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F. B. PLUMMER

and

E. C. SARGENT

Bureau of Economic Geology

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The benefits of education and of useful knowledge, generally diffused through a community, are essential to the preservation of a free government.

Sam Houston

Cultivated mind is the guardian genius of Democracy, and while guided and controlled by virtue, the noblest attribute of man. It is the only dictator that freemen acknowledge, and the only security which freemen desire.

Mirabeau B. Lamar

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UNDERGROUND WATERS AND SUBSURFACE TEMPERATURES OF THE WOODBINE SAND IN NORTHEAST TEXAS

By F. B. Plummer and E. C. Sargent

INTRODUCTION

RESEARCH PROJECT FOSTERED BY AMERICAN PETROLEUM INSTITUTE

The investigation of the chemical composition and temperature of underground waters* in oil fields was recommended to the American Petroleum Institute by a research committee of which Mr. K. C. Heald[1] is chairman. The institute through its research funds has enabled the authors to conduct subsurface investigations in Texas (A. P. I. Research Project 25-B). One year of the work has been devoted to geochemical and geothermal studies of the Woodbine sand in east Texas, and one year to similar investigations in the Red River valley oil fields of north Texas. The results of the work in the Woodbine sand province are covered in this bulletin. The data obtained in the Red River valley are now being compiled and will be published in a later paper.

OBJECTIVES OF THE INVESTIGATION

The objectives of the investigation in east Texas have been fourfold: (1) To measure the temperature gradients in wells that penetrate the Woodbine sand in all parts of the province and to ascertain to what extent temperature gradients in the vicinity of abnormal structure and oil pools vary from those in wells on normal structure. (2) To study the chemical composition of the underground waters and

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*This paper contains final results of investigations of underground temperatures and chemical composition of underground waters in oil fields, listed as Project 25B, Pt. II, of the American Petroleum Institute research program. Financial assistance in this work has been received from a fund of the American Petroleum Institute administered by the Institute with the coöperation of the Central Petroleum Committee of the National Research Council.

The results of Pt. I of Project 25B have been completed by E. M. Hawtof under the direction of E. H. Sellards and published in Bulletin 205 of the American Petroleum Institute. Results of Pt. III by F. B. Plummer and V. E. Barnes are in preparation.

[1]Heald, K. C., The study of earth temperatures in oil fields on anticlinal structure: Am. Pet. Inst. Prod. Bull. No. 205, pp. 1-8, 1930.

Issued April, 1932.

ascertain how the composition changes in different parts of the province, especially in relation to abnormal structure and to oil pools. (3) To determine to what extent, if any, a change in the chemical content of the water is responsible for the abnormal temperature gradients along faults and on salt domes. (4) To compile the analytical and thermal data into tables, maps, and diagrams useful to petroleum engineers and geologists.

The temperature measurements and most of the chemical analyses have been made by the junior author. The plan of the work and the preparation of the maps and reports are the joint work of the two authors who are equally responsible for the interpretation and the presentation of the data recorded in the following pages.

ACKNOWLEDGMENTS

The authors are greatly indebted to the various oil companies operating in this area for their coöperation in allowing temperature observations in their wells, especially to the officials of the Amerada Petroleum Company, Atlantic Refining Company, Gulf Production Company, Pure Oil Company, Humble Oil Company, and Sun Oil Company; to Dr. C. E. Van Orstrand and Mr. E. M. Hawtof for valuable help and advice regarding the measurements of underground temperature; to Mr. Paul Applin of the Cosden Oil Company, to Mr. Paul Weaver of the Gulf Production Company and to Mr. Claude Dally of Fort Worth for well data and helpful advice; to Mr. W. S. Adkins of the Bureau of Economic Geology; Mr. Norman Thomas of Pure Oil Company, Mr. F. W. Rolshausen of the Humble Oil Company, and Dr. Gayle Scott of Texas Christian University for information regarding the stratigraphy of the Woodbine sand; and to Dr. E. H. Sellards for valuable assistance, especially for making available the facilities and coöperation of the Bureau of Economic Geology, without which the work could not have been completed. The authors also acknowledge gratefully much assistance from Mrs. Helen J. Plummer, who drafted many of the diagrams, copied and arranged the tables, and edited the manuscript.

GEOLOGY OF THE WOODBINE SAND

DEFINITION

The Woodbine sand was named by R. T. Hill[2] and defined by him as certain arenaceous beds lying above the Lower Cretaceous or Comanche series and at the base of the Upper Cretaceous made up largely of ferruginous, argillaceous sands accompanied by bituminous laminated clays. The formation is of great economic importance. The sand supports a thick growth of oak timber in otherwise open prairie country that early gave to its outcrop the term "cross timbers," and furnished almost the only supply of wood for the pioneer settlers. Later, the sand proved to be a chief source of water for the farms and towns located along its western and northern edge. Recently deeper wells have opened up enormous pools of oil along its eastern edge, so that it has proved to be the most prolific oil sand in the state.

EXTENT

The Woodbine formation outcrops in a belt one to thirteen miles wide extending from northern McLennan County northward through Hill, Johnson, Tarrant, Denton to northeastern Cooke County. From northeastern Cooke County, the outcrop swings eastward along the Red River valley following the Oklahoma-Texas boundary nearly to the Arkansas line. The outcrop is narrowest in McLennan County where in places it is less than a mile in width; and widest in Denton, Cooke, and Grayson counties where it has an expanse of thirteen miles. Beneath the surface, the formation dips southeastward and thins gradually until it pinches out in Limestone, Anderson, Cherokee, and southern Rusk counties. Eastward it also pinches out against the Sabine uplift and wells drilled east of a line drawn from the southeast corner of Rusk County through northeastern Gregg into central Cass County encounter no sand. The outcrop and subsurface extent of the sand is shown approximately on the map, Plate I, and block diagram, figure 1.

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[2]Hill, R. T., Geography and geology of the Black and Grand Prairies, Texas: U. S. Geol. Survey, 21st Ann. Rept., pt. 7, pp. 293-294, 1900.

Small outliers or patches of the sand occur in a few places south of the main sheet.[3] The formation, in general, is a broad wedge of sand and sandy clay, which is thickest at the outcrop, thins southeastward, and extends beneath the surface 120 miles east and west and 150 miles north and south over an area of at least 18,000 square miles.

LITHOLOGY

The Woodbine formation can be divided on the basis of lithology into four divisions:

4. Fine-grained sands and sandy clays, in places calcareous, in others glauconitic and non-calcareous, passing into fossiliferous shales of Eagle Ford age. *Exogyra columbella* zone.
3. Sandy clays, bentonitic clays, siltstones, volcanic ash beds, and sands that are grey, reddish, purplish-grey, and mottled, or oxidized to yellow and red, fine grained, fossiliferous in places. *Aguileria cumminsi* zone.
2. Sandstone, grey and reddish-gray, brown; contains on the outcrop leaf impressions and streaks of black lignite.
1. Basal clay (regarded as Comanche age by Gayle Scott); brownish-red, compact, noncalcareous fossiliferous joint clay; in places silty and carbonaceous. *Mantelliceras* sp.? zone.

Division No. 1 was named by Taff[4] the Basal clays, division No. 2 the Dexter sands, and divisions 3 and 4 were designated the Timber Creek beds, a term applied earlier to upper Dakota sands by C. A. White. R. T. Hill[5] referred the lower two divisions to the Dexter sands and the upper two to the Lewisville beds. These subdivision names have fallen into desuetude, for the most part because they are not mappable units outside Red River valley.

Bed No. 1—the basal clay member is composed of brownish-red compact, siliceous, fossiliferous joint clay. Bed No.

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[3]Adkins, W. S., Geology and mineral resources of McLennan County, Texas: Univ. Texas Bull. 2340, p. 58, 1923.

[4]Taff, J. A., and Leverett, S., Report on the Cretaceous area north of the Colorado River: Geol. Survey Texas 4th Ann. Rept., p. 285, 1893.

[5]Hill, R. T., Geography and geology of the Black and Grand Prairies, Texas: U. S. Geol. Survey 21st Ann. Rept., pt. 7, pp. 302 and 308, 1900.

2—the lower sand member is a medium-grained and excessively cross-bedded sand. In general, it is thicker and more arenaceous to the north, thins and becomes finer grained and less ferruginous to the south. Bed No. 3—the middle clay member consists of irregularly bedded lentils of clay 25 feet or more in thickness. Impure clays, siltstones, sands, and sandy clays succeed one another in varying proportions, and bands of very thin lignite, and lignitic sandy clay are interspersed here and there in the section. A single bed

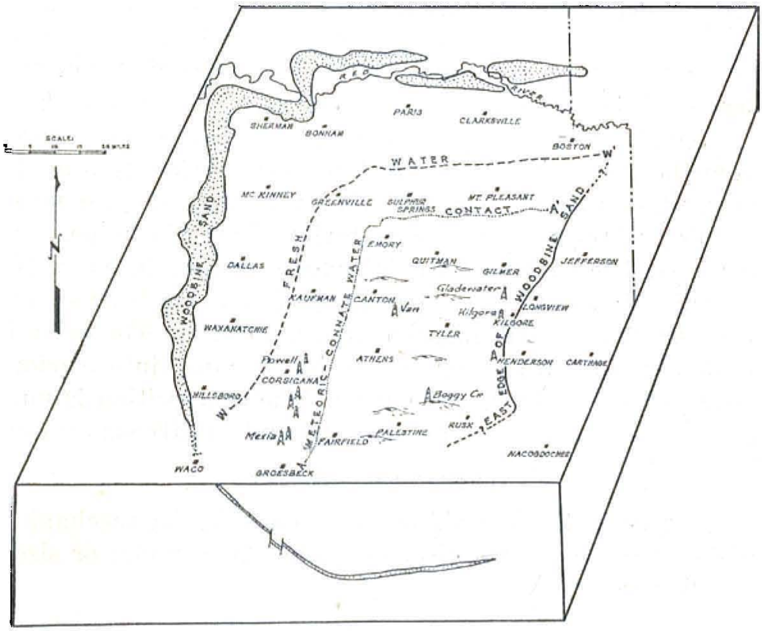

Fig. 1.—Block diagram of east Texas showing the Woodbine outcrop, the locations of oil fields (indicated by derricks) and salt domes, and the fresh-water, brackish-water, and salt-water areas in the Woodbine formation.

of homogeneous rock rarely exceeds five feet. Bed No. 4—the upper sand member is composed of laminated sands and sandy clays, interstratified with brown sands,, ferruginous reddish-brown sandstone, purplish sandstone, and argillaceous mottled sandstone, which contain large lenticular calcareous concretions. A layer of water-laid volcanic material occurs in the upper part of the section. The ash can be traced from well to well from east of Fort Worth to the Amerada Wade well in Upshur County. It increases in thickness eastward until it reaches 125 feet or more in the Van field,[6] Van Zandt County. The volcanic material is in the form of silty bentonite and ash. It consists of fine-grained tuffaceous, cross-bedded, soft, green and red, impure ash in places altered by underground waters to bentonite. The material is for the most part unconsolidated, though in some places it is loosely cemented and cut by minute quartz veins. In the oil field at Van, Van Zandt County, where 650 feet of Woodbine have been penetrated, the upper part contains much fine volcanic material. Beneath this the oil-producing zone is a pure, sharp, angular, friable, porous, quartz sand. The sand from the cores from the Amerada Wade No. 1 in Upshur County and the Amerada Christian No. 1 in Smith County contain much of this water-laid volcanic material. Both the upper and lower sand members of the Woodbine change in character laterally. In some places they are soft and thin bedded, and in other places hard, massive, and quartzitic. The color is predominantly white or green but grades into various shades of red, yellow, and brown. The composition is pure quartz grains cemented by siliceous and calcareous cement.

TEXTURE AND POROSITY

The sand of the Woodbine can be classified by mechanical analyses and with the miscroscope into five grades or sizes, as follows:

Grade	Screen	Diameter
1	– 28	–.589 mm. (.0232 in.)
2	28– 48	.589–.295 mm. (.0116 in.)
3	48–100	.295–.147 mm. (.0058 in.)
4	100–200	.147–.074 mm. (.1129 in.)
5	200–	.074 mm. and finer

The results of forty-two such mechanical analyses are shown graphically in figure 2. Most of the samples have about 70 per cent of their grains in grade 4—that is, most

6E. M. Rice, geologist, Pure Oil Company, personal communication.

of the grains are less than .295 mm. in diameter. Less than 20 per cent belong to grade 2, and the remainder fall in grades 4 and 5. The porosity of the cores from which the underground samples were taken averages about 25 per cent. A comparison of all the screen analyses show but slight differences between the upper, middle, and lower layers of the Woodbine formation. Samples from the outcrop give about the same results as those obtained from well cores. Samples of saturated oil sands have 75 to 85 per cent of almost uniform grains in grade 3, and the grains are more uniform in size and shape and have a higher porosity than most cores that do not contain oil. Most oil sands from the Rusk and Gregg county fields consist of pure white sand grains and have a higher porosity that averages about 33 per cent. Volcanic ash occurs between the grains in some samples and reduces the pore space. In samples of high percentage of ash the porosity runs as low as 11 per cent. The sand along the east side of the Woodbine sand sheet appears to be somewhat purer and more porous than the sand in the middle of the area.

Certain layers of sand in some places show recrystallization. Clear faces of quartz crystals have formed over the rounded quartz grains. In another place there are pure clear quartz crystals that appear to have grown between the sand grains. The sand is a clear, angular aggregate of quartz crystals, with very little evidence of etching and rounding. The silica was derived evidently from the volcanic ash in the sand. Where this ash and siliceous cement are present in quantity the porosity of the sand ranges only from 9 to 11 per cent.

