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GROUND-WATER EXPLORATION IN THE NATCHITOCHES AREA LOUISIANA

BY

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ABSTRACT

The water supply of the city of Natchitoches has been obtained for many years from shallow wells screened in fine-grained sands of the Wilcox formation. These sands have been locally overdeveloped, and the supply of water stored in the sands has been depleted gradually as the recharge from rainfall has failed year by year to equal the withdrawals by wells. An exploratory program designed to locate an adequate supply of ground water was initiated in the fall of 1943 by the city of Natchitoches. This program, directed by the Geological Survey, United States Department of the Interior, included the drilling, electric logging, and testing of nine exploratory wells which penetrated water sands of the Sparta sand and the Wilcox formation. An ample supply of soft potable water was found in these formations south of the city.

Geologic and hydrologic data obtained from the test drilling suggest that the city of Natchitoches may be situated upon a downthrown fault block defined on the southwest by a fault along Youngs Bayou and on the southeast by a fault extending from Old River toward Cane River Lake. Salt water, unlike connate sea water in composition, is present in the sands underlying most of the city. A similarity of topographic, geologic, and hydrologic conditions in this area to those in salt-dome areas in nearby parishes is evident.

The Sparta sand and the upper sands of the Wilcox formation crop out in a narrow band extending from Natchitoches westward into Texas. Moderate supplies of soft water are available from these sources. The city of Natchitoches should be able to obtain as much as 1,000,000 gallons a day from three to five properly developed supply wells screened in these sands in secs. 10, 56, and 57, T. 8 N., R. 7 W. Additional water for increased future needs may be obtained by extending this well field to the west.

INTRODUCTION

Ground-water investigations were begun in Natchitoches in March 1941 by the Geological Survey, United States Department of the Interior, in cooperation with the Louisiana Department of Conservation and the city of Natchitoches, to determine the advisability of drilling additional water wells within the city limits. This study, made by T. B. Stanley, Jr., was completed in September 1941, and the results indicated that, although large quantities of hard water are available from the Recent alluvium of the Cane River flood plain, little additional soft water can be obtained from wells within the city limits.

After a severe water shortage during the very dry summer and fall of 1943, the city of Natchitoches decided to undertake a ground-water exploration program in the area south and east of the city before giving further consideration to a proposal to impound surface water in the nearby swamp known as Sibley Lake. If adequate supplies of soft ground water could be found within a distance of 5 miles, the construction of three to five wells and the necessary pipe line would be economically feasible. The test drilling was paid for entirely by the city of Natchitoches but was directed by the authors at the request of the city officials. This report summarizes and interprets the information obtained during the testing program, together with that from records of previously drilled wells, and offers suggestions for the development of a new well field.

Acknowledgment is made of the aid and cooperation of Mayor Edwin McClung, G. H. Pierson, A. F. Ortmeyer, and S. L. Perry, of the city of Natchitoches. L. P. Blevins, well contractor, gave whole-hearted cooperation in obtaining necessary data, and R. T. Wade, Schlumberger Well Surveying Corp., offered helpful suggestions in the interpretation of the electric logs. The writers are indebted to O. E. Meinzer, of the Geological Survey at Washington, and J. Huner, Jr., Louisiana State geologist, for reviewing this report.

EXPLORATORY PROGRAM

The exploratory program in the Natchitoches area consisted of the drilling, electric logging, and testing of nine test holes located to the south and east of the city. (See fig. 53, wells 20–28.) Samples of the sands and water contained therein were collected and analyzed in the laboratory. The water level, temperature, yield, and drawdown were determined for each sand that appeared to have possibilities as an aquifer. Records from previously drilled wells and test holes were collected and assembled along with these data.

METHOD OF TEST DRILLING

The test holes, 6 inches in diameter and 339 to 991 feet deep, were drilled by hydraulic rotary methods, in which the drilling is accomplished by rotating a fish-tail bit on the end of a string of drill pipe while mud fluid is pumped down the drill pipe under pressure. The fluid carries the cuttings to the surface and seals the wall of the hole. The hole usually is not cased during the drilling operations, although in some wells surface casing is required to prevent the shallow, poorly consolidated sands from caving. No surface casing was necessary in the test holes in the Natchitoches area. Both natural mud and Aquagel, a processed commercial drilling mud, were used in drilling these holes. Generally the Aquagel was not used as long as the natural

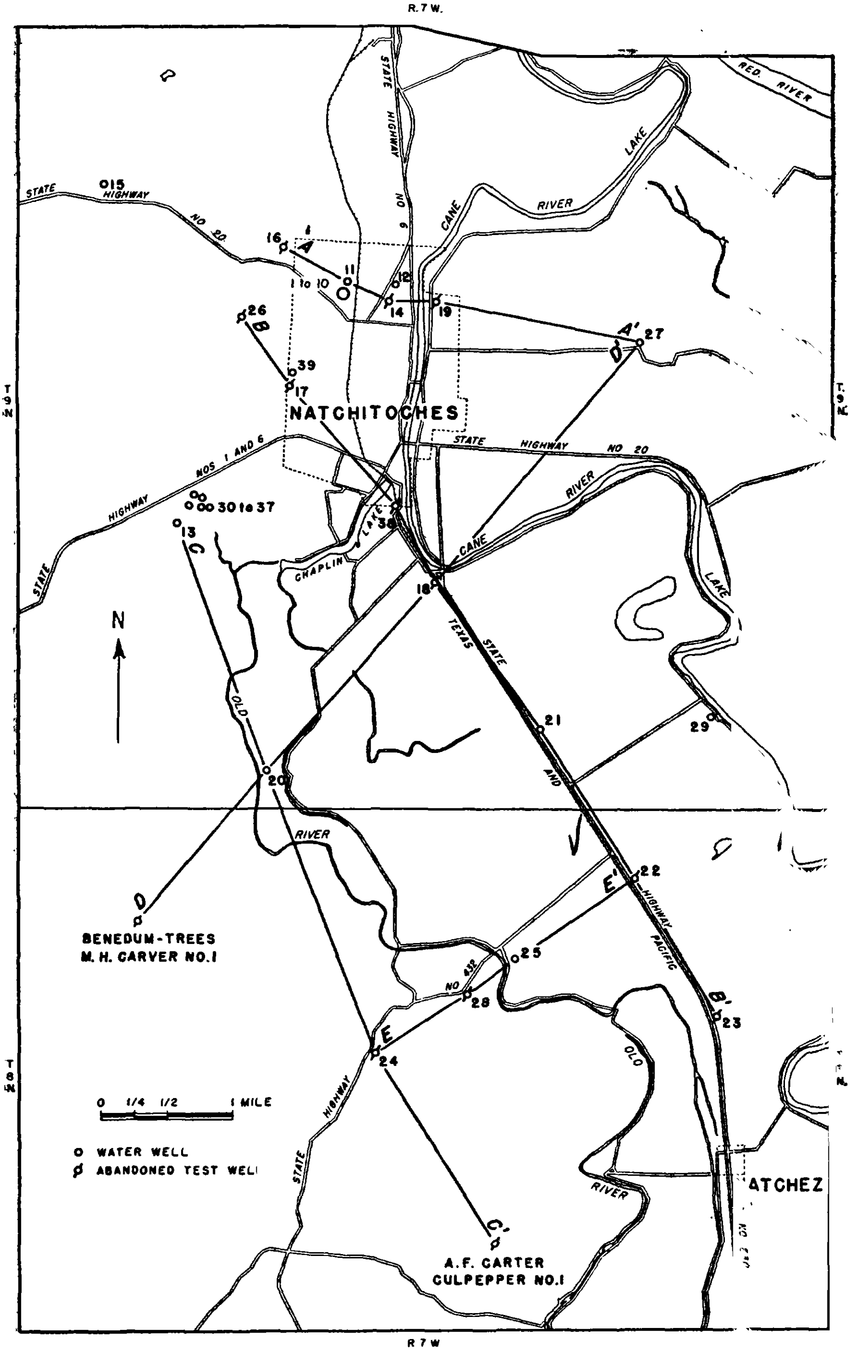


FIGURE 53.—Map showing location of wells in the Natchitoches area, Louisiana.

mud was sufficiently viscous to hold up the wall of the hole through the water sands. The test holes were plugged with heavy mud and stiff clay upon completion of the testing.

SAMPLING METHODS

Specifications for the test drilling included a clause providing for the proper collection of samples at 10-foot intervals in each water sand. Whenever a sand was penetrated the drilling was suspended for 10 to 30 minutes (the length of time depending upon the depth of the hole and volume output of the mud pump) while the mud was circulated to clean out the hole. When it was judged that all or most of the drill cuttings had been removed, the ditch returning mud to the pits was cleaned out. Drilling was then resumed until 10 feet of sand had been penetrated or the bottom of the sand reached by the bit. Again drilling was stopped and the mud was circulated for 10 to 30 minutes before collecting sample portions at 5-foot intervals along the ditch. The combined sample portions were washed free of drilling mud, placed in clean quart size cardboard containers, labeled, and sent to the laboratory for mechanical analysis. The mechanical analyses of these samples were found to be very useful for comparative purposes, even though the rotary method of drilling does not permit accurate sampling of unconsolidated materials.

DRILLERS' LOGS

A record of the formations penetrated in each test hole was made by the drillers on the basis of drill cuttings, drilling time, action of the rotary table and mud pump, and changes in fluid level in the mud pit. The personal equation enters into such records to a considerable degree, and the use of such records requires some discretion. It has been found that the logs recorded by an experienced driller, familiar with both the drilling rig and the underground conditions, generally agree fairly well with the electric logs insofar as the principal water sands and hard rock layers are concerned. However, even the best drillers' logs do not show all of the small sand and clay beds that are often lumped together as "sand and shale," and in some wells even thick water sands have been overlooked.

Both drillers' logs and electric logs are desirable in water wells. The driller's log generally supplies accurate information, permitting the tentative correlation of water sands as the well progresses; the electric log made after completing the hole offers mechanically recorded evidence of the formations penetrated and gives considerable information on the character of the water sands and the water therein.

ELECTRIC LOGS

After completing each test hole it was conditioned by circulating the drilling mud for a period of 1 to 3 hours to insure uniformity of mud in all parts of the hole and to build up a heavy mud cake in the water sands to prevent caving upon withdrawal of the drilling tools. As soon as possible after the removal of the drilling tools an electric log of the formations penetrated was made by one of the several commercial firms specializing in such services for oil wells.

An electric log is a record of the self-potential and apparent resistivity of the formations penetrated by the drilled hole. The self-potential is recorded as the difference in electric potential between the formations in the hole and a point on the land surface. The apparent resistivity of the formations is determined by sending a current of electricity into the wall of the hole and measuring the rate of potential drop. The equipment used in making these measurements consists of a system of electrodes which are lowered into the hole; a multiconductor cable spooled on a power-driven winch which raises or lowers the electrodes; a measuring sheave which records the depth of the electrodes; electrical measuring instruments and a source of electromotive force on the land surface connected to the electrodes by the multiconductor cable; and a plotting mechanism which records measured values of self-potential and resistivity on film.

SELF-POTENTIAL CURVE

The measured self-potential is shown on the left side of the film or electric log as a single trace, arbitrarily termed "the first curve." (See pl. 3.) In some instances an amplified version of this curve is also shown on the left side of the log, usually as a dashed line. The first curve has been generally considered to represent the algebraic sum of potentials generated by electrofiltration and electrochemical action during and after the drilling of the hole.[1] Recently, however, Lee [2] pointed out the possibility that natural earth potentials might exist prior to drilling operations. Because any one of these potentials comprising the recorded self-potential may be either positive or negative under different conditions, it is extremely difficult to judge the relative magnitude of each from the first curve.

The electrofiltration potential is derived from the movement of fluid into or out of the formation due to differences in formational pressure

[1] Deussen, Alexander, and Leonardon, E. G., Electrical exploration of drill holes: Am. Petroleum Inst., Drilling and production practice, pp. 48, 49, 1935. Gillingham, W. J., Electrical logging in the Appalachian fields: Pennsylvania State College Min. Ind. Exper. Sta. Bull. 21, p. 4, 1937.

[2] Lee, F. W., The possibility of electrical stratification in the earth as disclosed by surface measurements of currents and potentials: Am. Geophysical Union Trans., Terrestrial magnetism and electricity, pp. 383-399, 1939.

and the weight of the mud column in the hole. When an electrolyte, such as the drilling fluid, is caused to flow through a permeable medium, such as a sand, an electromotive force is set up in the direction of the flow. This electromotive force is directly related to the permeability of the medium and to the pressure differential and electrical resistivity of the fluid. It is inversely related to the viscosity of the fluid.

The electrochemical potential is caused by two electrolytes (drilling fluid and formational water) of different ionic concentration coming in contact through a permeable medium (sand). The flow of the current is toward the more highly concentrated electrolyte, which may be either the drilling mud or the formational water. It is generally assumed that this potential adds to the electrofiltration potential, but it appears that this would not be true if the more concentrated solution is the drilling mud, as it sometimes is in water wells.

For many years it was thought that the electrofiltration potential was dominant, and for that reason the first curve was commonly termed the "porosity log." Recent studies tend to discredit this idea and to emphasize the complicated nature of the components of the recorded self-potential. In 1942 Dickey [3] made the following statement regarding the relative effect of natural earth potentials on the first curve:

> It has been demonstrated that potential differences exist naturally in the ground at certain points, particularly at geological discontinuities, such as the boundary between a sand and a shale stratum. It is probable that these natural differences of potential are always present, whether or not a well is drilled, and the sandstones are usually negatively charged with respect to the shales.
>
> Little is known of the cause of these natural potentials, and their importance has only recently been recognized. In most published articles on electric logging the potentials have been ascribed entirely to filtration and concentration potentials . . . . Recent work seems to indicate that the natural potentials existing in the ground, regardless of whether or not a well is drilled, are the major source of the potentials measured in electric logging.

