per mile. To the east of this area the rate of dip is not determinable, but the records of deep wells indicate a decided flattening of the dip in the Urbana district.

The generalized structure of the Gulf series, drawn on top of the Meakin sand as recorded in deep wells, is shown in Plate XX. The top of the Meakin sand lies at depths of 2,100 to 2,150 feet below sea level in the northwestern part; at 2,400 to 2,550 feet below sea level in the southwestern part; and at 2,600 to 2,750 feet below sea level in the northeastern part of Union County. The dominant structural trends are northwest-southeast, which correspond rather closely with the strike of the

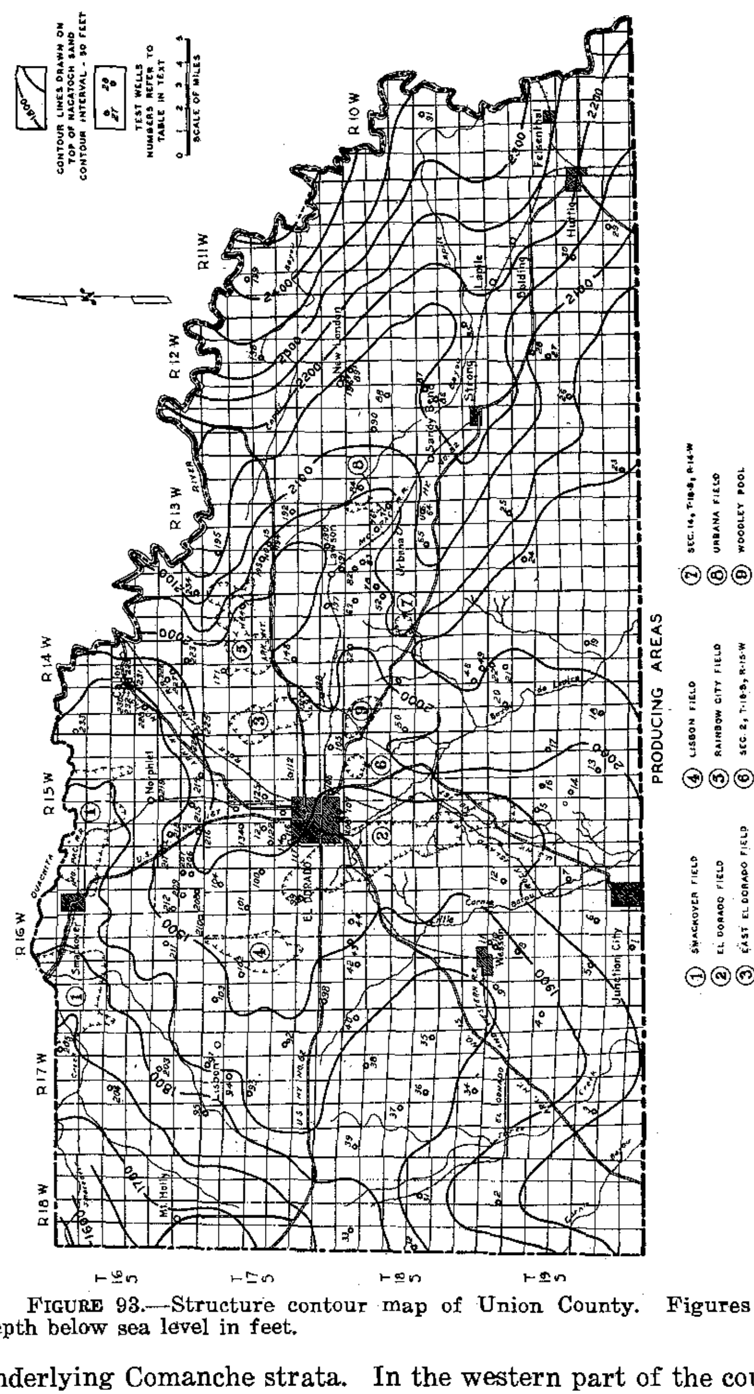

FIGURE 93.—Structure contour map of Union County. Figures give depth below sea level in feet.

underlying Comanche strata. In the western part of the county a structural trend begins in the Stephens field and extends southeastward into the northwest corner of T. 19 S., R. 16 W. The top of the Meakin sand lies at depths of 2,150 feet below sea level in the northeastern corner of Union County but plunges along the axis to lie at a depth of 2,350 feet below sea level at the south end in T. 19 S., R. 16 W. The plunge is not at a uniform rate but is interrupted by flattening to form structural terraces upon which may be locally superimposed closures of a few feet.

Another structural trend begins in the Norphlet district of the Smackover field, extends southeast through the Rainbow City field and the Lawson district in the northeast corner of T. 18 S., R. 13 W., where it bends to the east and continues in that direction through the Urbana district and through the northern part of T. 18 S., R. 12 W. This structural trend terminates in the Smackover fault immediately to the north of the Norphlet dome. Along the axis the structural features are represented by structural noses and structural terraces, and locally by domes with a few feet of closure. A syncline parallels this structural trend on the south. The eastward deflection of the axis is believed to reflect the influence of the uplift immediately to the south in Louisiana. The structure of the producing areas have been described in Part II. The structure of Union County, contours drawn on top of the Nacatoch sand, is shown in Figure 93.

List of wells drilled in Union County

No., Company Farm & Number	Location Sec.	Twp.	R.	T. D.	Elev.*	Depth to Nacatoch feet	Depth to red shale feet	Oldest formation penetrated
1 Williams Oil Co., Brown No. 1	4	20S	16W	2229	265[a]	2193	———	Naactoch
2 Morefield & Foster, Edwards No. 1	2	19S	18W	3014	246[d] 253.77[a]	2186	———	Tokio-Woodbine
3 Hinton and Mattocks, Murphy No. 1	29	19S	17W	3008	216[d] 224.4[a]	2109	———	Tokio-Woodbine
4 O'Brien et al, Fee No. 2	13	19S	17W	3036	263[d]	2140	———	Tokio-Woodbine
5 Mutual Oil Co., Spooner No. 1	29	19S	16W	2141	210.9[h] 207[d]	2141	———	Nacatoch
6 Jones & Murphy, McDonald No. 1	27	19S	16W	3012	225[d]	2170	———	Tokio-Woodbine
7 Carnahan et al, Combs No. 1	24	19S	16W	3007	141[a]	2165	———	Tokio-Woodbine
8 Union Petrol. Co., Helms No. 1	9	19S	16W	2142	186.1[d]	2038	———	Nacatoch
9 Kemp et al, Gaza No. 1	6	19S	16W	2605	224[d] 207[a]	2105	———	Browns-town
10 Doern et al, Bradley No. 1	4	19S	16W	2512	207[d] 172[h]	2108	———	Ozan
11 W. G. Doern, Fletcher No. 1	4	19S	16W	3016	251[d] 226[a]	2095	———	Tokio-Woodbine

No., Company Farm & Number	Location Sec.	Twp.	R.	T. D.	Elev.*	Depth to Nacatoch feet	Depth to red shale feet	Oldest formation penetrated
12 Milo Drilling Co., Trimble No. 1	1	19S	16W	—	173^{d}	2095	—	Brownstown
13 Fullilove Drlg. Co., Pepper No. 1	26	19S	15W	2504	246^{d} 235.7^{g}	2235	—	Marlbrook
14 Richardson et al, Meek No. 1	22	19S	15W	3008	150^{d}	2215	—	Tokio-Woodbine
15 Bailey et al, Cobb No. 1	16	19S	15W	2164	222^{a} 174.3^{d}	21 0	—	Nacatoch
16 Nichols-Stock, Anglin No. 1	15	19S	15W	2245	241^{l} 241^{d} 235.17^{a}	2203	—	Nacatoch
17 So. Oil & Land Co., Brezeale No. 1	13	19S	15W	2237	210.66^{a} 204.66^{d}	—	—	Nacatoch
18 Garrett-Modisette, Ford No. 1	30	19S	14W	2375	226^{a} 193^{d}	—	—	—
19 Jones & Murphy, Union Saw Mill No. 1	27	19S	14W	3045	186.26^{a} 186.86^{a}	2145	2945	Basal Upper Cretaceous red beds
20 Jones & Murphy, Loutre Shingle Co. No. 1	5	19S	14W	2701	139^{d} 147^{h}	2160	—	Tokio-Woodbine
21 Raridan Oil Co., J. Ogden No. 1	4	19S	14W	—	222^{d} 223	2240	—	Tokio-Woodzine
22 Magnolia Petrol. Co., Chandler No. 1	4	19S	14W	3485	205^{d} 210^{a}	2210	3150	Travis Peak
23 A. H. Tarver, Sample No. 1	36	19S	13W	2508	234^{d} 241^{o}	2295	—	Marlbrook
24 Allison et al, Howard No. 1	8	19S	13W	3003	239^{d}	2215	2970	Basal Upper Cretaceous red beds
25 Wingfield et al, Morrison No. 1	3	19S	13W	3105	176^{d}	2244	2902	Travis Peak
26 Starke et al, Little No. 1	21	19S	12W	2734	211^{d} 223^{a}	2270	—	Tokio-Woodhine
27 Matthews et al, Lewis No. 1	14	19S	12W	2684	150^{d} 135.6^{a}	2170	—	Tokio-Woodbine
28 Matthews, Teel No. 2	11	19S	12W	2663	134^{d}	2205	2850	Travis Peak
29 Ark. Orlg. Co., Townes No. 1	34	19S	11W	2702	90	2285	2615	Basal Upper Cretaceous red beds
30 Block Oil Co., Easter No. 1	21	19S	11W	—	100	—	—	—
31 Lion O. & R. Co., Murphy Ld. Co. No. 1	23	18S	18W	3078	245^{a}	2089	3060	Basal Upper Cretaceous red beds
32 Trinity Petrol. Co., Edgar Lbr. Co., (Pressley & Calig) No.1	23	18S	17W	3200	263^{a} 257			Woodbine
33 Lion O. & R. Co., Craig No. 1	4	18S	18W	—	278^{d}	2078	3180	Glen Rose
34 D. H. Allday, J. B. Moore No. 1	33	18S	17W	3002	234^{d}	2048	—	Tokio-Woodbine

No., Company Farm & Number	Location Sec.	Twp.	R.	T. D.	Elev.*	Depth to Nacatoch feet	Depth to red shale feet	Oldest formation penetrated
35 Nat. G. & Fuel Corpn., J. A. Taylor No. 1	23	18S	17W	3165	257[d] 253.81[a]	2055	3148	Basal Upper Cretaceous red beds
36 Forest Oil Co., Mayfield No. 1	21	18S	17W	2914	264[d] 276	2060	-------	Tokio-Woodbine
37 Big Four Oil Co., Rogers No. 1	17	18S	17W	3017	241[d] 245[a]	2015	-------	Tokio-Woodbine
38 Calgo Oil Co., Primm No. 1	9	18S	17W	3105	250.7[d]	2045	-------	Travis Peak
39 Arrendale et al, Murphy No. 1	6	18S	17W	2220	248[d] 254[a]	2080	-------	Nacatoch
40 Wall et al, Johnston No. 1	1	18S	17W	3040	192[d] 194.1[a]	-------	-------	Tokio-Woodbine
41 White Oil Co., Murphy No. 1	22	18S	16W	3026	195.26[a] 148[d] 157.1[h]	2045	-------	Tokio-Woodbine
42 Magnolia Petrol. Co., Eckstrom No. 1	5	18S	16W	3320	229[c] 229[d]	2119	3092	Travis Peak
43 A. H. Stolz et al, Wait No. 1	4	18S	16W	2927	259[d] 256[h]	2174	-------	Tokio-Woodbine
44 Standard Oil Co., E. Aaronson No. 1	3	18S	16W	3333	203.48[d]	2120	3035	Travis Peak
45 Constantine Refg. Co., Hill No. 1	1	18S	16W	2242	253[a]	2225	-------	Nacatoch
46 Weiss and Goedke, Thurlkill No. 1	29	18S	15W	3009	219.42[a]	2111	-------	Tokio-Woodbine
47 Beall & Thomas, Pendleton No. 1	36	18S	14W	3026	235[d] 254.6[a]	2236	-------	Tokio-Woodbine
48 J. H. Williams et al, Robertson No. 1	33	18S	14W	3007	173[d] 175.8[g]	2168	-------	Tokio-Woodbine
49 Patt Marr & Morris Drlg. Co., Robertson No. 1	33	18S	14W	2347+	219.5[a]	-------	-------	-------
50 Jones & Grimes, J. Williams No. 1	18	18S	14W	2235	234[a]	2219	-------	Nacatoch
51 Gulf Refg. Co. (Robb et al) Thomas No. 1	16	18S	14W	2800	203[d] 195[a]	2210	-------	Tokio-Woodbine
52 Walbar Drlg. Co., Morrison No. 1	12	18S	14W	2625	258[d] 264[a]	2280	-------	Ozan
53 Jones & Grimes, J. T. Van Hook No. 10	8	18S	14W	2252	248[a]	2230	-------	Nacatoch
54 T. J. Woodley et al, Van Hook No. 1	7	18S	14W	2210	243.3[a] 232.5[a]	2192	-------	Nacatoch
55 Jones & Grimes, J. T. Van Hook No. 1	7	18S	14W	2195	199.98[a]	2180	-------	Nacatoch
56 Jones & Grimes, Hill No. 1	7	18S	14W	2243	236.31[a]	2220	-------	Nacatoch
57 Grimes Bros., Van Hook No. 9	7	18S	14W	2224	221[a]	2206	-------	Nacatoch
58 Nat. G. & Petrol. Co., Lovett No. 1	6	18S	14W	2194	213.10	2187	-------	Nacatoch
59 Jones & Grimes, Alphin No. 1	6	18S	14W	2184	210[a]	2155	-------	Nacatoch
60 Jones & Grimes, [illegible]	5	18S	14W	[illegible]	[illegible]	[illegible]		Nacatoch