Determination of the porosity of Woodbine sand samples from various localities are presented in the following table:

WELL	COMPANY	LOCATION	DEPTH Feet	POROSITY Per cent
Thompson No. 1	Moss, Keyes, & Urschel	Mexia field	3013	27.81[a]
Rossen No. 1	Trans-Continental	Nigger Cr. field	2800?	25.8 [a]
Rossen No. 3	Trans-Continental	Nigger Cr. field	2828	26.02[a]
Hillburn No. 2-A	Sun Co.	Richland field	2990	26.33[b]
Tunnell No. 2	Pure Oil Co.	Van field	2426	26.35[c]
Tunnell No. 2	Pure Oil Co.	Van field	2558	25.15[c]
Tunnell No. 2	Pure Oil Co.	Van field	2640	32.0 [c]
Tunnell No. 2	Pure Oil Co.	Van field	2680	26.8 [c]
Wade No. 1	Amerada Oil Co.	Upshur County	3658	26.45[c]
Wade No. 1	Amerada Oil Co.	Upshur County	3714	14.1 [c]
Wade No. 1	Amerada Oil Co.	Upshur County	3806	11.58[c]
Wade No. 1	Amerada Oil Co.	Upshur County	3907	8.82[c]
Tate No. 1	Humble O. & R. Co.	Gregg County	3460	23.84[c]
White No. 2	Vacuum Oil Co.	Gregg County	3500	20.00[c]
Stinchcomb No. 3	Vacuum Oil Co.	Gregg County	3658	31.20[c]
Beaver No. 2	Vacuum Oil Co.	Gregg County	3521	14.40[c]
Beaver No. 2	Vacuum Oil Co.	Gregg County	3526	21.85[c]
Tate No. 7	Vacuum Oil Co.	Gregg County	3460	24.50[c]

Average[d] of porosity percentages from Gregg County=22.63.

[a]Determinations by Chas. E. Sutton, U. S. Bureau Mines.

[b]Determination by Engineering Department, Sun Oil Co.

[c]Determinations by R. B. Newcome, Jr., Department of Petroleum Engineering, The University of Texas.

[d]According to Winn the average porosity of the sand in the east Texas field as determined from 71 analyses is 26.25 per cent.

NOTE.—The acetylene-tetrachloride method using Russell volumetric tubes, or modified Russell tubes, were employed in all determinations.

STRATIGRAPHIC RELATIONS

The Woodbine formation in most places along the western outcrop lies unconformably on the Grayson marl of the Washita series. The contact of the basal sand and underlying marl is sharp and easily recognized. In some places between the Grayson and Woodbine is an unconsolidated fossiliferous brown clay that varies from 5 to 20 feet in thickness and is commonly called the basal clay. This bed is thought by Gayle Scott[7] to be Comanche in age. In Grayson County and possibly in Fannin County, the upper beds of the Woodbine overlap the Grayson and rest upon the underlying Main Street limestone.[8] In the eastern

[7]Scott, Gayle, The producing sands of east Texas: Pub. Dallas Pet. Geol., p. 2, March 7, 1931.

[8]Stephenson, L. W., Notes on the stratigraphy of the Upper Cretaceous formations of Texas and Arkansas: Am. Assoc. Pet. Geol. Bull. vol. 11, p. 2, 1927.

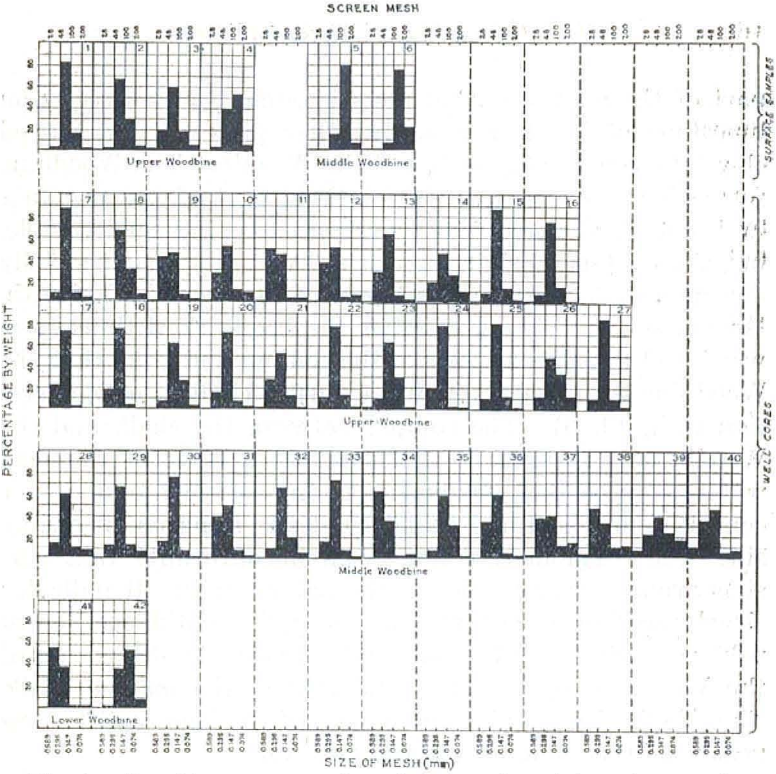

Fig. 2.—Graphic representation of the results of forty-two mechanical analyses of Woodbine sand.

1-4. Arthur Bluff on Red River, Lamar County
5, 6. About 7 miles south of Alvarado, Johnson County, on Highway No. 2
7. Water well, Bonham, Fannin County
8. Riley et al, E. B. Crouch No. 2, Wortham field, core, 3177′–3178′
9. Amerada Pet. Corp., Christian No. 1, Smith County, core, 5166′
10. Amerada Pet. Corp., Christian No. 1, Smith County, core, 5148′
11. Amerada Pet. Corp , Wade No. 1, Upshur County, core, 3685′–3687′
12. Amerada Pet. Corp., Wade No. 1, Upshur County, core, 3670′
13. Amerada Pet. Corp., Wade No. 1, Upshur County, core, 3649′
14. Amerada Pet. Corp., Wade No. 1, Upshur County, core, 3550′–3552′
15. Humble O. & R. Co., Cook No. 1, Boggy Cr. field, core, 3688′–3690′
16. Humble O. & R. Co., Cook No. 1, Boggy Cr. field, core, 3690′–3694′
17. Humble O. & R. Co., Gammill No. 1, Boggy Cr. field, core, 4390′
18. Humble O. & R. Co., Gammill No. 1, Boggy Cr. field, core, 4392′
19. Pure Oil Co., Tunnell No. 2, Van field, Van Zandt County, core, 2520′
20. Pure Oil Co., Tunnell No. 2, Van field, Van Zandt County, core, 2426′
21. Pure Oil Co., Tunnell No. 1, Van field, Van Zandt County, core, 2680′
22. Pure Oil Co., Tunnell No. 2, Van field, Van Zandt County, core, 2640′
23. Pure Oil Co., Tunnell No. 2, Van field, Van Zandt County, core, 2550′
24. Pure Oil Co., McKie No. 25, Powell field, Navarro County, core, 2882′
25. Pure Oil Co., McKie No. 25, Powell field, Navarro County, core, 2893′
26. Tidal Oil Co., Land No 1, Rusk County, core, 3681′–3699′
27. Tidal Oil Co., Tolover No. 1, Rusk County, core, 3657′–3663′
28. Amerada Pet. Corp., Christian No. 1, Smith County, core, 5290′
29. Amerada Pet. Corp., Christian No. 1, Smith County, core, 5247′–5257′
30. Amerada Pet. Corp., Christian No. 1, Smith County, core, 5267′–5283′
31. Amerada Pet. Corp., Christian No. 1, Smith County, core, 5352′–5358′
32. Amerada Pet. Corp., Christian No. 1, Smith County, core, 5344′
33. Amerada Pet. Corp., Christian No. 1, Smith County, core, 5283′
34. Amerada Pet. Corp., Wade No. 1, Upshur County, core, 3753′
35. Amerada Pet. Corp., Wade No. 1, Upshur County, core, 3722′
36. Amerada Pet. Corp., Wade No. 1, Upshur County, core, 3740′
37. Pure Oil Co., Gilbert No. 1, Van field, Van Zandt County, core, 2883′
38. Pure Oil Co., Gilbert No. 1, Van field, Van Zandt County, core, 2900′
39. Pure Oil Co., York No. 1, Van field, Van Zandt County, core, 2930′
40. Pure Oil Co., Gilbert No. 1, Van field, Van Zandt County, core, 2886′
41. Amerada Pet. Corp., Christian No. 1, Smith County, core, 5410′
42. Amerada Pet. Corp., Wade No. 1, Upshur County, core, 3830′–3835′

part of the area, the sand rests in some places directly on limestone of Washita age. In other places, brownish-red clay intervenes between it and the Washita. The Woodbine formation is overlain in the western part of the province by Eagle Ford shale. The two formations are conformable, but the contact is sharp, and the two units may be easily distinguished. In the eastern part of the province in Smith, Henderson, and Gregg counties the Eagle Ford thins eastward and disappears toward the Sabine uplift, so that the Woodbine is in contact with the Austin chalk (geologic section G-H, Pl. 5). The contact between the chalk and the Woodbine is marked in well cores by a layer of rounded, water-worn pebbles one quarter to one-half inch in diameter consisting of chert and chalk pebbles in a matrix of chalky silt. The conglomerate marks an unconformity that persists around the west side of the Sabine uplift. It indicates clearly erosion on this part of the uplift and deposition of pebbles during the time interval between the deposition of the Woodbine beach sands and that of the marine chalk. The Eagle Ford, if ever deposited on the uplift, was removed by erosion during this interim.

MEASURED SECTIONS OF WOODBINE FORMATION

Details of the thickness and lithologic character of the Woodbine formation are shown in the following description sections and in the graphic cross-sections, Plates II to VII.

Section of Woodbine formation east of Tarrant station, Tarrant County[9]

Thickness
Feet

South of the railroad below the first bridge west of the county line—

Sandstone ledge, locally a shell conglomerate containing *Barbatia micronema* Meek, *Ostrea soleniscus* Meek, *Ostrea carica* Cragin, *Ostrea* sp., *Exogyra* sp., and other Lewisville fossils. The upper portion is indurated, laminated, and especially fossiliferous. Exposed in three cuts nearest the Tarrant-Dallas county line. This is the top of the Woodbine and is overlain

[9]Winton, W. M., and Adkins, W. S., The geology of Tarrant County, Texas: Univ. Texas Bull. 1931, pp. 76–77, 1919.

	Thickness Feet
by Eagle Ford shale. Between the two localities it has locally a dip of 2½ degrees east	7
Light yellowish sand with limonitic stain, usually unconsolidated and containing *Ostrea* sp. (with large attachment scar)	5
Arenaceous, yellow-brown shales containing *Ostrea* sp.	8
Three ironstone bands interbedded with bluish, sandy shale	2
Thin-bedded, closely laminated shale with dimension layers of iron-stained red shale and containing gypsum, limonite and oyster shells *(Ostrea carica).* The lower 10 feet is especially fossiliferous	22
Section in the cuts west of this locality exposes all the foregoing and in addition in a deep run about a mile east of Tarrant the following section is exposed—	
Bluish-red shale and limonitic stain and abundant gypsum. *Ostrea carica* is rare in the top	20
Loosely laminated thin-bedded brown shale, weathering to a rough-faced cliff	5
Compact, laminated brown shale forming a smooth cliff face	2
Three thin red ironstone layers with interbedded compact blue clay	4
Bluish limonitic shale	12
There is a break in the section at this point. A cut along the Rock Island Railway, ½ mile east of Tarrant exposes the following section—	
Thin-bedded red sandstone, no fossils seen. Minor faulting present. Gypsum present. Dip is 2° east in the west end of the cut, and straightens out to 1° in the east end	10
Blue shales containing gypsum and lignite seams. No fossils	12

Cores obtained from Pure Oil Company's W. J. McKie, No. 25, 320-acre lease, Broyles Survey, Powell oil field

	Thickness *Feet*	Depth *Feet*
Shale, dark bluish gray, very fine grained, non-calcareous, thinly laminated, contains no sand grains. Made up of very fine siliceous clay particles, and a few fine specks of carbonaceous matter; Eagle Ford	3	2872–2875
Clay, silty, fine grained, light gray, non-calcareous, and carbonaceous. Consisting of 80% clay,		

	Thickness *Feet*	Depth *Feet*
20% very fine sand grains of dark opaque quartz, and a few black carbonaceous particles. The sand is composed of about 50% fine grains, .03 to .06 mm. in size, mixed with 50% dark quartz, averaging .15 to .3 mm. in size	3	2875–2878
Oil sand, brownish gray, very soft, unconsolidated and noncalcareous, consisting of well-assorted, clear, rounded and subangular quartz grains, .3 mm. in average size. Many grains are flattened, 3 times as long as thick	4	2878–2882
Oil sand, brownish-gray, soft, unconsolidated, similar to preceding but slightly finer. Grains .15 to .3 mm. in diameter	6	2882–2888
Sand, brownish gray, unconsolidated	1	2888–2889
Sand, brownish gray, unconsolidated	4	2889–2893
Quartz sand, grayish brown, soft, fine grained, well sorted, uniform, subangular quartz grains .15 mm. in size. Contains less than 1% black minerals. Many of the grains have crystalline faces	2	2893–2895
Calcareous sand, light gray, mixed with fragments of oyster shells; about 4% shell material and 96% sand. Sand well rounded and angular, clear quartz grains, .15 to .3 mm. in size	1	2895–2896

Pure Oil Company's Gilbert No. 1, northeast part of Van field

Clay, fine calcareous, dark gray, soft; does not disintegrate easily in water. Very fine, contains very minute angular quartz fragments and numerous fish scales	.5	2873–2873.5
Ash, light gray, very soft, fine calcareous	6.5	2873.5–2880
Sand, light gray, medium grained, partially cemented. Grains are .15 to .5 mm. in diameter, subangular and angular; 95% clear quartz, 5% black chert. Sand grains set in loose matrix of white and greenish-white calcareous cement, which dissolves in acid, leaving fine gray elongate particles of silt	1	2880–2881
Sand, light gray, medium grained, cemented with calcite. Grains are .3 mm. in diameter, about 40% rounded etched and clear quartz, 10% angular quartz less than .15 mm. in diameter; 1% black chert; 1% pink quartz	1	2881–2882
Calcareous sand, light gray, medium grained, soft, partially consolidated. Grains are .4 mm. in diameter, subangular, 90% milky white		