RESISTIVITY CURVE

The apparent resistivity is shown on the right side of the electric log as one, two, or three curves, depending upon the number of different electrode spacings used. (See pl. 3.) These curves describe the formations penetrated by the drilled hole in terms of their resistance to the flow of an electric current. Measurable differences in the character of the formations in this respect are primarily dependent not upon the minerals in the formations but rather upon their physical characteristics and fluid content. Increases in apparent resistivity are recorded by deflections of the resistivity curves to the right on the electric log. Differences in the magnitude of deflection

[3] Dickey, P. A., Electrical well logging in the Eastern States: Pennsylvania Topog. and Geol. Survey, Progress Rept. 129, pp. 8, 9, 1942.

of the three curves in the same formation are the result of differences in their effective penetration, which is proportional to the spacing of the electrodes in the hole. The electrode spacings used in the surveys for this investigation were 10 inches, 39 inches, and 15 feet. Different spacings are used in other regions and by other electric-logging firms. The solid line, called the normal or "second" curve, expresses the resistivity recorded by two electrodes 10 inches apart. This accurately indicates the tops and bottoms of formations more than 3 or 4 feet thick by sharp deflections to the right or left. However, it does not give a true idea of the resistivity of the natural formation because of the relatively shallow penetration of the current and the considerable influence of the drilling mud upon it. The dotted line or "third curve" registers the resistivity recorded by electrodes 39 inches apart. The penetration of the current with this spacing is somewhat greater than that of the second curve, but formational contacts are not as accurately defined. The dashed line or "fourth curve" is recorded by electrodes 15 feet apart. This spacing gives the greatest penetration of the formations, and, as a result, the most accurate recording of the resistivity of the formations and contained water. A considerable lag in the deflections marking the tops and bottoms of formations is always present in this curve. The third and fourth curves have been omitted from plate 3 for the sake of simplicity.

INTERPRETATION

In general it may be said that an electric log is interpreted by examining the form of the self-potential and resistivity curves with consideration of the resistivity and viscosity of the drilling mud and the temperature range in the hole. There is no handy rule of thumb for this interpretation, but the following is generally true in shallow fresh-water wells:

Shales and clays are indicated when both the self-potential and resistivity are low. The almost straight self-potential curve recorded in shale or clay is sometimes referred to as the "shale base"; that is, any deviation from this line indicates a change in the porosity of the formation. This shale base may shift abruptly between marine and continental sediments but remains relatively constant in sediments of one origin.

Fresh-water sands are indicated by sharp deflections of the resistivity curves to the right and more moderate deflections of the self-potential curve to either the left or right away from the shale base.

Salt-water sands are indicated by little or no deflection of the resistivity curves to the right and moderate to pronounced deflection of the self-potential curve to the left. Brackish water is often shown by the third and fourth curves recording less resistivity than the second curve, owing to the presence of the less saline mud fluid in the sand adjacent to the drilled hole.

Hard dense rocks are indicated by a sharp deflection to the right of all three resistivity curves and little or no deflection of the self-potential curve from the shale base.

DRILL-STEM TESTS

On the basis of information obtained from the electric log, driller's log, and sand samples, the most promising water sands in each test hole were selected for further tests, known by local water-well drillers as "drill-stem tests." This term as generally used in petroleum exploration refers to the use of a patented testing device on the drill stem that allows the fluid in the formation to flow into and partly fill the drill stem under natural pressure. This same device can be and has been used in testing some water wells but is not in common use by water-well drillers. Instead, many drillers place a short screen section on the drill stem in the sand to be tested and pump the formational water through the drill stem by air. This permits the collection of water samples and the measurement of water level, temperature, yield, and drawdown with a minimum of delay.

The formational tests in the test holes were made by setting 10 feet of screen on the drill stem in the selected sand with an improvised canvas or burlap packer above the sand. A commercially manufactured packer for this type of work would have been more satisfactory but was not available. After placing the screen and packer, the mud cake on the sand to be tested was broken down by alternately washing by forcing water into the well and pumping the well by air. In order to retain the mud seal on the upper sands the mud column above the packer was disturbed as little as possible. During the pumping of water from the formation the level of the mud in the hole outside the drill stem was carefully observed to detect any failure of the packer to hold.

After testing the lowermost sand first, the bit was run in the hole and heavy mud was circulated until the sand was sealed. Then the screen was placed opposite the next lowest sand, and the process was repeated until all of the selected sands, usually four in each hole, were tested.

The data obtained from such tests must necessarily be used with discretion. The measurements of yield and drawdown in the test hole give little indication of the probable performance of the final supply well but help somewhat to show the relative water-bearing properties of the different sands. The water samples (for preliminary analysis only), the temperature recordings, and the static water level measurements are usually satisfactory and worth while.

RESULTS OF EXPLORATION

The benefits of an adequate test-drilling program prior to any large development of ground water are apparent from the results obtained in this project. The definite knowledge of the depth, character, and correlation of each water sand and the data on quality, temperature, and artesian head of the water therein make it possible to evaluate the potentialities of each sand in each well before any great expenditure of funds is made. These data also enable the driller and city officials to determine the most suitable construction method and pumping equipment. It is generally advisable to conduct the test-drilling program and the actual water-supply development separately in order to establish a basis for exact specifications which save time, money, and misunderstandings for both the well owner and the driller.

GENERAL GEOLOGY

The city of Natchitoches is located along the western edge of the Red River Valley on the banks of Cane River Lake, a relict meander of the Red River. (See fig. 54.) The Red River Valley, extending diagonally across Natchitoches Parish from northwest to southeast, has been cut into the Tertiary highlands by the Red River and partly filled with alluvium. The Tertiary formations exposed on the bluffs and underlying the flood plain are thick deposits of shallow marine, littoral, deltaic, and continental sediments of Eocene age about which only meager data are available for this locality. Considerable information about the paleontology and regional correlations of these Eocene formations has been published by Harris,[4] Veatch,[5] Spooner,[6] Moody,[7] Howe,[8] Ellisor,[9] Huner,[10] Barry and LeBlanc,[11] and others, but no areal geologic maps or detailed subsurface studies of the area between Natchitoches and Natchez have been printed.

The Eocene formations contain numerous very fine to medium coarse-grained water sands, which exhibit the extremely irregular character, thickness, and lateral extent of continental deposits.

[4] Harris, G. D., A preliminary report on the geology of Louisiana: Louisiana Geol. Survey report for 1899, pp. 141-148, 1899.

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

[6] Spooner, W. C., Interior salt domes of Louisiana: Am. Assoc. Petroleum Geologists Bull., vol. 10, No. 3, pp. 217-292, 1926.

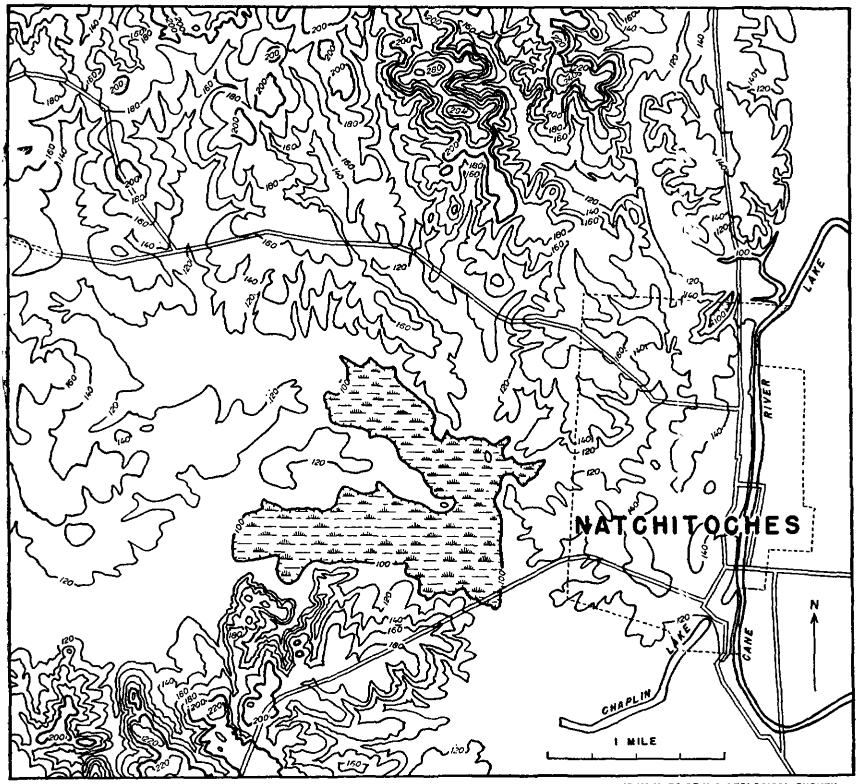
[7] Moody, C. L., Tertiary history of region of Sabine Uplift, Louisiana: Am. Assoc. Petroleum Geologists Bull., vol. 14, No. 5, pp. 531-551, 1931.

[8] Howe, H. V., Review of Tertiary stratigraphy of Louisiana: Am. Assoc. Petroleum Geologists Bull., vol. 17, No. 6, pp. 613-655, 1933.

[9] Ellisor, A. C., Correlation of the Claiborne of east Texas with the Claiborne of Louisiana: Am. Assoc. Petroleum Geologists Bull., vol. 13, No. 10, pp. 1335-1346, 1929.

[10] Huner, J., Jr., Geology of Caldwell and Winn Parishes: Louisiana Dept. Cons. Geol. Bull. 15, 1939.

[11] Barry, J. O., and LeBlanc, R. J., Lower Eocene faunal units of Louisiana: Louisiana Dept. Cons. Geol. Bull. 23, 1942.



FROM MAPS OF U.S. GEOLOGICAL SURVEY
CAMPTI AND BERMUDA QUADRANGLES

FIGURE 54.—Sketch map showing topography at Natchitoches, La.

The relatively thin-bedded sands of the Wilcox formation[12] and the massive sands of the Sparta sand are the most important aquifers. South of Natchez, La., the sands in the Cockfield formation are well developed and water-bearing, but only part of a section of the Cockfield formation is present within the area under consideration. The sands of both the Wilcox and Sparta are overlain and underlain by impermeable beds and yield water under artesian conditions, except in their respective outcrop areas. From the northwestern part of the city of Natchitoches southward successively younger rocks crop out in the hill land or underlie the flood plain in the following sequence: Wilcox formation; Claiborne group, including Cane River formation, Sparta sand, Cook Mountain formation, and Cockfield formation. In the Red River Valley the beveled outcrops of these formations are buried beneath alluvium ranging from a few feet to 104 feet in thickness. The possible presence of thin remnants of Pleistocene

[12] The term "Wilcox formation" is used by the U. S. Geological Survey; the name "Sabine group" is preferred by the Louisiana Geological Survey.

terraces on the Eocene formations at Natchitoches has not been investigated in this study. Table 1 gives a generalized description of the geologic formations and their water-bearing properties.

STRUCTURAL GEOLOGY

The Natchitoches area is structurally situated on a regional monoclinal flexure described by Veatch[13] in 1906 as extending from Angelina County, Tex., through Louisiana north of Natchitoches, Winnfield, and Columbia, to the Mississippi River north of Vicksburg. This regional structure developed in Tertiary time along a line of weakness that almost parallels the outcrop of the Wilcox formation west of Red River. Howe[14] has summarized the effect of this monocline on the accumulation of petroleum as follows:

> The Angelina-Caldwell flexure separates northern Louisiana, with its numerous Cretaceous fields, from central and southern Louisiana, in which areas the oil production is of Tertiary age. North of this "flexure" Cretaceous formations lie at relatively shallow depths and are gently folded into the broad Sabine Uplift on the west and Monroe Uplift on the east. On each uplift are smaller, sharper folds which have served for the localization of oil and gas deposits. The depressed area between the major uplifts contains the salt domes of north Louisiana as well as a number of other structures on which salt has not been encountered.
>
> Southward from the Angelina-Caldwell flexure, in that portion of Louisiana west of the Mississippi River, the regional dip of the Tertiary formations is to the southeast at a rate of from 100 feet per mile to probably more than 200 feet per mile, and the Cretaceous formations are depressed under the thick accumulation of Eocene and younger sediments. The position of the Angelina-Caldwell flexure appears to coincide remarkably with the position of the Sabine (Wilcox) shoreline.

This regional monocline is complicated in the Natchitoches area by several faults and an abrupt change in the direction of the regional strike from northeast to almost due north. These local structural conditions are illustrated in figure 55, a structural map of the area in which subsurface control was adequate to contour the top of the Wilcox formation, and on plate 3, which shows geologic cross sections along the lines indicated in figure 53. Three major faults, one near Natchez and two near Natchitoches, are indicated by abrupt changes in formational dip, abnormal artesian conditions, and the anomalous presence of salt water in fresh-water sands. Vertical displacements of 75 to 100 feet appear to have occurred along each of the faults, giving rise to topographic irregularities wherever the faults are not buried beneath the flood-plain alluvium.

The fault near Natchez trends northeastward between well 24 in sec. 56, T. 8 N., R. 7 W., and the A. F. Carter Culpepper No. 1 oil

13 Veatch, A. C., op. cit., p. 315, 1906.

14 Howe, H. V., Louisiana petroleum stratigraphy: Louisiana Dept. Cons. Gen. Min. Bull. No. 27, pp. 19, 20, 1936.

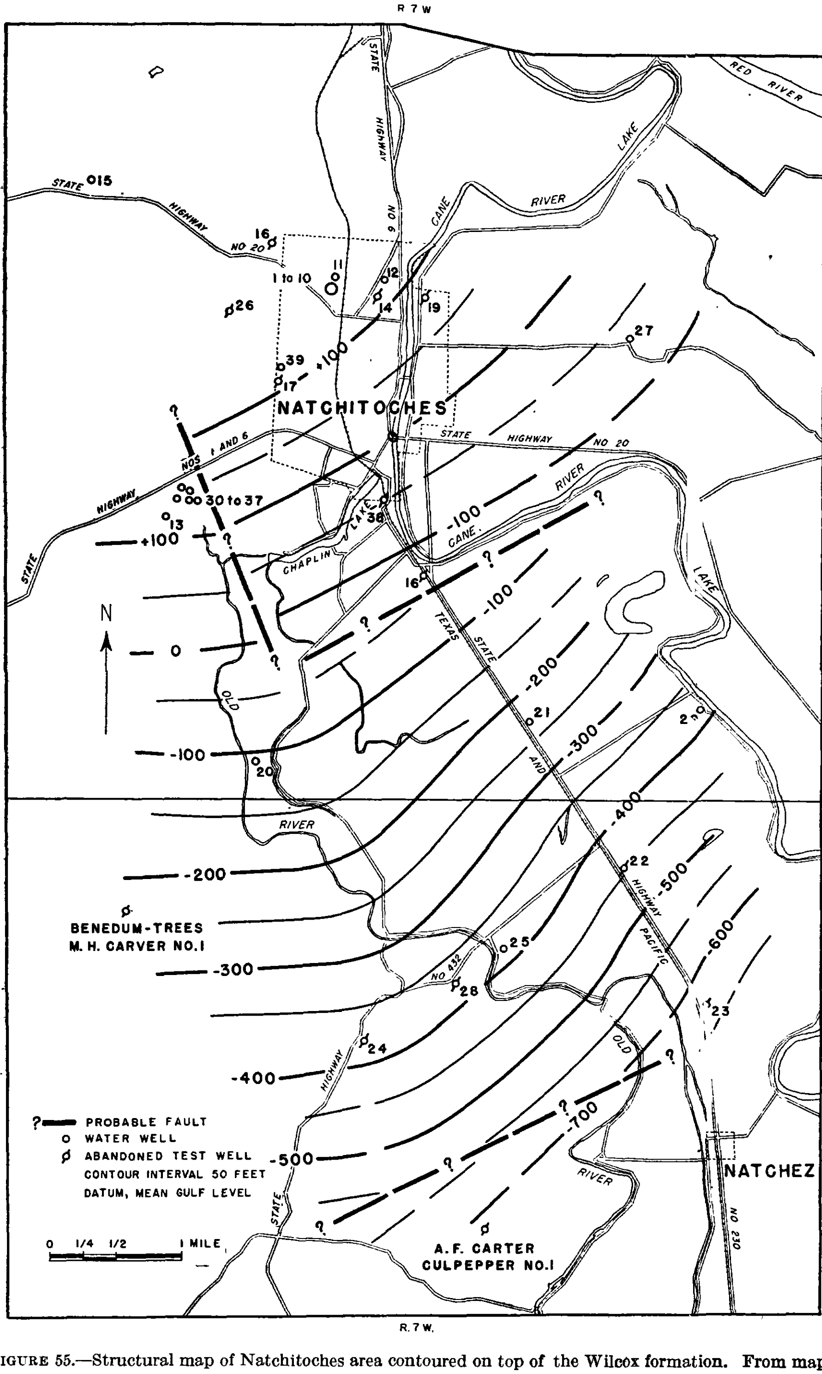


FIGURE 55.—Structural map of Natchitoches area contoured on top of the Wilcox formation. From maps of the United States Geological Survey, Campti and Bermuda quadrangles.