No., Company Farm & Number	Location Sec.	Twp.	R.	T. D.	Elev.*	Depth to Nacatoch feet	Depth to red shale feet	Oldest formation penetrated
61 Jones & Grimes, J. A. Rowland No. 1	5	18S	14W	2206	212.35[a]	2190	....	Nacatoch
62 E. M. Brown, Grace No. 1	3	18S	14W	2666	229.93[f] 242[d] 243.66[a]	2215	....	Ozan
63 Humble O. & R. Co., Cordell No. 1	1	18S	14W	3124	171[a]	2218	2947	Basal Upper Cretaceous red beds
64 Thorpe et al, Peck No. 1	22	18S	13W	2702	156.76[a] 150[d]	2250	....	Ozan
65 Penn-Wyoming O. Co., Union Saw Mill No. 1	21	18S	13W	3089	198[d] 203[h]	2260	3069	Basal Upper Cretaceous red beds
66 Olvey et al, Simmons No. 1	15	18S	13W	2682	180[a]	2215	....	Ozan
67 Simms O. Co., Crawford No. 1	14	18S	13W	2731	159.62[a]	2230	....	Tokio-Woodbine
68 Marine Oil Co., Winn Estate No. 1	11	18S	13W	2705	225.93[a]	2247	....	Tokio-Woodbine
70 Marine Oil Co., Thompson No. A-2	10	18S	13W	3004	183[a]	2220	2963	Basal Upper Cretaceous red beds
71 Marine Oil Co., Thompson No. B-1	10	18S	13W	2707	213[a]	2242	....	Tokio-Woodbine
72 Marine Oil Co., Winn No. B-1	10	18S	13W	3002	199.44[a]	2223	2868	Basal Upper Cretaceous red beds
73 The Sun Co., Thompson No. 1	10	18S	13W	2657	164[a]	2240	....	Tokio-Woodbine
74 Marine Oil Co., Thompson No. 1	10	18S	13W	2660	166[a]	2195	....	Tokio-Woodbine
75 Simms Oil Co., Simmons No. 1	9	18S	13W	3115	147[b] 150[h] 153.55[a] 163.6	2198	2898	Travis Peak
76 Simms Oil Co., Ballard No. 1	9	18S	13W	2556	173.75[k]	2198	....	Ozan
77 Nat. G. & Fuel Corp., Cordell No. 1	9	18S	13W	3100	134.03[a]	2174	2886	Basal Upper Cretaceous red beds
78 Garrett-Modisette Drlg. Co., Union Saw Mill No. 1	7	18S	13W	4309	189[f] 192[d]	2208	2901	Travis Peak
79 Walber et al, Cordell No. 2	6	18S	13W	2984	179[a] 167[a]	2235	2887	Basal Upper Cretaceous red beds
80 Humble O. & R. Co., Webb No. 1	6	18S	13W	3027	201[g]	2266	2950	Basal Upper Cretaceous red beds
81 Phillips Petrol. Co., D. Dennie No. 1	6	18S	13W	3039	196[d] 184[a]	2242	2908	Basal Upper Cretaceous red beds

No., Company Farm & Number	Location Sec.	Twp.	R.	T. D.	Elev.*	Depth to Nacatoch feet	Depth to red shale feet	Oldest formation penetrated
82 Superior Oil Co., Cordell No. 1	5	18S	13W	2985	163[d] 160	2215	2885	Basal Upper Cretaceous red beds
83 So. Crude O. Co., Hill No. 1	5	18S	13W	3004	150 153[d]	2215	2865	Basal Upper Cretaceous red beds
84 Wingfield et al, Hadley No. 1	2	18S	13W	2600	159[d]	2220	....	Ozan
85 Peer Oil Co., Hollis No. 1	36	18S	12W	3354	102[a] 97[d] 103.7	2145	2791	Travis Peak
86 H. L. Hunt et al, Dykes No. 1	21	18S	12W	3445	116 118.8[b]	2230	2850	Travis Peak
87 The Texas Co., Wallace Clark Mer. Co. No. 1	21	18S	12W	2844	134.6[a] 137[d]	2122	....	Tokio-Woodbine
88 Bondurant et al, Turbeville No. 1	9	18S	12W	2665	170[d] 183.9[a]	2260	....	Ozan
89 Bondurant et al, Stegall No. 1	3	18S	12W	3045	124[a]	....	2858	Basal Upper Cretaceous red beds
90 Bondurant et al, Garner No. 1	8	18S	12W	2635	202	2320	....	Ozan
91 Ohio Oil Co., Ark. Lbr. Co. No. 1	21	18S	10W	3004	68.8[a]	2407	2808	Basal Upper Cretaceous red beds
92 Love Bros., Darden (Edgar) No. 1	23	17S	17W	2500	251[d] 244.56[a]	2120	....	Tokio-Woodbine
93 Bradley & Cazort, Pate No. 1	16	17S	17W	2480	188[d] 177[g]	2075	....	Tokio-Woodbine
94 Wingfield et al, Gallagher No. 1	10	17S	17W	3007	194[d] 197.32[a]	1950	2910	Basal Upper Cretaceous red beds
95 Walker Drlg. Co., Flournoy No. 1	5	17S	17W	3007	218[d] 211[a]	2025	....	Ozan
96 Kelly Joint, Walker No. 1	5	17S	17W	2535	254[a]	2025	....	Ozan
97 Nebraska Oil Co., Gallagher (Nelson) No. 1	3	17S	17W	2110	160[a] 172[d]	2060	....	Nacatoch
98 Nat. G. & Fuel Corpn., F. H. Carey No. 1	31	17S	16W	2201	225[d] 224.1[a]	2125	....	Nacatoch
99 Imperial O. & G. Prod. Co., Goodwin No. 1	26	17S	16W	3112	....	....	....	Tokio-Woodbine
100 Rice et al, Newton No. 1	13	17S	16W	3286	235[a]	2150	3227	Basal Upper Cretaceous red beds
101 Rogers et al, Hayney No. 1	11	17S	16W	....	189[a]	2145	....	Marlbrook
102 Edwin M. Jones, Dumas No. 1	8	17S	16W	2560	203.54[d]	2150	....	Ozan
103 Owens et al, Duke No. 1	6	17S	16W	2745	229[d]	2140	....	Ozan

No., Company Farm & Number	Location Sec.	Twp.	R.	T. D.	Elev.*	Depth to Nacatoch feet	Depth to red shale feet	Oldest formation penetrated
104 Ackerley et al, (Crutchfield et al) Murphy No. 1	1	17S	16W	2171	222[a]	2148	-------	Nacatoch
105 Timms et al, Banks No. 1	36	17S	15W	2250	237.96[a]	2235	-------	Nacatoch
106 Crestline, Talford No. 1	34	17S	15W	2224	236[a]	2181	-------	Nacatoch
107 Mitchell O. Co., Dr. Wilson (Kinard) No. 1	33	17S	15W	2240	-------	2150	-------	Nacatoch
108 Union Central O. Co., Burns No. 1	33	17S	16W	2062	-------	2000	-------	Nacatoch
109 Dr. List et al, List No. 1	25	17S	15W	2328	225	2172	-------	Nacatoch
110 The Ohio Oil Co., J. P. Murphy No. 1	24	17S	15W	2931	208.21[a]	2158	-------	Tokio-Woodbine
111 Olvey & Holleyfield, Kirksey No. 1	24	17S	16W	2198	-------	2187	-------	Nacatoch
112 Quaker City Petrol. Co., Polk & Ezzell No. 1	23	-7S	15W	2804	246[a] 195.8[a] 218[f]	2192	-------	Tokio-Woodbine
113 Bradley & Cazort, Forest Park (Miles) No. 1	21	17S	15W	2576	205[a]	2025	-------	Ozan
114 Richardson O. Co., Hudson No. 1	20	17S	16W	-------	238.41[a]	-------	-------	-------
115 Wilder O. & G. Co., Dumas No. 1	20	17S	15W	2169	207.02[a] 205[a]	2152	-------	Nacatoch
116 Wilder O. & G. Co., (J. E. Stock) Dumas No. 2	20	17S	15W	2170	191.44[1]	2169	-------	Nacatoch
117 Ark. Drlg. Co., Rodgers No. 1	20	17S	15W	2202	-------	2197	-------	Nacatoch
118 Humble O. & R. Co., Hammond No. 1	19	17S	15W	2695	180[a]	2098	-------	Tokio-Woodbine
119 Standard Oil Co., J. R. Ingram No. 1	19	17S	15W	2194	245.72	2185	-------	Nacatoch
120 El Dorado O. Synd., Well No. 1	19	17S	15W	2230	-------	2195	-------	Nacatoch
121 El Dorado O. Synd., Neihuss No. 1	19	17S	15W	2192	199.4[1]	2146	-------	Nacatoch
122 Cooper-Henderson, Hammond No. 1	19	17S	15W	3200	203.91[1]	2140	-------	Glen Rose
123 Quaker City Petrol. Co., Dumas No. 1	17	17S	15W	2282	198.5[a]	2179	-------	Nacatoch
124 D. J. Johnston, Tr., Haney No. 1	17	17S	15W	2152	170.31[a]	2140	-------	Nacatoch
125 Quaker City Petrol. Co., Mittendorf No. 1	15	17S	15W	3135	142.40[a] 133.40[a]	2141	-------	Tokio-Woodbine
126 Quaker City Petrol. Co., Sloan No. 1	14	17S	15W	2192	201.55[a]	2177	-------	Nacatoch
127 Gulf Refining Co., Polk & Ezzell No. 1	13	17S	15W	2227	252.31[a]	2195	-------	Nacatoch
128 H. I. Morgan, Ezzell No. 2	12	17S	15W	3202	194[a]	2150	2978	Basal Upper Cretaceous red beds or Travis Peak
129 D. R. & Paul S. Keever, Ezzell No. 3	12	17S	15W	2132	140[a]	2130	-------	Nacatoch
130 D. R. & Paul S. Keever, Ezzell No. 4	12	17S	15W	2159	140[a]	2120	-------	Nacatoch

No., Company Farm & Number	Location Sec.	Twp.	R.	T. D.	Elev.*	Depth to Nacatoch feet	Depth to red shale feet	Oldest formation penetrated
132 Quaker City Petrol. Co., Polk & Ezzell No. 2	11	17S	15W	2198	-------	2172	-------	Nacatoch
133 Mazda O. Corpn., Boyd No. 1	9	17S	15W	2692	123.47[a]	2115	-------	Tokio-Woodbine
134 Imperial O. & G., Products Co., Calvert No. 1	8	17S	15W	2152	-------	2133	-------	Nacatoch
135 Humble O. & R. Co., Pratt (Fee) No. 1	5	18S	15W	-------	-------	-------	-------	-------
136 Gulf Refg. Co., J. W. McGoughn No. 1	29	17S	14W	3073	231.2[a]	2318	3000	Basal Upper Cretaceous red beds
137 Walbar Drlg. Co., Williams (2nd Hole) No. 1	36	17S	14W	2628	210.35[a]	2283	-------	Saratoga
138 Falvey & Turner, Grace No. 1	32	17S	14W	2272	238.7	2260	-------	Nacatoch
139 Nat. G. & Petrol. Co., C. L. Smith No. 2	30	17S	14W	2208	-------	2207	-------	Nacatoch
140 El Dorado Nat. G. Co., Gaddy No. 1	20	17S	14W	2214	232.9[a]	2210	-------	Nacatoch
141 El Dorado Nat. G. Co., Gaddy No. 2	30	17S	14W	2277	263.98[f]	-------	-------	Nacatoch
142 Terryfield O. & G. Co., Smith No. 1	30	17S	14W	2213	235[a]	2212	-------	Nacatoch
143 East Side O. & G. Co., McCurry No. 1	30	17S	14W	2300	300.76 291.57[f]	-------	-------	-------
144 Myerscough & Halsey, Well No. 2	29	17S	14W	2189	210[a]	2184	-------	Nacatoch
145 Myerscough & Halsey, Smith No. 3	29	17S	14W	2184	204[a]	2181	-------	Nacatoch
146 Imperial O. & G. Prod. Co., D. E. Morgan No. 2	29	17S	14W	2211	230.50[a]	2210	-------	Nacatoch
147 Imperial O. & G. Prod. Co., T. L. Smith No. 3	29	17S	14W	2223	243.24[a]	2222	-------	Nacatoch
148 Powell et al, Beckham No. 1	22	17S	14W	2236	212.42[f] 212.53[a]	2223	-------	Nacatoch
149 Gulf Refg. Co. of La., C. L. Smith No. A-1	20	17S	14W	2219	243[a]	2214	-------	Nacatoch
150 Gulf Refg. Co. of La., C. L. Smith No. A-2	20	17S	14W	2215	236.10[a]	2211	-------	Nacatoch
151 Gulf Refg. Co., of La., C. L. Smith A-3	20	17S	14W	2167	232.17[a]	2158	-------	Nacatoch
152 Gulf Refg. Co. of La., C. L. Smith No. A-4	20	17S	14W	2204	227.03[a]	2200	-------	Nacatoch
153 Gulf Ref. Co. of La., C. L. Smith No. A-5	20	17S	14W	2190	203.6[a]	2186	-------	Nacatoch
154 S. Ark. O. & G. Co., McCurry No. 1	19	17S	14W	2191	210.5[1] 209.49[f]	2165	-------	Nacatoch
155 Gulf Refg. Co. of La., Polk et al No. 2	18	17S	14W	2148	172.55[a]	2145	-------	Nacatoch
156 Gulf Refg. Co. of La., Polk et al No. 3	18	17S	14W	2134	-------	2134	-------	Nacatoch
157 Gulf Refg. Co. of La., Polk et al No. 5	18	17S	14W	2144	173.65[a]	2140	-------	Nacatoch
158 Gulf Refg. Co. of La., Polk et al No. 6	18	17S	14W	2145	173.65	2141	-------	Nacatoch
159 J. E. Stock, Ezzell No. 1	18	17S	14W	2867	164.1[a]	2139	-------	Tokio-Woodbine
160 Nat. G. & Fuel Co., Tuft No. 1	18	17S	14W	2910	172[a]	2138	2894	Basal Upper Cretaceous red beds
161 Patt Marr, (Latark O. Co.) J. B. Graves No. 1	17	17S	14W	2880	194.23[a]	2169	-------	Tokio-Woodbine