	Thickness *Feet*	Depth *Feet*
quartz, 9% gray quartz, 1% black chert, set in a matrix of minute quartz grains .03 mm. or less in diameter, mixed with the larger grains	3	2882–2885
Sand, gray, calcareous, medium grained, containing much silt. Grains are .3 mm. in diameter, subangular, 50% clear white quartz, 48% gray quartz, 1% purple quartz, and 1% black chert	1	2885–2886
Joint clay, gray, compact, poorly laminated, calcareous, colloidal, containing thin layers or lentils of sand. The sandy layers contain thin seams of lignite. The clay contains about 10% of fine, subangular quartz grains .15 mm. in diameter, consisting of quartz, bluish-green chert, buff-colored quartz, a few limonite grains and much ashy material. The coal is brownish black, fibrous, and woody. No trace of plant leaves or small stems. The sand is dull grayish white, medium grained. The grains are made up of 95% dull grayish-white quartz, 4% glauconite, and 1% black chert. All grains are subangular and .3 to .5 mm. in size; with the sand is a matrix of silt, consisting of much volcanic ash. Another sample of the sandstone is gray, medium grained, non-calcareous. It consists of 93% well-rounded white sand grains about .3 mm. in diameter, 1% glauconite, 1% dark chert grains, and less than 5% fine silt	9	2886–2895
Sandstone, soft, gray, medium grained, non-calcareous, containing thin streaks of black carbonaceous matter. The sand consists of 97% angular milky quartz grains .3 to .6 mm. in size; some quartz grains show crystalline faces; 1% dark gray cherty grains, 2% black carbonaceous material, and less than 3% fine silt	2	2895–2997
Sandstone, gray, fine grained, medium, hard, calcareous. It consists of 5% angular quartz grains .3 to .46 mm. in size set in a matrix of fine, exceedingly angular grains .03 to .06 mm. in size. A small amount of calcareous silt is mixed with the fine grains	3	2897–2900
Sandstone, greenish gray, medium grained, soft, non-calcareous, consisting of 99% rounded quartz grains .15 to .3 mm. in size, mixed with 1% dark green and black glauconite grains. The sample contains less than 2% of silt	2	2900–2902

	Thickness *Feet*	Depth *Feet*
Siltstone, greenish gray, soft, fine, slightly calcareous, containing small pinkish spherulites. The silt consists of minute angular quartz or glass grains .03 mm. or less in diameter mixed with a fine matrix of siliceous clay, possibly of volcanic origin. The sample also contains small spherules .3 to .8 mm. in diameter of solidly cemented grains, having the aspect of minute concretions	1	2902–2903
Siltstone, greenish gray, fine grained, non-calcareous, containing thin, wavy veins a fraction of a millimeter in thickness. The silt consists of 94% fine silt, 5% minute sand grains .06 mm. in diamater, and 1% marcasite or pyrite grains. The veins consist of minute pink quartz crystals deposited along contorted, broken lines	1	2903–2904
Clay, light greenish gray, fine grained, soft, non-calcareous, colloidal, containing 95% fine silt, 5% small angular quartz grains .03 mm. in size, and few small light-colored spherulites .15 mm. in diameter	12	2904–2916

Pure Oil Company's York No. 1, Van oil field

Siltstone, greenish gray, slightly pinkish, soft and non-calcareous. Consists of 95% fine angular quartz grains .03 to .06 mm. in diameter, 5% fine clay particles	6	2916–2922
Sandy siltstone, gray, soft, very fine, non-calcareous. It consists of about 90% fine, angular, clear quartz grains averaging .15 mm. in diameter and 10% fine clay, easily separated by washing	3	2922–2925
Sand or siltstone, light gray, very fine, non-calcareous. The sand consists of fine angular quartz .1 to .15 mm. in diameter, mixed with about 5% of fine siliceous clay particles	4	2925–2929
Silty clay, light gray, colloidal, non-calcareous. In water it washes down to a small residue, made up of minute, angular quartz grains, some of which are cemented in small nodules, and a very few grains of dense black chert	1	2929–2930
Siltstone, light gray, soft, fine grained, non-calcareous, like the preceding	10	2930–2939
Clay, light blue-gray, soft, non-calcareous, and colloidal, containing a few very fine angular quartz grains less than .03 mm. in size	1	2939–2940

	Thickness *Feet*	Depth *Feet*
Clay, light blue-gray, soft, silty, slightly calcareous and colloidal. Much more gritty than preceding. The clay consists of 80% fine clay silt, 19% angular and subrounded quartz grains .15 to .03 mm. in size, and 1% minute pyrite grains	2	2940–2942

Humble Oil Company & Bateman Crim No. 1, Rusk County

Chalk, hard, dark gray, fossiliferous, impure and gritty	1	3673–3674
Chalk, hard, dark gray, fossiliferous, impure and gritty; breaks with concoidal fracture	1	3680–3681
Chalk, light gray, very impure, gritty. Large proportion of fine, silty particles	1	3685–3686
Chalk, gray, consisting of rounded pebble and rounded water-worn oyster shell fragments, ¼ to ½ inch in diameter set in a matrix of chalky silt. Pyrite and glauconite grains common	2	3686–3688
Sandstone, white, fine grained, friable, non-calcareous, pure and evenly assorted quartz sand consisting of minute angular grains .03 to .15 mm. in diameter	3	3688–3691
Sandstone, white, uniformly fine grained, evenly bedded, non-calcareous; consists of 95% transparent, angular, and subangular quartz grains .03 to .3 mm. in diameter; 1% chert grains, and 4% fine clay, silt, or ash	1	3691–3692
Oil sand, white, stained brown with oil; medium-sized grains; very pure, well assorted, rounded and subangular sand .15 to .3 mm. in diameter; 27% porosity (best)	2	3698–3700
Shale, dark gray, silty, consolidated, non-calcareous, fossiliferous (small ammonoid), containing some ash	5	3700–3705
Sand, dirty white, soft, friable, fine, pure, colorless, angular quartz grains in matrix of ash; .03 to .2 mm. in size, average about .15 mm.	2	3705–3707
Volcanic ash, grayish white, thin bedded, flakes off in hard chips; exceedingly fine. Washed sample contains 5% of fine angular quartz grains .03 to .1 mm. in size, mixed with mass of exceedingly fine silica particles	13	3707–3720
Sand, gray, medium grained, oil stained	4	3720–3724
Sandstone, grayish brown, medium grained, friable, poorly bedded, made up of well-assorted rounded sand grains, averaging .15 mm. in size	2	3724–3726

	Thickness *Feet*	Depth *Feet*
Silty ash or ashy silt, light gray, very fine grained, friable, non-calcareous	1	3726–3727
Conglomerate, rounded pebbles of clay, or ash and chert, set in a non-calcareous matrix of medium to coarse quartz sand; about 80% sand, 20% pebbles, strained brown with oil. Sand grains are angular and subangular, unequal sized .15 to .47 mm. in diameter; some show crystal faces	2	3727–3729
Pebbles, mostly white, non-calcareous ash pebbles in a matrix of fine gray, gritty sand and silt. Six angular chert pebbles, one rounded		3729
Oil sand, white, stained brown with oil. Even grained, pure quartz sand .15 to .3 mm. in diameter	5	3729–3734
Shale, dark grey, hard, thinly bedded, non-calcareous, consisting of very fine argillaceous clay particles mixed with 10% of fine angular quartz grains .01 to .06 mm. in diameter	2	3736–3738
Oil sand, medium grained, friable, made up of well assorted subangular quartz grains, stained brown with oil, .15 to .3 mm. in diameter	5	3745–3750

Amerada Oil Company's Christian No. 1, Smith County

Clay, chocolate-red, mottled with gray, compact, unlaminated, colloidal clay. Washed in water, residue is fine, amorphous, non-calcareous particles	4	4998–5002
Shale, light gray, thinly laminated, non-calcareous, silty, consisting of 90% fine silt, 10% small angular dark smoky quartz grains .15 mm. in average size. A few are .3 or .4 mm. in diameter	18	5002–5020
Shale, dark gray, hard non-calcareous, sandy, consisting of 90% silt, and 10% small subangular quartz grains .15 mm. in diameter	5	5020–5025
Siltstone, light gray, hard, non-calcareous. The washed sample consists of 10% fine transparent quartz grains .03 mm. in diameter	13	5025–5038
Clay, dark chocolate-maroon, mottled with greenish gray streaks, compact, hard and non-calcareous	8	5038–5046
Clay, mottled purplish red and greenish gray, fine grained, silty, compact, and non-calcareous	26	5046–5072
Siltstone, greenish gray, mottled with purple streaks, fine grained, non-calcareous. Washed sample consists of small angular quartz grains		

	Thickness *Feet*	Depth *Feet*
.03 to .15 mm. in size set in matrix of fine clay particles	3	5072–5075
Siltstone, gray, sandy, mottled with purple and yellowish-brown streaks. Very fine, hard and non-calcareous. The washed sample contains fine grains of transparent quartz .03 to .15 mm. in size	1	5075–5076
Siltstone, gray, poorly bedded, non-calcareous, containing fine sand grains .03 to .15 mm. in size	9	5076–5095
Clay, blue-gray, fine, non-calcareous, colloidal clay that breaks in a concoidal fracture, and does not disintegrate easily in water. It is free from grit or sand grains	3	5085–5088
Clay, blue-gray, fine, colloidal, non-calcareous	5	5088–5093
Clay, blue-gray, fine non-calcareous colloidal, joint clay, which breaks in concoidal fracture, and does not disintegrate easily in water. It is free from grit or sand grains	5	5093–5098
Clay, dark purplish red, mottled with gray-green veins and blotches. Hard, fine grained, gritty. The washed residue contains angular chocolate and colorless quartz grains .03 to .15 mm. in diameter	19	5098–5112
Siltstone, greenish gray, faintly mottled with streaks of maroon. Fine grained and hard. When washed, the residue contains clear angular quartz grains .03 to .3 mm. in diameter, averaging .15 mm.	2	5112–5114
Sand, light greenish gray, fine grained, hard non-calcareous. The washed sample consists of fine angular quartz grains .15 mm. in size in a matrix of green siliceous clay, perhaps bentonite	6	5114–5120
Sand, light greenish gray, medium grained non-calcareous. The washed sample consists of angular and round grains .15 to .3 mm. in size in a matrix of green bentonite	8	5120–5128
Sand, greenish gray, hard, medium grained, non-calcareous. The washed sample consists of angular quartz grains in matrix of greenish siliceous bentonite	9	5128–5137
Sand, greenish gray, hard, medium grained, non-calcareous. The washed sample consists of angular and subangular quartz grains in a matrix of siliceous clay	11	5137–5148

	Thickness *Feet*	Depth *Feet*
Sand, dark brownish purple, hard, medium grained, non-calcareous, consisting of subangular quartz grains stained brown by iron .15 mm. in size	1	5148–5149
Sand, grayish white, hard, medium grained, non-calcareous, consisting of subangular and rounded quartz grains .2 mm. in size in a matrix of white siliceous clay or ash. One fragment contains a blotch of black carbonaceous matter	8	5149–5157
Sand, greenish gray, hard, medium grained, non-calcareous. The washed sample shows angular and rounded clear quartz grains .03 to .15 mm. in size	15	5157–5172
Shale, dark gray, hard, silty, non-calcareous, containing about 10% of fine quartz grains	1	5172–5173
Shale, dark gray, thinly laminated, hard, fine grained, non-calcareous. Some layers are silty, others very fine grained siliceous shale	3	5173–5176
Sand, light gray, coarse grained, friable, well assorted. The washed sample is made up of uniform sized rounded quartz grains .4 mm. in size	16	5176–5192
Sand, dark brownish-maroon, hard, fine grained, consisting of angular grains .03 to .1 mm. in size set in a matrix maroon silt	2	5192–5194
Sand or siltstone, dark reddish brown, hard, fine grained. Made up of fine angular grains of quartz stained reddish brown, set in a matrix of siliceous silt	21	5194–5215
Sand, light greenish gray, medium grained, friable, non-calcareous, consisting of rounded quartz grains .3 to .45 mm. in size, set in a matrix of greenish siliceous clay, perhaps volcanic ash	15	5215–5230
Sand, light greenish gray, hard, fine grained, thinly laminated, subangular and angular quartz grains .03 to .1 mm. in size	1	5246–5247
Sand, light greenish gray, friable, medium grained, thinly laminated, composed of quartz grains mixed with some green siliceous clay. Grains .03 to .15 mm. in size	6	5241–5247
Sandy shale, light greenish gray, friable, medium grained, thinly laminated	10	5247–5257
Sandy shale, light greenish gray, well laminated, fine grained, containing streaks and specks of carbonaceous matter	10	5257–5267

	Thickness *Feet*	Depth *Feet*
Sand, light gray streaks with greenish-gray partings, soft, friable, medium grained, well assorted sand grains .3 mm. in size	16	5267–5283
Sand, light gray, medium grained, friable, pure well assorted, rounded quartz grains .3 mm. in size	9	5283–5292
Sand, light gray, medium grained, friable, well assorted, quartz grains .15 to .3 mm. in size	15	5292–5307
Sand, greenish gray, hard, medium grained, rounded quartz grains in a matrix of greenish siliceous clay, possibly bentonite. Sand grains well rounded .3 mm. in diameter	3	5295–5298
Clay, purplish red and greenish gray, mottled, hard non-calcareous, free from silt	4	5307–5311
Clay, greenish-gray, compact, colloidal, siltless, talcose	6	5311–5317
Shale, greenish gray, mottled with gray-brown, hard, breaks, with concoidal fracture, non-calcareous, and contains a little fine silt	13	5317–5330
Sandstone, light gray, fine grained, thin bedded, well assorted non-calcareous. The washed sample consists of subangular quartz grains .1 to .15 mm. in size	5	5330–5335
Sandstone, the core shows beautiful thin, intricate cross-bedding, probably dune bedding. Paper thin layers of dark silt alternate with sand laminae .03 to .1 mm. thick	5	5330–5335
Sand, light gray, almost white, friable beach sand. Well assorted, made up of clear subangular and rounded quartz grains .15 to .3 in diameter	7	5337–5344
Sand, light gray, almost white, friable beach sand. Well assorted, made up of clear subangular and rounded quartz grains .15 to .3 mm. in diameter	8	5344–5352
Sand, light gray, friable, coarse, well assorted. Contains a seam of black carbonaceous matter, perhaps coal and blotches of greenish clay in some cases altered to yellow or buff limonite. The washed sample consists of 90% angular clear quartz grains .3 mm. in average size, 9% angular grains stained yellow with iron carbonate, and 1% black aggregates of carbonaceous material	6	5352–5358
Sand, light gray, friable, coarse, containing very thin streaks of dark greenish-gray silt or clay.		