test in sec. 36½, T. 8 N., R. 7 W. (See fig. 55.) The apparent dip of the Wilcox formation between well 24 and Culpepper No. 1 is about 220 feet per mile, which indicates a structural break in the intervening area when compared to the lesser dip of 120 feet per mile between wells 13, 20, and 24. (See pl. 3, sec. *C-C'*.) As further evidence of this break, the upper sands of the Wilcox in Culpepper No. 1 contain brackish to salty water, whereas the same sands in wells 13, 20, and 24 contain fresh water. The formations on the southeast side of this fault are about 100 feet lower structurally than those on the northwest side. The strike of the fault cannot be accurately ascertained from the data available, but the abrupt termination of Big Henry Branch in the swamp area in secs. 34½ and 35½, T. 8 N., R. 7 W., suggests the direction indicated in figure 55.

Two faults near Natchitoches lie at right angles to each other and probably intersect about 2 miles southwest of the city in the vicinity of Old River. One of them trends southeastward from Sibley Lake along Youngs Bayou, passing into a slight structural nose about 1 or 2 miles south of State Highways 1 and 6. (See fig. 55 and pl. 3, sec. *E-E'*.) The maximum vertical displacement of this fault is about 100 feet. It forms a scarp to the west of Youngs Bayou. The water in the upper sands of the Wilcox to the west is fresh; that to the east is salty. The other fault extends northeastward from its probable intersection with the Youngs Bayou fault at least as far as Cane River Lake. This structural break, shown on plate 3, sections *B-B'* and *D-D'*, has a vertical displacement of about 75 feet, with the downthrown side to the northwest. Salt water is present in the upper sands of the Wilcox on the downthrown side. The fault is obscured by flood-plain alluvium but may be reflected in the abnormal drainage pattern south of Chaplin Lake. (See fig. 53.) It is interesting to note the effect of this fault or barrier upon the artesian pressure gradient, which normally decreases away from the outcrop. The water level of the first sand in the Wilcox in well 18, on the north (downthrown) side, was about 104 feet above mean gulf level, while the water levels in wells 21, 22, and 23 on the south side were respectively, 127, 148, and 157 feet above mean gulf level. This shows an increase away from the nearest outcrop of the sand and implies that recharge is obtained laterally from the west. Small amounts of natural gas found in the fresh water south of the fault may account for part of the higher artesian pressures, but the relative isolation of the salt water up dip from the fresh water supports the idea of normal artesian conditions modified by a fault barrier.

The relative positions of the two faults suggest that the city of Natchitoches and the Louisiana State Normal College may be situated upon a downthrown fault block defined on the southwest by the fault along Youngs Bayou and on the southeast by the fault extending from Old River toward Cane River Lake. Unfortunately the lack of adequate well records prevents the definition of the northeast and northwest limits of this block, but the widening of the contours between wells 14 and 19 on the structural map (fig. 55) and the presence of brackish water in the upper sands of the Wilcox in well 19 may be significant. If credence can be given the drillers' logs reported for wells 1, 11, 14, and 16 which were drilled 3 to 30 years ago, some flattening of the formational dip at the city well field may be inferred. Necessary subsurface control farther northwest has been lost through the failure to preserve a log of formations penetrated in the salt-water well at the country club (well 15). In a road cut near this well, steep dips to the southeast were noted in the sandy shales of the Wilcox formation. Considerably more data and detailed work are needed to outline this structure properly.

The upper sands of the Wilcox formation in this downthrown block contain brackish or salt water except in or near the recharge area where fresh water enters the outcrops. The shallow wells at relatively higher elevations in the northwestern part of the city are the only fresh-water wells on the fault block. Brine has been reported in the sands of the Wilcox penetrated by well 38 at Natchitoches Oil Mill and by other wells drilled on or near the Louisiana State Normal College campus during the past 45 years. The uppermost sand in the Wilcox in well 18, near the Cane River bridge south of the city on State Highway 230, yielded water that contained 17,200 parts per million of chloride. The Louisiana State Normal College wells, about 1 mile west of the campus, and wells 20, 21, 22, 24, 25, 28, and 29, 1 to 5 miles south of Natchitoches, are located beyond the faults limiting the west and south sides of the downthrown block and consequently yield fresh water.

The origin of this fault block may be associated with the origin of the topographic feature known as Sibley Lake, west of the city. This so-called lake is in reality a swamp drained only by Youngs Bayou to the south, along which a fault is indicated. This swamp is almost completely circled by hills (see fig. 54), receiving runoff from the upper end of Youngs Bayou on the west, Rio Hondo on the northwest, several unnamed streams on the north, and Bayou Jacko on the east. As shown in figure 54, a sketch map of the topography of this area, the surface of the swamp is less than 100 feet above mean gulf level. This indicates that subsidence similar to the central collapse over salt domes, described by Spooner,[15] may be responsible for both Sibley Lake and the downthrown fault block at Natchitoches.

[15] Spooner, W. C., op. cit., pp. 223-224.

The existence of a salt dome in this area cannot be proved from the available data, but the fact that the salt water from the first sand in the Wilcox in well 18 is not similar in chemical composition to connate sea water but resembles a soft sodium-bicarbonate water mixed with salt-dome brine[16] lends support to the theory. Veatch[17] in 1906 expressed the belief that subsurface leakage of brine from known salt domes far to the north had contaminated the ground water at Natchitoches. In view of the new data at hand, this long-distance migration of brine seems very doubtful. Wells dug 12 to 16 feet deep into the outcrop of the uppermost sand of the Wilcox in the Bayou Jacko lowlands west of the city are known to yield brackish or salty water. (See table 3, well 39.) Geophysical investigations by commercial operators may already have proved or disproved the existence of salt-dome structure at Natchitoches, but the results of such investigations have not been available to the writers.

QUALITY OF WATER

The chemical character of the water from the formations cropping out in this area is discussed further in this report in the section on Geologic formations and their water-bearing properties.

Thirty-nine samples of water from 9 wells and 10 test holes, representing the character of the water in each water sand at different localities, were collected and analyzed in the water resources laboratories of the Geological Survey at Austin, Tex., and Washington, D. C. The analysts were M. D. Foster, L. W. Miller, W. W. Hastings, and J. H. Rowley. The results of this analytical work are shown in table 4. The method of obtaining drill-stem samples in the test holes is described in the section on Drill-stem tests.

In general the natural waters from the sands of the Wilcox and Sparta formations are of the soft sodium-bicarbonate type, gradually increasing in mineralization down dip until they resemble sea water in composition. However, the local effect of faulting, associated with the probable structural deformation west of Natchitoches, is to create anomalies in the normal change in chemical character of the waters. This is illustrated by the water from the first sand of the Wilcox in well 18 at the south edge of the city. This water, fresh in wells up dip to the north, along the strike to the west, and down dip to the south, contains 17,200 parts per million of chloride. Its composition resembles that of a soft sodium-bicarbonate water contaminated by salt-dome brine rather than that of sea water,[18] as would be expected under normal conditions.

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[16] Foster, M. D., personal communication.
[17] Veatch, A. C., op. cit., p. 78.
[18] Foster, M. D., personal communication.

At localities where the waters in the sands of the Wilcox and Sparta are fresh, they usually contain large amounts of bicarbonate and have moderately large total dissolved solids. Aside from the fact that objectionable amounts of iron are somewhat more common in the waters of the Wilcox, the waters from the two aquifers are about equally satisfactory for human consumption. The iron content of the waters from the Wilcox formation ranges from 0.02 to 12 parts per million; that of waters from the Sparta sand ranges from 0.08 to 5.4 parts per million. Fluoride slightly in excess of 1 part per million was found in one sample from the Sparta sand.

The water from the Recent alluvium in the flood plain is hard and generally contains objectionable amounts of iron. The chloride content was not found to be excessive in any of the samples tested. However, the water from the Recent alluvium is not satisfactory for public supply without treatment. Where the sands of the Wilcox and Sparta directly underlie the Recent alluvium there may be either upward or downward leakage between the sands, depending upon the respective pressures in the sands, and the chemical character of the waters at such places may represent a mixture.

GEOLOGIC FORMATIONS AND THEIR WATER-BEARING PROPERTIES

In the following discussion, beginning with the Wilcox formation, the geological formations underlying this area are listed in the order in which they were deposited and in which they crop out from north to south. The wells referred to are described in table 2, and their locations are shown by number in figure 53. Analyses of water from most of these wells are given in table 3. The texture of the water sands is shown by the mechanical analyses in table 5.

EOCENE SERIES

WILCOX FORMATION

The sediments of the Wilcox formation [19] crop out in a relatively wide belt extending from southwestern Sabine Parish northeastward to the Red River near Natchitoches and thence northward into Arkansas. These sediments, representing alternating marine and nonmarine deposition near the strand line in Wilcox time, are composed principally of dark finely laminated, micaceous sands and clays of irregular character, thickness, and distribution. The sands, which predominate in the section, are generally laminated or cross-bedded in structure with only a few that appear on the outcrop to be massive. Most of the sands are fine-grained although coarse-grained phases are present at a few places. The clays and shales range from buff to

[19] Referred to as Sabine group by the Louisiana Geological Survey.

black in color and contain considerable lignitic material and some layers of marine shells and glauconite. Concentrations of pyrite nodules large enough to be logged as rock have been found in water wells penetrating the Wilcox sediments, and sandy limestone is not uncommon.

According to Spooner [20] the Wilcox sediments range in thickness from 800 feet in northern Louisiana to more than 2,500 feet in this area. However, in some recent publications [21] the lower part of this section is now considered to be of Midway age. As water wells in the Natchitoches area penetrate only a few hundred feet of Wilcox sediments, the discussion of this problem is not pertinent in this report.

Fresh water is found at Natchitoches in three sands in the upper 200 feet of the Wilcox formation. These sands are irregular in character and thickness, grading partly into sandy shale and shale at some locations. The upper sand marks the transition from the arenaceous continental deposits of the Wilcox formation to the marine clay and marl of the Cane River formation of the Claiborne group. Uncomformable relations reported to exist between the Wilcox formation and the Claiborne group were not apparent in this area. The upper sand crops out north and west of Natchitoches, forming gray sandy soil. There are numerous exposures along State Highway 6 west to Hagewood and a particularly good one in a road cut about half a mile south of Hagewood on State Highway 39. In general the sand is fine to medium-coarse in texture with considerable cross-bedding and includes many clay pebbles. It is almost always micaceous, and the basal portion generally contains large amounts of glauconite and shell fragments. In water wells and test holes the thickness of the upper sand ranged from 26 to 50 feet, the maximum thickness being in well 17 where the sand lies near the land surface; in other wells the average thickness was about 40 feet. Some of the differences in thickness from well to well are caused by the upper part of the sand lensing into sandy clay or shale, as in well 21. (See pl. 3, sec. *C–C′*.) Mechanical analyses (see table 5) show that this sand is the coarsest sand of the Wilcox, and the geologic cross sections indicate that it is the most uniform in thickness.

The second sand of the Wilcox formation is very irregular in character and contains many hard rock layers and clay lenses. Its thickness ranges from 9 to 45 feet, increasing down dip. The texture is fine and the permeability low. Usually 20 to 40 feet of clay and rock separate it from the upper sand.

[20] Spooner, W. C., op. cit., p. 234.

[21] LeBlanc, R. J., and Barry, J. O., Fossiliferous localities of Midway group in Louisiana: Am. Assoc. Petroleum Geologists Bull., vol. 25, pp. 734–737, 1941. Murray, G. E., Midway microfauna of northwestern Louisiana: Am. Assoc. Petroleum Geologists Bull., vol. 25, pp. 738–742, 1941.

The third sand of the Wilcox formation appears about 30 feet below the second, and its thickness, which is even more irregular than that of the second sand, ranges from only a few feet to 37 feet. Down dip it grades into fine sand with intercalated clay and layers of rock. This sand is relatively unimportant as an aquifer in the Natchitoches area.

The sands of the Wilcox formation are so fine-grained near the outcrop that most wells so located must be screened in two sands to produce small to moderate quantities of water. Wells 1 to 12 at the city water plant in northwestern Natchitoches draw upon the first and second sands, yielding an average of 30 gallons a minute per well. Salt water is found below the second sand. The wells are closely spaced and the sands are fine, resulting in overpumping in that area. At the Louisiana State Normal College well field, wells 30 to 37 are screened in the second and third sands, which are better developed at this locality. Here, too, close spacing combined with the fine texture of the sands has caused some difficulty. The yields of these wells are not accurately known but are about the same as those of the city wells. The college wells are situated west of a fault extending southeastward along Youngs Bayou. This probably accounts for the presence of salt water in the same sands only a mile or so east, at the college proper.

Test holes drilled into the sands of the Wilcox formation where they underlie the flood plain show that these sands have sufficient pressure for the water to flow at the surface at all locations south of well 18. Well 18, apparently located on the downthrown side of a fault (see pl. 3, sec. *B–B′*), has an abnormally low water level of 104 feet above mean gulf level (8 feet below the land surface). The remainder of the tests in the flood plain recorded water levels in the sands of the Wilcox ranging from about 115 to 157 feet above mean gulf level (4½ to 58 feet above land surface). Quantities of gas present in some of the tests may be partly responsible for some of the higher artesian pressures recorded. The yields of the test wells ranged from 5 gallons a minute in well 20 to 30 gallons a minute in well 25. However, 30 feet of screen was set in well 25 as compared with only 10 feet in the others.