No., Company Farm & Number	Location Sec.	Twp.	R.	T. D.	Elev.*	Depth to Nacatoch feet	Depth to red shale feet	Oldest formation penetrated
162 Patt Marr, (Wilson O. Co.) Moody No. 1	16	17S	14W	2815	246[a]	2222	....	Tokio-Woodbine
163 Patt Marr, J. C. Moody No. 2	16	17S	14W	3004	264.87[a]	2249	....	Tokio-Woodbine
164 Simrall et al, Finley No. 1	12	17S	14W	3175+	110[d] 115[n]	2154	2940	Basal Upper Cretaceous red beds
165 Magna Prod. Co., Dumas No. 1	11	17S	14W	3240	180[a] 178[a]	2145	2980	Basal Upper Cretaceous red beds
166 Magna Prod. Co., Townsend No. 1	10	17S	14W	3047	171[a] 163[d]	2173	....	Basal Upper Cretaceous red beds
167 Garrett-Modisette, Gregory No. 1	10	17S	14W	2749	151[n]	2120	....	Tokio-Woodbine
168 Pure Oil Co., Gregory No. 1	10	17S	14W	3153	123[d]	2135	2890	Basal Upper Cretaceous red beds
169 Chew et al, Kelley No. 1	9	17S	14W	2225	242[a]	2222	....	Nacatoch
170 Clark & Greer, Roseboom (Tufts) No. 1	7	17S	14W	2872	158.06[a]	2138	....	Tokio-Woodbine
171 Rovenger O. Corpn., McCain No. 1	4	17S	14W	3095	160[n] 150[a]	2175	2879	Basal Upper Cretaceous red beds
172 Ohio Oil Co., R. Pumphrey No. 1	2	17S	14W	3013	119[n]	2200	2870	Basal Upper Cretaceous red beds
173 Ohio Oil Co., R. Pumphrey No. 2	2	17S	14W	3014	119[n]	2200	2910	Basal Upper Cretaceous red beds
174 Ohio Oil Co., R. Pumphrey No. 3	2	17S	14W	....	150.41[n]	2260	2930	Basal Upper Cretaceous red beds
175 Ohio Oil Co., Goode No. 1	2	17S	14W	3205	124.38[n]	2120	2910	Basal Upper Cretaceous red beds
176 Ohio Oil Co., Goode No. 2	2	17S	14W	....	142.82[n]	2209	2960	Basal Upper Cretaceous red beds
177 Edwin M. Jones, Crain No. 1	2	17S	14W	3062	166[n] 162.42[a]	2270	2815	Basal Upper Creta- per Cretaceous red beds
178 Edwin M. Jones, W. R. Crain No. 2	2	17S	14W	3012	114.57 118[n]	2230	2892	Basal Upper Cretaceous red beds
179 Edwin M. Jones, W. R. Crain No. 3	2	17S	14W	4014	160[n]	2245	2908	Travis

No., Company Farm & Number	Location Sec.	Twp.	R.	T. D.	Elev.*	Depth to Nacatoch feet	Depth to red shale feet	Oldest formation penetrated
180 Edwin M. Jones, W. R. Crain No. 4	2	17S	14W	3067	158.48[n] 155[a]	2263	2915	Basal Upper Cretaceous red beds
181 Ohio Oil Co., W. R. Crain No. 1	1	17S	14W	3014	111[a] 109[n]	2195	2880	Basal Upper Cretaceous red beds
182 Ohio Oil Co., W. R. Crain No. 2	1	17S	14W	3020	118.06[n]	2210	2855	Basal Upper Cretaceous red beds
183 Ohio Oil Co., W. R. Crain No. 3	1	17S	14W	2996	105.27[a]	2210	2856	Basal Upper Cretaceous red beds
184 Ohio Oil Co., W. R. Crain No. 5	1	17S	14W	3047	149.78[n]	2250	2865	Basal Upper Cretaceous red beds
185 Ohio Oil Co., W. R. Crain No. 6	1	17S	14W	3031	127.57[n]	2206	2907	Basal Upper Cretaceous red beds
186 Ohio Oil Co., W. R. Crain No. 7	1	17S	14W	3035	129.19[n]	2205	2860	Basal Upper Cretaceous red beds
187 Ohio Oil Co., Will Pumphrey No. 1	1	17S	14W	3037	103.35[a]	......	2861	Basal Upper Cretaceous red beds
188 Ohio Oil Co., J. W. Pumphrey No. 1	1	17S	14W	3212	143[n] 137[d]	......	2941	Basal Upper Cretaceous red beds
189 Magnolia Petrol. Co., Carroll No. 1	1	17S	14W	2985	100[n] 97[d]	2120	2867	Basal Upper Cretaceous red beds
190 E. T. Teter et al, Burnside No. 1	33	17S	13W	3056	220[h] 234.6[a]	2216	2939	Basal Upper Cretaceous red beds
191 Superior Oil Co., Jerry No. 1	32	17S	13W	3022	163[a]	2215	2947	Basal Upper Cretaceous red beds
192 Wingfield et al, McGough No. 1	22	17S	13W	3105	156[h] 153.51[a]	2240	2939	Basal Upper Cretaceous red beds
193 Lion O. & R. Co., Horn No. 1	17	17S	13W	3216	233[a]	2230	3152	Basal Upper Cretaceous beds
194 Carleton-Owens, C. H. McGough No. 1	16	17S	13W	2508	225.8	......	......	......
195 McLaughlin O. & G. Co., Stough No. 1	5	17S	13W	3023	170[d] 170.7[a]	......	......	Tokio-Woodbine
196 Bondurant et al, Will Clarke	34	17S	12W	2611	179[d] 160[a]	2325	......	Marlbrook

No.	Company Farm & Number	Location Sec.	Twp.	R.	T. D.	Elev.*	Depth to Nacatoch feet	Depth to red shale feet	Oldest formation penetrated
97	Federal Petrol. Co., Union Saw Mill No. 2	28	17S	12W	3218	183[d] 185.5[a]	2325	2980	Basal Upper Cretaceous red beds
98	Federal Petrol. Co., Union Saw Mill No. 1	14	17S	12W	3001	77[d] 85.5[a] 95.5	—	2925	Basal Upper Cretaceous red beds
99	Sundby, Fruen & Booth, Rowland No. 1	8	17S	11W	3104	110	2305	2885	Basal Upper Cretaceous red beds
200	Miller et al, McKae No. 1	33	16S	18W	2050	191.9[a]	—	—	—
201	Ohio Oil Co., Lewis No. 1	23	16S	18W	2044	191[d]	1911	—	Nacatoch
202	Ark. Invincible, McRae No. 1	16	16S	18W	2737	161.25[d]	1765	—	Tokio-Woodbine
203	Olvey et al, Yocum No. 1	27	16S	17W	3190	227[d]	2052	—	Tokio-Woodbine
204	Ohio Oil Co., Sue Gordon No. 1	15	16S	17W	2957	188[a] 180[d]	1942	—	Toiko-Woodbine
205	Y. E. Hildreth, Smith No. 1	2	16S	17W	2852	197.4[a]	2002	—	Tokio-Woodbine
206	Beadel & Field, O. F. Murphy No. 1	36	16S	16W	2105	156[a]	2072	—	Nacatoch
207	Flo-Ark. Oil Co., Murphy No. 1	36	16S	16W	—	204[d]	2157	—	—
208	Magnolia Petrol. Co., Pearl Murphy Jr., No. 1	35	16S	16W	2785	164	2005	—	Tokio-Woodbine
209	Bauxite Oil Co., Murphy No. 1	35	16S	16W	2068	158.74[a]	2067	—	Nacatoch
210	W. H. Harper, Matthews No. 1	34	16S	16W	2855	147[a] 133[d]	2048	—	Tokio-Woodbine
211	Magnolia Petrol. Co., B. N. Murphy No. 1	28	16S	16W	3500	200[a]	2052	3080	Travis Peak
212	Edwin M. Jones, A. D. Murphy No. 1	26	16S	16W	3542	147.46[a]	2067	3035	Travis Peak
213	Magnolia Petrol. Co., Union Lbr. Co. No. 1	21	16S	16W	2656	190.5[a]	2055	—	Tokio-Woodbine
214	Klotsch et al, Lester No. 1	35	16S	15W	2184	177[d] 176.6[g]	2057	—	Nacatoch
215	Ark. Fuel O. Co., Burton No. 1	33	16S	15W	3302	116.38[d]	2000	—	Travis Peak
216	Transc. Oil Co., (Wilford et al) Goodwin-Dumas No. 1	32	16S	15W	3001	165[d] 154.77[a]	2114	2955	Basal Upper Cretaceous red beds
217	Pure Oil Co., Nancy Lawton No. 1	30	16S	15W	3555	172.32[d]	2080	9205	Travis Peak
218	Ark. Fuel O. Co., J. R. Dumas No. 2	29	16S	15W	2651	126[d]	2005	—	Tokio-Woodbine
219	Patt Marr, Armstrong No. 1	27	16S	15W	2051	114.4[d]	2047	—	Nacatoch

No.	Company Farm & Number	Location Sec.	Twp.	R.	T. D.	Elev.*	Depth to Nacatoch feet	Depth to red shale feet	Oldest formation penetrated
220	Haviland Co., Inc., T. E. Hinshaw No. 1	23	16S	15W	2358	99.88[j] 97.8[i]	1989	-------	Marlbrook
221	Sam M. Richardson, E. G. Murphy No. 3	23	16S	15W	2371	93[a]	1955	-------	Marlbrook
222	Federal Petrol. Co., J. T. Murphy No. 4	22	16S	15W	3052	140[a]	2008	2873	Basal Upper Cretaceous red beds or Travis Peak
223	Isola Oil Trust, Matthews No. 1	34	16S	14W	2257	197[d]	-------	-------	Nacatoch
224	Lendon Petrol. Co., (Douche et al) Davis No. 3	31	16S	14W	2500+	181[a] 180[g]	2148	-------	-------
225	Lenden Petrol Co., (Douche et al) Tufts No. 1	31	16S	14W	2181	188[a]	2140	-------	Nacatoch
226	Stone Oil Co., Davis No. 1	28	16S	14W	2171	199[d]	2115+	-------	Nacatoch
227	Thompson et al, Carleton (Long) No. 1	28	16S	14W	2750	149[d]	2100	-------	Tokio-Woodbine
228	Traffic Oil Co., Goodwin No. 1	20	16S	14W	3022	174[d]	2081	2865	Basal Upper Cretaceous red beds
229	Ward & Williams, Goodwin No. 1	16	16S	14W	2552	126[a]	2135	-------	Ozan
230	Williams et al, (Ward & Williams) Goodwin No. 2	16	16S	14W	2443	112.86[a] 114[d]	2154	-------	Ozan
231	Williams et al, (Ward & Williams) Goodwin No. 3	16	16S	14W	2428	116[a]	-------	-------	Ozan
232	E. M. Brown, Jr., et al, Goodwin No. 1	16	16S	14W	2634	112,96[a]	2152	-------	Ozan
233	Sid Umsted et al, Arnold & Usery No. 1	6	16S	14W	2785	83[a]	-------	2765	-------
234	Owenwood O. Corpn., Goode No. 1	31	16S	13W	3105	115[a]	2182	2874	Basal Upper Cretaceous red beds
235	Carter-Morgan, McKinney No. 1	4	18S	15W	3089	205.94[a]	2115	3016	Basal Upper Cretaceous red beds
236	Rushing et al, Gregory No. 1	11	17S	14W	2570+	166[a]			
237	Lyell et al, Stegall No. 1	11	17S	13W	3350	170[d]	2212	2968	Travis Peak
238	Magna Prod. Co., Rowland No. 1	14	17S	14W	2999	150	2163	2870	Basal Upper Cretaceous red beds
239	E. M. Jones, Stegall No. 1	22	17S	14W	3250	180	2198	2919	Travis Peak
240	Magna Prod. Co., Rowland No. 2	14	17S	14W	2974	125.3	2080	2935	Basal Upper Creta- beds ceous red
241	J. D. Moore, Tr., Pagan No. 1	18	18S	11W	3304	141.8	2328	2852	Travis Peak

No., Company Farm & Number	Location Sec.	Twp.	R.	T. D.	Elev.*	Depth to Nacatoch feet	Depth to red shale feet	Oldest formation penetrated
242 Imperial O. Co., Kavanaugh No. 1	1	17S	15W	3401	----	2168	2980	Travis Peak
243 Wilson & Chapman, Thompson	4	17S	15W	2350	144	2145	----	Saratoga
244 J. P. Hawkins, Goodwin No. 1	6	17S	15W	2575	----	----	----	----
245 Man & Hooser, Norton No. 1	12	18S	15W	3508	185	2178	2970	Travis Peak
246 Oil Well Corpn., Snyder No. 1	6	17S	14W	3350	----	----	----	----
247 Pure Oil Co., Gaddy No. 1	13	17S	14W	3804	----	----	----	----
248 O. W. Estes, Bates No. 1	13	17S	14W	3602	----	----	----	----
249 Walber, Wilson No. 1	25	17S	13W	3304	----	----	----	----
250 Patterson & Neighbors, Barnett No. 1	33	17S	14W	3251	260	2208	----	Basal Upper Cretaceous red beds
251 O. W. Estes, Telford No. 1	35	17S	15W	2906	223a	2130	----	Tokio-Woodbine
252 Gulf Refg. Co., Rosa L. Cook No. 1	1	18S	15W	3765	----	----	----	----
253 Barnett, Pace No. 1	11	16S	18W	3040	----	----	----	----
254 T. J. Bush, Tr., McDonald No. 1	11	17S	18W	3573	203	1870	----	----
255 Hawthorne O. & G. Co., Smith No. 1	8	16S	17W	3525	141	1860	2818	Travis Peak
256 Sunby et al, Yocum No. 1	29	16S	17W	3536	----	----	----	----
257 S. B. Hickman et al, Hogg No. 1	35	16S	17W	----	----	----	----	----
258 E. L. Foster, Murphy Ld. Co. No. 1	22	17S	17W	1400	----	----	----	Wilcox
259 Garrett & Modisette, Murphy Ld. Co. No. 1	30	17S	17W	3515	271	2116	3058	Travis Peak
260 Trinity Petrol. Co., Edgar Lbr. Co. No. 1	21	18S	18W	3250	273 318.5	2138	----	Tokio-Woodbine
261 Ark. Fuel Oil Co., Burns No. 1	14	18S	17W	3535	209	2018	3062	Glen Rose
262 Arrendale & Edmonds, Gallagher & Nelson No. 1	18	18S	17W	2274	271	2036	----	Nacatoch or Saratoga
263 H. O. Miller, Lilly Hill No. 1	10	18S	16W	2875	167	2086	----	Tokio-Woodbine
264 Shell Petrol. Co., Carroll No. 1	19	18S	16W	3503	230	2006	3100	Glen Rose
265 Staples, Ainsworth No. 1	8	19S	16W	2183	164.5	----	----	----
266 Coates, Tr., McDuffie No. 1	32	19S	16W	4506	211	2075	3260	Travis Peak
267 Terry Summerfield O. Co., Green No. 1	19	19S	15W	2590	----	----	----	----
268 R. J. McMurry, Sale No. 1	23	19S	15W	3505	----	----	----	----
269 C. Gibbs, Tr., Morris No. 1	32	19S	15W	2515	----	----	----	----
270 Lion O. & R. Co., Stowe No. 1	4	17S	13W	2315	162	----	2943	Travis Peak