	Thickness *Feet*	Depth *Feet*
The grains are subangular, average .45 mm. in size	24	5358–5382
Sand, light gray, medium grained, pure, well assorted quartz sand, consisting of clear colorless subangular grains averaging .2 mm. in size	27	5382–5409
Sand, dark gray, medium grained, friable, well assorted, consisting of angular and subangular sand grains .3 to .6 mm. in size, averaging .3 mm.	1	5409–5410

STRUCTURE

The Woodbine sand sheet has been titled southeastwardly and gently warped in the form of a very broad, gently plunging trough, with its deepest portion in Anderson and Cherokee counties. The southeast slope of the sheet is cut by a number of normal faults and narrow grabens, which trend along a northeast-southwest belt from Waco and Groesbeck to Texarkana. The faults have been described by Pratt,[10] Lahee,[11] Judson,[12] Fohs,[13] Hill and Sutton,[14] and others. They have displacements varying from 50 to 600 feet (Pl. I), which are thought to have been formed by coastward settling of the sediments. Colloidal clays and marls upon standing long ages lose water, shrink in volume (up to 50 per cent), and change slowly from clays to shales. This loss results in a general settling, which is greatest where the clays are thickest, that is, the seaward side of a coastal plain. The strata along the monocline shrink, crack, slip, and are displaced downward and seaward. Where settling is slight the dip of the strata is increased. Where the downward movement is large a normal fault is formed. Where the shrinkage is excessive and the coastward creep

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[10]Pratt, Wallace E., and Lahee, F. H., Faulting and petroleum accumulation at Mexia, Texas: Am. Assoc. Pet. Geol. Bull., vol. 7, pp. 226–236, 1923.

[11]Lahee, F. H., Oil and gas fields of the Mexia and Tehuacana fault zones, Texas: Structure of Typical American Oil Fields, vol. 1, pp. 304–388, 1929.

[12]Judson, Sidney A., Resumé of discoveries and developments in northeast Texas in 1928: Am. Assoc. Pet. Geol. Bull., vol. 13, p. 611, 1929.

[13]Fohs, F. Julius, Structural and stratigraphic data of northeast Texas petroleum area: Econ. Geol., vol. 18, pp. 709–731, 1923.

[14]Hill, H. B., and Sutton, Chase E, Petroleum engineering in the Wortham oil field, Limestone and Freestone counties, Texas: U. S. Bur. Mines Rept., April, 1927.

Hill, H. B., and Sutton, Chase E., Production and development problems in the Powell oil field, Navarro County, Texas: U. S. Bur. Mines Bull. 284, 1928.

is effective a graben results. When a crack or plane of slippage is formed the block in front creeps away from the block behind. The latter lacking support settles down, so that most of the northeast Texas faults are displaced downward on the back or landward side of the fault. Such faults play out downward and probably do not reach below the top of the underlying basement rocks.

That part of the east Texas trough southeast of the fault zone is disrupted extensively by salt domes. Some of the domes are deep seated; others are elevated nearly to the surface. The domes have been described by E. T. Dumble,[15] O. B. Hopkins,[16] E. De Golyer,[17] Sidney Powers,[18] C. A. Cheney,[19], and B. C. Renick.[20]

Boggy Creek dome, which contains a small oil pool, is a good example. The outline of the salt plug is shown in figure 7. The dome is a nearly vertical uplift of salt elongated in a northeast-southwest direction and trending in the direction of the Mexia-Powell faults. Some of the salt shows a vertical upward thrusting of at least 4000 feet. In Germany[21] such domes rise out of closely folded and faulted Permian basement rocks through overlying Mesozoic and Tertiary strata. It is thought that the east Texas domes have been squeezed up out of the axes of elongate deeply buried anticlines and broken folds as have some of the salt

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[15]Dumble, E. T., Texas Geol. Survey, 1st Ann. Rept., p. 33; 2nd Ann. Rept. (1891), p. LXXVII, Anderson County, pp. 304, 305, 315, 316, Smith County, pp. 206, 209, 224, 316, 323, Freestone County, p. 316, Van Zandt County, pp. 223, 316, 317; 3rd Ann. Rept., pp. 46, 76, 77.

[16]Hopkins, O. B., The Palestine salt dome, Anderson County, Texas: U. S. Geol. Survey Bull. 661-G, 1917.

[17]De Golyer, E., The West Point salt dome, Freestone County, Texas: Jour. Geol., vol. 27, pp. 647–663, 1919.

[18]Powers, Sidney, and Hopkins, O. B., The Brooks, Steen, and Grand Saline salt domes, Smith and Van Zandt counties, Texas: U. S. Geol. Survey Bull. 736–G, 1922.

Powers, Sidney, Interior salt domes of Texas: Am. Assoc. Pet. Geol. Bull., vol. 10, pp. 1–60, 1926.

[19]Cheney, C. A., Salt domes of northeastern Texas: Oil and Gas Jour., January 6, 1922, p. 82; reviewed by K. C. Heald, Am. Assoc. Pet. Geol. Bull., vol. 6, p. 58, 1922.

[20]Renick, B. C., Recently discovered salt domes in east Texas: Am. Assoc. Pet. Geol. Bull., vol. 12, pp. 527–547, 1928.

[21]Van der Gracht, W. A. J. M. van Waterschoot, The structure of the salt domes of northwestern Europe as revealed in salt mines: Geology of Salt Dome Oil Fields, Am. Assoc. Pet. Geol., pp. 45–49, 1926.

domes of Europe. The movement has taken place intermittently during late Cretaceous and Tertiary time, so that older strata are folded and compressed more than the younger. Some of the uplifting has taken place since the formation of the normal faults and grabens.

The Van field is an illustration of another type of dome in which salt has not been reached by the drill. It is much broader, its flanks are much less steep, and the deep formations are less elevated than those of typical salt domes. It is broken by a large fault having a maximum throw of 400 feet. It is a structure intermediate in type between the faults of the Powell-Mexia line and the salt domes of the Palestine area. It is probably underlain at considerable depth by salt, although this has not been proved.

The structure of the Woodbine sand between the salt plugs and the Mexia-Powell fault zone is not well known. Most of the wells have been drilled in the immediate vicinity of the salt plugs, and the area between domes is untested in most places. The accompanying structure map furnishes only a very generalized picture of the attitude of the Woodbine sand (Pl. I). The map is included because of its usefulness in showing the location of the various wells, whose temperatures have been measured and waters analyzed, and the relation of these wells to the larger structural features. It is not intended to delineate all the minor tectonic details. The cross-sections (Pls. II to VII) show the thickness and dip of the sand as recorded in well logs.

AGE AND CORRELATION

The Woodbine formation belongs in the lower part of the Gulf series, the basal strata of the Upper Cretaceous. It has been correlated with the Dakota sands of the Rocky Mountain district, with the Pergoitoire sands of Kansas, and the Lower Tuscaloosa sands of Alabama. In terms of the European section, according to W. S. Adkins,[22] it belongs in the middle of the Cenomanian division on the basis of its ammonoids. Adkins correlates it with part of the

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22Adkins, W. S., Bureau of Economic Geology, personal communication lower *Acanthoceras* zone of Spath,[23] placing it between the *Mantelliceras costatum* subzone and *Acanthoceras rotomagense* subzone.

The following fossils have been identified from the Woodbine formation:

Upper sands—
- Metengonoceras sp.
- Acanthoceras sp.
- Metoicoceras sp.
- Ostrea carica Cragin
- Ostrea soleniscus Meek
- Ostrea lyoni Shumard
- Exogyra columbella (Meek)
- Exogyra ferox Cragin
- Barbatia micronema (Meek)

Middle clays and sands—
- Aguileria cumminsi White
- Ostrea carica Cragin
- Exogyra ferox Cragin
- Cerithium tramitense Cragin
- Cerithium interlineatum Cragin
- Trigonarca siouxensis (Hall and Meek)
- Modiola filisculpta Cragin
- Arca tramitensis Cragin
- Turritella coalvillensis Meek
- Barbatia micronema Meek

Basal sands—
- Cytherea leveretti Cragin
- Cytherea taffi Cragin
- Pteria salinensis White
- Ampullina humilis (Cragin)
- Nerita sp.
- Trigonarca siouxensis (Hall and Meek)
- Arca tramitensis Cragin
- Neritopsis tramitensis Cragin
- Turritella cf. seriatim var. granulata Gabb (non Roemer)

Basal clay—
- Mantelliceras
- Anchura sp.
- Plicatula aff. arenaria Meek
- Tapes cyprimeriformis Stanton (?)
- Avicula aff. gastrodes Meek

[23]Spath, L. F., On the zones of the Cenomanian and uppermost Albian: Proc. Geol. Assoc., vol. 37, p. 420–432, 1926.

UNDERGROUND WATERS IN THE WOODBINE SAND

PREVIOUS WORK ON UNDERGROUND WATERS OF THE WOODBINE SAND

The first published statement regarding underground waters in north Texas appears to have been made by R. T. Hill[24] in 1887. In this pioneer report Hill reviewed the underground water conditions in north Texas and pointed out the principal water reservoirs. Three years later at the request of the department of agriculture he wrote[25] a more extended report on water conditions in eastern New Mexico and western Texas and made a few references to the north Texas region. In 1892, J. A. Taff,[26] assisted by S. Leverett in the employ of the Texas Geological Survey, made a survey of the Cretaceous area north of Colorado River and reported on the artesian water. These workers described accurately the underground character of the Woodbine, pointed out the eastward and southward thinning of the formation, noted the occurrence of more clay in the well sections in the area around Dallas and Terrell than on the outcrop, and described the places in the province where flowing wells could be expected. Nine years later, in 1901, R. T. Hill[27] completed his monograph on the Black and Grand Prairies of Texas and devoted more than two hundred and fifty pages to a description and discussion of underground water conditions. His report is so complete and thorough that it becomes a reference book for all later workers in the area. He not only discusses the principles governing underground water, and describes all the principal wells and the character and extent of the water-bearing strata, but he also describes the chemical qualities of the waters and presents a few detailed water analyses. He states: "It would be an interesting experiment to collect and analyze these

24Hill, R. T., The topography and geology of the Cross Timbers and surrounding regions in northern Texas: Am. Jour. Sci., 3rd ser. vol. 33, April, 1887.

25Hill, R. T., Occurrence of artesian and other underground water in Texas, eastern New Mexico, and Indian Territory west of the ninety-seventh meridian: Ex. Doc No. 222, 51st Congress, 1st session, 1890.

26Taff, J. A., and Leverett, S., Report on the Cretaceous area north of the Colorado River: Geol. Survey Texas 4th Ann. Rept., pp. 309–336, 1893.

27Hill, R. T., Geography and geology of Black and Grand Prairies, Texas: U. S. Geol. Survey 21st Ann. Rept., pt. 7, pp. 387–646, 1901.

various waters and to compare their analysis with one another and with those rocks from which they flow, and the writer hopes that this will yet be done." Thus this intrepid geologist anticipated by forty years the chemical work on the underground waters which are now being carried out. In 1906 A. C. Veatch[28] published a work similar in scope to that of Hill on the underground water resources of northern Louisiana and southern Arkansas in which he discusses the underground water conditions in the area adjoining Texas on the east, describes the Woodbine sand briefly, and gives some data on water wells in northeast Texas.

C. H. Gordon[29] in 1911 published a brief account of the underground waters of northeastern Texas. He describes the Woodbine sand briefly, gives a little new data on its thickness, and presents a table of water analyses, most of which are from formations other than Woodbine.

Alexander Deussen[30] in 1914 studied the underground waters of the southeastern part of the Coastal Plain. He gives a general account of the geology and underground waters but does not specifically describe or discuss the Woodbine sand.

Since the work of these underground water experts was completed, a number of county reports[31] by the Bureau of Economic Geology of Texas have described the Woodbine sand and its waters locally. Except for the more accurate delineation of the outcrop of the Woodbine, these reports add but little that is new to the descriptions of the water sands furnished by the earlier workers.

28Veatch, A. C., Geology and underground water resources of northern Louisiana and southern Arkansas: U. S. Geol. Survey Prof. Paper 46, p. 24, 1906.

29Gordon, C. H., Geology and underground waters of northeastern Texas: U. S. Geol. Survey Water-Supply Paper 276, 1911.

30Deussen, Alexander, Geology and underground waters of the southeastern part of the Texas Coastal Plain: U. S. Geol. Survey Water-Supply Paper 335, 1914.

31Shuler, Ellis W., Geology of Dallas County, Univ. Texas Bull. 1818, 1918.

Adkins, W. S., Geology of Tarrant County, Univ. Texas Bull. 1931, 1919.

Winton, W. M., and Scott, G., Geology of Johnson County, Univ. Texas Bull. 2229, 1922.

Adkins, W. S., Geology of McLennan County, Univ. Texas Bull. 2340, 1923.

Bybee, H. P., and Bullard, Fred M., Geology of Cooke County, Univ. Texas Bull. 2710, 1927.

Adkins, W. S., and Arick, M. B., Geology of Bell County, Univ. Texas Bull. 3016, 1930.

As a result of the discovery of oil and gas at Mexia and Powell, a number of reports[32] on the oil fields published during the last five years have contributed to our knowledge of the subsurface conditions of the Woodbine sand. The knowledge gained from correlating well logs and examining samples from oil tests has enabled geologists to outline the eastern and southern extent of the sand more accurately, to describe its lithology and to measure its subsurface porosity.

PLAN OF WATER INVESTIGATIONS

The study of the chemical composition of the waters in east Texas has been planned to ascertain how the chemical content of the Woodbine water changes from the outcrop down dip, the relationship of chemical content of the water to abnormal structure, to accumulations of oil, to different degrees of porosity, to changes in lithology of the sand, and to different underground temperatures. Although water samples from many oil tests and a few deep water wells have been collected and analyses published,[33] no systematic

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[32]Pratt, Wallace E., and Lahee, F. H., Faulting and petroleum accumulation at Mexia, Texas: Am. Assoc. Pet. Geol. Bull., vol. 7, pp. 226–236, 1923.

Lahee, F. H., The Currie oil field, Navarro County, Texas: Am. Assoc. Pet. Geol. Bull., vol. 7, pp. 25–26, 1923; Further notes on the origin and nature of the Currie structure, Navarro County, Texas: vol. 10, pp. 61–71, 1926.