Salt water was recorded in the sands of the Wilcox formation in wells 18, 26, 27, 38, and the A. F. Carter Culpepper No. 1. The salt water in wells 18 and 38 is probably a result of contamination by salt-dome brine. This contamination is probably related to two faults (see pl. 3, secs. *B–B′* and *D–D′*), one trending northeast-southwest between wells 18 and 21, and the other northwest-southeast, separating the college well field from wells 18 and 38. A sample from well 18 tested 17,200 parts per million of chloride and, according to M. D. Foster of the Water Resources Branch Laboratory, resembled a soft sodium-bicarbonate water mixed with brine from a salt dome. The salt water recorded in the Culpepper oil test is also associated with faulting. (See pl. 3, sec. *C–C′*.) Where geologic conditions are normal and the waters fresh, both the hardness and the chloride content of the waters range from about 5 to 100 parts per million. The waters contain variable amounts of iron, ranging from 0.05 to 12 parts per million. The bicarbonate content usually exceeds 400 parts per million.

CLAIBORNE GROUP

CANE RIVER FORMATION

The Cane River formation, the basal marine formation of the Claiborne group which directly overlies the Wilcox formation, is named for the excellent exposures of marine clays and marls along the west bank of Cane River Lake at Natchitoches. Its outcrop parallels that of the sandy Wilcox formation to the west and north, forming flat-land topography in contrast to the irregular hills of the Wilcox and Sparta. The upper part of the Cane River formation is composed principally of dark glauconitic sandy clay and shale with abundant microfossils. The lower part consists of fossiliferous glauconitic sandy shale and marl. A soft limestone about 6 feet thick occurs about 40 feet above the base of the formation. This 6-foot limestone bed is a key marker horizon, as it is easily identified on the electric logs and drillers' logs. In the Natchitoches area the Cane River formation ranges from 106 to 135 feet in thickness, thickening down the dip as shown on plate 3, sections *B–B′* and *C–C′*. In this area there are no productive water-bearing sands in the Cane River formation, and the little water that does occur in the sandy shales is highly mineralized.

SPARTA SAND

Beds of light-colored sand and sandy clay with some lignitic material and only a very few scattered fossils overlie the Cane River formation. These beds are known collectively as the Sparta sand, which was recognized by Spooner [22] as extending from the lowest fossiliferous horizon of the Cook Mountain formation to the marine clays of the Cane River formation. Spooner's description of the Sparta sand as given below applies very well to the formation in the Natchitoches area, except that the thickness here does not exceed 300 feet.

> The lower half of the Sparta sand is made up chiefly of massive sand with interbedded subordinate members of laminated sandy clay. The massive sands are made up of quartz grains somewhat coarser than found in the Wilcox forma-

[22] Spooner, W. C., op. cit., p. 236, 1926.

tion. The upper half contains a relatively greater amount of clay than the lower half. Massive sands alternate with beds of finely laminated sandy clay, in part lignitic and in many places containing fossil leaves. The upper 50 feet of beds contain a considerable amount of lignitic material and some thin lignitic beds which are particularly well exposed in the vicinity of the town of Bienville. The beds are commonly light colored, but, depending upon the amount of iron and carbonaceous matter, red and brown-colored beds occur. Fossils are generally absent from the Sparta sand, but a few species of near-shore forms are found near the middle of the formation. The Sparta sand has a thickness of 400 to 500 feet, with the greater thickness in the northern part of the salt-dome region.

Massive sands of the Sparta crop out south and southwest of the city of Natchitoches and form the belt of sandy hills that lies south and southeast of Bayou Souris. The northeast trend of these sandy ridges is interrupted by the Red River Valley where the Sparta sand is buried beneath Recent alluvium.

Previous to the test drilling by the city of Natchitoches the Sparta sand had never been developed in any water wells in this vicinity. This is surprising in view of the poor quality of the water from the Recent alluvium, in which many farm wells have been finished, and the relatively shallow depth to the Sparta sand in most of the area. Seven of the nine test wells drilled by the city tested the Sparta sand, five of them (wells 22, 23, 24, 25, and 28) penetrating complete sections of the Sparta. One other well, the oil test, A. F. Carter Culpepper No. 1, in sec. 36½, T. 8 N., R. 7 W., also drilled through a complete section of the Sparta sand. On the basis of these drillings the total thickness of the Sparta sand ranges from 260 to 283 feet, thickening down dip to the south. The percentage of sand in the section also increases down dip, being less than 20 percent in well 25 and more than 80 percent in the A. F. Carter Culpepper No. 1. The sands are generally fine to medium coarse-grained, the finer material predominating. (See table 5.) Despite the irregular and unpredictable character of the sand bodies, the principal water sands are probably interconnected, as the water levels recorded in drill-stem tests at different sand horizons in the Sparta agree very well. Drill-stem tests of the Sparta sand were made in six of the test holes. The water levels ranged from 101 feet above mean gulf level (8 feet below land surface) in well 21, to 127 feet above mean gulf level (80 feet below land surface) in well 24. Intermediate artesian heads are present between these wells, showing a pressure gradient eastward. This is in accord with geologic evidence pointing to recharge of the water sands in the hill lands west of the flood plain. The yields obtained in the drill-stem tests ranged from 5 to 48 gallons a minute, the highest yield being from well 24. These yields are valuable only for comparative purposes and do not represent the probable yields of supply wells in the formation tested. Fresh water was found in all of the drill-stem tests except those in well 23, the southeasternmost test well. The water from this well was slightly brackish; the sample from the upper part of the Sparta sand tested 559 parts per million of chloride and the one from the lower part of the Sparta sand, 341 parts per million. This limits the area in which fresh water may be found in the Sparta sand beneath the flood plain to the land south of wells 20 and 21 and northwest of well 23. In the hill land the Sparta sand contains fresh water as far south as Flora and probably as far west as the Texas line.

The fresh water from the Sparta sand is generally soft and alkaline. In the nine samples analyzed (see table 3) the hardness ranged from 4 to 114 parts per million and averaged 33.5 parts per million. The maximum figure, 114 parts per million, was recorded for a sample from well 21, where the beveled edge of the Sparta sand is directly overlain by Recent alluvium containing hard water. It is thought that the sample of water from supposed Sparta sand in well 21 was a mixture of waters from the Sparta sand and the Recent alluvium. This conclusion is borne out by the relatively high iron content of the sample, 1.1 parts per million. The bicarbonate content of the samples averaged 317 parts per million. None of the samples contained fluoride in excess of 1 part per million.

COOK MOUNTAIN FORMATION

The Cook Mountain formation is comprised of fossiliferous marine sands and clays lying between the nonmarine sandy sediments of the Cockfield formation and Sparta sand. The sands are generally fine-grained and very irregular in character, usually containing numerous hard layers of ferruginous sandstone. The color of the sands ranges from light gray to brown and red. The clays are of many different colors, depending upon the amounts of iron, carbonaceous material, and glauconite present. Nodular limestone horizons and marl beds occur in the lower part of the formation, and both the uppermost and lowermost beds are extremely fossiliferous. The thickness of the formation in the Natchitoches area ranges from 224 to 244 feet. Owing to its relative impermeability this formation cannot be considered as a possible source of water supply at Natchitoches.

In the course of the field work in the outcrop area of the Cook Mountain formation south of Natchitoches an interesting vertebrate fossil was found by the junior author in the lower part of the section (Huner's Milams member of the Cook Mountain formation)[23] which is exposed at the edge of the hills adjacent to the flood plain in sec. 10, T. 8 N., R. 7 W., about 100 feet north of well 28. The fossil material was

[23] Huner, J., Geology of Caldwell and Winn Parishes: Louisiana Dept. Cons. Geol. Bull. No. 15, pp. 91, 95, 1939.

collected and sent to J. B. Reeside, Jr., of the Geological Survey in Washington, D. C., who referred the material to Remington Kellogg of the United States National Museum. The following is a quotation from a letter from Reeside regarding the identity of the specimen:

> Remington Kellogg, of the U. S. National Museum, reports that the specimen from the Cook Mountain formation in Natchitoches Parish is an entirely new Archaeocete (the toothed whales formerly known as Zeuglodonts). It still lacks a name and, being new, gives little help in correlation. The occurrence is the earliest recorded for this group of animals in the Gulf region.

H. V. Howe, of Louisiana State University, identified the following list of microfossils from the clay matrix of the specimen and confirmed the field identification of the matrix as marl from the Milams member of the Cook Mountain formation.

FORAMINIFERA

Siphonina claibornensis
Siphonina goochi
Siphoninella claibornensis
Gyroidina soldanii octocamerata
Eponides guayabalensis
Anomalina costiana
Anomalina umbonata
Ceratobulimina eximia
Planulina kniffeni
Cibicides pseudowuellerstorfi
Cibicides lawi
Cibicides sassei
Cibicides mauricensis
Asterigerina hadleyi
Globorotalia centralis
Globorotalia crassata
Globorotalia spinulosa
Globigerina topilensis
Globigerina ouachitaensis
Globogerina mexicana
Textularia zapotensis
Karreriella mauricensis
Robulus alate-limbatus
Robulus pseudocultratus
Robulus jugosus
Lagena mauricensis
Lagena ouachitaensis
Guttulina austriaca
Gullulina irregularis
Globulina minuta
Globulina gibba
Nonion florienensis
Nonion planatum
Nonion micrum
Nonionella mauricensis
Discocyclina perpusilla
Triloculina garretti
Triloculina trigonula
Triloculina mindenensis
Triloculina natchitochensis
Uvigerina blanca-costata
Loxostomum claibornense
Bulimina robertsi
Quinqueloculina mauricensis
Massilina mauricensis
Operculinoides sabinensis
Cornuspira olygogyra
Glandulina laevigata
Kobulus mexicanus
Dentalina winniana
Discorbis? globulospinosa

OSTRACODA

Cythereis cooleycreekensis
Cythereis winniana
Cythereis undosa
Cytheridea montgomeryensis
Cytheridea oliveri
Cytheropteron proboscense
Loxoconcha claibornensis
Loxoconcha chamfera
Brachycythere russelli
Brachycythere watervalleyensis

COCKFIELD FORMATION

The Cockfield formation is exposed at the surface in the southern part of the Natchitoches area west of Natchez. It consists of fine light-colored sands, generally massive in structure, with laminated, thin-bedded sandy clays and lignitic silty shales. Although no marine fossils are reported in the formation, numerous horizons of fossil leaves and concretionary zones do exist. The entire section has not been penetrated by wells in this area, but it is reported to exceed 500 feet in thickness in oil tests in adjacent areas. The only well cited in this report that penetrated the Cockfield formation is the A. F. Carter Culpepper No. 1, which is located on the downthrown side of a fault. (See fig. 55.) This oil test drilled through 163 feet of the Cockfield, beginning at the land surface.

The Cockfield formation yields fresh water to wells several miles farther south. At Flora wells ranging from 300 to 350 feet in depth draw upon this source. Because of the low permeability of the water sands the yields of these wells are not large. The water is reported to be moderately soft to moderately hard, 50 to 120 parts per million, and to contain rather large amounts of bicarbonate and sulfate.

PLEISTOCENE AND RECENT SERIES

Sand, gravel, and clay of Pleistocene and Recent age mantle the older formations in central Louisiana. The Pleistocene deposits have been described by Fisk [24] as four formations, Prairie, Montgomery, Bentley, and Williana, which form four terraces above the present Red River flood plain. Huner [25] mapped these terraces in nearby Winn Parish, but such work has not been done in Natchitoches Parish. Remnants of these terraces may exist in the hills in the Natchitoches area under consideration, but they are too thin and scattered to warrant consideration as aquifers. The flood plain along Cane River Lake is underlain by Recent alluvium ranging in thickness from a few feet to about 104 feet. This alluvium grades downward from clay into coarse sand and gravel. The upper red-colored clay is 25 to 35 feet thick and overlies bodies of fine sand and sandy clay, which extend to a depth of about 50 to 60 feet. The coarse material is generally below a depth of 60 feet. Gravel is not present at all locations, although the sand is generally coarse enough to yield moderately large supplies of water.

The water level in the Recent alluvium ranges from 9 to 17 feet below the land surface. Yields of 3 to 25 gallons a minute were obtained in drill-stem tests of this alluvium. The temperature of the water is

[24] Fisk, H. N., Geology of Avoyelles and Rapides Parishes: Louisiana Dept. Cons. Geol. Bull. 18, p. 175, 1940.

[25] Huner, J., Jr., op. cit., pp. 46–55.

about 67° F. All of the water is hard, the hardness ranging from 342 to 510 parts per million, and the iron content usually exceeds 3 parts per million. (See table 3.) This water is not suitable for most domestic purposes without treatment.

SUMMARY AND CONCLUSIONS

In the area between Natchitoches and Natchez (upper half of T. 8 N., R. 7 W., and all of T. 9 N., R. 7 W.) the geologic formations that will yield a water supply of at least 1,000,000 gallons a day are the upper sands of the Wilcox formation, the Sparta sand and the Cockfield formation of the Claiborne group, and the Recent alluvium. Water from the Recent alluvium is the most accessible, as wells located just east of Cane River Lake would supply the desired quantity. However, this water is not satisfactory for public supply without treatment, as it is very hard and contains objectionable amounts of iron. The water from the Cockfield formation is generally moderately soft to moderately hard and is well suited for domestic or industrial use, but the formation is present only in the extreme southern part of the area. The distance involved in piping water to the city from wells in this formation prohibits consideration of it as a possible source of water for the public supply of Natchitoches.

The upper sands of the Wilcox formation which underlie Natchitoches supply small amounts of fresh water to municipal wells in the north part of the city and to the wells of the Louisiana State Normal College southwest of the city. Between the two well fields the sands of the Wilcox contain salt water, the occurrence of which is probably associated with structural deformation in the Sibley Lake area. The water-bearing sands have been overdeveloped at both well fields, and it would be inadvisable to drill additional wells at either place. The site for a new well field, therefore, must be south of the city, beyond the areas of faulting and salt-water contamination, as described in the section on structural geology.

Test wells 20 and 21 revealed that the upper sands of the Wilcox formation at these locations contain fresh water but are too thin and fine-grained to warrant the installation of supply wells. The proximity of faulting and the unfavorable location with respect to the area of recharge further impair their possibilities. Test well 22 recorded sands of the Wilcox of favorable thickness and texture, but the danger of salt-water intrusion renders this location undesirable. The chloride content of waters from the Wilcox formation in well 22 is 95 to 103 parts per million, but in well 23, 1¼ miles south, these waters are salty. (See pl. 3, sec. *B–B′*.) Heavy pumpage in the vicinity of well 22 might cause the salt water to encroach upon the pumped wells. The locations of test wells 24, 25, and 28 appear to be satisfactory for supply wells in the Wilcox formation.