No., Company Farm & Number	Location Sec.	Twp.	R.	T. D.	Elev.*	Depth to Nacatoch feet	Depth to red shale feet	Oldest formation penetrated
271 Federal Petrol. Co., Union Sawmill No. 1	5	17S	12W	3340	118	2250	2860	Travis Peak
272 Pitcher et al, Ark. Tbr. Co. No 1	21	17S	11W	3107	65	....	2930	Basal Upper Cretaceous red beds
273 Modisette Drlg. Co., Union Sawmill No. 1	1	18S	14W	3330	226	2239	2931	Travis Peak
274 Carter et al, Burnside No. 1	23	18S	14W	2310	....	....	....	....
275 Bell et al, Terrell No. 1	23	18S	14W	2594	....	....	....	....
276 Oil Well Corpn., Union Sawmill No. 1	10	19S	1 W	2365	222	2190	....	Saratoga
277 E. M. Jones, Loutre Lbr. Co. No. 1	17	19S	14W	3505	139	2135	2958	Travis Peak
278 Jones et al, Murphy No. 1	36	19S	14W	3035	150	2158	....	Basal Upper Cretaceous red beds
279 E. M. Jones, Hardy & Murphy No. 1	34	19S	14W	4069	141	....	2920	Travis Peak
280 So. Crude O. Pur. Co., Oliver No. 1	11	18S	13W	3629	150.5	2210	2848	Travis Peak
281 Oil Fields Corpn., Simmons No. 1	13	18S	13W	3602	167	2305	2875	Travis Peak
282 C. H. Murphy, Union Sawmill No. 1	18	18S	13W	3615	188	2200	2895	Travis Peak
283 Ark. Drlg. Co., Norris No. 1	17	18S	12W	3400	144.5	2210	2990	Travis Peak
284 H. L. Hunt, Trammell No. 1	28	18S	12W	4365	108	2308	2855	Travis Peak
285 H. L. Hunt, Dopson No. 1	3	19S	12W	3307	133	....	....	Travis Peak
286 Harrell, Tr., Teel No. 1	11	19S	12W	3177	149	2175	....	Basal Upper Cretaceous red beds
287 R. W. Rhodes, Union Sawmill No. 1	14	19S	11W	1775	156	....	2784	Travis Peak
288 Rhodes, Tr., Union Sawmill No. 1	14	19S	11W	3210	156	....	2785	Travis Peak
289 Stark et al, Powell No. 1	35	18S	15W	3510	205	2155	3205	Trinity
290 Ark. Drlg. Co., Cargill No. 1	4	18S	13W	3341	195	2275	2892	Travis Peak

* Letters refer to key to datum for elevation on page 261.

WHITE COUNTY

The part of White County west of a line running northeast-southeast a few miles west of the St. Louis, Iron Mountain, and Southern Railway is in the Ozark province. The remainder of the county is in the Gulf Coastal Plain.

The Ozark province is underlain by Paleozoic sandstones and shales of Pennsylvanian age. The Paleozoic rocks pass beneath the Coastal Plain sediments and extend eastward with increasing depths; estimated to be about 1,250 feet below sea level in the southeastern corner of White County. The Quaternary alluvium which immediately underlies the surface of the Coastal Plain area to estimated depths of 100 to 150 feet is of Pleistocene and Recent age. These deposits rest unconformably upon Paleozoic and Eocene strata.

Upper Cretaceous strata of Arkadelphia and Nacatoch age underlie most of the Coastal Plain area of White County. They are a few feet thick in the area bordering the Ozark province but increase in thickness to the southeast and are estimated to be 150 feet thick in the southeast corner of the couny. The strata dip to the southeast. The top of the Nacatoch formation is estimated to lie at depths of 1,100 feet below sea level in the southeastern corner of the county.

Structure contour map of White County, drawn on top of Nacatoch sand, is shown in Figure 94.

List of wells drilled in White County

No.,	Company Farm & Number	Location Sec.	Twp.	R.	T. D.	Elev.*	Depth to Nacatoch feet	Depth to red shale feet	Oldest formation penetrated
1	W. C. Chancellor, Stephenson No. 1	14	7N	7W	1960	--------	--------	--------	Paleozoic
2	Arkansas Invincible, Gravemire No. 1	29	8N	6W	1864	--------	--------	--------	Paleozoic

* Letters refer to key to datum for elevation on page 261.

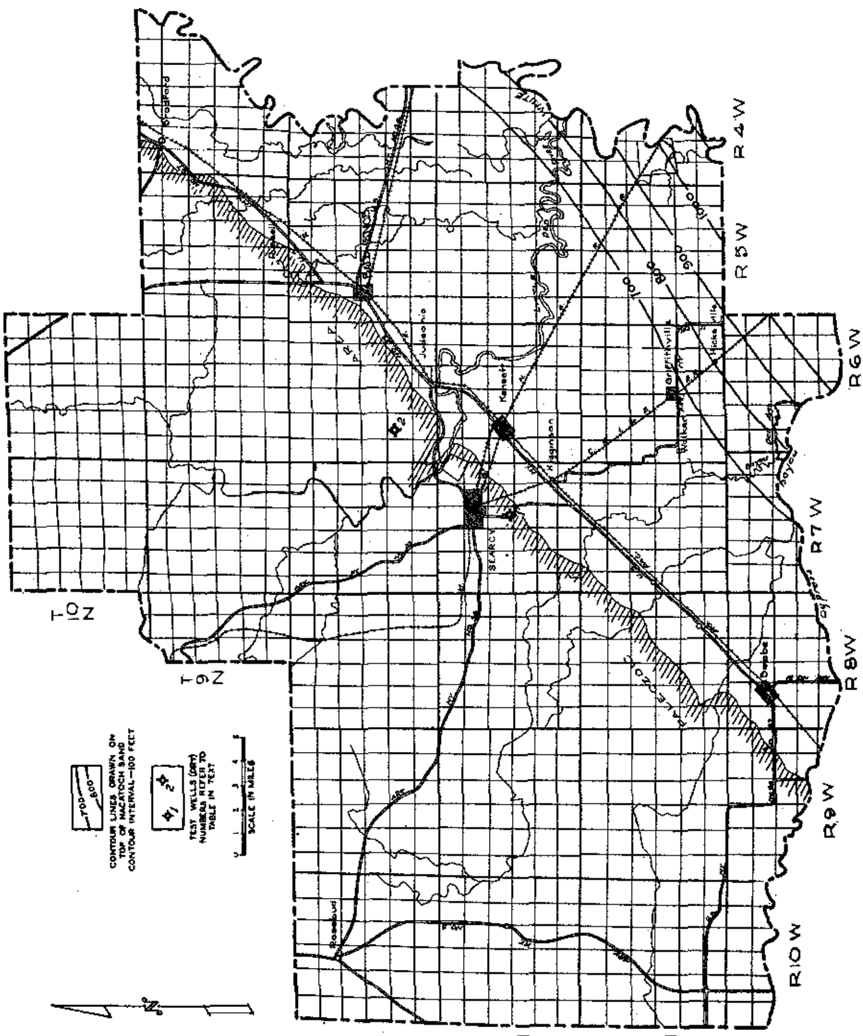

FIGURE 94.—Structure contour map of White County. Figures give depth below sea level in feet.

WOODRUFF COUNTY

LOCATION

Woodruff County is bounded on the south by Monroe County, on the west by Prairie and White counties, on the north by Jackson County, and on the east by St. Francis and Cross counties.

GENERAL FEATURES

The three principal topographic subdivisions of the upper Mississippi embayment are: Crowley's Ridge, the Advance lowland, and Mississippi lowland, lying respectively west and east of Crowley's Ridge. Woodruff County lies entirely within the Advance lowland, the surface of which is in general a gently undulating plain 190 to 235 feet above sea level.

STRATIGRAPHY

The materials at the surface throughout Woodruff County, consist of loams, clays, sands, and gravels of Recent and Pleistocene age, which unconformably overlie strata of Eocene age. The Eocene strata range in thickness from about 100 feet in the northwestern part to 1,950 feet in the southeastern part of the county. The Cretaceous strata increase in thickness from about 100 feet in the northwestern part to about 425 feet in the southwestern part of the county. A generalized section of formations is given in Table 57. (See also Fig. 14.)

TABLE 57.—*Generalized section of formations in Woodruff County*

System	Series	Formation	Thickness in feet	Character
Quaternary	Pleistocene and Recent		50-150	Alluvial sands, gravels and clays.
		Unconformity		
Tertiary	Eocene	Undifferentiated	100-1350	Principally sand, clay and sandy clays, in part lignitic; subordinate thin beds of glauconitic sand.
		Midway clays	50-550	Gray and bluish-gray, chiefly noncalcareous clays, characterized by siderite concretions.
		Unconformity		
Cretaceous	Gulf	Arkadelphia marl	0-100+	Gray to dark-gray marl and shale.
		Nacatoch sand and Saratoga chalk	100-250	Chiefly fine-textured glauconitic sand and sandy limestone, with subordinate beds of shale, chalk and limestone.
		Marlbrook marl or older	0-175	Sand, marl, and chalks.
		Unconformity		

Basement rocks

BASEMENT ROCKS

The Coastal Plain sediments were deposited upon a nearly level floor of folded and truncated Paleozoic rocks. Subsequent warping has lowered the floor and tilted it toward the southeast, until it now lies at a depth of about 100 feet below sea level in the northeastern corner and about 2,400 feet below sea level in the southeastern corner of the county. The basement rocks are believed to be essentially the same as the Paleozoic rocks at the surface in the adjacent part of the Arkansas Valley region.

CRETACEOUS

GULF SERIES

The Cretaceous strata decrease in thickness and change laterally in character from east to west as the margin of the Mississippi embayment is approached. The Cretaceous strata are estimated to be 100 feet thick in the northwestern corner of the county, represented by the Arkadelphia marl and Nacatoch sand, and about 500 feet in the southeastern corner of the county, where the Marlbrook marl is believed to be present, in addition to the above named formations. The Arkadelphia marl consists of gray calcareous shale, which, toward the west, become slightly sandy. The Nacatoch is made up principally of sand and sandstone, in part glauconitic with subordinate beds of shale and limestone. The Marlbrook, when present, is in part marl and chalk and in part sandy shale with the sand content increasing from east to west.

TERTIARY

EOCENE SERIES

The Eocene strata have an estimated thickness of about 150 feet in the northwestern part, and about 1,900 feet in the southeastern part of the county. The available data do not permit accurate correlation of the strata which includes the equivalents of the Midway, Wilcox, and Claiborne formations.

The Midway is estimated to range in thickness from about 50 feet in the northwestern part to about 550 feet in the southeastern part of the county. The Claiborne is not believed to be represented in the northwestern part of the area.

QUATERNARY

PLEISTOCENE AND RECENT SERIES

Quaternary alluvium of Pleistocene and Recent age underlie the surface to depths estimated at 50 to 150 feet. Although irregularly bedded, they grade downward in general from fine silty loams or clays at the surface through fine sands to coarse sands and gravels at the base.

STRUCTURE

The structure of Woodruff County is shown in Plate XV, and Figure 95, by means of contour lines drawn on the top of the Nacatoch sand at intervals of 100 feet. The data used in determining the structure are obtained from a relatively few deep wells, therefore, is necessarily generalized.

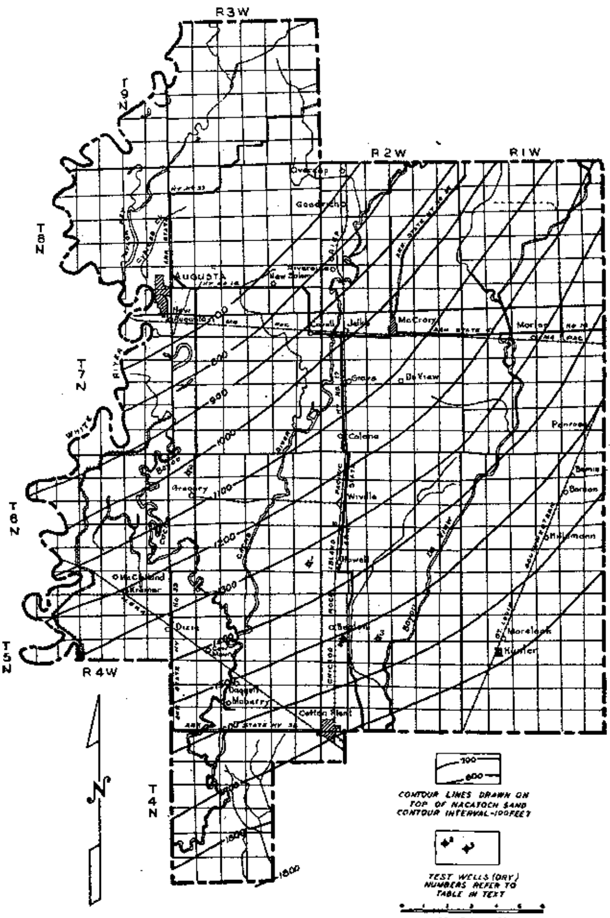

FIGURE 95.—Structure contour map of Woodruff County. Figures give depth below sea level in feet.

The top of the Nacatoch sand is from a few feet to about 100 feet below sea level in the northwestern and about 1,900 feet below sea level in the southeastern corner of the county. The dip is toward the southeast at the rate of 35 to 70 feet per mile.