Hill, H. B., and Sutton, Chase E., Petroleum engineering in the Wortham oil field, Limestone and Freestone counties, Texas: U. S. Bur. Mines Rept., April, 1927.

Hill, H. B., and Sutton, Chase E., Production and development problems in the Powell oil field, Navarro County, Texas: U. S. Bur. Mines Bull. 284, 1928.

Judson, Sidney A , Resumé of discoveries and developments in northeast Texas in 1928: Am. Assoc. Pet. Geol. Bull., vol. 13, p. 611, 1929.

Lahee, F. H., Oil and gas fields of the Mexia and Tehuacana fault zones, Texas: Structure of Typical American Oil Fields, Am. Assoc. Pet. Geol., vol. 1, pp. 304–388, 1929.

Levorsen, A. I., The east Texas oil field: Inter. Pet. Tech., vol. 8, pp. 261–268, 1931.

[33]Hill, R. T., Geography and geology of the Black and Grand Prairies, Texas: U. S. Geol. Survey 21st Ann. Rept., pt. 7, pp. 447–451, 1900.

Gordon, C. H., Geology and underground waters of northeastern Texas: U. S. Geol. Survey Water-Supply Paper No. 276, pp. 73–75, 1911.

Hill, H. B., and Sutton Chase E., Petroleum engineering in the Wortham oil field, Limestone and Freestone counties, Texas: U. S. Bur. of Mines Rept., pp. 19–21, 1927; Production and development problems in the Powell oil field, Navarro County, Texas; U. S. Bur of Mines Bull. 284, pp. 55–59, 1928.

Cohen, Chester, Chemical analyses of Texas well waters: Texas State Dept. Health, pp. 1–45, Aug. 1, 1931.

survey of the chemical content of the waters of a single porous sand has been made in Texas. Our work, therefore, has comprised the collection of a series of waters taken from all parts of the Woodbine sand sheet with special reference to significant structural features, the chemical analysis of the samples, and the interpretation of results.

Samples were obtained first from shallow wells near the outcrop of the formation, and then the work was gradually extended to wells farther and farther down the dip. The exact stratigraphic position of each sample was checked with the log of the well and with carefully prepared geologic cross-sections, in order to be sure that the water came from the Woodbine formation. In the deeper parts of the basin east of the fault lines, fewer wells were available. The few analyses obtained in this area have been supplemented by analyses, furnished by oil companies, of waters from wells drilled for oil but now abandoned and plugged. In all, over two hundred water analyses have been collected, the results plotted graphically, and the data studied and compared with the results obtained from the temperature measurements.

METHOD OF WATER ANALYSIS

COLLECTION OF SAMPLES

Sampling of the oil-field water for chemical analysis is carried out as follows:

1. The log and casing record of the well are studied in order to make certain that the water is coming from the Woodbine formation and to determine the position of the water sand within the formation.
2. The well is bailed until the water in the bailer is the same as that in the sand.
3. The sample is collected in a clean, half-gallon bottle. If the well is flowing the sample is collected from the flow line at the well, never from water standing in open tanks or slush pits.
4. During drilling operations satisfactory samples can be obtained from some wells by running a formation

tester[34] and filling the bottle from the contents of the barrel of the tester.

5. All samples are kept tightly corked in the glass containers until the analysis is made.

PREPARATION OF REAGENTS

Solutions and indicators.—The following solutions are prepared by dissolving in distilled water the quantities indicated and making up to one liter at 20 degrees Centigrade.

10 per cent diammonium acid phosphate	100 grams
10 per cent barium chloride	100 grams
10 per cent ammonium chloride	100 grams
10 per cent (by volume) sulphuric acid	100 ml. conc. acid
0.1 N potassium permanganate	3.161 grams
0.1 N silver nitrate	16.989 grams
0.1 N sodium carbonate	5.300 grams
Dilute ammonia	400 ml. conc. ammonia

All solutions are standardized by titrating against standard solutions.

To prepare "magnesia wash solution," 200 grams of ammonium nitrate are dissolved in 400 ml. of concentrated ammonium hydroxide and made up to one liter with distilled water.

The following indicators are made according to the following directions:

Methyl orange—dissolve 1 gram of methyl orange in 1 liter of water.

Phenolphthalein—Dissolve 5 grams of phenolphthalein in 500 ml. of 50% ethyl alcohol; neutralize with standard alkali until pink appears; then remove color with a drop of weak acid.

Potassium chromate—dissolve 60 grams of potassium chromate in a small amount of distilled water; add enough silver nitrate to produce a slight red precipitate. Filter and make up to 1 liter.

Standard soap solution.[35]—The following solutions should first be made:

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[34]George, H. C., Oil well completion and operation: Univ. Okla. Press, pp. 30–31, Norman, Okla.

[35]Standard methods for the examination of water and sewage: American Public Health Association, 6th ed., pp. 28–32, 1925.

(a) Standard calcium chloride solution.—Dissolve 0.2 of a gram of pure calcite (calcium carbonate) in a little dilute hydrochloric acid, being careful to avoid loss of solution by spattering. Evaporate the solution to dryness several times with distilled water to expel excess of acid. Dissolve the residue in distilled water and dilute the solution to 1 liter. One ml. of this dilution is equivalent to 0.2 mg. of calcium carbonate.

(b) Stock soap solution.—Dissolve 100 grams of shredded dry white castile soap in 1 liter of 80-per cent ethyl alcohol, and allow this solution to stand several days before standardizing. Pure potassium oleate made from lead plaster and potassium carbonate may be used in place of castile soap. Denatured alcohol cannot be used.

Then dilute 20 ml. of the calcium chloride solution in a 250-ml. glass stoppered bottle to 50 ml. with distilled water, which has been recently boiled and cooled. Add soap solution from a burette, 0.2 or 0.3 ml. at a time, shaking the bottle vigorously after each addition, until a lather remains unbroken for 5 minutes over the entire surface of the water while the bottle lies on its side. Then adjust the strength of the stock solution with 70 per cent alcohol so that the resulting soap solution will give a permanent lather when 6.40 ml. of it is properly added to 20 ml. of standard calcium chloride solution diluted to 50 ml. Usually 75 or 100 ml. of the stronger stock solution are required to make 1 liter of standard soap solution. The quantity of calcium carbonate equivalent to each milliliter of standard soap solution consumed in titration is indicated in Table 1.

TABLE 1.—*Total hardness*[36] *in parts per million of $CaCO_3$ for each tenth of a milliliter of soap solution when 50 c. c. of the sample is titrated.*

Milliliters of soap solution	0.0	0.1	0.2	0.3	0.4	0.5	.06	0.7	0.8	0.9
0.0	......	......	......	......	......	......	......	0.0	1.0	3.2
1.0	4.8	6.3	7.9	9.6	11.1	12.7	14.3	15.6	16.9	18.2
2.0	19.5	20.8	22.1	23.4	24.7	26.0	27.3	28.6	29.9	31.2
3.0	32.5	33.8	35.1	36.4	37.7	39.0	40.3	41.6	42.9	44.3
4.0	45.7	47.1	48.6	50.0	51.4	52.9	54.3	55.7	57.1	58.6
5.0	60.0	61.4	62.9	64.3	65.7	67.1	68.6	70.0	71.4	72.9
6.0	74.3	75.7	77.1	78.6	80.0	81.4	82.9	84.3	85.7	87.1
7.0	88.6	90.0	91.4	92.9	94.3	95.7	97.1	98.6	100.0	101.5

[36] *Idem.*, p. 29

REMOVAL OF INSOLUBLE RESIDUE

Before making the analysis the suspended material is removed[37] by filtering through filter paper. If oil is present, it is first removed by a separatory funnel, then the sample is decanted and filtered. The process is carried out rapidly enough to prevent loss by evaporation, and the clear water is placed immediately in an air-tight flask. It is then ready for analysis.

DETERMINATION OF HYDROXIDES, CARBONATES, AND BICARBONATES

One hundred ml. of the original filtered sample is placed in a 250-ml. beaker and 3 or 4 drops of phenolphthalein indicator solution added. Red coloration indicates the presence of normal carbonate. The solution is titrated with 0.1 N sulphuric acid until the coloration just disappears. The number of milliliters used[38] corresponds to "P" of Table 2. Then to the same solution 2 drops of methyl orange indicator are added, and the titration is carried to the neutral point, as shown by this indicator. The total number of milliliters of 0.1 N sulphuric acid used in both titrations corresponds to "T" of Table 2, in which are shown the

TABLE 2.—*Relations[39] between alkalinity to phenolphthalein and alkalinity to methyl orange in presence of hydroxide, carbonate, and bicarbonate.*

Results of Titration	Value of radical expressed in terms of ml. of 0.1 N sulphuric acid		
	Hydroxide	Carbonate	Bicarbonate
$P = 0$	0	0	T
$P < \frac{1}{2} T$	0	2P	T–2P
$P = \frac{1}{2} T$	0	2P	0
$P > \frac{1}{2} T$	2P–T	2(T–P)	0
$P = T$	T	0	0

NOTE.—T equals total alkalinity in presence of methyl orange; P equals alkalinity in presence of phenolphthalein.

[37] Reistle, C. E., Jr., and Lane, E. C., A system of analysis for oil-field waters: U. S. Bur. Mines Tech. Paper 432, pp. 1–14, 1928.

[38] Standard methods for the examination of water and sewage: Am. Public Health Assoc. 5th ed., p. 35, 1923.

[39] Standard methods for the examination of water and sewage: Am. Public Health Assoc., 6th ed., p. 35, 1925.

relations between alkalinity to phenolphthalein and to methyl orange in the presence of hydroxide, carbonate, and bicarbonate.

One ml. of 0.1 N sulphuric acid is equivalent to 1.7 mg. of hydroxide, 3.0 mg. of carbonate, or 6.1 mg. of bicarbonate. Since 100 ml. of the original sample is used in the titration, these values multiplied by 10 give the corresponding figures in terms of 1 liter of original sample—namely, 17 mg. for hydroxide, 30 mg. for carbonate, and 61 mg. for bicarbonate. The latter values, when multiplied by the proper figures calculated according to Table 2, give the concentration in parts per million (miligrams per liter) for hydroxide, carbonate, and bicarbonate, respectively.

DETERMINATION OF ACIDITY

The acidity of a natural water represents essentially the contents of free carbon dioxide, mineral acids, and salts that hydrolize to give hydrogen ions. Acidity is determined by titration with a standard solution of a strong alkali and is reported as parts per million of calcium carbonate. The condition is rare in oil-field waters, and when met can be determined by the methods of the American Public Health Association.

DETERMINATION OF CHLORIDES

Ten ml. of the original filtered water sample is titrated with 0.1 N silver nitrate, using 1 ml. of a potassium chromate solution as indicator, until the reddish ćolor of silver chromate is permanent. One ml. of 0.1 N silver nitrate is equivalent to 3.5457 mg. of chlorine; therefore since 10 ml. of water is taken for titration, the number of milliliters of 0.1 N silver nitrate used, multiplied by 354.57, gives the concentration of chloride in parts per million (milligrams per liter).

A satisfactory end point cannot be obtained when more than 8 to 10 ml. of 0.1 N silver nitrate is required. If the sample is acid, it is neutralized with sodium carbonate; if hydroxide is present, dilute acetic acid is added until the cold solution will just discharge the color of phenolphthalein. Acidity due to chlorides having an acid reaction, such as aluminum chloride, is treated with an excess of a neutral solution of sodium acetate and titrated as usual. If the solution is too highly colored to titrate, those ions which give the color are precipitated by sodium hydroxide or sodium carbonate, and the filtrate is neutralized with acetic acid before titration. To obtain trustworthy results, sulphide waters should be boiled with a few drops of nitric acid and then neutralized.

Many oil-field waters or brines contain large quantities of chlorides of sodium, calcium, and magnesium. If the chloride content of a water is high, a small amount is diluted with distilled water free from chlorides, and an aliquot part taken for analysis; if very low in chlorides, a portion of the sample is concentrated for the analysis.

DETERMINATION OF SULPHATES

One hundred ml. of the original sample is measured into a 250-ml. beaker, evaporated to dryness on a steam bath or hot plate, and then baked overnight at 105 degrees Centigrade. The residue is moistened with 10 ml. of concentrated hydrochloric acid, dissolved in 100 ml. of water, and the solution boiled and then filtered to remove silica and insoluble material. The filter is thoroughly washed, and to the boiling filtrate a hot 10 per cent solution of barium chloride is added drop by drop with constant stirring until no further precipitation occurs, then 100 ml. in excess is rapidly added, and the solution allowed to digest for one-half hour at the boiling point. The solution is covered and allowed to stand at room temperature for at least 12 hours.

The precipitate of barium sulphate is filtered and thoroughly washed with warm water, using a 9-cm. ashless, washed filter paper of dense, firm texture. The precipitate and filter paper are placed in a weighed porcelain crucible, ignited in an electric muffle furnace, cooled in a desiccator, and weighed. Since 1 mg. of barium sulphate represents 0.4115 mg. of sulphate and 100 ml. of sample is used, the weight of barium sulphate in milligrams multiplied by 4.115 is the concentration of sulphate in parts per million (milligrams per liter).

DETERMINATION OF SILICA, IRON, AND ALUMINUM

Silica, iron, and aluminum are not determined in this system of analysis. They must be removed, however, before the metallic ions calcium and magnesium can be determined.

The appropriate amount of sample (100 ml. to 1000 ml.), is placed in a porcelain evaporating dish, made slightly acid with hydrochloric acid, and evaporated to dryness, and baked in an oven at 105 degrees centigrade for at least six hours to render the silica insoluble. To the contents of the dish 5 ml. of concentrated hydrochloric acid and 50 ml. of distilled water are added, boiled 15 to 30 seconds, transferred to a 9-cm. filter paper and washed thoroughly with hot water. The filter paper and its contents are rejected; the filtrate and washings are treated to remove iron and aluminum. To oxidize all the iron present, a few drops of nitric acid are added and the solution boiled. It is evaporated, if necessary, to a volume of about 100 ml., 10 ml. of a 10 per cent solution of ammonium chloride added, made slightly alkaline by adding dilute ammonium hydroxide, and boiled for about 10 minutes. The precipitated iron and aluminum, if present, are removed by filtering through a 9-cm. filter paper and washed with hot water. The precipitate is rejected.