The Sparta sand does not underlie Natchitoches and the immediate vicinity, but the beveled edge of the formation was penetrated by both wells 20 and 21, located about 1½ miles south of Natchitoches. (See pl. 3, secs. *B–B′* and *C–C′*.) Water sands of the Sparta tested in wells 20, 21, and 23 are not considered worthy of development, because they either contain highly mineralized water or are too thin and fine-grained. West of the valley the sands of the Sparta are thicker and more permeable, the water levels are higher, and the quality of the water is good. Test wells 24 and 28 revealed sands in the Sparta that are suitable for development in supply wells.

It is thought that four or five properly developed wells drawing upon the sands of the Wilcox formation and the Sparta sand in secs. 10, 56, and 57, T. 8 N., R. 7 W., will supply as much as 1,000,000 gallons of water a day. The most feasible distribution of these wells, if the pipe line is laid along the highway right-of-way, is either a T-shaped or straight-line pattern, with the wells at approximately half-mile intervals to minimize the pumping interference between wells drawing upon the same sand. In either case the first two well locations would be the same, that is, supply well 1, screened in the first sand of the Wilcox, at the Old River bridge on State Highway 432 and supply well 2, screened in the Sparta sand, at the location of test well 28 half a mile southwest of well 1 on State Highway 432.

In following the T pattern, supply well 3 would be drilled about half a mile north of well 2, and well 4, half a mile south of well 2. If a fifth well is needed it is possible that a double location could be made at one of the previously drilled sites where sands of both the Wilcox and Sparta appear favorable. This T pattern would place all of the wells on the flood plain and result in a minimum of drilling footage. Probably all of the wells would flow at the surface to a small extent, but that is not significant, because the total pumping lift necessary to bring the water to the land surface and pump it through the pipe line into the city would be about the same whether the wells are on the lowland or in the hills.

In following the straight-line pattern, the pipe line would be extended into the hills along State Highway 432 toward test well 24. Supply wells 3 and 4 would be situated at approximately half-mile intervals southwest of supply well 2. It is likely that two wells, one in the Sparta sand and one in the first sand of Wilcox formation, might be feasible at the location of well 3 or well 4. This pattern of wells requires deeper wells than the other pattern but offers some offsetting advantages. The sands of the Sparta appear to be thicker and coarser in the hill land than in the valley, and therefore larger yields may be expected from wells tapping this formation in the hills. The wells in the hills may be located adjacent to the highway, whereas supply wells 3 and 4 in the lowland would require the construction and maintenance of side roads.

Regardless of the plan decided upon, it will be advisable to drill pilot holes at the locations before the large-diameter holes are drilled. The supply wells should be equipped with meters and air-line gages, so that accurate records of pumpage and water levels may be kept.

The results of this investigation are of regional value when it is recalled that the water sands of the Sparta and Wilcox extend westward into Texas and northward into Arkansas. A few large water supplies, principally for paper mills, have been developed from the Sparta sand north and east of the Red River, but no large developments have been made in Louisiana west of the Red River. The establishment of new industrial plants requiring moderately large supplies of soft water is feasible in west-central Louisiana immediately south of the outcrop of the Sparta sand. The irregular character of this formation does not permit accurate estimates of the yields to be expected in wells, so the selection of favorable sites for ground-water supplies will require additional exploratory drilling. As it may be desirable for the city of Natchitoches to extend its proposed well field to the west in case of increased consumption in the future, it will not be advisable to develop another large ground-water supply within several miles of the proposed city well field.

TABLE 1.—*Outline of stratigraphy in Natchitoches area, Louisiana*

System	Series	Group	Formation	Approximate total thickness (feet)[1]	Character of rocks	Water-bearing properties
Quaternary.	Recent.			0–104	Silt, clay, sand, and gravel, confined to stream valleys.	Yields moderate quantities of hard water containing considerable amount of iron.
	Pleistocene.			?	Clay, sand, and gravel as terraces along stream valleys.	Too thin to be source of water in this area.
Tertiary.	Eocene.	Claiborne group.	Cockfield formation.	500 (?)[2]	Massive irregular light-colored sands with thin-bedded sandy clays and lignitic clays with marine fossils.	Yields small to moderate quantities of soft water.
			Cook Mountain formation.	224–244	Varicolored glauconitic and carbonaceous clays, cross-bedded ferruginous sands, fossiliferous marl, and ironstone.	Relatively impermeable, with little or no fresh water.
			Sparta sand.	260–283	Massive irregular sands with interbedded sandy clay.	Test wells indicate moderate to large supplies of soft water may be obtained where sandy phases are well developed.
			Cane River formation.	106–135	Chocolate brown clays, glauconitic marl, and sandy shales with marine fossils.	Relatively impermeable, with no fresh water.
			Wilcox formation.	2,500 (?)[3]	Dark finely laminated sands and clays with considerable lignite.	Sands in upper 200 feet yield small to moderate quantities of soft fresh water. Permeability is generally low.

[1] Total thickness of complete section in wells in this area.
[2] Cockfield formation reported to exceed 500 feet in thickness.
[3] Wilcox formation, including lower section now assigned to Midway group by Louisiana Geological Survey, reported to approximate 2,500 feet in thickness.

TABLE 2.—*Records of wells in the Natchitoches area, Louisiana*

[PS, Public supply; Ab, abandoned; T, test; D, domestic; S, stock. Numbers designating the wells are the same as those in table 3 and fig. 53. Altitudes based on topographic maps of U. S. Geological Survey or aneroid traverses]

No.	Location	Owner	Date completed	Diameter (inches)	Total depth (feet)	Aquifer (depth in feet)	Screen setting (depth in feet)	Static water level in feet above (+) or below (−) land surface	Date of measurement	Altitude of land surface at test location	Yield (gallons per minute)		Temperature (°F.)	Use	Remarks
											Flow	Pump			
1 (Na-11)	S. cor. power plant, in irreg. sec. 45, T. 9 N., R. 7 W., Natchitoches.	City of Natchitoches.	July 1913	8	102	Wilcox (18-62)	20-60							PS	
2 (Na-12)	SW. side power plant in irreg. sec. 45, T. 9 N., R. 7 W., Natchitoches.	do	do	6	80	Wilcox	15-55							PS	Reported pumped 45 gallons per minute in 1913.
3 (Na-13)	W. cor. power plant, in irreg. sec. 45, T. 9 N., R. 7 W., Natchitoches.	do		6	90	do								PS	
4 (Na-16)	NW. side power plant, in irreg. sec. 45, T. 9 N., R. 7 W., Natchitoches.	do		8	90	do								PS	
5 (Na-17)	N. cor. power plant in irreg. sec. 45, T. 9 N., R. 7 W., Natchitoches.	do		8	85	do								PS	
6 (Na-15)	W. cor. plant property in irreg. sec. 45, T. 9 N., R. 7 W., Natchitoches.	do		6	60	do								Ab	
7 (Na-18)	Across road NW. of power plant, irreg. sec. 44, T. 9 N., R. 7 W., Natchitoches.	do		8	65	do								PS	
8 (Na-19)	do	do		8	190	do								PS	
9 (Na-20)	do	do		8	190	do								PS	
10 (Na-21)	do	do		8	200	do								PS	
11 (Na-52)	N. cor. plant property in irreg. sec. 45, T. 9 N., R. 7 W., Natchitoches.	do	June 1941	6	255	Wilcox (40-61) (146-160)	39-70 135-156			132		30		PS	2 screens. Lower screen set in sandy shale. Salt water in sand at 221-254 feet.

12 (Na-64)	W. side ball park 3 blocks E. of power plant, irreg. sec. 42, T. 9 N., R. 7 W., Natchitoches.	do	July 1941	6	119	Wilcox	72-112			142				PS	Yields red-colored water.
13 (Na-62)	S. end street off State Highway 1, irreg. sec. 81, T. 9 N., R. 7 W., Natchitoches.	do	July 15, 1943	8	237	do	98-116 150-186	−90.9	Feb. 3, 1944	170		50	67.5	PS	Temporary supply well. Electric survey July 14, 1943.
14 (Na-14)	NW. side ball park, irreg. sec. 42, T. 9 N., R. 7 W., Natchitoches.	do	May 5, 1940	6	231	Wilcox (189-200)	190-200			140				Ab	Reported fresh water.
						Wilcox (202-232)	222-232								Reported salt water.
15 (Na-33)	S. side country club swimming pool, sec. 13, T. 9 N., R. 7 W.	do	Before 1940 (?)	8	400	Wilcox	4 screens			164				PS	Yields salt water.
16 (Na-63)	SE. end irreg. sec. 123, T. 9 N., R. 7 W., Natchitoches (P. A. Welch property).	do	May 1940	6	399	Wilcox (384-399)	No test			162				Ab	Reported sands too fine to yield water.
17 (Na-49)	Test hole, N. end Collins St., sec. 43, T. 9 N., R. 7 W., Natchitoches.	do	May 19, 1941	4	605	Wilcox (188-208).	198-208		May 1941	125				T	Small yield. Chloride content 180 parts per million.
						Wilcox (460-484).	460-484	−23.1	do					T	Brackish water; chloride content 1,460 parts per million.
18 (Na-50)	Test hole, NE. end irreg. sec. 74, T. 9 N., R. 7 W., Natchitoches.	do	May 31, 1941	4	509	Alluvium (63-85).	75-85	−10.0	do	110				T	Hardness 585 parts per million.
						Wilcox (238-282).	272-282	−6.0	do					T	Salt water; chloride content 17,200 parts per million.
19 (Na-51)	Test hole, across Cane River Lake, NW ¼ sec. 36, T. 9 N., R. 7 W.	do	June 6, 1941	4	93	Alluvium (67-80).	70-80	−11.7	do					T	Fine gray sand; 80-93 feet may be Wilcox.
20 (Na-53)	Test hole 1, W. side irreg. sec. 87, T. 9 N., R. 7 W.	do	Sept. 13, 1943	6	339	Alluvium (20-46).	39-44	−11.2	Sept. 13, 1943	110		3	71 (?)	T	Electric survey Sept. 8, 1943. Packer failed in drill-stem test of upper sands.
						Sparta (56-66)	59-64	−7.0	Sept. 11, 1943			6	72 (?)	T	
						Wilcox (210-240).	223-228	+4.5	Sept. 10, 1943		5		69 (?)	T	Gas bubbles. Farm well set here.
21 (Na-54)	Test hole 2, SW. end irreg. sec. 105, T. 9 N., R. 7 W., on State Highway 230.	do	Oct. 4, 1943	6	434	Alluvium (74-104).	95-105	−12.3	Oct. 4, 1943	109		7.5	69.5	T	Electric survey Sept. 28, 1943.
						Sparta (156-162).	150-160	−7.6	Oct. 3, 1943			5	71	T	
						Wilcox (366-382).	370-380	+18.2	Oct. 1, 1943		10		71	T	Small quantity of gas.
						Wilcox (421-430).	417-427	+21.7	Sept. 29, 1943		12		72	T	Considerable gas. Farm well set in Wilcox sands.

TABLE 2.—*Records of wells in the Natchitoches area, Louisiana*—Continued

No.	Location	Owner	Date completed	Diameter (inches)	Total depth (feet)	Aquifer (depth in feet)	Screen setting (depth in feet)	Static water level in feet above (+) or below (−) land surface	Date of measurement	Altitude of land surface at test location	Yield (gallons per minute)		Temperature (°F.)	Use	Remarks
											Flow	Pump			
22 (Na-56)	Test hole 3, irreg. sec. 60, T. 8 N., R. 7 W., on State Highway 230.	City of Natchitoches.	Nov. 24, 1943	6	695	Alluvium (58–101).	85–95	−9.3	Nov. 24, 1943	105		25	66.5	T	Electric and caliper surveys Nov. 11, 1943.
						Sparta (390–416).	403–413	+16.5	Nov. 22, 1943		3.5	15	67.5	T	
						Wilcox (550–596).	584–594	+43.2	Nov. 20, 1943		8	8	65	T	
						Wilcox (644–684).	670–680	+30.3	Nov. 15, 1943		5			T	
23 (Na-57)	Test hole 4, irreg. sec. 79, T. 8 N., R. 7 W., on State Highway 230.	do	Dec. 13, 1943	6	991	Sparta (348–366)	351–361	+8.3	Dec. 4, 1943	105	8		67.5	T	Electric survey Dec. 11, 1943. Brackish water.
						Sparta (538–595)	574–584	+19.3	Dec. 7, 1943		5		69	T	Sparta sands tested before drilling deeper Semibrackish water.
						Wilcox (726–766)	754–764	+52.8	Dec. 14, 1943		26		77	T	Salt water and gas.
						Wilcox (820–848)	836–846	+44.3	Dec. 13, 1943		26		72.5	T	Salt water and gas. Flowed by heads.
24 (Na-55)	Test hole 5, SE. side irreg. sec. 56, T. 8 N., R. 7 W. on State Highway 432.	do	Nov. 1, 1943	6	706	Sparta (290–386).	372–382	−80.0	Nov. 1, 1943	206		48	71	T	Electric survey Oct. 21, 1943.
						Sparta (430–448).	435–445	−79.1	Oct. 27, 1943			6	70	T	
						Wilcox (578–609).	594–604	−59.1	do			8	70	T	
						Wilcox (639–684).	672–682	−87.0	Oct. 25, 1943			5	70	T	
25 (Na-58)	Test hole 6, NE. part irreg. sec. 10, T. 8 N., R. 7 W.	do	Jan. 6, 1944	6	810	Alluvium (59–71).	66–69	−17.1	Dec. 23, 1943	107				T	Electric survey Jan. 3, 1944.
						Sparta (126–145).	126–145	−9.1	Jan. 7, 1944			6	67	T	
						Sparta (254–269).	250–280	+16.4	Jan. 6, 1944		6		68.5	T	
						Wilcox (490–538).	500–530	+38.5	Jan. 4, 1943		30		71	T	Gas show. Farm well set here.
						Wilcox (654–674).	650–680	+59.0	Jan. 11, 1943		20		70	T	