List of wells drilled in Woodruff County

No., Company, Farm & Number	Location Sec.	Twp.	R.	T. D.	Elev.*	Depth to Nacatoch feet	Depth to red shale feet	Oldest formation penetrated
1 Knox-Adams, Howell No. 1	25	6N	3W	1628	227	1624	....	Nacatoch
2 W. N. Gregory, Gregory No. 1	6	6N	3W	1675	200	....	....	Paleozoic
3 KnoxAdams, James No. 1	9	5N	2W	1896	220	1342	....	Nacatoch
4 Glassel & Myer, Rosser No. 1	7	5N	2W	2011	253			Paleozoic

* Letters refer to key to datum for elevation on page 261.

APPENDIX

UPPER CRETACEOUS OSTRACODA OF ARKANSAS

(Originally published by the Arkansas Geological Survey in 1929. Revised 1931.)

By Merle C. Israelsky

INTRODUCTION

Only those forms which it was felt could be readily distinguished are described in this paper. No ostracods were found in the samples of Tokio at our disposal. Throughout the overlying horizons however, *Nesidea* (Bairdia) and typical *Cytheridea* are common; while occasional specimens of *Paracypris* and *Bythocypris* (?) occur. In generic treatment an attempt has been made to follow G. W. Muller[1].

An effort was made to consult all the papers on the Mesozoic and Tertiary Ostracoda and all the monographs on the Recent Ostracoda. The services of the Research Bureau, National Research Council, were especially valuable in supplying photostatic copies of papers not otherwise available.

The meager literature on the Ostracoda of the European Cretaceous has prevented any comparison of faunules. As will be seen in the descriptive text, few of our species compare closely with described forms. Comparisons are made only where some reasonably close resemblance exists.

Considering only the more or less commonly occuring forms we find *Cythereis hannai* n. sp., *Cythereis bicornis* n. sp., and *Cytheropteron tokiana* confined to the Brownstown formation; *Cythereis ponderosana* n. sp. and *Cytheropteron ponderosana* n. sp. in the Ozan, Annona, and Marlbrook; *Cythereis spoori* n. sp. in the Brownstown and Ozan; *Cytheropteron ledaforma* n. sp. *Cythereis costatana* n. sp, and *Cythereis ivii* n. sp. in the Saratoga, Nacatoch and Arkadelphia; and *Cythereis hazardi* n. sp. in the Nacatoch and Arkadelphia, the environment of the Saratoga chalk apparently being unfavorable to its existence.

L. W. Stephenson[2] divides the Upper Cretaceous or Gulf series into five major divisions: The Woodbine and its equivalents, the Eagle Ford and its equivalents, the Austin chalk and its equivalents, all of which contain characteristic ammonites; the *Exogyra ponderosa* zone and the *Exogyra costata* zone, characterized respectively by these two large oyster-like forms.

No marine Woodbine nor Eagle Ford is known in Arkansas. The Austin chalk of Texas is represented by the Tokio formation. The *Exogyra ponderosa* zone is represented by the Brownstown

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[1] Das Tierreich, vol. 31, Ostracoda, Berlin, 1912.

[2] North Carolina Geol. and Econ. Survey, vol. 5, The Cretaceous formations of North Carolina, ... 1923, and other papers.

marl, the Ozan formation, the Annona chalk, and the Marlbrook marl. The *Exogyra costata* zone is represented by the Saratoga chalk, the Nacatoch sand and marl, and the Arkadelphia marl[3].

Special appreciation is due Mr. William Spooner, who collected most of the surface samples on which this report is based; Mr. Roy T. Hazard, who often accompanied Mr. Spooner in the field; Mr. Garland Grigsby, who picked a large number of the samples considered; Mr. Richard Norton, who permitted the study of Arkadelphia slides in his possession; Mr. Malcolm Helm, who drew the figures under the writer's direction; and Mr. John S. Ivy, who kindly gave permission for the publication of these notes.

Upper Cretaceous Ostracoda found in Arkansas

Species	Axogyra Ponderosa Zone				Exogyra Costata Zone		
	Brownstown	Ozan	Annona	Marlbrook	Saratoga	Nacatoch	Arkadelphia
Cytherura spooneri n. sp.		r		r			
Cytherura ? dubia n. sp.					r		
Cytherura ? saratogana n. sp.					r		
Cytheropteron sp. A.	c	c	c		c	c	c
Cytheropteron sp. B.		c		c	c	c	c
Cytheropteron ledaforma n. sp.					fc	c	c
Cytheropteron tokiana n. sp.	c						
Cytheropteron ponderosana n. sp.		fc	fc	fc			
Cytheropteron saratogana n. sp.					r		
Loxoconcha fletcheri n. sp.					r		
Cythere bruceclarki n. sp.				r			
Cytheridea ? saratogana n. sp.					r		
Cytheridea ? hannai n. sp.		r					
Cythereis ozanana n. sp.		r					
Cythereis ponderosana n. sp.		c	c	c			
Cythereis tridenta n. sp.				r			r
Cythereis communis n. sp.		c	c	c	c	c	c
Cythereis ivii n. sp.					c		r
Cythereis saratogana n. sp.					r		
Cythereis costatana n. sp.					c	c	c
Cythereis hannai n. sp.	c						
Cythereis spoori n. sp.	fc	fc					
Cythereis bartoni n. sp.					r		
Cythereis plummeri n. sp.		r					
Cythereis hazardi n. sp.						fc	c
Cythereis bicornis n. sp.	c						

In the above check list the following abbreviations are used:

[3] See Dane, C. H., Arkansas Geol. Survey, Bull. 2, 1929, for details.

c, common; fc, fairly common; r, rare. These letters do not indicate the number of specimens found, but the frequency of occurrence of the species in samples.

DESCRIPTIONS OF SPECIES[4]

Cytherura spooneri n. sp.

Plate IV A, Figs. 7a, 7b

Description.—Viewed from the side, oblong-ovate; the anterior margin gently rounded, the dorsal nearly straight, the ventral nearly straight, the posterior somewhat attenuated, with the point lying above the medial line; the entire margin thickened; within the margins the surface is covered with polygonal pits, most of which appear to be pentagonal, except on the mammillate spine-bearing knob (spine missing on figured specimen) which lies below the median line near the posterior end of the ventral border; greatest height anterior.

Viewed from below the carapace appears as an elongated diamond truncated anteriorly, the anterior portion longer than the rear.

Hinge without teeth.

Length.—.82 mm.

Remarks.—A closely related but distinct species is *Cythere umbonata* Williamson[5] of the English Cretaceous.

Specimens found after figure was drawn show spines or knob are normal to the length of the shell.

Named for Mr. William C. Spooner, at whose instigation this paper was written.

Holotype.—80233 U. S. Nat. Mus.

Type locality.—Ozan formation, sec. 20, T. 10 S., R. 26 W., Arkansas.

Known occurrence.—Ozan formation (rare) and Marlbrook marl (rare).

Cytherura? dubia n. sp.

Plate IV A, Fig. 6

Description.—Seen from the side, subrhomboidal; anterior and posterior margins sharply rounded, dorsal and ventral margins gently rounded; a weak medial ridge slopes slightly upward from before to behind; strong pits above and below ridge; margins thickened; anterior dorsal tubercle present.

Length.—.44 mm.

Remarks.—This form is somewhat similar to Kuiper's[6] figure of *Cythereis truncata* Reuss, reported from the Oligocene, Miocene, and Pliocene of Europe. *Cytherura clathrata* O. Sars,[7]

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[4] The figured specimens are deposited in the United States National Museum.
[5] Jones, T. R., Mon. Entom. Cret. Form. of England, Paleo. Soc., London, 1849, p. 12, pl. 2, figs. 3a-3g.
[6] Kuiper, Oligocane und Miocane Ostrac. Nederlanden, Groningen, 1918, pl. 3, fig. 31.
[7] Brady, G. S., Trans. Linn. Soc. London, vol. 26, p. 446, pl. 29, figs. 43-46.

a Recent and Pleistocene species, is less closely allied, but an examination of examples of this species shows that it lacks hinge teeth. According to Muller[8] its generic position is doubtful. The anterior dorsal tubercle of *C? dubia* suggests *Cythereis.* [9]

Holotype.—80234 U. S. Nat. Mus.

Type locality.—Saratoga chalk, NW.¼ sec. 3, T. 9 S., R. 22 W., Arkansas.

Known occurrence.—Saratoga chalk (rare).

Cytherura? saratogana n. sp.

Plate IV A, Fig. 8

Description.—Shell thin, glassy, outline as seen from side, elongate subovate; dorsal margin nearly straight, ventral gently curved, anterior sharply rounded, posterior bluntly pointed; ornamented with irregular discontinuous, gently rounded ridges and corresponding furrows, which tend to be concentric with the periphery.

Length.—.67 mm.

Remarks.—*Cytherura costulata* Lienenklaus[10], a Tertiary species, is ornamented with longitudinal ridges and furrows and also has a quite different outline.

Holotype.—80235 U. S. Nat. Mus.

Type locality.—Saratoga chalk, NW¼ sec. 3, T. 9 S., R. 22 W., Arkansas.

Known range.—Saratoga chalk (rare).

Cytheropteron sp. A.

Plate I A, Figs. 1a, 1b, 1c

Description.—Viewed from the side, subovoid; higher before than behind. Viewed from above or below, outline is broadly fusiform, slightly attenuated before and behind; valve contact sinuous dorsally, but slightly sinuous ventrally.

Length.—.99 mm.

Remarks.—As it seems likely that with more material it will be found that this form as here treated is a composite, no specific determination has been attempted. As no closely allied forms have come to the writer's attention from the Comanchean, specimens are figured, as their presence at least suggests a post-Comanchean age.

Plesiotype.—80236 U. S. Nat. Mus.

Locality.—Saratoga chalk, NW¼ sec. 3, T. 9 S., R. 22 W., Arkansas.

Known occurrence.—Tokio formation, Ozan formation, Annona chalk, Saratoga chalk, Nacatoch sand, Arkadelphia marl (common throughout).

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[8] Muller, G. W., Das Tierreich, vol. 31, Ostracoda, Berlin, July, 1912, p. 372.

[9] *Specimens from Mississippi show this to be a Cythereis.*

[10] ... Bd. 46, 1894, pl. 17, figs. 1a-1c.

Cytheropteron sp. B.
Plate I A, Figs. 2a, 2b, 2c, 3

Description.—Seen from the side, subquadrangular; anterior margin gently rounded, posterior sharply rounded spinose; dorsal margin gently rounded, ventral sharply curved and carrying a slightly raised ridge; other margins thickened; surface slopes rapidly from thin dorsal edge to wide ventral surface; strong anterior-dorsal tubercle with pit behind. Seen on edge, fusiform; valve contact sinuous ventrally, nearly straight dorsally.

Length.—.77 mm. (Saratoga species).

Remarks.—Those applied to the preceding species apply equally well here.

Plesiotype.—80237 U. S. Nat. Mus.

Locality.—Saratoga chalk, NW¼ sec. 3, T. 9 S., R. 22 W., Arkansas.

Plesiotype.—(Lost) Ozan formation.

Known occurrence.—Ozan formation, Marlbrook marl, Saratoga chalk, Nacatoch sand, Arkadelphia marl (common throughout).

Cytheropteron ledaforma n. sp.
Plate I A, Figs. 5, 6, 7

Description.—Viewed from side, rostrate, having the appearance of a *Leda*[11]; dorsal margin gently bowed, lower sinuous, anterior margin gently rounded, posterior attentuate. In edge view female subovate, male slightly fusiform. Shell smooth.

Length.—.66 mm.

Remarks.—Specimens from the Nacatoch and Arkadelphia exhibit fine longitudinal striae on the ventral surface. These were probably destroyed in removing the figured specimens from the chalk in which they occurred.

A species somewhat resembling this, but differing in having a much lesser relative height and also in being punctate, is *Cythere (?) shattucki* Ulrich and Bassler[12].

Cotypes.—80238 A, B, C, U. S. Nat. Mus.

Type locality.—Saratoga chalk, NW¼ sec. 3, T. 9 S., R. 22 W., Arkansas.

Known occurrence.—Saratoga chalk (fairly common), Nacatoch sand (common), Arkadelphia marl (common).

Cytheropteron tokiana n. sp.
Plate I A, Figs. 8 ,9a, 9b

Description.—Viewed from side, ovoid-oblong; the anterior and posterior margins gently rounded, the dorsal and ventral margins nearly straight; the alar projection at its apex extending but slightly below the ventral margin at the valve contact;

[11] Leda, a genus of the Pelecypoda.

[12] Ulrich and Bassler, Maryland Geol. Survey, Miocene, 1904, pl. 38, fig. 10.

a large tubercle occurs at the confluence of the dorsal and anterior margin. The shell surface slopes gently from the dorsal margin to the point of the alar projection. Viewed from above or below the outline is hastate, the head long, the shaft short, the barbs rounded.

Length.—.1 mm.

Remarks.—The most closely comparable figure is that referred to *Cythere serrulata* (Bosquet) by Reuss[13].

Called *C. tokiana* because of its apparent restriction to the Tokio formation.

Cotypes.—80239 A, B, U. S. Nat. Mus.

Type locality.—Tokio formation, NE cor. SE¼ sec. 23, T. 10 S., R. 28 W., Arkansas.

Known occurrence.—Tokio formation (common).

Cytheropteron ponderosana n. sp.

Plate II A, Figs. 1a, 1b, 1c

Description.—Viewed from the side, oblong-ovoid; the anterior margin gently rounded, the posterior more sharply rounded, with broad, irregular spines at the rear, dorsal margin slightly curved, the ventral nearly straight and terminated behind by the sharp declivity which descends to the semicircular posterior shelf; the surface of the shell slopes gently upward from the dorsal to the ventral margin, where it joins the ridge of the alar projection. Seen from above or below the outline is sharply sagittate, the barbs slightly bent inward, the head long and flaring, the shaft short and compressed. A large tubercle occurs at the confluence of the dorsal and anterior margins.

Length.—.88 mm.

Remarks.—*Cytheropteron alatum* (Bosquet) var. *robust* Jones and Hinde[14] is close to our species, but lacks the spine-like projection of the wing, as well as differing in detail of outline.

Even closer is *Cythereis cornuta* var. *americana* Ulrich and Bassler[15], but the two may be distinguished readily in edge position.