DETERMINATION OF CALCIUM

The combined filtrate and washings from the iron and aluminum precipitation are concentrated, if necessary, to approximately 200 ml., made distinctly alkaline with ammonium hydroxide and heated to boiling. A saturated solution of ammonium oxalate is added drop by drop with constant stirring until no further precipitation occurs; then 10 ml. more ammonium oxalate solution is added rapidly, and the whole is boiled for two minutes, stirring constantly, if necessary, to prevent loss by bumping. The solution is kept warm for three hours, filtered through a 9-cm. ashless filter paper, and washed thoroughly with hot water. The filtrate and washings are reserved for the magnesium determination.

The filter paper containing the calcium oxalate is punctured and the precipitate washed with hot water into the beaker in which it was precipitated. It is well to place 10 ml. of hot 10 per cent sulphuric acid into the beaker before washing in the oxalate. The filter paper is washed alternately with hot 10 per cent sulphuric acid and hot water until free from the precipitate, using care that only negligible portions of the filter paper are washed into the solution. After the calcium oxalate is dissolved the solution is brought to 70 degrees centigrade and titrated to a faint pink with 0.1 N potassium permanganate; when this point is reached, the punctured filter paper is dropped into the solution and gently agitated, care being taken not to disintegrate it. The pink color will remain unless the washing of the paper was incomplete and then only a few more drops of permanganate should be required to bring back the pink color. This quantity should be noted and added to the amount originally used. Since 1 ml. of 0.1 N potassium permanganate is equivalent to 2.0035 mg. of calcium, the number of milliliters of permanganate used, multiplied by 2.0035 times the appropriate factor for size of sample taken, is the concentration of calcium in parts per million (milligrams per liter).

DETERMINATION OF MAGNESIUM

The filtrate and washings from the calcium determination are concentrated to about 150 ml. Twenty ml. of 10 per cent diammonium acid phosphate is added to the boiling solution, boiled three to five minutes, and allowed to cool. When cold, it is agitated thoroughly with a stirring rod until all the precipitate has formed, and then slowly from a burette, with constant stirring, 5 ml. of concentrated ammonia is added. The precipitate is allowed to stand overnight or at least six hours, then filtered through an ashless filter paper, washed free from chlorides with 3 per cent ammonia, and given a final wash with "magnesia wash solution." The precipitate and filter paper while moist with the magnesia wash solution are transferred to a weighed porcelain crucible, placed in a cold muffle furnace, and brought to full red heat. By this procedure the ammonium salts are volitalized and the paper burned completely at a low temperature. The final result is a snow-white mass of magnesium pyrophosphate; this is cooled in a dessicator and weighed. Since 1 mg. of magnesium pyrophosphate contains 0.2184 mg. of magnesium, the weight in milligrams multiplied by 0.2184 times the appropriate factor for size of sample is the concentration of magnesium in parts per million (milligrams per liter).

DETERMINATION OF SODIUM

Determination of the alkali metals by analysis is usually unnecessary. The concentration of the sodium in the solution may be calculated as follows: the sum of the reacting values of the positive radicals found in the analysis is subtracted from the sum of the reacting values of the negative radicals, and the difference, which is assumed to be the reacting value of sodium, is divided by the reaction coefficient of sodium (0.0435) or multiplied by 23. This gives the amount of sodium in parts per million (milligrams per liter). The method of calculating reaction values and reaction coefficients is explained on a following page.

DETERMINATION OF TOTAL SOLIDS

To determine the amount of mineral matter in solution an appropriate amount of the filtered water is evaporated in a weighed silica dish. When dry, the dish is placed in an oven at 105 degrees Centigrade for one hour and then taken out, cooled, and weighed. The weight of the residue multiplied by the factor for the size of sample will be the total solids in parts per million (milligrams per liter). A method of estimating the amount of total solids in moderately concentrated solutions from the specific gravity is given on a following page.

DETERMINATION OF TOTAL HARDNESS

A 50-ml. sample of the water[40] is placed in a 250-ml. bottle, and soap solution added to it in small quantities in

[40]Standard methods for the examination of water and sewage: Amer. Pub. Health Assoc., 6th ed., pp. 28-32, 1925.

precisely the same manner as described under the standardization of the soap solution. The total hardness of the water in parts per million of calcium carbonate is obtained from the number of milliliters of soap solution used by interpolating from Table 1.

To avoid mistaking the false or magnesium end point for the true one when adding the soap solution to waters containing magnesium salts, the burette is read after the titration is apparently finished and then about 0.5 ml. more of soap solution is added. If the end-point was due to magnesium the lather will disappear. Soap solution must then be added until the true end point is reached. Usually the false lather persists for less than five minutes.

If more than 7 ml. of soap solution is required for 50 ml. of the water, take less of the sample and dilute it to 50 ml. with distilled water which has been recently boiled and cooled. This step reduces somewhat the disturbing influence of magnesium which consumes more soap than an equivalent amount of calcium.

The strength of the soap solution should be determined from time to time, to make sure that it has not materially changed.

REACTING VALUES AND REACTION COEFFICIENTS

The practice of expressing the results of water analyses in terms of "reacting values" has been given prominence by the work of Stabler[41] and Palmer.[42] Reporting water analyses in milligrams per liter of the various ions shows the relative concentrations of the active constituents, but according to Palmer it does not indicate the chemical value of the waters. To compare the chemical properties of waters, he suggests a method intended to indicate the reactive capacities of the positive and negative radicals. These reacting values can be calculated by dividing the concentration of each radical in milligrams per liter (as determined

[41]Stabler, Herman, The mineral analysis of water for industrial purposes and its interpretation by the engineer: Eng. News, vol. 60, p. 356, 1908; Some stream waters of the western United States: U. S. Geol. Survey Water-Supply Paper 274, pp. 1–188, 1911.

[42]Palmer, Chase, The geochemical interpretation of water analyses: U. S. Geol. Survey Bull. 479, pp. 1–31, 1911.

by analysis) by the appropriate equivalent combining weight (atomic weight divided by valence) expressed in milligrams; or the reacting values may be found, as is done by Stabler, by multiplying the concentration of the radicals (in parts per million as determined by analysis) by the reciprocals of the corresponding equivalent combining weights. These reciprocals are called "reaction coefficients." Thus, sodium has an atomic weight of 23; its reaction coefficient is 1/23 or 0.0435. The sulphate radical (SO_4) has a molecular weight of 96 and a valence of 2; its equivalent combining weight is $96 \div 2 = 48$; its reaction coefficient is 1/48 or 0.0208. The following table gives the necessary reaction coefficients based on the international atomic weights of the chemical elements for 1925:

TABLE 3.—*Reaction coefficients of elements and radicals commonly used in water analysis.*

Positive radicals		Reaction coefficients	Negative radicals		Reaction coefficients
Hydrogen	(H)	0.9920	Hydroxide	(OH)	0.0588
Aluminum	(Al)	0.1113	Carbonate	(CO_3)	0.0333
Calcium	(Ca)	0.0499	Bicarbonate	(HCO_3)	0.0164
Magnesium	(Mg)	0.0822	Sulphate	(SO_4)	0.0208
Sodium	(Na)	0.0435	Chloride	(Cl)	0.0282
Potassium	(K)	0.0256	Nitrate	(NO_3)	0.0161
Ferrous iron	(Fe)	0.0358	Sulphide	(S)	0.0624

The method of calculating the reacting values of a water is illustrated by the following analysis of water from the Magnolia Petroleum Company's Flury No. 1, Rusk County, Texas:

Radical	Parts per million		Reaction coeff.		Reacting values	Reacting values *Per cent*
Sodium (Na)	22,050.0	×	0.0435	=	959.0	46.3
Calcium (Ca)	1,176.0	×	0.0499	=	58.8	2.8
Magnesium (Mg)	197.0	×	0.0822	=	16.2	.8
Sulphate (SO_4)	384.0	×	0.0208	=	8.0	.4
Chloride (Cl)	36,400.0	×	0.0282	=	1020.0	49.3
Bicarbonate (HCO_3)	336.0	×	0.0164	=	6.0	.3
			Total value		2068.0	99.9

The results of analyses of east Texas waters showing reacting values of their constituents are given in Table 6.

GRAPHIC REPRESENTATION OF WATER ANALYSES

The mineral content of underground waters is reported commonly in parts per million (milligrams per liter) and in terms of "reacting values." The reacting values are calculated by the method outlined above, the percentage of each reacting value is worked out, and the results are plotted graphically.

A number of schemes have been suggested[43] for showing the percentages in graphic form.

A simple method used by the authors consists of plotting the reacting values on cross-section paper, using a double column, one for the positive ions (sodium, calcium, and magnesium), and the other for negative ions (chloride, sulphate, and bicarbonate). The scale is governed by the concentration range of the waters under comparison, and colors can be used to indicate each radical.

A comparison of a number of analyses is shown by placing the strips side by side and noting the relative sizes of the color symbols representing the various radicals. A typical series of these analyses strips is presented in figure 3.

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[43] Collins, W. D., Graphic representation of water analyses: Ind. and Eng. Chemistry, vol. 15, p. 394, 1923.

Rogers, G. S., Sunset-Midway oil field, California, pt. 2, Geochemical relations of the oil, gas, and water: U. S. Geol. Survey Prof. Paper 117, p. 60, 1919.

Tickell, E. G., A method for the graphical interpretation of water analysis: Summary of Operations California Oil Fields, vol. 6, No. 9, pp. 5–11, 1921.

Reistle, C. E., Jr., Identification of oil field waters by chemical analysis: U. S. Bur. Mines Tech. Paper 404, p. 22, 1927.

Bastin, E. S., The problem of the natural reduction of sulphates: Am. Assoc. Pet. Geol. Bull., vol. 10, p. 1284, 1926.

Estabrook, E. L., Analyses of Wyoming oil-field waters: Am. Assoc. Pet. Geol. Bull., vol. 9, pp. 243–244, 1925.

Parks, E. M., Water analyses in oil production and some analyses from Poison Spider, Wyoming: Am. Assoc. Pet. Geol. Bull., vol. 9, pp. 932–935, 1925.

The changes in chemical composition in various parts of the subsurface sand are shown best by salinity curves and isosalinity maps. In the salinity curves the distance in miles from the outcrop to the location of the well tested is plotted on the horizontal lines of cross-section paper. The concentration of the chloride in parts per million (milligrams per liter), or the percentage reaction value, is plotted on the vertical lines, and a curve is drawn through the

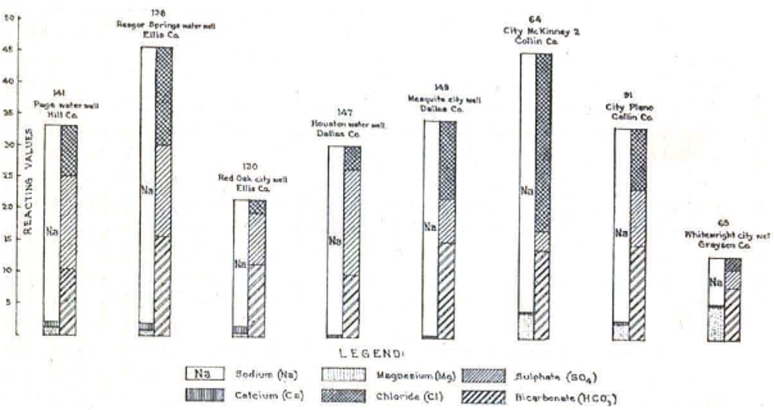

Fig. 3.—Graphs showing the chemical composition of a series of waters collected from depths varying from 400 to 1400 feet in the fresh-water area of the Woodbine-sand province.

established points (fig. 4). Spots of abnormal salinity show at once in such curves. The isosalinity maps are made by plotting on a map at the location of the well the concentration of the salt in parts per million, or the percentage reaction value, and by drawing lines (isosalinity lines) through the points of equal salinity. Spots of abnormal salinity are shown on the map by curves and closed lines, just as domes are indicated by closed contours (fig. 5).

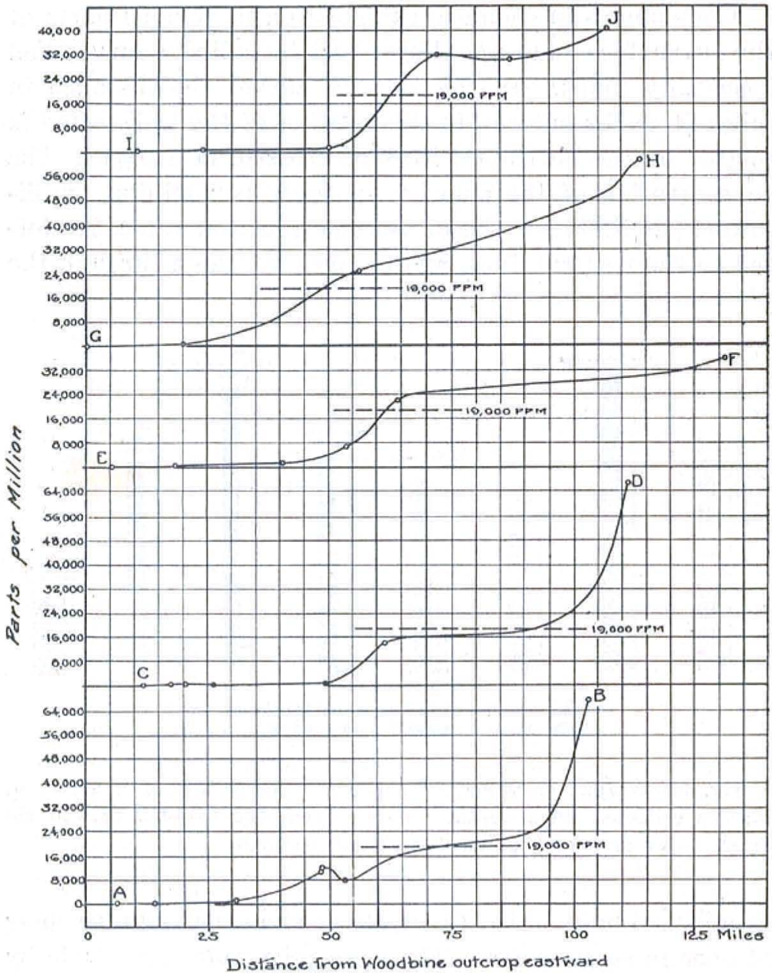

Fig. 4.—Curves showing increase in chloride content from the outcrop toward the center of the Woodbine sand sheet along lines A-B, C-D, E-F, G-H, I-J on the map, Plate VIII.