26 (Na-59)	Test hole 7, SW. part irreg. sec. 46, T. 9 N., R. 7 W.	do	Jan. 31, 1944	6	556	Wilcox	No tests.			123				T	Electric survey Jan. 31, 1944. Brackish water in all sands.
27 (Na-60)	Test hole 8, center irreg. sec. 34, T. 9 N., R. 7 W.	do	Feb. 12, 1944	6	461	Alluvium (70-85).	No test.			124				T	Electric survey Feb. 10, 1944. Fresh water. Farm well set here.
						Wilcox	No tests.								Brackish water.
28 (Na-61)	Test hole NE part irreg. sec. 15, T. 8 N., R. 7 W.	do	Mar. 22, 1944	6	750	Sparta (207-260).	240-250	+12.0		109	20	35	68	T	Electric survey Mar. 21, 1944.
						Wilcox (501-548).	540-559	+33.6			6				Gas.
29 (Na-27)	NE¼ sec. 104, T. 9 N., R. 7 W., behind house.	C. Morgan	1940	3	550	Wilcox (500-550).	500-550			115				D	Gas bubbles in water.
30 (Na-29)	College No. 1, NE. part sec. 81, T. 9 N., R. 7 W.	Louisiana State Normal College.		12	230	Wilcox								Ab	No accurate records available.
31 (Na-30)	College No. 7, NE. part sec. 81, T. 9 N., R. 7 W.	do		12	160	do								Ab	Do.
32 (Na-31)	College No. 4, NE. part sec. 81, T. 9 N., R. 7 W.	do		12	700	do		−33.7	Apr. 18, 1941	170				Ab	No accurate records available. Salt water.
33 (Na-22)	College No. 8, NE. part sec. 81, T. 9 N., R. 7 W.	do		8	239	do		−30.0	1943					PS	No accurate records available.
34 (Na-23)	College No. 12, NE. part sec. 81, T. 9 N., R. 7 W.	do		8	222	do		−39.0	1943					PS	Do.
35 (Na-24)	College No. 11, NE. part sec. 81, T. 9 N., R. 7 W.	do		8	234	do		−40.0	1943					PS	Do.
36 (Na-25)	College No. 13, NE. part sec. 81, T. 9 N., R. 7 W.	do		10	262	do								PS	Do.
37 (Na-26)	College No. 14, NE. part sec. 81, T. 9 N., R. 7 W.	do		10	182	do								PS	Do.
38 (Na-65)	NE. end sec. 77, T. 9 N., R. 7 W., at oil mill.	Natchitoches Oil Mill, Inc.	Mar. 1913	8-4	1000	do								Ab	Questionable record. Salt water.
39 (Na-66)	Irreg. sec. 139, T. 9 N., R. 7 W., near Bayou Jacko.	Ellis Dean		36	12	do	12							S	Brackish water; chloride content 1,525 parts per million.

TABLE 3.—*Partial analyses of water samples from wells in the Natchitoches area, Louisiana*

[Analyses by M. D. Foster, L. W. Miller, W. W. Hastings, and J. H. Rowley. Parts per million except pH. W, Wilcox formation; S, Sparta sand; R, Recent alluvium]

Well No.	Depth of screen (feet)	Geologic formation	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium and Potassium (N+K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	Hardness as $CaCO_3$	pH
1 (Na-11)	80	W	12	26	13	33	4	74	77	0.0	0.10	305	118	
9 (Na-20)	190	W					30	30	23	.1			50	
10 (Na-21)	200	W	3.4	5.7	3.9	25.5	33	42	10	.0	.0	141	30	
11 (Na-52)	61 160	W					174	26	49	.1	1.0		27	
11 (Na-52)	254	W					490	45	[1] 382	.2			18	
13 (Na-52)	116 186	W					178	9	8				99	
17 (Na-49)	208	W					73	60	180	.4			105	
17 (Na-49)	484	W					1,202	12	1,460	1.4			42	
18 (Na-50)	85	R					784	1	87	1.1			510	
18 (Na-50)	282	W					460	12	17,200				1,440	
19 (Na-51)	93	R					484	13	28	.2	.25		378	
20 (Na-53)	228	W	.09	2.6	1.3	221	574	2	15		.0	544	12	
21 (Na-54)	105	R	4.2	76	37	191	708	3	122	.6	.0	787	342	7.1
21 (Na-54)	160	S	1.1	24	13	367	689	14	235	.6	.0	1,001	114	7.7
21 (Na-54)	380	W	.61	2.2	1.4	272	646	2	50	.4	.0	665	12	8.1
21 (Na-54)	427	W	.29	2.0	.8	305	672	1	84	.4	.0	733	8	8.1
22 (Na-56)	95	R	3.4	92	52	199	768	144	68	.5			444	6.8
22 (Na-56)	413	S	.56	2.5	1.3	129	298	4	29	.6			12	8.0
22 (Na-56)	594	W	6.0	4.0	1.4	321	676	12	103	.8			16	8.0
22 (Na-56)	680	W	2.3	3.4	1.4	295	626	8	95	.6			14	7.8
23 (Na-57)	361	S	5.4	7.7	2.7	512	360	50	559	.02	7.6	1,410	30	8.2
23 (Na-57)	594	S	.72	3.7	.6	321	262	3	347	.2	1.2	818	12	8.3
23 (Na-57)	764	W	.13	49	22	2,640	555	10	3,890	.0	.8	7,010	213	8.3
23 (Na-57)	846	W	4.2	48	22	2,900	529	2	4,310	.0	2.5	7,660	210	8.2
24 (Na-55)	382	S	.34	17	3.2	90	208	46	22	.6	.0		56	7.3
24 (Na-55)	445	S	.10	9.6	1.4	93	192	50	15	.6	.0		30	7.9
24 (Na-55)	604	W	.05	3.4	.7	275	656	3	48	.8	.0		12	8.4
24 (Na-55)	682	W	11	3.4	1.5	236	608	3	18	.4	.0	579	14	8.3
25 (Na-58)	90	R	5.1	18	39	85	401	5	37		5.0	412	206	8.8
25 (Na-58)	145	S	.14	5.1	2.1	293	464	5	193	1.0	.0	748	21	7.8
25 (Na-58)	269	S	.08	1.3	.2	110	199	2	55	.2	.0	288	4	8.0
25 (Na-58)	530	W	.06	2.5	.6	297	679	3	67	.4	.0	730	8	8.4
25 (Na-58)	672	W	.10	3.8	1.6	527	774	3	370	.8	.0	1,330	16	8.3
25 (Na-61)	250	S	.52	7.1	1.3	149	184	4	134	.6	.8	388	23	6.8
28 (Na-61)	550	W	.02	3.4	1.0	296	678	3	68	.6	.2	706	12	8.5
29 (Na-27)	550	W					577	3	157	.4	.2		30	
36 (Na-25)	262	W	.07	9.1	2.6	58.6	164	17	6.6	.0	1.4	209	33	
37 (Na-26)	182	W					186	13	6	.0			63	
39 (Na-66)	12	W					351	400–500	1,525	.0			1,770	

[1] Later field tests after continued pumping indicated chloride content increased to about 550 parts per million.

TABLE 4.—*Logs of wells in the Natchitoches area, Louisiana*

[Records of wells are included in table 2, and locations are shown in fig. 53. Data from drillers' logs, electric logs, and samples]

Well 1 (Na-11)

	Depth (feet)
Eocene series:	
Wilcox formation:	
Red and yellow clay	0–18
Fine sand	18–62
Black sand (?) and lignite	62–128

Well 11 (Na-52)

	Depth (feet)
Eocene series:	
Wilcox formation:	
Soil and clay	0–3
Medium-grained yellow sand	3–15
Ferruginous yellow sandy clay	15–24
Medium-grained yellow sand	24–40
Medium-grained gray sand	40–61
Tough clay	61–87
Glauconitic sand	87–89
Sandy shale	89–91
Gray sandstone	91–92
Sandy shale	92–118
Shale	118–146
Sand and shale	146–160
Dark-brown sandstone	160–161
Sandy shale	161–207
Gray sandstone	207–208
Sandy shale	208–221
Very fine sand (brackish water)	221–254
Sandstone	254–255

Well 13 (Na-62)

	Depth (feet)
Pleistocene (?) series:	
Yellow sand	0–4
Fine red sand	4–7
Eocene series:	
Claiborne group:	
Cane River (?) formation:	
Red sandy clay	7–36
Stiff clay	36–44
Wilcox formation:	
Sand	44–48
Clay	48–54
Sandy clay	54–60
Clay	60–66
Sand	66–70
Sandy shale	70–74
Clay	74–84
Sandy shale	84–88
Shale	88–94
Sandy shale	94–98
White sand	98–116
Gray shale	116–150
Lignitic sand	150–187

TABLE 4.—*Logs of wells in the Natchitoches area, Louisiana*—Continued

Well 13 (Na-62)—Continued

	Depth (feet)
Eocene series—Continued	
Wilcox formation—Continued	
Sandy shale	187–205
Sand	205–210
Fine sand and clay	210–221
Clay	221–237

Well 14 (Na-14)

	Depth (feet)
Eocene series:	
Claiborne group:	
Cane River (?) formation:	
Red clay	0–30
Wilcox formation:	
Sand	30–70
Shale	70–95
Sand	95–114
Shale	114–132
Rock	132–133
Sandy shale	133–150
Tough clay	150–189
Sand	189–200
Rock	200–202
Sand (brackish water)	202–231
Rock	231–232

Well 16 (Na-63)

	Depth (feet)
Eocene series:	
Wilcox formation:	
Red clay	0–15
Sand	15–68
Tough clay	68–85
Rock	85–87
Tough clay	87–97
Sandy shale	97–168
Tough clay	168–183
Sandy shale	183–200
Rock	200–207
Shale	207–219
Tough clay	219–228
Fine sand	228–238
Shale	238–254
Sand	254–269
Tough clay	269–290
Sand	290–300
Tough clay	300–308
Rock	308–310
Shale	310–337
Sand	337–345
Shale	345–357
Sand	357–379
Shale	379–384
Sand	384–399

TABLE 4.—*Logs of wells in the Natchitoches area, Louisiana*—Continued

Well 17 (Na-49)

	Depth (feet)
Eocene series:	
Claiborne group:	
Cane River (?) formation:	
Red clay	0–12
Wilcox formation:	
Fine sand, basal part very glauconitic	12–62
Blue clay	62–79
Gray sandstone	79–81
Sand	81–90
Rock	90–92
Stiff clay	92–100
Very fine sand	100–102
Lignitic sandy shale	102–146
Fine sand	146–148
Rock	148–149
Gray sandy shale	149–150
Coarse-grained sandstone	150–151
Gray sandy shale with sandstone streaks	151–180
Fine sand	180–184
Gray sandy shale	184–188
Fine sand (fresh water)	188–208
Gray sandy shale	208–221
Hard gray sandstone	221–223
Gray shale	223–244
Fine sand	244–260
Shale	260–267
Fine sand	267–283
Shale	283–301
Fine sand	301–326
Shale	326–328
Sandy shale	328–369
Very fine fossiliferous sand	369–374
Rock	374–376
Sandy shale, small gas show	376–410
Stiff clay	410–460
Fine sand (salt water)	460–484
Soft lignite	484–487
Stiff blue clay	487–520
Gray sandy shale	520–540
Brittle gray sandstone	540–541
Gray shale	541–544
Brittle gray sandstone	544–545
Medium-grained sand	545–547
Brittle gray sandstone	547–548
Sand and shale	548–559
Hard rock	559–560
Sandy shale	560–562
Hard rock	562–563
Shale	563–571
Sand	571–600
Blue clay	600–605

TABLE 4.—*Logs of wells in the Natchitoches area, Louisiana*—Continued

Well 18 (Na-50)

	Depth (feet)
Recent alluvium:	
Red sandy clay	0–29
Blue clay	29–33
Sand	33–38
Blue clay	38–63
Sand and gravel	63–85
Eocene series:	
Claiborne group:	
Sparta (?) sand:	
Blue shale	85–125
Cane River formation:	
Fossiliferous and glauconitic marly clay	125–144
Green sandy shale	144–190
Sandy shale and lignite	190–219
Sandy shale	219–230
Stiff clay	230–238
Wilcox formation:	
Coarse sand (salt water)	238–282
Shale	282–303
Rock	303–304
Shale	304–309
Rock	309–310
Stiff clay	310–315
Rock	315–317
Brittle pyrite sands	317–334
Shale	334–342
Very fine sand	342–350
Shale	350–352
Fine sand	352–357
Shale	357–374
Fine sand	374–377
Lignitic sandy shale	377–393
Sandy shale	393–460
Rock	460–461
Sandy shale	461–495
Very fine sand	495–506
Stiff clay	506–509

Well 19 (Na-51)

	Depth (feet)
Recent alluvium:	
Red clay	0–29
Very fine red sand	29–67
Coarse red sand	67–80
Eocene series:	
Wilcox formation:	
Very fine gray sand	80–93

TABLE 4.—*Logs of wells in the Natchitoches area, Louisiana*—Continued

Well 20 (Na-53)

	Depth (feet)
Recent alluvium:	
Sandy loam	0–3
Red sandy clay	3–14
Dark blue clay	14–16
Red clay	16–30
Coarse yellow sand	30–46
Eocene series:	
Claiborne group:	
Sparta sand:	
Fine gray sand and shale	46–50
Lignitic shale	50–52
Coarse gray sand with lignite and shells	52–66
Hard gray shale	66–84
Blue and green clay	84–106
Cane River formation:	
Rock	106–107
Sandy shale	107–132
Shale	132–156
Shale and hard rock layers	156–166
Glauconitic fossiliferous marl	166–174
Soft shale	174–204
Sandy shale	204–212
Wilcox formation:	
Medium-grained to coarse-grained sand with mica, lignite, and shells	212–240
Sandy shale	240–244
Green shale	244–250
Sand with mica, lignite, and shells	250–254
Hard shale	254–255
Fine micaceous sand	255–258
Shale	258–262
Fine-grained to medium-grained sand	262–274
Stiff clay	274–276
Fine sand	276–280
Sandy shale	280–282
Fine sand and sandy shale	282–288
Stiff clay	288–303
Rock	303–304
Stiff clay	304–307
Sand	307–308
Sandy clay	308–315
Medium-grained sand with lignite and shells	315–318
Soft shale	318–322
Sand	322–327
Rock	327–328
Sandy shale	328–339

TABLE 4.—*Logs of wells in the Natchitoches area, Louisiana*—Continued

Well 21 (Na-54)

	Depth (feet)
Recent alluvium:	
Red sandy loam	0–2
Red clay	2–14
Red sandy clay	14–43
Blue clay	43–46
Soft shale	46–67
Coarse yellow sand	67–104
Eocene series:	
Claiborne group:	
Sparta sand:	
Sandy shale	104–134
Fine sand with shale partings	134–144
Shale	144–146
Fine sand	146–153
Sandy shale	153–158
Medium-grained sand with shale partings	158–172
Stiff clay	172–218
Hard sand	218–219
Sand	219–224
Cane River formation:	
Sandy shale	224–245
Stiff clay	245–271
Glauconitic sand	271–273
Hard shale	273–296
Hard fossiliferous marl	296–301
Green shale with sand streaks	301–310
Soft shale	310–315
Hard shale	315–318
Hard brown shale	318–325
Soft shale with shells and glauconite	325–336
Sandy shale	336–349
Wilcox formation:	
Fine sands, shale, and lignite	349–366
Medium-grained sand	366–380
Rock	380–381
Sandy shale and lignite	381–388
Sand	388–398
Sandy shale	398–406
Fine sand	406–415
Sandy shale, lignite, and shells	415–421
Coarse sand with shells	421–430
Sandy shale	430–432
Stiff clay	432–434