Called *C. ponderosana* because of its apparent restriction to the *Exogyra ponderosa* zone.

Holotype.—80240 U. S. Nat. Mus.

Type locality.—Ozan formation, SE¼ sec. 28, T. 8 S., R. 22 W., Arkansas.

Known occurrence.—Ozan formation, Annona chalk, Marlbrook marl (fairly common throughout).

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[13] Reuss, Paleontographica, Bd. 20, 1871-75, pl. 27, fig. 8. Not Cypridina serrulata Bosquet. Mem. Soc. Roy. Liege, Tome 4, 2d. part., 1848-49, p. 370, pl. 4, fig. 2.

[14] Suppl. Mon. Cret. Entom. England and Ireland, London, 1890, p. 35, pl. 2, figs. 24-27.

[15] Maryland Geological Survey, Miocene, 1904, pl. 37, figs. 29-33.

Cytheropteron saratogana n. sp.

Plate II A, Figs. 4a, 4b, 4c

Description.—Viewed from side, roughly oblong; the anterior margin gently rounded, the posterior sharply rounded with broad, irregular spines along the lower portion, the dorsal slightly curved, the ventral nearly straight and terminated behind by the sharp declivity which descends to the semicircular posterior shelf; surface of the shell slopes gently from the dorsal to the ventral margin, along which is a ridge; other margins thickened; a strong tubercle at the confluence of the anterior and dorsal margins. Seen from above or below the outline is sharply hastate, the anterior portion long, the posterior short and compressed, the barbs rounded. The alar projection is strongly bent downward.

Length.—.99 mm.

Remarks.—A closely allied species is *Cytheropteron alatum* (Bosquet) var. *robusta* T. R. Jones and Hinde, which differs in detail.

Called *C. saratogana* because of its apparent limitation to the Saratoga formation.

Holotype.—80241 U. S. Nat. Mus.

Type locality.—Saratoga chalk, NW¼ sec. 3, T. 9 S., R. 22 W., Arkansas.

Known occurrence.—Saratoga chalk (rare).

Loxoconcha fletcheri n. sp.

Plate II A, Figs. 2, 3

Description. — Seen from side, subquadrangular; gently rounded anteriorly and posteriorly; nearly straight dorsally and ventrally, these margins subparallel; marginal rim broad; surface coarsely pitted.

Length.—.44 mm.

Remarks.—If our reference of this species to *Loxoconcha* is correct, the species is noticeable for its relatively great length in proportion to its height.

Named for Mr. Corbin D. Fletcher of Shreveport, La.

Cotypes.—80242 A, B, U. S. Nat. Mus.

Type locality.—Saratoga chalk, NW¼ sec. 3, T. 9 S., R. 22 W., Arkansas.

Known range.—Saratoga chalk (rare).

Cythere bruceclarki n. sp.

Plate II A, Figs. 5, 6

Description.—Seen from side, the outline is subovoid; surface punctate, a shallow transverse groove anterior to the center (overemphasized as figured), giving the shell the outward appearance of a *Cytheridea.* The hingement of the left valve consists of a well-developed anterior socket and a feebly developed posterior socket, with no teeth present. The pore canals appear to be simple.

Length.—.44 mm., .48 mm.

Remarks.—The hinge characters and the simple port canals place the species in *Cythere.*

Cotypes.—80243 A, B, U. S. Nat. Mus.

Type locality.—Marlbrook marl, NW cor NE¼ sec. 32, T. 11 S., R. 27 W., Arkansas.

Known occurrence.—Marlbrook marl (rare).

Named for Prof. Bruce L. Clark of the University of California.

Cytheridea? saratogana n. sp.
Plate II A, Figs. 7, 8, 9

Description.—Viewed from side, broadly subovate; dorsal, anterior, and ventral margins gently rounded, posterior pointed, rostrate; shell thin at dorsal valve contact, thick below, with slight ridge at the confluence of the lateral and ventral surfaces. Viewed on edge broadly subovate, broadest anterior to the center. The hinge is like that of *Cytheridea.* The external shell layer is missing; therefore its ornamentation, if any, is unknown.

Length.—.50 mm.

Remarks.—Except for its hinge this species fits poorly into *Cytheridea.*

A form incorrectly figured under the name of *Cytheropteron concentricum* (Reuss[16]) bears a general resemblance but is readily distinguished. Another allied form is *Cytheridea trinitense* Vanderpool[17], which shows the same type of hinge. As Vanderpool remarks, *C. trinitense* is very common in the Trinity. It also occurs in the Fredericksburg. Closely related species abound in the Washita. In contrast to the abundance of this group in the Comanchean, *C. saratogana* is the only species encountered in the Gulf series of Arkansas, and it but rarely.

Called *C. saratogana* because of its apparent restriction to the Saratoga formation.

Cotypes.—80244 A, B, C, U. S. Nat. Mus.

Type locality.—Saratoga chalk, center sec. 8, T. 11 S., R. 25 W., Arkansas.

Known occurrence.—Saratoga chalk (rare).

Cytheridea? hannai n. sp.
Plate II A, Figs. 10a, 10b

Description.—Seen from side, subrhomboidal; valve margins slightly sinuous except the dorsal, which is nearly straight;

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[16] Egger, J. G., Abh. k. bayer. Akad. der Wiss., II Cl., 21 Bd., 1 Abth., 1899, pl. 27, fig. 57. Not *Cytherina concentrica* Reuss, Verstein bohm. Kreidform., 2 Abth., 1846, pp. 104-105, pl. 24, figs. 22a-22c.

[17] Vanderpool, H. C., Journal of Paleontology, vol. 2, No. 2, June, 1928, p. 106, pl. 14, figs. 3, 4, 5, 6.

ornamented with large tubercles; whole surface, including tubercles, finely pitted. The hinge is of the *Cytheridea* type.

Length.—.56 mm.

Remarks.—Like the preceding species, this fits but poorly into *Cytheridea.* The tubercles serve to distinguish it from the preceding species and likewise from those in the Comanchean.

A few species of *Iliocypris* vaguely resemble this species in side view but are otherwise quite distinct.

Named for Dr. Marcus A. Hanna, of Houston, Texas.

Holotype.—80245 U. S. Nat. Mus.

Type locality.—Ozan formation, SE.¼ sec. 28, T. 8 S., R. 22 W., Arkansas.

Known occurrence.—Ozan formation (rare).

Cythereis ozanana, n. sp.
Plate III A, Figs. 1, 2, 3

Description.—Seen from side, subovate; higher before than behind; dorsal margin slightly sinuous, ventral margin gently curved, the anterior gently rounded, the posterior sharply rounded; marginal ridge noticeably thicker anteriorly and dorsally than posteriorly and ventrally, the dorsal portion of the ridge being separated from the anterior by a shallow groove and turning downward anteriorly; the marginal ridge bounded on the inside by a discontinuous shallow groove, above which, on its ventral course, are shallow pits; a somewhat comma-shaped medium ridge runs from behind the anterior groove to about two-thirds the distance to the rear margin; the "head" of the "comma" is bounded below and behind by a deep depression; another depression occurs near the anterior extremity of the dorsal marginal ridge above the "tail" of the comma-shaped ridge; the dorsal anterior tubercle ties in the groove between the anterior and dorsal marginal ridges. Seen from above or below the outline is ovate-sagittate, the head long, the shaft short; valve contacts slightly sinuous; from above the dorsal marginal ridges have the appearance of reflexed lips.

Length.—.82 mm.

Remarks.—This species is rather close to *Cythereis ponderosana* n. sp., but may readily be distinguished by its sharply bent dorsal ridge and shorter median ridge.

Cotypes.—80246 A, B, C, U. S. Nat. Mus.

Type locality.—Ozan formation, NE.¼ sec. 23, T. 11 S., R. 29 W., Arkansas.

Known occurrence.—Ozan formation (rare).

Cythereis ponderosana n. sp.
Plate III A, Figs. 5, 6, 7, 8

Description.—Seen from side, subovate; much higher in front than behind; anterior extremity broadly rounded, ornamented with short spines, posterior extremity narrow, acutely rounded, dorsal margin slightly curved, with a small sinus behind anterior-dorsal tubercle, ventral margin gently curved; strong medial ridge widening anteriorly and merging into smooth area occupying forward third of shell; weak dorsal and ventral ridges present, with pits on their inward slopes. In edge view subovate, pointed before and behind; from above the dorsal ridges have the appearance of reflexed lips.

Length.—.88 mm., .66 mm.

Remarks.—*Cythereis triplicata* Roemer[19] is slightly suggestive of this species in side view only.

Called *C. ponderosa* because of its apparent limitation to the *Exogyra ponderosa* zone.

Cotypes.—80247 A, B, U. S. Nat. Mus.

Type locality.—Annona chalk, center NE.¼ NE.¼ sec. 29, T. 11 S., R. 27 W., Arkansas.

Known occurrence.—Ozan formation, Annona chalk, Marlbrook marl (common throughout).

Cythereis tridenta n. sp.
Plate III A, Figs. 4a, 4b, 4c

Description.—Outline viewed from side, subovoid; higher before than behind; the anterior and posterior margins gently rounded, the dorsal and ventral nearly straight; the whole circumference thickened, most broadly at the anterior and posterior margins; three longitudinal ridges present, the dorsal short, extending from about the center to a short distance behind, the medial and ventral extend from before the center to behind the center, the medial being nearly straight, the ventral slightly bowed; a small tubercle occurs at the confluence of the dorsal and anterior margins. From above or below the outline appears irregularly ovoid, attenuated before and behind and slightly indented just behind the middle; the marginal ridge appears liplike dorsally.

Length.—.66 mm.

Holotype.—80248 U. S. Nat. Mus.

Type locality.—Marlbrook marl, NW. cor. NE.¼ NE.¼ sec. 32, T. 11 S., R. 27 W., Arkansas.

Known occurrence.—Marlbrook marl (rare), Arkadelphia marl (rare).

Cythereis communis n. sp.
Plate III A, Figs. 9, 10, 11, 12, 13

Description.—Shell seen from side, oblong; scarcely higher in front than behind; anterior extremity rounded, with short, blunt spines below the middle; posterior extremity gently rounded, with short, blunt spines below the middle, dorsal mar-

[19] Roemer, Verstein. Kreidebirg. 1840, pl. 16, fig. 16.

with short spines, posterior extremity narrow, acutely rounded, dorsal margin slightly curved, with a small sinus behind anterior-dorsal tubercle, ventral margin gently curved; strong medial ridge widening anteriorly and merging into smooth area occupying forward third of shell; weak dorsal and ventral ridges present, with pits on their inward slopes. In edge view subovate, pointed before and behind; from above the dorsal ridges have the appearance of reflexed lips.

Length.—.88 mm., .66 mm.

Remarks.—*Cythereis triplicata* Roemer[18] is slightly suggestive of this species in side view only.

Called *C. ponderosa* because of its apparent limitation to the *Exogyra ponderosa* zone.

Cotypes.—80247 A, B, U. S. Nat. Mus.

Type locality.—Annona chalk, center NE.¼ NE.¼ sec. 29, T. 11 S., R. 27 W., Arkansas.

Known occurrence.—Ozan formation, Annona chalk, Marlbrook marl (common throughout).

Cythereis tridenta n. sp.
Plate III A, Figs. 4a, 4b, 4c

Description.—Outline viewed from side, subovoid; higher before than behind; the anterior and posterior margins gently rounded, the dorsal and ventral nearly straight; the whole circumference thickened, most broadly at the anterior and posterior margins; three longitudinal ridges present, the dorsal short, extending from about the center to a short distance behind, the medial and ventral extend from before the center to behind the center, the medial being nearly straight, the ventral slightly bowed; a small tubercle occurs at the confluence of the dorsal and anterior margins. From above or below the outline appears irregularly ovoid, attenuated before and behind and slightly indented just behind the middle; the marginal ridge appears liplike dorsally.

Length.—.66 mm.

Holotype.—80248 U. S. Nat. Mus.

Type locality.—Marlbrook marl, NW. cor. NE.¼ NE.¼ sec. 32, T. 11 S., R. 27 W., Arkansas.

Known occurrence.—Marlbrook marl (rare), Arkadelphia marl (rare).

Cythereis communis n. sp.
Plate III A, Figs. 9, 10, 11, 12, 13

Description.—Shell seen from side, oblong; scarcely higher in front than behind; anterior extremity rounded, with short, blunt spines below the middle; posterior extremity gently rounded, with short, blunt spines below the middle, dorsal mar-

[18] Roemer, Verstein. Kreidebirg, 1840, pl. 16, fig. 16.

gin nearly straight, nodose, ventral margin straight, somewhat noded; a median ridge with strong anterior and posterior nodes with constriction between; the tubercle at the junction of the anterior and dorsal margins not prominent; the whole surface excepting the nodes and ridges finely pitted. Viewed from above or below the outline is roundly sagittate, attenuated before and behind, with V-shaped reentrants at the extremities; dorsally the marginal ridges along the valve contact are thick, nodose.

Length.—.77 mm. (average).

Remarks.—A species close to this form, if not identical, occurs in the Washita.

Cotypes.—80249 A, B, C, D, E, U. S. Nat. Mus.

Type locality.—Nacatoch sand, SE.¼ sec. 2, T. 9 S., R. 22 W., Arkansas.

Known occurrence.—Ozan formation, Annona chalk, Marlbrook marl, Saratoga chalk, Nacatoch sand, Arkadelphia marl (common throughout).

Cythereis ivii n. sp.

Plate III A, Figs. 14a, 14b, 14c

Description.—Viewed from the side, elongate subovoid, dorsal margin nearly straight, anterior and ventral margins gently rounded, posterior pointed. Valve margins thick, a slight ridge above the medial line starting about one-third the way back from the anterior margin and extending to about an equal distance from the rear; a deep elongate pit is found above and before the anterior extremity of the ridge; surface coarsely pitted. Viewed on edge roundly sagittate, the head long, the shaft very short; the overlap of the valves more prominent dorsally than ventrally.

Length.—.77 mm. (average).

Remarks.—Named for Mr. John S. Ivy, Chief Geologist of the Palmer Corporation, Shreveport, La., to whom I am indebted for permission to publish these notes.

Holotype.—20250 U. S. Nat. Mus.