NORMAL CONSTITUENTS OF WOODBINE WATERS

NORMAL MINERAL CONTENT

Fresh or nearly fresh water characterizes the upper and lower members of the Woodbine in all wells located in a belt about 20 miles wide extending across northeast Texas, south of and bordering the outcrop of the sand (fig. 1). In this belt the water has the composition represented by the graphic chart in figure 3. It contains rarely more than 2900 parts per million of total solids or over 540 parts per million chlorides. The bicarbonates have a concentration of about 1000 parts per million. The upper member of the Woodbine formation contains approximately the same amount of total solids as the lower member. In some places the lower sand member carries hydrogen sulphide derived from the interbedded lignitic layers. In crossing the fresh-water belt from northwest to southeast the percentage of chlorides and total solids in both the upper and lower water layers gradually increases. The bicarbonates decrease from 1000 parts per million at the outcrop to less than 500 parts per million thirty miles southeast of the outcrop. The increase in chloride content per mile is shown by the curves in figure 4. At a distance of about forty miles from the outcrop the concentration of chlorides reaches 2500 parts per million, and the water becomes too salty to drink. This line of 2500-parts-per-million concentration is shown on the map, figure 1 (line W-W′). From this line southward the rate of increase is more gradual, and a concentration of sea water (19,000 parts per million) is reached at a point about seventy miles from the outcrop (fig. 1, line A-A′). South of this line the change is slight, except in the vicinity of salt domes. The 19,000-parts-per-million isochloride[44] line follows approximately the strike of the outcrop of the sand. Going northeastward the isochloride lines bend and follow the structure lines. The position of the isochloride line depends upon the thickness and the porosity of the sand and upon the position of the saline deposits and the faults. Where faults and salt plugs are absent the isosalinity lines follow approximately the regional structural lines, since the Woodbine is in general uniform in texture and porosity.

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[44]Line of equal concentration of sodium chloride.

TOTAL MINERAL SOLIDS

The total mineral solids in the Woodbine waters range from 184,000 milligrams per liter to less than 1,000 milligrams per liter. The concentration in general increases with depth, but is governed to a considerable extent by the freedom of circulation, which in turn is controlled by local and regional structure. As the distribution of chloride is also affected by this same condition, marked variation in the total concentration of the deeper waters is usually associated with variation in the proportion of chloride. Thus the waters in the fresh-water area, where the chloride content is lowest, contain an average of about 1,500 milligrams per liter total mineral solids, whereas the waters of the fault fields which have between 10,000 and 30,000 milligrams per liter of chlorides contain between 17,000 and 52,000 milligrams per liter of total mineral solids.

The principal constituents (in parts per million) of Woodbine water in east Texas wells are presented in Table 7.

ALKALIES

The alkalies (sodium and potassium) are by far the most abundant bases in the Woodbine waters both in the fresh-water area and in the deeper waters. They and their equivalent acid radicals constitute over ninety per cent of the total mineral content. In the fresh-water area the alkalies are less prominent, but are more abundant than other elements. The waters associated with oil in the fault-line fields and other oil fields in the Woodbine area contain alkalies almost to the exclusion of the other bases.

ALKALINE EARTHS

In most of the waters from the fresh-water area the alkaline earths (calcium and magnesium) are present in much smaller amounts than the alkalies, though in a few areas the amounts are approximately equal. In the deeper waters the relative proportion of the alkaline earths is still lower, not only because of the high concentration of the alkalies, but also because the alkaline earths themselves are generally present in smaller amounts.

SULPHATES

In some parts of the fresh-water area sulphate is the predominating acid radical, and in general the sulphates run high in the fresh-water area. As the water becomes deeper the sulphates decrease, and in the vicinity of the oil fields the concentration of sulphate is small (figs. 5 and 6) and in some places it almost disappears. Most of the waters associated with the oil do not show even a trace of sulphates, and many of them carry less than 0.2 per cent. The decrease of sulphate in the waters near the oil reservoirs and its absence from waters most closely associated with the oil are believed by Rogers[45] to be the result of chemical reaction with constituents of the oil or gas, and by others[46] to be due to the action of bacteria that extract sulphur from sulphates.

CHLORIDES

Chloride concentration varies greatly in east Texas waters. As the chlorides of all the common bases are highly soluble in water, they are not important as rock-forming constituents and are concentrated chiefly in the ocean. A high concentration of chlorides in ground water usually indicates that the water is partly or wholly of oceanic origin or that it has been leached out of saline deposits. The chloride in the Woodbine waters south and east of the main fault line are believed to be connate or oceanic in origin, whereas the waters in the fresh-water area are meteoric waters that have migrated through the sand from the outcrop. Some of the connate waters have probably been mixed with meteoric waters carrying sulphates or carbonates. In other places the waters have dissolved soluble salts out of the rock formations. The amount of chloride is controlled largely by the amount of water circulation.

45Rogers, G. S., Chemical relations of the oil-field waters in San Joaquin Valley, California: U. S. Geol. Survey Bull. 653, p. 44, 1917.

46Bastin, E. S., The problem of natural reduction of sulphates: Am. Assoc. Pet. Geol. Bull., vol. 10, pp. 1270–1299, 1926.

Thiel, George A., Experiments bearing on the biochemical reduction of sulphate waters: Econ. Geology, vol. 25, pp. 242–250, 1930.

The slower the circulation, the more chloride the water contains. Nowhere does the water of the Woodbine sand have a chemical composition the same as that of ocean waters today. Northwest of the Mexia fault line it is less salty than ocean water. Southeast of the fault line, both at Van and in the east Texas oil field, it is much more salty. Along the Mexia-Powell line the chemical composition of the Woodbine water most closely approximates that of ocean water, as shown by the following analyses (in parts per million).

	Sea water[a]	Mexia[b]	Boggy Creek[b]	East Texas[b]
Calcium	430	648	3,260	1,176
Magnesium	1,330	109	407	197
Sodium	10,890	11,540	36,000	22,050
Bicarbonate	----------	348	266	366
Carbonate	80	----------	----------	----------
Sulphate	2,740	----------	304	384
Chloride	19,680	19,050	62,100	35,400
Total solids	35,620	31,488	102,302	60,573

[a]Grabau, A. W., Principles of Stratigraphy, p. 148, 1924.

[b]Woodbine water analyses Nos. 13, 204, and 207, Limestone, Anderson, and Rusk counties respectively, Table 7.

CARBONATES AND BICARBONATES

Few of the Woodbine water samples contain carbonates, but instead bicarbonates. Bicarbonates are quite high in the shallow fresh-water area—in some places they occur in larger amounts than the chloride and sulphates combined. As the water becomes deeper the bicarbonates decrease, as do the sulphates (figs. 5 and 6). The reason for the decrease in bicarbonates on approaching the oil fields is due to the absence of carbonate surface waters.

ABNORMAL MINERAL CONSTITUENTS OF WOODBINE WATERS

RELATIONSHIP OF SALT CONCENTRATION TO STRUCTURE

All areas of abnormal structure in northeast Texas show abnormally high concentration of salts in the underground water. Anticlinal structures show the least change, normal faults furnish higher salt concentration, and salt domes the highest of all. For example, in Fannin and Collin counties, in the area of the Preston anticline, the water contains an abnormally high amount of chlorides. The isosalinity lines on the map are deflected northward, and the area of uplift is outlined by curved lines (Pl. VIII). Farther south the concentration is normal until the fault line is reached. A few miles northwest of the Powell fault the concentration of chlorides is 2,500 parts per million. Wells along the fault line have waters with a concentration of 17,000 parts per million (see curve, fig. 4, and map, Pl. VIII). At Boggy Creek near the top of the salt dome the concentration of chlorides reaches a total concentration of 112,000 parts per million of chlorides (fig. 5).

An abnormal concentration of the chloride content in the Woodbine waters was found along all the faults, although the amount of the chlorides varied in different fault-line fields. The highest concentration was found on the Sulphur River fault in Hunt and Hopkins counties, where the waters contained over 30,000 parts per million of chlorides. The next highest concentration is at Mexia, the southwesternmost fault investigated, which has a chloride content in its waters of 18,000 parts per million. At Currie the concentration is 12,000; at Richland 9,000; and at Powell 17,000 parts per million (Pl. VIII). The results suggest that the larger the displacement of the fault the greater the chloride content. The concentration is greatest close to the fault, and decreases as the distance from the fault increases (fig. 8). In the new east Texas field the concentration of chlorides is also high, averaging 38,000 parts per million.

Abnormal concentration of the chlorides was found also in the Woodbine sand around salt domes. The water from ten wells was tested at Boggy Creek salt dome in Anderson and Cherokee counties, where the normal concentration should be about 20,000 to 30,000 parts per million. The chloride content was found to range from 57,000 in wells

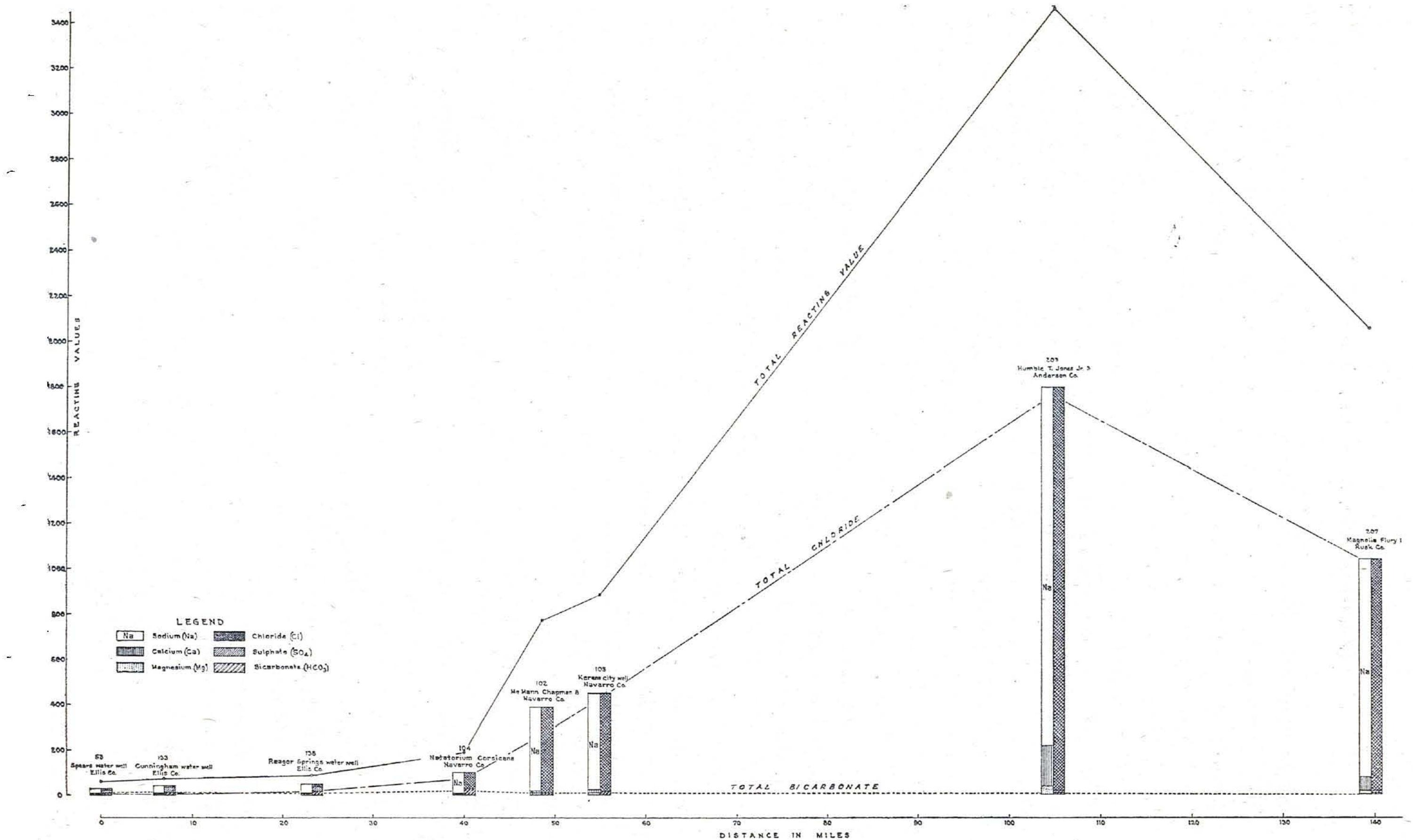

Fig. 5.—Cross-section showing reacting values of total solids, chlorides, and bicarbonates across the Woodbine sand sheet, and the graphic representation of the reacting values of these waters.

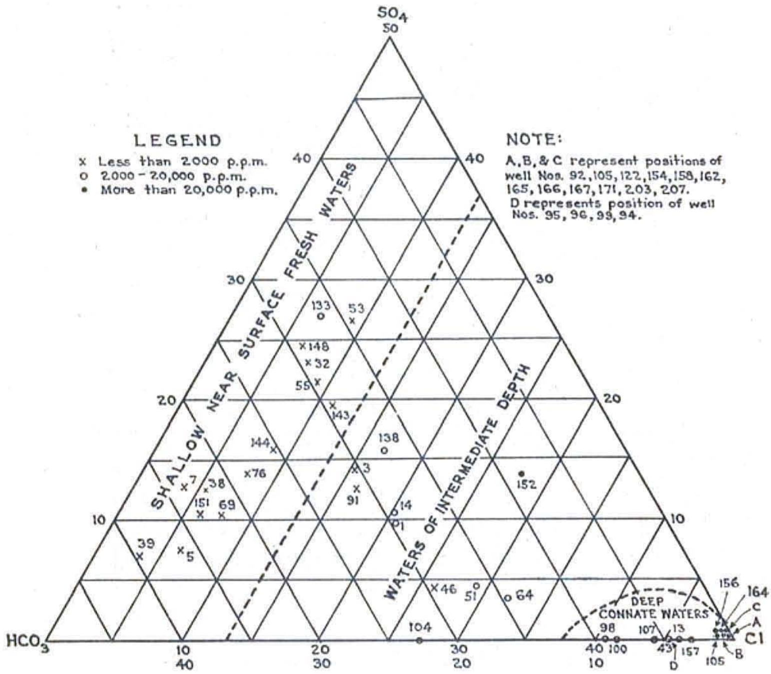

Fig. 6.—Triaxial diagram showing proportion of sulphate (SO_4), bicarbonate (HCO_3), and chloride (Cl) content of waters from fifty wells in east Texas. The figure near the symbol represents the number of the well as listed in Table 5. The proportions of each constituent are plotted in percentage reacting values and therefore aggregate 50 per cent. Wells located near the right-hand corner are consequently high in chlorides and low in both bicarbonates and sulphates. Those located near the left-hand corner are low in chlorides and high in bicarbonates. Note that the deep wells are in the "chloride area," all the shallow water wells fall in the "bicarbonate-sulphate area." A few wells of intermediate depth fall in the "mixed-water area."

farthest from the salt plug to 112,000 parts per million in wells located on the plug (fig. 7).