Well 22 (Na-56)

	Depth (feet)
Recent alluvium:	
Waxy red clay	0–20
Blue-gray clay	20–25
Yellow-gray clay with concretions	25–35
Fine red sand	35–43
Stiff blue clay	43–58

TABLE 4.—*Logs of wells in the Natchitoches area, Louisiana*—Continued

Well 22 Na-56—Continued

	Depth (feet)
Recent alluvium—Continued	
Medium-grained yellow sand	58–70
Coarse yellow sand and gravel	70–101
Eocene series:	
Claiborne group:	
Cook Mountain formation:	
Shale, shells, lignite	101–104
Green clay	104–108
Yellow-gray shale	108–115
Gray clay	115–132
Sandy shale	132–150
Shale	150–155
Sparta sand:	
Gray sandy shale	155–176
Fine sand	176–188
Sand and shale	188–232
Fine sand	232–234
Sand and shale	234–262
Fine sand	262–279
Gray shale	279–286
Fine sand	286–300
Sandy shale	300–314
Fine sand	314–328
Stiff gray clay	328–345
Gray shale	345–375
Stiff gray clay	375–390
Fine sand	390–400
Sandy shale	400–402
Fine-grained to medium-grained sand	402–415
Cane River formation:	
Sandy shale	415–426
Rock	426–427
Sandy shale	427–468
Stiff clay	468–480
Glauconitic sandy shale	480–494
Shale	494–500
Hard marly clay	500–504
Sandy shale	504–508
Stiff clay	508–527
Glauconitic sandy shale	527–550
Wilcox formation:	
Medium-coarse sand with shells and lignite	550–596
Fine sand and shale	596–637
Sandy shale	637–644
Medium-grained sand	644–684
Sandy shale	684–691
Fine sand	691–694
Rock	694–695

TABLE 4.—*Logs of wells in the Natchitoches area, Louisiana*—Continued

Well 23 (Na-57)

	Depth (feet)
Recent alluvium:	
Red soil	0–1
Red sandy clay	1–21
Fine red sand	21–32
Red sandy clay	32–34
Fine red sand	34–47
Medium-grained red sand	47–71
Decayed wood	71–73
Coarse red sand	73–93
Eocene series:	
Claiborne group:	
Cook Mountain formation:	
Soft red clay	93–106
Soft red clay with rock layers	106–119
Soft red clay	119–130
Soft red clay with rock layers	130–149
Soft red clay	149–164
Rock layers with shells	164–170
Stiff yellow clay	170–188
Gray shale with rock, lignite, and shells	188–198
Hard shale with lignite and shells	198–220
Stiff gray clay	220–230
Hard gray shale	230–246
Sandy shale with shells	246–270
Stiff clay	270–282
Sandy shale	282–317
Sparta sand:	
Very fine sand	317–332
Shale	332–347
Medium-grained sand	347–368
Fine sand and shale	368–399
Stiff clay	399–409
Fine sand	409–426
Sandy shale and lignite	426–442
Sand	442–460
Shale	460–472
Fine-grained to medium-grained sand	472–509
Fine sand with shale partings	509–538
Fine-grained to medium-grained sand	538–595
Cane River formation:	
Shale	595–602
Sandy shale	602–626
Hard shale, shells, and lignite	626–674
Glauconitic marly clay	674–682
Stiff clay	682–706
Sandy shale	706–715
Rock	715–716
Shale	716–720
Hard lime rock	720–722
Sandy shale	722–727

TABLE 4.—*Logs of wells in the Natchitoches area, Louisiana*—Continued

Well 23 (Na-57)—Continued

	Depth (feet)
Eocene series—Continued	
Wilcox formation:	
Fine lignitic sand (soft water)	727–766
Sandy shale	766–778
Sandy shale with rock	778–785
Sandy shale	785–820
Fine silty sand (salt water)	820–848
Sandy shale	848–852
Fine sand and shale	852–860
Sandy shale	860–862
Fine sand	862–865
Sandy shale	865–875
Fine sand	875–877
Brown sandy shale	877–888
Fine sand	888–898
Hard rock	898–900
Sandy shale	900–914
Stiff clay	914–920
Fine sand (salt water)	920–934
Shale	934–941
Sandy shale	941–948
Shale	948–952
Fine sand (salt water and gas)	952–991

Well 24 (Na-55)

	Depth (feet)
Eocene series:	
Claiborne group:	
Cook Mountain formation:	
Red clay with ironstone gravel	0–4
White bentonitic clay	4–24
Red ferruginous sand	24–28
Mottled shale with shells and selenite crystals	28–48
Hard green shale	48–53
Yellow and brown shale with shells	53–59
Rock with lignite	59–61
Sandy shale and lignite	61–70
Soft mottled shale	70–80
Gray shale with rock layers	80–84
Soft shale	84–88
Fine sand	88–92
Stiff gray clay	92–105
Hard gray shale	105–122
Gray sandy shale	122–158
Mottled sandy shale with selenite crystals	158–173
Sparta sand:	
Hard fine sand and lignite	173–200
Sandy shale	200–213
Fine sand	213–222
Shale	222–225
Fine gray sand and lignite	225–248

TABLE 4.—*Logs of wells in the Natchitoches area, Louisiana*—Continued

Well 24 (Na-55)—Continued

	(Depth feet)
Eocene series—Continued	
Claiborne group—Continued	
Sparta sand—Continued	
Medium-grained sand with lignite	248–266
Lignitic sandy shale	266–294
Fine-grained to medium-grained sand	294–386
Stiff clay	386–400
Sandy shale	400–430
Medium-grained to coarse-grained sand	430–448
Cane River formation:	
Stiff clay	448–464
Hard shale	464–475
Stiff clay	475–488
Shale	488–500
Stiff clay	500–522
Glauconitic marl rock	522–526
Glauconitic sandy shale with shells	526–548
Stiff clay	548–578
Wilcox formation:	
Coarse sand with lignite and shells	578–609
Sandy shale	609–639
Coarse sand	639–684
Shale	684–699
Sandy shale	699–703
Rock	703–704

Well 25 (Na-58)

	Depth (feet)
Recent alluvium:	
Red sandy loam	0–1
Black sandy clay	1–3
Red sandy clay	3–10
Fine red sand	10–12
Red sandy clay	12–26
Stiff gray clay	26–52
Red clay	52–59
Coarse red sand with shell fragments	59–71
Eocene series:	
Claiborne group:	
Cook Mountain formation:	
Gray shale and silt	71–84
Sparta sand:	
Sandy shale	84–104
Fine sand	104–110
Sandy shale and lignite	110–128
Fine sand	128–147
Sandy shale and lignite	147–180
Stiff gray clay	180–195
Sand and shale	195–212

TABLE 4.—*Logs of wells in the Natchitoches area, Louisiana*—Continued

Well 25 (Na-58)—Continued

	(Depth feet)
Eocene series—Continued	
Claiborne group—Continued	
Sparta sand—Continued	
Sandy shale	212–226
Sand	226–236
Sandy shale and lignite	236–258
Coarse sand and lignite	258–269
Stiff clay	269–300
Shale and lignite	300–308
Stiff clay	308–336
Sandy shale	336–348
Fine sand	348–356
Cane River formation:	
Hard shale with streaks of sand and lignite	356–365
Hard shale with shells and pyrite and lime concretions	365–427
Stiff clay	427–436
Hard marly clay with hard layers	436–442
Stiff clay	442–466
Shale and shells	466–470
Hard shale	470–476
Sand shale	476–490
Wilcox formation:	
Medium-grained sand	490–538
Sandy shale	538–549
Fine sand	549–558
Sandy shale	558–567
Hard rock	567–570
Hard sandy shale	570–588
Fine sand	588–590
Hard rock	590–591
Red shale	591–596
Fine sand	596–602
Shale	602–614
Hard rock	614–618
Shale	618–626
Sandy shale with hard layers	626–638
Stiff clay	638–645
Sandy shale	645–655
Medium-grained sand	655–673
Sandy shale, shells, and lignite	673–688
Sand	688–699
Shale, shells, and lignite	699–708
Sand	708–722
Shale and lignite	722–730
Fine sand, lignite, and shells	730–782
Shale	782–790
Fine sand and shells	790–807
Hard shale with pyrite	807–813

TABLE 4.—*Logs of wells in the Natchitoches area, Louisiana*—Continued

Well 26 (Na-59)

	Depth (feet)
Eocene series:	
Wilcox formation:	
Sandy loam	0–3
Red sandy clay	3–10
Red clay	10–18
White clay	18–24
Fine white sand (brackish water)	24–30
White clay	30–31
Lignitic sandy silt	31–45
Light-gray shale	45–49
Fine-grained to medium-grained gray sand (brackish water)	49–67
Gray sandy shale and lignite	67–95
Lignite	95–97
Fine lignitic sand (brackish water)	97–108
Red shale	108–122
Fine red sand (brackish water)	122–136
Ironstone	136–138
Fine blue sand	138–144
Soft brown shale	144–155
Dark-gray shale	155–170
Sandy shale	170–194
Fine blue sand	194–206
Soft gray sandy shale	206–248
Fine gray sand	248–254
Soft gray shale	254–275
Fine sand	275–290
Soft gray shale with shells	290–294
Fine dark sand	294–315
Gray sandy shale	315–326
Hard rock	326–330
Gray shale	330–350
Fine sand	350–374
Soft gray shale	374–391
Soft brown shale and lignite	391–430
Hard rock	430–431
Soft shale and lignite	431–486
Hard shale	486–488
Soft sandy shale	488–510
Fine sand	510–514
Sandy shale	514–520
Hard clay	520–534
Hard rock	534–537
Stiff clay	537–556

Well 27 (Na-60)

	Depth (feet)
Recent alluvium:	
Red sandy loam	0–3
Red sandy clay	3–10
Fine red sand	10–14
Red clay	14–35
Fine red sand	35–40

TABLE 4.—*Logs of wells in the Natchitoches area, Louisiana*—Continued

Well 27 (Na-60)—Continued

	Depth (feet)
Recent alluvium—Continued	
Brown clay	40–65
Soft blue sand shale	65–70
Coarse red sand and gravel with shell fragments	70–95
Eocene series:	
Claiborne group:	
Cane River formation:	
Soft gray shale	95–128
Gray shale with shell fragments	128–143
Soft gray fossiliferous marl and glauconite	143–149
Soft gray lignitic shale	149–195
Wilcox formation:	
Fine gray sand	195–208
Brown shale and lignite	208–214
Fine gray sand	214–232
Alternating sand and shale sand	232–242
Soft green sandy shale	242–270
Alternating sand and shale	270–295
Hard clay	295–299
Soft gray sandy shale	299–331
Hard sandstone	331–334
Green sandy shale	334–341
Fine sand	341–346
Soft gray shale	346–350
Fine sand	350–366
Soft gray shale	366–369
Fine sand	369–381
Sandy shale	381–398
Rock with pyrite	398–402
Fine sand	402–410
Sandy shale	410–428
Fine sand	428–436
Sandy shale with hard layers	436–446
Medium-grained sand	446–460
Hard rock	460–461

Well 28 (Na-61)

	Depth (feet)
Eocene series:	
Claiborne group:	
Cook Mountain formation:	
Black soil	0–1
Yellow clay with selenite crystals	1–16
Gray shale	16–39
Gray sandy shale with shells	39–48
Hard shell layer	48–50
Stiff clay	50–76
Sandy shale	76–96
Sparta sand:	
Soft shale	96–118
Fine sand	118–138

TABLE 4.—*Logs of wells in the Natchitoches area, Louisiana*—Continued

Well 28 (Na-61)—Continued

	Depth (feet)
Eocene series—Continued	
Claiborne group—Continued	
Sparta sand—Continued	
Stiff clay	138–150
Soft sandy shale	150–208
Coarse sand	208–223
Fine sand	223–225
Medium-coarse sand	225–252
Fine sand	252–262
Sandy shale with lignite and shells	262–278
Sandy shale	278–309
Fine sand	309–339
Shale	339–347
Fine sand	347–372
Cane River formation:	
Hard shale	372–438
Sandy shale	438–446
Hard marly clay	446–454
Stiff clay	454–465
Hard brown shale	465–472
Soft green shale	472–501
Wilcox formation:	
Fine to medium-coarse sand with shells	501–550
Sandy shale	550–556
Fine sand	556–562
Sandy shale	562–564
Fine sand	564–572
Hard shale	572–575
Hard rock	575–577
Soft shale and fine sand	577–588
Hard rock	588–589
Sandy shale	589–594
Hard shell bed	594–595
Shale	595–598
Sandy shale	598–604
Rock (gas)	604–607
Hard shale	607–620
Sandy shale	620–636
Stiff clay	636–646
Shale	646–654
Pyrite nodules	654–658
Sandy shale	658–660
Stiff clay	660–672
Sand and shale	672–682
Hard shale	682–692
Hard gumbo	692–706
Fine sand (brackish water)	706–716
Shale	716–724
Sandy shale	724–740
Stiff clay	740–750

TABLE 4.—*Logs of wells in the Natchitoches area, Louisiana*—Continued

Well 29 (Na-27)

	Depth (feet)
Recent alluvium:	
Clay	0–20
Sand and gravel	20–100(?)
Eocene series:	
Claiborne group:	
Sparta sand:	
Sand	100(?)–294
Shale	294–350
Cane River formation:	
Stiff clay	350(?)–500
Wilcox formation:	
Coarse sand	500–550

Well 38 (from old records)

	Depth (feet)
Recent alluvium:	
Surface clay	0–45
Blue clay	45–47
Sand	47–60
Eocene series:	
Claiborne group:	
Cane River formation:	
Sandy clay, shells, lignitic material	60–85
Clay	85–100
Grayish sand	100–125
Soft shell rock	125–135
Hard clay	135–145
Greenish hard rock	145–146
Wilcox formation:	
Black shale with lignite	146–175
Coarse sand (salt water)	175–195
Black shale	195–204
Hard and soft rock	204–230
Shale	230–270
Tough clay	270–280
Red sand	280–318
Gray sand	318–325
Shale and clay	325–338
Hard rock with pyrite	338–340
Sand (salt water)	340–350
Shale and clay	350–390
Sand	390–410
Clay	410–420
Shale, clay, and lignite	420–450
Shale	450–470
Hard rock	470–472
Shale	472–500
Fine gray sand	500–530
Sand	530–560
Stiff clay	560–563
Brown rock, gas show	563–575
Fine sand	575–580

TABLE 4.—*Logs of wells in the Natchitoches area, Louisiana*—Continued

Well 38 (from old records)—Continued

	Depth (feet)
Eocene series—Continued	
Wilcox formation—Continued	
Clay and lignite	580–600
Shale	600–615
Lignite and shale	615–630
Black and gray shale	630–725
Stiff clay	725–735
Soft shale	735–745
Stiff clay	745–750
Shale and boulders	750–785
Stiff clay	785–810
Fine gray sand, gas show	810–825
Blue sandy shale	825–838
Shale	838–841
Fine sand	841–845
Shale	845–853
Stiff clay	853–856
Shale	856–860
Hard black shale	860–875
Fine blue sand with shells	875–890
Hard clay	890–895
Clay	895–940
Hard shale	940–960
Black shale	960–973
Sand	973–995
Rock	995–997
Blue clay	997–1000

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	Depth (feet)
Eocene series:	
Claiborne group:	
Sparta sand:	
Sand	0–217
Cane River (?) formation:	
Shale and sand	217–300
Rock	300–304
Shale	304–325
Wilcox formation:	
Sand	325–355
Sand and shale	355–407
Shale, sand, and boulders	407–800
Sand and shale	800–1060

Total depth of well, 5,339 feet.