Type locality.—Saratoga chalk, NW.¼ sec. 3, T. 9 S., R. 22 W. Arkansas.

Known occurrence.—Saratoga chalk (common), Arkadelphia (rare).

Cythereis saratogana n. sp.

Plate III A, Figs. 15a, 15b, 15c

Description.—Seen from side, elongate, subovate; dorsal and ventral margins nearly straight, anterior and posterior margins gently rounded; a slight ridge around the entire perimeter bounded on the inside by a discontinuous groove; ornamented within the groove by coarse pitting and a conspicuous rounded tubercle lying below the median line and about one-third the distance from the center to the rear margin. Viewed from above or below the outline is roundly hastate, the head long, the shaft short.

Length.—.66 mm.

Remarks.—Named *C. saratogana* because of its apparent restriction to the Saratoga chalk.

Holotype.—80251 U. S. Nat mus.

Type locality.—Saratoga chalk (rare), NW.¼ sec. 3, T. 9 S., R. 22 W., Arkansas.

Cythereis costatana n. sp.
Plate III A, Figs. 16a, 16b, 16c

Description.—Viewed from side, outline subovate; higher before than behind; gently rounded anteriorly, slightly more abruptly rounded behind, with a few short digitations: dorsal and ventral margins but slightly rounded; the dorsal-anterior tubercle elongate, the posterior tubercle rounded; the whole of the surface within the marginal ridge is pitted. Viewed on edge the outline is narrowly sagittate, the head long, the shaft short. Valve contacts sinuous.

Length.—.72 mm.

Remarks.—*Cythereis lonsdaleana* Jones[19] has a somewhat similar outline, but the ornamentation is quite different.

Named *S. costatana* because of its apparent restriction to the *Exogyra costata* zone.

Holotype.—80255 U. S. Nat. Mus.

Type locality.—Nacatoch sand, SE.¼ sec. 2, T. 9 S., R. 22 W., Arkansas.

Known occurrence.—Saratoga chalk, Nacatoch sand, Arkadelphia marl (common throughout).

Cythereis hannai n. sp.
Plate IV A, Figs. 1a, 1b, 1c

Description.—Viewed from side, the outline is subovate; anterior margin gently rounded, ornamented with low tubercle; posterior margin less gently rounded, ridged; dorsal margin slightly sinuous, ornamented with low tubercles except at the extremities, where prominent tubercles occur; ventral margin gently curved, ridged; within the marginal ridge is found a depression limiting the central coarsely pitted area; pits polygonal; in this area tubercle occurs below the anterior-dorsal tubercle and above the median line, another is found below the median line and slightly anterior to the posterior dorsal tubercle.

Viwed on edge outline is irregularly hastate, with the valve contacts nearly straight.

Length.—.55 mm.

Remarks.—Named for Dr. G. Dallas Hanna of the California Academy of Sciences.

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[19] Jones, T. R., op. cit., pl. 5, fig. 12.

Holotype.—80253 U. S. Nat. Mus.

Type locality.—Tokio formation, NE. cor. SE.¼ sec. 23, T. 10 S., R. 28 W., Arkansas.

Known occurrence.—Tokio formation (common).

Cythereis spoori n. sp.

Plate IV A, Figs. 4, 5

Description.—Viewed from the side the outline is ovate-oblong; anterior margin gently rounded, with fluted rim, posterior gently rounded, with fluted rim, dorsal and ventral margins subparallel and slightly sinuous; surface covered with coarse polygonal pits; strong tubercle lies about one-third the length from the anterior margin, slightly above the median line; strong dorsal-anterior tubercle present.

Viewed on edge, broadly hastate; dorsal margins tuberculate.

Length.—.49 mm., .66 mm.

Remarks.—Named for Mr. Harry C. Spoor of Shreveport, Louisiana.

Cotypes.—80254 A, B, U. S. Nat. Mus.

Type locality.—Brownstown marl, SW.¼ sec. 33, T. 10 S., R. 28 W.

Known occurrence.—Brownstown marl (fairly common), Ozan formation (fairly common).

Cythereis bartoni n. sp.

Plate III A, Figs. 17a, 17b

Description.—Seen from the side, the outline is elongate, subovate; dorsal and ventral margins but slightly curved, anterior and posterior margins gently rounded; margin slightly thickened all around; strong dorsal-anterior tubercle present; surface coarsely pitted, with the intervening ridges beset with fine spines (broken off most specimens); posterior extremity slightly shelving. Seen in edge view hastate, somewhat diamond shaped.

Length.—.73 mm.

Remarks.—Readily distinguished from *Cythereis plummeri* n. sp., by the lack of the prominent anterior-median tubercle.

Named for Dr. Donald C. Barton of Houston, Texas, in appreciation of the aid and encouragement given the writer in his early microscopic work.

Holotype.—80255 U. S. Nat. Mus.

Type locality.—Saratoga chalk, NW.¼ sec. 3, T. 9 S., R. 22 W., Arkansas.

Known occurrence.—Saratoga chalk (rare).

Cythereis plummeri n. sp.

Plate IV A, Figs. 2, 3

Description.—Outline from side, subquadrate; anterior and posterior margins gently rounded, heavily ridged and digitate; the dorsal and ventral margins nearly straight, the ventral having a heavy ridge; posterior extremity slightly shelving; surface coarsely pitted, with a prominent tubercle anterior to the center; a few fine spines remain near the posterior end of the better preserved specimen figured, the surface evidently having been covered with them; anterior and posterior margins digitate.

Length.—.78 and .88 mm.

Remarks.—*Cythere ericea* Brady[20] is somewhat similar in appearance but lacks the strong anterior tubercle and the posterior shelf.

Named for Mr. Frederick B. Plummer in remembrance of his kindly interest and cooperation in the writer's early microscopic work.

Cotypes.—80256 A, B, U. S. Nat. Mus.

Type locality.—Ozan formation, NE.¼ NE.¼ sec. 23, T. 11 S., R. 29 W., Arkansas.

Known occurrence.—Ozan formation (rare).

Cythereis hazardi n. s.
Plate IV A, Fig. 9

Description.—Outline from side, subquadrate; anterior end greatly rounded, with a few broad spines; posterior gently rounded, with broad spines along entire margin; dorsal margin nearly straight, with a notch about one-third the distance from the anterior end, gently reentrant before, sharply behind; ventral margin gently rounded, with a slight projection near the rear extremity; the median ridge irregularly constricted, bordered by irregular elongate pits whose major axes are more or less normal to the median ridge; irregular ridges border the pits, connecting the medial ridge to the low dorsal ridge and to the ventral ridge, which rises gently from before to behind and is terminated by an elongate depression, which extends from the termination of the medial ridge downward onto the ventral surface; the ventral ridge ends posteriorly in a broad platform.

Length.—.71 mm.

Remarks.—*Cythere polytrema* Brady and allied forms have some resemblance to *C. hazardi*[21] but are easily distinguished.

Named for Mr. Roy T. Hazard of Shereveport, La., who frequently accompanied Mr. Spooner in the field.

Holotype.—20257 U. S. Nat. Mus.

Type locality.—Nacatoch sand, NW. cor. NE.¼ NE.¼ sec. 17, T. 11 S., R. 25 W., Arkansas.

Known occurrence.—Nacatoch sand (fairly common), Arkadelphia marl (common).

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[20] Brady, G. S., Voyage Challenger, Zool. v. 1, 1880, p. 107, pl. 17, figts. 1a-1b.
[21] Brady, G. S., op. cit., p. 87, pl. figs. 5a-5h.

Cythereis bicornis n. sp.

Plate IV A, Figs. 10a, 10b, 10c

Description.—Viewed from side, outline is ovate-oblong; anterior end gently rounded, the posterior more sharply rounded, dorsal slightly curved downward medially, ventral slightly curved downward medially; the strong, sinuous medial ridge is tuberculate anteriorly and at about the middle of its length; ridges extend dorsally to that margin and ventrally to another less pronounced sinuous ridge; a strong tubercle appears behind the center and below th medial ridge. In edge view outline is sagittate, the head broad and sinuous, terminated by the prominent tubercles; the shaft compressed.

Length.—.66 mm.

Remarks.—This form appears to be unique.

Holotype.—80258 U. S. Nat. Mus.

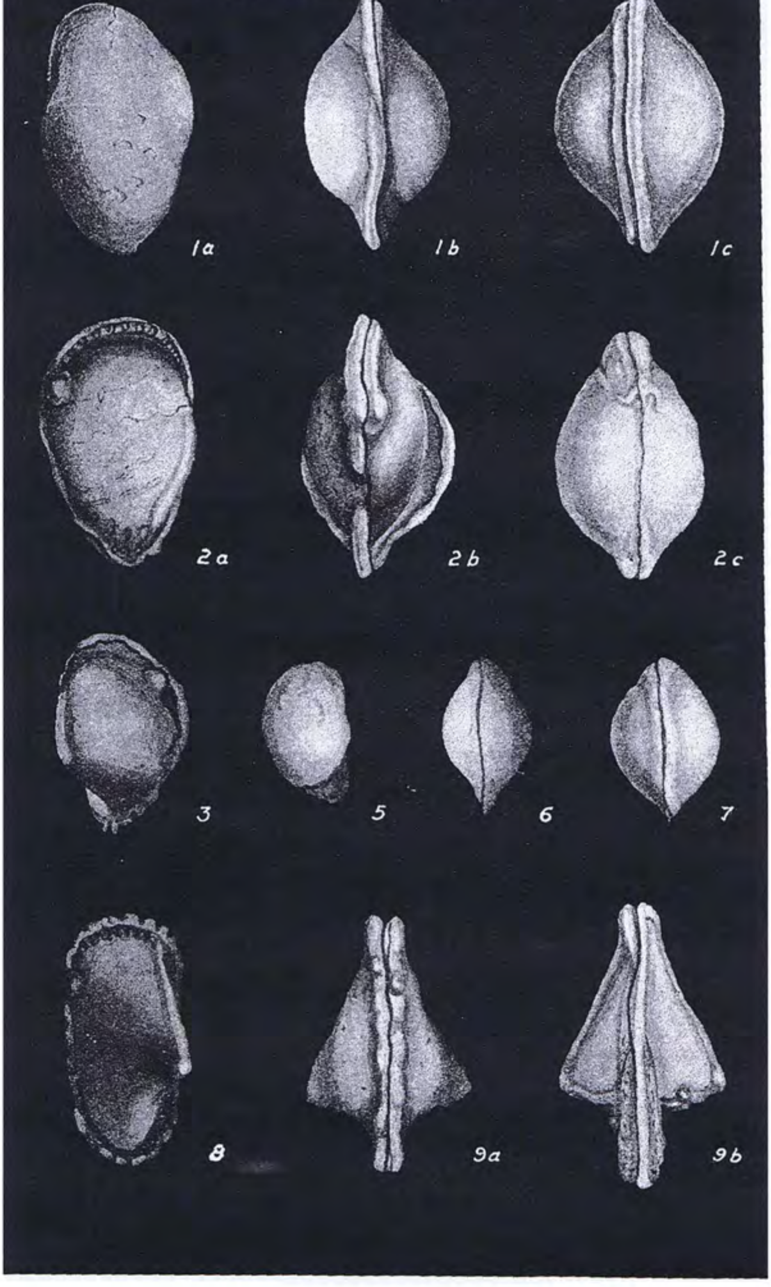
Type locality.—Tokio formation, NE. cor. SE.¼ sec. 23, T. 10 S., R. 28 W., Arkansas.

Known occurrence.—Tokio formation (common).

Explanation of Plate I A

FIGURE 1a. *Cytheropteron sp. A.* Figured specimen No. 80,236 U. S. Nat. Mus. View right side.
FIGURE 1b. Same speciment. Dorsal view.
FIGURE 1c. Same specimen. Ventral view.
FIGURE 2a. *Cytheropteron sp. B.* Figured specimen lost. View right side.
FIGURE 2b. Same specimen. Dorsal view.
FIGURE 2c. Same specimen. Ventral view.
FIGURE 3. *Cytheropteron sp. B.* Figured specimen No. 80,237 U. S. Nat. Mus. View left side.
FIGURE 5. *Cytheropteron ledaforma* n sp. Cotype No. 80,238-A U. S. Nat. Mus. View right side.
FIGURE 6. Same species. Cotype No. 80,238-B U. S. Nat. Mus. Dorsal view.
FIGURE 7. Same species. Cotype No. 80,238-C U. S. Nat. Mus. Ventral view.
FIGURE 8. *Cytheropteron tokiana* n. sp Cotype No. 80,239-A U. S. Nat. Mus. View right side.
FIRURE 9a. *Cytheropteron tokiana* n. sp. Cotype No. 80,239-B U. S. Nat. Mus. Dorsal view.
FIGURE 9b. Same specimen. Ventral view.

ARKANSAS GEOLOGICAL SURVEY BULLETIN 2 PLATE I A



Explanation of Plate II A

FIGURE 1a. *Cytheropteron ponderosana* n. sp. Holotype No. 80,240 U. S. Nat. Mus. View right side.

FIGURE 1b. Same specimen. Dorsal view.

FIGURE 1c. Same specimen. Ventral view.

FIGURE 2. *Loxoconcha fletcheri* n. sp. Cotype No. 80,242-A U. S. Nat. Mus. View right side.

FIGURE 3 Same species. Cotype No. 80,242-B U. S. Nat. Mus. View left side.

FIGURE 4a. *Cytheropteron saratogana* n. sp. Holotype No. 80,241 U. S. Nat. Mus. View left side.

FIGURE 4b. Same specimen. Dorsal view.

FIGURE 4c. Same specimen. Ventral view.

FIGURE 5. *Cythere bruceclarki* n. sp. Cotype No. 80,243-A U. S. Nat. Mus. View left side.

FIGURE 6. Same species. Cotype No. 80,243-B U. S. Nat. Mus. Inside view left valve showing hinge characters.

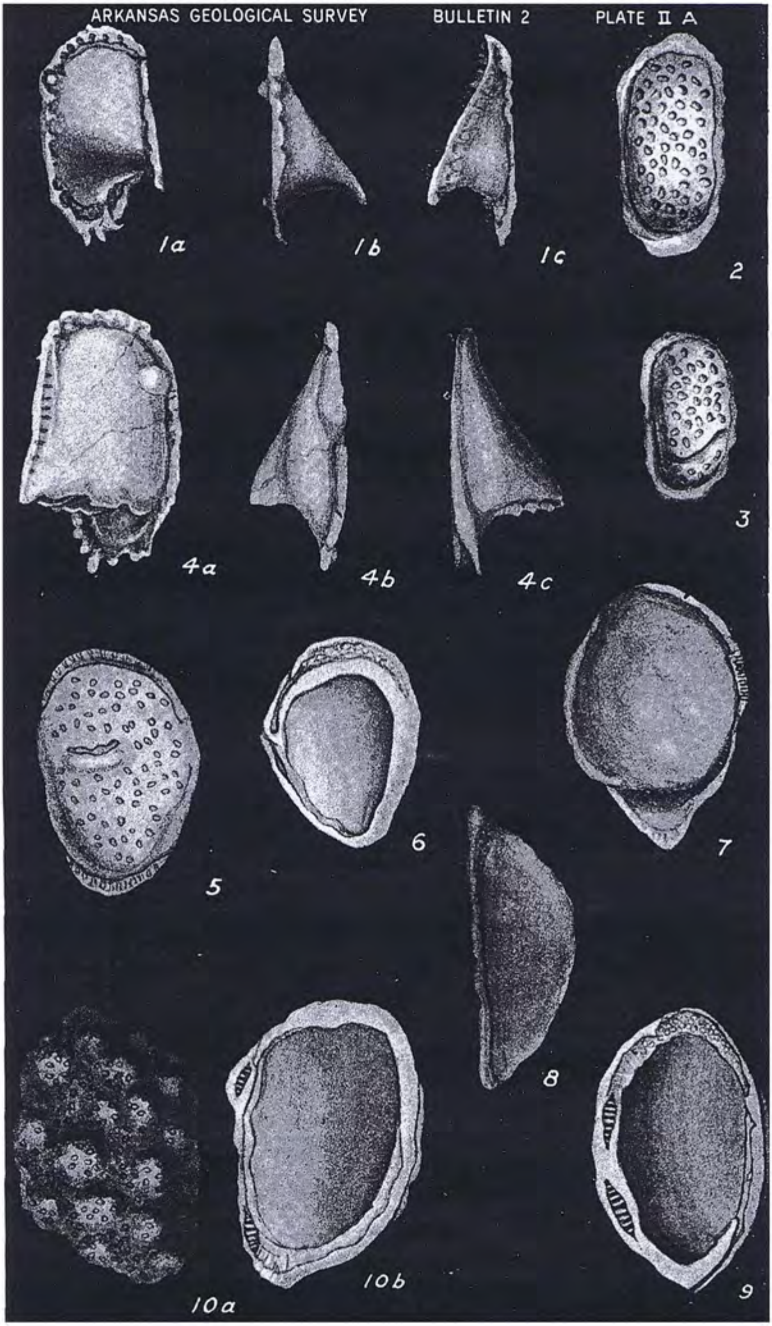
FIGURE 7. *Cytheridea ? saratogana* n. sp. Cotype No. 80,244-A U. S. Nat. Mus. View left side.

FIGURE 8. Same species. Cotype No. 80,244-B U .S. Nat. Mus. Ventral view of left valve.

FIGURE 9 Same species. Cotype No. 80,244-C U. S. Nat. Mus. Inner view of left valve showing hinge characters.

FIGURE 10a. *Cytheridea ? hannai* n. sp. Holotype No. 80,245 U. S. Nat. Mus. View left side.

FIGURE 10b. Same specimen. Inside view left valve showing hinge characters.


ARKANSAS GEOLOGICAL SURVEY
BULLETIN 2
PLATE II A
1a
1b
1c
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4a
4b
4c
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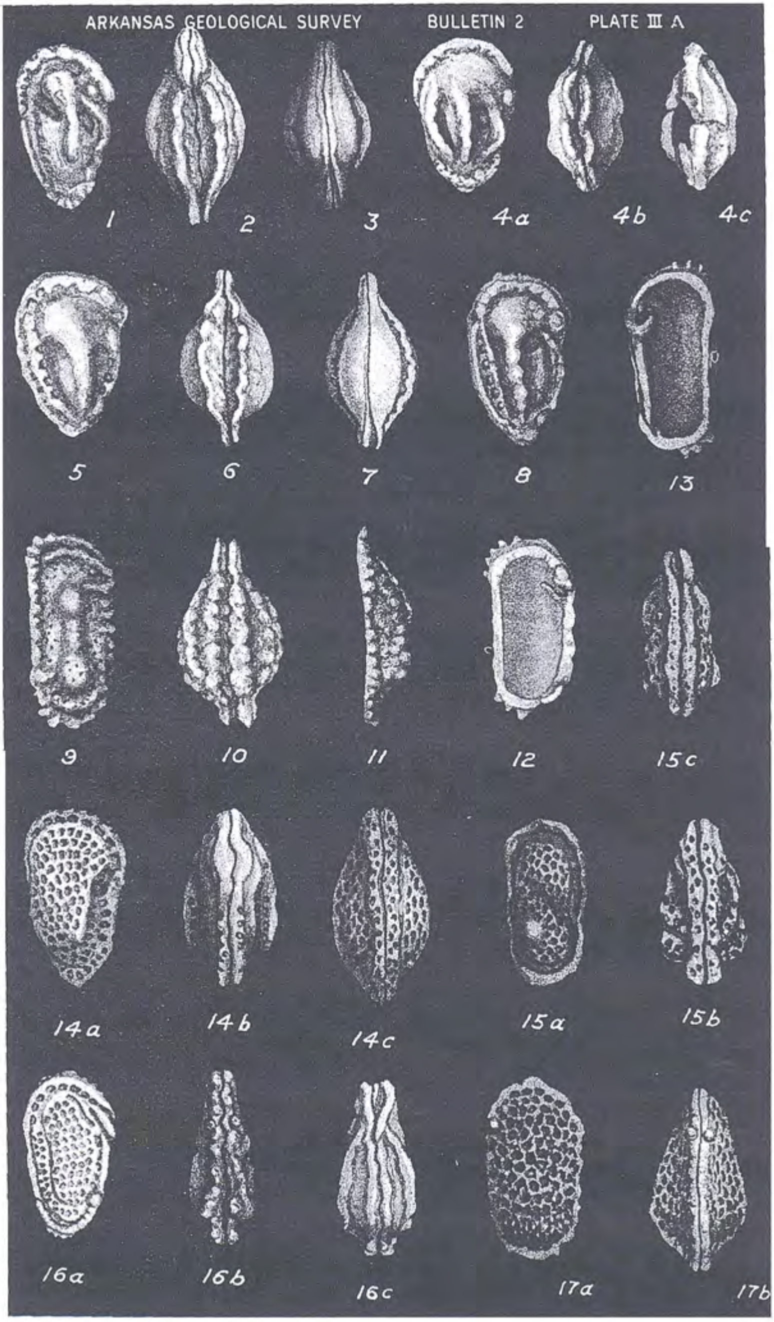
10a
10b

Explanation of Plate III A

FIGURE 1. *Cythereis ozanana* n. sp. Cotype No. 80,246-A U. S. Nat. Mus. View left side.
FIGURE 2. Same species. Cotype No. 80,246-B U. S. Nat. Mus. Dorsal view.
FIGURE 3. Same species. Cotype No. 80,246-C U. S. Nat. Mus. Ventral view.
FIGURE 4a. *Cythereis tridenta* n. sp. Holotype No. 80,248 U. S. Nat. Mus. View left side.
FIGURE 4b. Same specimen. Dorsal view.
FIGURE 4c. Same specimen. Ventral view, somewhat tilted.
FIGURE 5. *Cythereis ponderosana* n. sp. Cotype No. 80,247-A U. S. Nat. Mus. View left side.
FIGURE 6. Same species. Cotype lost.
FIGURE 7. Same species. Cotype lost.
FIGURE 8. Same species. Cotype No. 80,247-B. U. S. Nat. Mus. View left side.
FIGURE 9. *Cythereis communis* n. sp. Cotype No. 80,249-A U. S. Nat. Mut. View left side.
FIGURE 10. Same species. Cotype No. 80,249-B U. S. Nat. Mus. Dorsal view.
FIGURE 11. Same species. Cotype No. 80-249-C S. U. Nat. Mus. Ventral view of left valve.
FIGURE 12. Same species. Cotype No. 80,249-D U. S. Nat. Mus. Inside view right valve showing characters.
FIGURE 13. Same species. Cotype No. 80,249-E U. S. Nat. Mus. Inside view left valve showing hinge characters.
FIGURE 14a. *Cythereis ivii* n. sp. Holotype No. 80,250 U. S. Nat. Mus. View left side.
FIGURE 14b. Same specimen. Dorsal view.
FIGURE 14c. Same specimen. Ventral view.
FIGURE 15a. *Cythereis saratogana* n. sp. Holotype No. 80,251 U. S. Nat. Mus. View left side.
FIGURE 15b. Same specimen. Dorsal view.
FIGURE 15c. Same specimeu. Ventral view.
FIGURE 16a. *Cythereis costatana* n. sp. Holotype No. 80,252 U. S. Nat. Mus. View left side.
FIGURE 16b. Same specimen. Dorsal view.
FIGURE 16c. Same specimen. Ventral view.
FIGURE 17a. *Cythereis bartoni* n. sp. Holotype No. 80,255 U. S. Nat. Mus. View right side.
FIGURE 17h. Same specimen. Dorsal view.


ARKANSAS GEOLOGICAL SURVEY BULLETIN 2 PLATE III A
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15c
14a
14b
14c
15a
15b
16a
16b
16c
17a
17b

Explanation of Plate IV A

FIGURE 1a. *Cythereis hannai* n. sp. Holotype No. 80,253U. S. Nat. Mus. View right side.

FIGURE 1b. Same specimen. Dorsal view.

FIGURE 1c. Same specimen. Ventral view.

FIGURE 2. *Cythereis plummeri* n. sp. Cotype No. 80,256-A U. S. Nat. Mus. Outline left side, given to show anterior digitations.

FIGURE 3. Same species. Cotype No. 80,256-B U. S. Nat. Mus. View left side.

FIGURE 4. *Cythereis spoori* n. sp. Cotype No. 80,254-A U. S. Nat. Mus. View right side.

FIGURE 5. Same species. Cotype No. 80,254-B U. S. Nat. Mus. Dorsal view.

FIGURE 6. *Cytherura ? dubia* n. sp. Holotype No. 80,234 U. S. Nat. Mus. View left side.

FIGURE 7a. *Cytherura spoori* n. sp. Holotype No. 80,233 U. S. Nat. Mus. View left side.

FIGURE 7b. Same specimen. Ventral view.

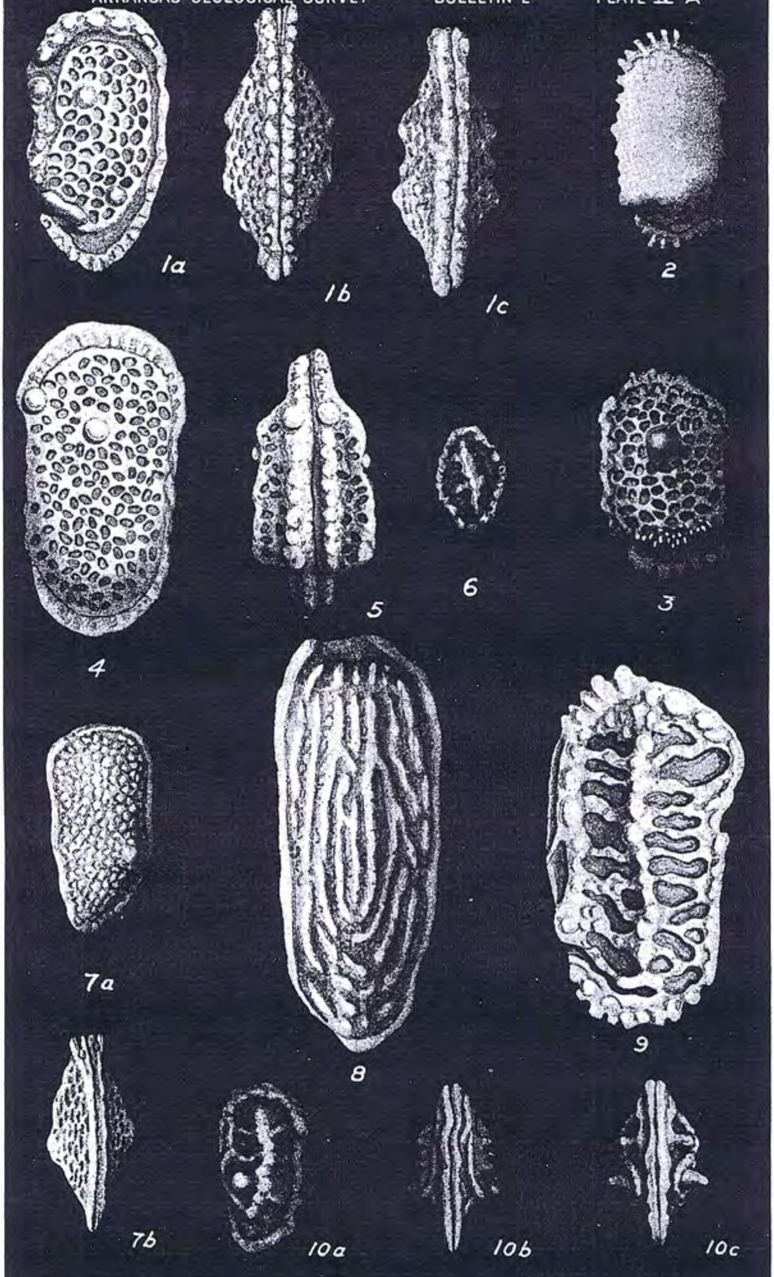
FIGURE 8. *Cytherura ? saratogana* n. sp. Holotype No. 80,235 U. S. Nat. Mus. View right side.

FIGURE 9. *Cythereis hazardi* n. sp. Holotype No. 80,257 U. S. Nat. Mus. View left side.

FIGURE 10a. *Cythereis bicornis* n. sp. Holotype No. 80,258 U. S. Nat. Mus. View left side.

FIGURE 10b. Same specimen. Dorsal view.

FIGURE 10c. Same specimen. Ventral view.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