A. F. Carter, Culpepper No. 1

	Depth (feet)
Eocene series:	
Claiborne group:	
Cockfield formation:	
Clay	0–10
Sand	10–70
Shale	70–88

TABLE 4.—*Logs of wells in the Natchitoches area, Louisiana*—Continued

A. F. Carter, Culpepper No. 1—Continued

	Depth (feet)
Eocene series—Continued	
Claiborne group—Continued	
Cockfield formation—Continued	
Sandy shale	88–94
Sand	94–118
Sandy shale	118–127
Coarse sand	127–165
Cook Mountain formation:	
Shale	165–214
Sand	214–224
Shale	224–228
Sand	228–236
Shale	236–249
Sand	249–255
Shale	255–285
Sand	285–294
Sandy shale	294–310
Sand	310–319
Sandy shale	319–350
Fine sand	350–369
Shale	369–375
Marl rock	375–385
Shale	385–390
Sand	390–398
Shale	398–409
Sparta sand:	
Sand	409–462
Shale	462–470
Sand	470–509
Shale	509–513
Fine sand	513–527
Shale	527–542
Coarse sand	542–608
Shale	608–611
Sand	611–621
Shale	621–623
Coarse sand	623–686
Shale	686–692
Cane River formation:	
Shale	692–709
Sandy shale	709–737
Shale	737–776
Marl rock	776–786
Shale	786–822
Wilcox formation:	
Fine sand and shale	822–833
Sand	833–852
Shale	852–857
Sand	857–894
Shale	894–900

TABLE 4.—*Logs of wells in the Natchitoches area, Louisiana*—Continued

A. F. Carter, Culpepper No. 1—Continued

Eocene series—Continued	
Wilcox formation—Continued	
Sand	900–934
Shale	934–945
Sand	945–972
Shale	972–985
Sand	985–990
Shale	990–993
Sand	993–1000

Total depth of well, 3,329 feet.

TABLE 5.—*Mechanical analyses of sand samples from wells in the Natchitoches area, Louisiana*

Well No.	Depth of sample (feet)	Mechanical analysis of sand fraction (percent by weight)							Geologic formation
		8–4 mm.	4–2 mm.	2–1 mm.	1–½ mm.	½–¼ mm.	¼–⅛ mm.	⅛–1/16 mm.	
11 (Na-52)	24–29			0.16	4.70	11.26	78.89	4.99	Wilcox.
	29–40			.94	1.47	1.96	92.63	3.00	Do.
	40–51		0.21	.49	.70	5.74	90.93	1.93	Do.
	51–61			.31	.53	2.82	90.08	6.26	Do.
	221–254				.35	1.74	48.48	49.43	Do.
13 (Na-62)	66–70				.97	8.71	58.80	31.52	Do.
	98–116				.24	3.35	68.21	28.20	Do.
	150–187				.16	4.42	89.00	6.42	Do.
17 (Na-49)	29–51		.04	.44	2.97	52.88	42.18	1.49	Do.
	196–208			1.62	2.15	7.36	73.20	15.67	Do.
19 (Na-51)	67–69			.10	4.84	58.10	36.18	.72	Recent.
	80–93			.40	1.50	3.67	48.30	46.13	Wilcox.
20 (Na-53)	30–40				2.82	45.37	48.00	3.81	Recent.
	40–48				3.00	53.78	39.28	3.94	Do.
	52–59				.34	51.04	39.61	9.01	Sparta.
	59–65				.64	77.68	21.48	.21	Do.
	212–221			.05	3.53	15.84	74.88	5.70	Wilcox.
	221–231			.09	5.31	36.13	54.86	3.61	Do.
	231–239			.08	16.88	40.49	39.48	3.07	Do.
21 (Na-54)	67–77		.10	.19	33.78	63.76	2.17		Recent.
	77–84			8.38	50.94	39.01	1.63	.04	Do.
	84. 104			2.06	29.17	62.23	6.54		Do.
	146–152			.91	8.17	57.97	17.82	15.13	Sparta.
	161–167		.07	16.44	31.74	39.69	5.58	6.48	Do.
	167–172			8.96	42.62	37.92	6.54	3.96	Do.
	218–224		9.23	30.89	29.02	22.67	4.21	3.98	Do.
	359–370		.50	4.58	10.51	19.45	62.42	2.54	Wilcox.
	370–380		1.39	8.94	30.75	38.17	19.89	.86	Do.
	380–391		1.18	7.84	21.03	37.68	30.65	1.62	Do.
	391–400		.91	10.51	31.28	38.49	18.28	.53	Do.
	400–410		1.11	6.00	31.43	45.66	15.19	.61	Do.
	410–416		.65	6.45	26.85	40.60	24.88	.57	Do.
	420–429		.58	10.53	18.90	66.62	3.17	.20	Do.
22 (Na-56)	58–69			.01	2.02	26.00	34.37	37.60	Recent.
	69–75			.07	.13	36.56	49.18	14.06	Do.
	75–90	.22		.28	26.21	58.54	14.75		Do.
	90–100			7.95	47.52	40.20	3.03	1.30	Do.
	100–101		.35	91.14	7.00	1.51			Do.
	178–185			.60	9.30	26.55	42.15	21.40	Sparta.
	314–323		3.73	3.36	5.05	15.57	59.11	13.18	Do.
	390–400			.11	.70	6.76	74.73	17.70	Do.
	400–415		.14	.07	.35	5.65	66.35	27.44	Do.

TABLE 5.—*Mechanical analyses of sand samples from wells in the Natchitoches area, Louisiana*—Continued

Well No.	Depth of sample (feet)	Mechanical analysis of sand fraction (percent by weight)							Geologic formation
		8–4 mm.	4–2 mm.	2–1 mm.	1–½ mm.	½–¼ mm.	¼–⅛ mm.	⅛–1/16 mm.	
22 (Na-56)—Con.	550–570	--------	.06	.50	10.11	54.48	28.26	6.59	Wilcox.
	570–577	--------	.02	1.03	24.12	63.36	10.71	.76	Do.
	577–587	--------	--------	.30	8.90	65.14	23.83	1.83	Do.
	587–599	--------	.06	2.02	25.71	60.34	7.85	4.02	Do.
	599–610	--------	--------	.09	3.65	31.16	49.20	15.90	Do.
	644–662	--------	--------	.08	.21	8.19	83.73	7.79	Do.
	662–673	--------	--------	--------	.10	7.58	83.78	8.54	Do.
	673–684	--------	--------	.04	.28	10.02	81.33	8.33	Do.
23 (Na-57)	38–48	--------	--------	--------	.11	.16	23.66	76.07	Recent.
	48–60	--------	--------	.10	.21	4.11	48.89	46.69	Do.
	60–70	--------	--------	--------	.08	77.27	22.40	.25	Do.
	73–80	--------	--------	--------	.57	52.78	38.48	8.17	Do.
	80–90	--------	--------	--------	.48	94.71	4.10	.71	Do.
	90–93	--------	--------	.18	8.62	86.18	4.70	.32	Do.
	317–331	--------	--------	.08	.35	2.04	47.65	49.88	Sparta.
	347–355	--------	--------	.11	.66	3.96	67.67	27.60	Do.
	355–365	--------	.08	.32	5.40	6.44	54.30	33.46	Do.
	365–376	--------	--------	.34	2.74	6.57	63.30	27.05	Do.
	376–387	--------	--------	.26	2.47	8.28	65.23	23.76	Do.
	387–399	--------	--------	.10	1.09	10.35	58.21	30.25	Do.
	409–418	--------	.05	.13	.77	23.33	53.90	21.82	Do.
	418–426	--------	--------	.12	.63	7.99	46.83	44.43	Do.
	442–450	--------	--------	.10	.64	13.24	75.31	10.71	Do.
	450–460	--------	.03	.06	.96	11.63	51.79	35.53	Do.
	472–481	--------	--------	.15	3.27	25.57	50.51	20.50	Do.
	481–492	--------	--------	.10	2.74	20.33	56.86	19.97	Do.
	492–503	--------	--------	.31	.37	28.08	65.71	5.53	Do.
	503–509	--------	--------	.22	1.45	22.93	62.92	12.48	Do.
	526–536	--------	--------	.24	1.93	10.86	62.25	24.72	Do.
	536–545	--------	--------	.12	1.45	14.21	64.99	19.23	Do.
	545–556	--------	--------	.17	1.38	20.95	73.72	3.78	Do.
	556–567	--------	--------	.07	.30	12.80	82.31	4.52	Do.
	567–577	--------	--------	.05	.46	24.43	72.54	2.52	Do.
	577–588	--------	--------	.03	.16	31.52	64.46	3.83	Do.
	588–593	--------	--------	--------	.21	44.02	44.83	10.94	Do.
	593–595	--------	--------	.09	1.64	50.64	36.48	11.15	Do.
24 (Na-55)	175–196	--------	--------	.16	.37	12.57	65.48	21.42	Do.
	217–259	--------	--------	.05	.28	4.71	57.67	37.29	Do.
	259–266	--------	.28	.57	.83	10.12	73.97	14.20	Do.
	294–302	--------	--------	.34	.45	2.63	49.84	46.74	Do.
	323–344	--------	--------	--------	.20	15.76	67.70	16.34	Do.
	344–365	--------	.41	.31	.44	14.11	66.32	18.41	Do.
	365–376	--------	--------	.04	.99	31.20	55.88	11.89	Do.
	376–386	--------	--------	.15	1.62	37.38	53.70	7.15	Do.
	430–438	--------	--------	.01	.67	50.86	44.48	3.98	Do.
	438–446	--------	.07	.16	.74	50.54	43.80	4.69	Do.
	579–589	--------	--------	.17	9.20	81.36	9.14	.13	Wilcox.
	589–599	--------	.01	.50	9.36	48.93	39.60	1.60	Do.
	599–607	--------	.05	1.00	12.04	72.56	14.13	.22	Do.
	639–641	--------	1.71	2.25	3.31	9.57	70.72	12.44	Do.
	641–652	--------	--------	.06	4.03	68.98	26.11	.82	Do.
	652–662	--------	--------	--------	5.09	83.71	10.81	.39	Do.
	662–673	--------	--------	.06	4.56	67.34	27.64	.40	Do.
	673–682	--------	--------	.04	18.15	73.74	7.51	.56	Do.
25 (Na-58)	63–71	--------	--------	.03	5.56	52.90	38.46	3.05	Recent.
	104–105	--------	.09	.12	5.84	4.90	48.89	40.16	Sparta.
	128–135	--------	--------	.22	.24	2.00	63.39	34.15	Do.
	135–145	--------	--------	.01	.03	2.36	89.76	7.84	Do.
	226–236	--------	.14	.69	1.35	16.50	52.12	29.20	Do.
	260–269	--------	--------	--------	.06	52.78	45.55	1.61	Do.
	348–356	--------	.51	1.18	1.76	14.23	56.84	25.48	Do.
	490–495	--------	.37	1.38	6.15	42.04	44.49	5.57	Wilcox.
	495–506	--------	.05	.66	4.07	40.47	52.64	2.11	Do.
	506–516	--------	--------	.10	6.33	58.04	25.79	9.74	Do.
	516–527	--------	.06	.34	14.44	74.22	10.01	.93	Do.
	527–538	--------	.11	1.49	25.60	63.21	8.84	.75	Do.
	550–558	--------	--------	.15	4.52	27.93	51.06	16.34	Do.
	664–673	--------	--------	.30	1.14	56.12	40.10	2.34	Do.

TABLE 5.—*Mechanical analyses of sand samples from wells in the Natchitoches area Louisiana*—Continued

Well No.	Depth of sample (feet)	Mechanical analysis of sand fraction (percent by weight)							Geologic formation
		8-4 mm.	4-2 mm.	2-1 mm.	1-½ mm.	½-¼ mm.	¼-⅛ mm.	⅛-1/16 mm.	
25 (Na-58)—Con.	688-699	--------	--------	.34	2.36	14.42	69.73	13.15	Wilcox.
	708-712	--------	.13	.94	4.30	13.64	54.39	26.60	Do.
	712-722	--------	.19	1.71	6.38	18.01	54.01	19.70	Do.
	732-749	--------	--------	1.07	3.49	10.07	46.20	39.17	Do.
	749-770	--------	.08	1.18	3.55	24.27	55.56	15.36	Do.
	770-782	--------	.36	1.37	4.05	21.88	53.49	18.85	Do.
28 (Na-61)	208-217	--------	--------	.19	.39	22.01	58.55	18.86	Sparta.
	217-229	--------	--------	.07	.86	65.08	33.19	.80	Do.
	229-239	--------	.11	.82	5.09	53.56	34.06	6.36	Do.
	239-250	--------	--------	.03	3.75	91.16	4.99	.07	Do.
	250-260	--------	--------	.15	33.87	30.78	30.58	4.62	Do.
	309-323	--------	--------	.01	3.84	31.85	42.39	21.91	Do.
	501-511	--------	--------	.14	.63	17.67	37.32	44.24	Wilcox.
	535-545	--------	.20	1.04	8.65	60.52	26.83	2.76	Do.
	545-550	--------	.39	1.46	11.85	63.46	21.15	1.69	Do.
	706-716	--------	.44	1.70	4.88	32.33	45.56	15.09	Do.

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