CAUSES OF ABNORMAL CONCENTRATION OF SALTS

The more rapid the movement of ground water, and the greater the amount of fresh water that is brought into the sand from the outcrop, the lower is the salinity. Hence any subsurface condition which changes the rate of flow influences the chemical content of the water. Other factors also

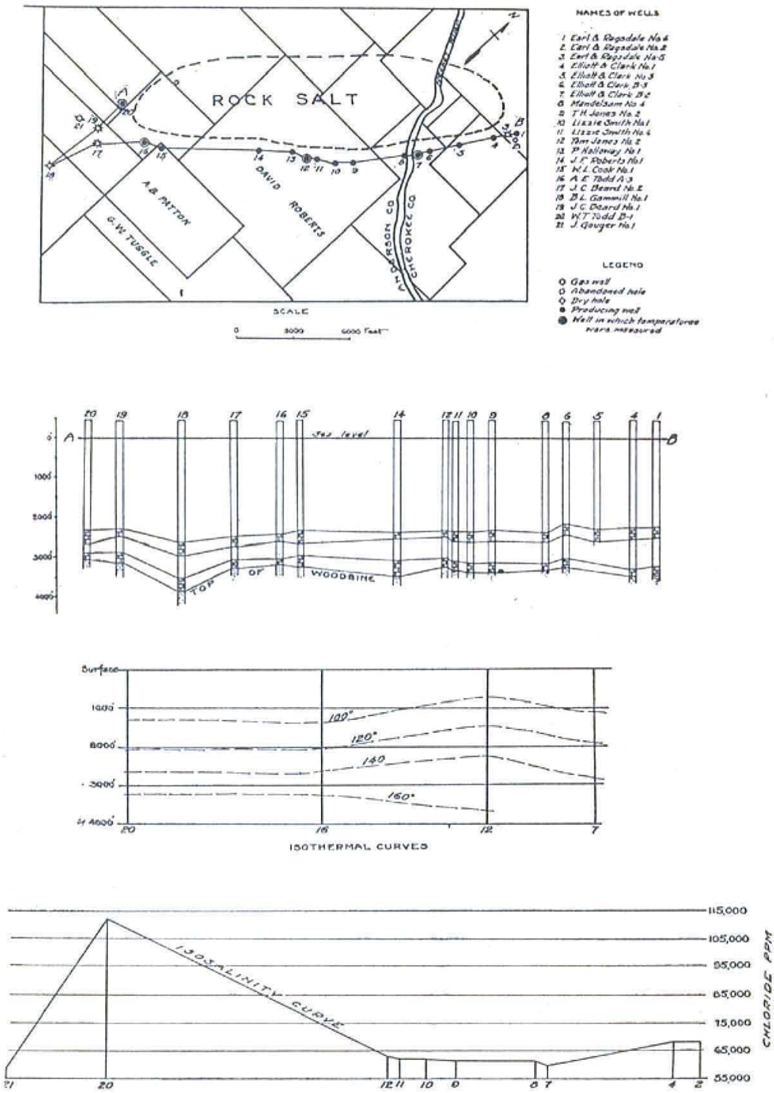

Fig. 7.—Map, cross-section, isothermal curves, and isosalinity curves of the Boggy Creek oil field, Anderson and Cherokee counties.

play a part, and the final causes of abnormal salt concentration may be summarized as follows:

1. Trapping of original sea water in pockets due to pinching out of a sand or cutting off of circulation as a result of folding or faulting.
2. Presence of a lense or plug of salt or other soluble compounds with which the water comes in contact.
3. Vertical migration of saline water upward along a fault, or open joint, or fracture line from a deeper source into a water sand of less salinity.
4. Local heating of underground waters by vulcanism or other causes, which will increase the solubility of the water and hence increase its mineral content.

The relative importance of these factors in increasing the saline content of Woodbine water is discussed briefly below.

1. *Trapping of sea water in underground strata.*—Salt water that is trapped by faults will remain as salt water, although the other parts of the sand sheet around about are flushed out and replaced by fresh water. Trapped fresh water or brackish water may dissolve soluble mineral matter from the sand with which it stands in contact, and the water may have a higher concentration than the moving waters in the same sand layers.

2. *Presence of salt in the strata.*—A salt plug or lens of salt in contact with water will dissolve and increase the concentration of the water. The strata above some salt plugs are cut by crevices through which the water flows and circulates upward into the water sands, increasing the salt content of the water.

3. *Vertical migration of saline waters upward along a fault.*—The migration from a deeper source may explain the higher concentration of salts in the Woodbine waters along the faults. Many of the faults are normal gravity faults, and along these planes of slipping openings or crevices may have furnished upward passages for deeper and more mineralized waters. Deep waters in east Texas have a higher salt content than shallow waters. The addition of deeper water to the Woodbine sand will increase its salinity. The evidence of such upward water movement is seen in veins of aragonite, calcite, and limonite, which occur in the fault zone. Obviously these minerals were deposited

by ascending mineralized waters. Also the fact that the water close to the fault is more saline and shows greater concentration of total solids than water at some distance away suggests that infiltration of deeper and more saline water has taken place (fig. 8).

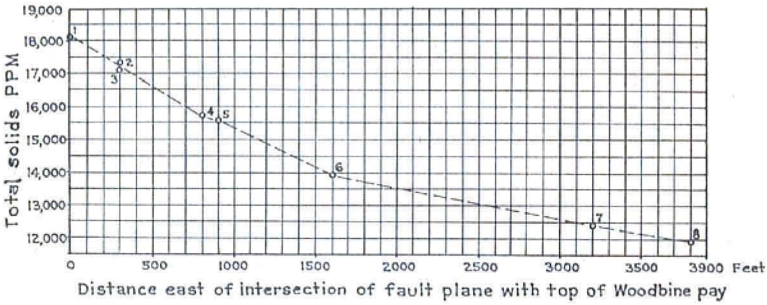

Fig. 8.—Curve showing the increase in the concentration of total solids toward the fault, Powell oil field, Navarro County. (After Hill and Sutton, U. S. Bur. Mines Bull. 284, fig. 14.)

1. Smith-Cerf No. 5, depth 2990′, Oct. 2, 1924
2. Pure Oil Co.,-J. O. Burke No. 1, depth 2963′, May 11, 1926
3. Pure-J. O. Burke No. 1, depth 2963′, May 2, 1924
4. Sun-Kent No. 3, depth 2867′, May 17, 1924
5. Hughes-McKie No. 1, depth 2869′, Aug. 1924
6. Hughes-McKie No. 9, depth 2873′, April 29, 1924
7. U. S. Texas-Ramsey No. 1, depth 2953′, April 2, 1924
8. Tidal-Thompson No. 2, depth 2991′, April 23, 1924

4. *Heating of underground water.*—The heating of underground water by deeply buried igneous material beneath fault zones and buried structures may influence the concentration of mineral matter in water. Heat from cooling igneous rocks warms the water. The warmer the water, the greater the solubility, and hence the larger amount of mineral matter dissolved and held in solution. There is no evidence, however, that cooling igneous rocks exist, or have existed beneath the faulted areas. Heating due to any other cause will have the same effect however, so that slightly higher concentration of mineral matter may be a good indication of local higher underground temperatures.

MOVEMENT OF UNDERGROUND WATERS

In general, the water contained in porous soils and rocks is not stationary but possesses an exceedingly slow, although perfectly definite, flow. The cause of the flow of water through a porous medium is the same as the cause of the water movement through pipes, that is, a difference of pressure from point to point. The difference in pressure in ground water is due generally to gravity. The rate of movement of water depends upon several controlling factors:

1. Size of the pore space in the water-bearing sand. The capacity to transmit water is enormously greater for large pores than for small.
2. Arrangement and uniformity of the sand grains. The presence of fine grains in the large openings retards water movement.
3. Hydrostatic pressure.
4. Temperature of water.

The Woodbine water from calculations made by Slichter's[47] method has a velocity of approximately 0.2 of a mile per year at the outcrop. Down dip from the outcrop the movement is slower. Somewhere between the outcrop and the middle of the basin, the movement is reduced nearly to zero.

The freedom of inlet and outlet of the water between the sand and the surrounding strata is an important factor in the rate of movement of underground water. It is evident that the water will not circulate in a bed unless the liquid entering at the outcrop can escape at the lower end of the lens, either into another lens or through some outlet. If the upper end is open and the lower end sealed, water will accumulate only up to the absorptive capacity of the sand; and if the hydrostatic head of the water thus trapped is not great enough to force an outlet, movement will cease until the pocket is opened. The structure of the rocks may exercise a similar effect in preventing circulation in any part of a sand sheet. Water may be trapped where

[47]Slichter, C. S., The motions of underground waters: U. S. Geol. Survey Water-Supply Paper 67, p. 24, 1902.

the abnormal structure is so shaped that it prevents water migration.

The isosalinity lines in east Texas, except where abnormal structure occurs, run in a line nearly parallel to the outcrop, except in the eastern part of the province where the lines bend slightly basinward. These lines show that the basinward movement of the Woodbine water is fairly uniform. This is because the sand is of even texture, and no "by-passing" occurs. Interesting experiments have been carried out on the movement of water through coarse sand[48] in a large cement trough between impervious layers of cement. The water was allowed to enter slowly along the up-dip side of the sand sheet and flow out through a few tubes penetrating the down-dip side. The downward movement, indicated by a red dye in the water, is not uniform. The liquid travels in little channels through lines of least resistance to the openings. "By-passing" of large areas in the water sand is the rule. In the underground waters in the Lower Cretaceous limestone in south-central Texas the salinity lines (as indicated by a small number of analyses only) are much more irregular than those in the Woodbine. The Lower Cretaceous water in south-central Texas is drained out by numerous large springs situated along the Balcones fault. Doubtless these springs are fed by underground lines of flow and that portions of the underground passageways in the limestone are flushed out much more than other areas.

There appear to be two types of underground-water migration: (1) a channel-like movement in which the water passes through lines of least resistance and by-passes less porous or less open areas; (2) a slow, even, downward seepage characterized by little by-passing. The Woodbine water movement appears to be of the latter type. No conspicuous springs occur along the faults that cut the Woodbine. The upward or outward escape of water in the lower part of the Woodbine basin is very slow, through almost

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[48]The sand grains averaged 1.981 mm. (0.078 in.) in diameter, and the porosity was about 40 per cent (Department of Petroleum Engineering, The University of Texas).

capillary spaces. The downward movement may be due in part to a settling or a sinking of the basin due to compacting of clay, so that the salt-water table is lowered slowly and meteoric water from above follows it slowly downward without mingling with it to any great extent along the plane of meteoric-connate-water contact. The plane of contact of the meteoric and connate waters in the Woodbine sand is much sharper and conforms much more nearly to the regional structure lines in east Texas than does the plane of contact in the Edwards limestone in south-central Texas.

INFLUENCE OF THE MOVEMENT OF UNDERGROUND WATERS ON THE POSITION OF OIL POOLS IN EAST TEXAS

The exact process of the genesis of crude oil out of the sediments and the mechanics of the migration and of the accumulation of petroleum into pools are still unsolved problems of petroleum geology. The result of the study of the composition of underground waters and of geothermal gradients in east Texas contributes little new data toward their solution. The relationship of the positions of oil pools to isosalinity lines, to geothermal lines, and to Woodbine shorelines, as worked out in connection with these chemical and thermal studies suggests a possible explanation for the spacing of the pools in the east Texas area.

The positions of the oil pools in east Texas, the edges of the Woodbine sand, the meteoric-connate water contact, and the 19,000-parts-per-million isochloride line are all shown on the diagram, figure 1. The best production of oil is along the west and east edge of the connate-water area, north of the 19,000-parts-per-million isochloride line (fig. 1, line A-A′). No oil pools occur along the south edge of the Woodbine sand sheet, and no oil pools have been found in the fresh-water area, though well-shaped structures capable of trapping oil are well known[49] north of the producing area. The largest oil pool in Texas lies along the

[49]For example, the large closed structure near Campbell and Commerce in Hunt and Hopkins counties; see map, Pl. I.

east border of the Woodbine sand sheet and plays out northward before the meteoric-connate plane of contact is reached (fig. 1). The locations of the oil pools in east Texas are controlled as much by the location of the connate-water belt as they are by the strike of the regional structure. Where the connate-water belt ends the line of oil pools discontinues. For example, the trend of the oil pools from Mexia to Powell is northeastward. North of Powell the faults favorable for oil pools are known, yet no production occurs. The next oil pool east of Powell is the Van pool. Van is located well within the connate-water belt (map, Pl. I, and block diagram, fig. 1).

The explanation of the occurrence of the oil pools in the central and eastern portion of the connate water belt more than in other parts of the sand sheet is an interesting problem. The accumulation of oil in a pool depends upon a number of factors, amongst which are the following:

1. Effectiveness of the structure to trap oil.
2. Porosity of the strata adjacent to, or in contact with, the source bed, thus enabling the oil to migrate from the source bed into the trap.
3. Efficiency of the propelling forces that move the oil into pools.
4. Amount, extent, and distribution of the source material from which the oil is derived.
5. Extent to which oil has been generated out of the source bed.

The Woodbine sand is porous and holds water throughout its extent, and it serves all the structures within its province more or less alike. The dark organic matter in the shales adjacent to the sand from which oil can be generated by heat or other processes extends throughout the province. A little less sand is found in the south edge of the province, where the Eagle Ford, Woodbine, and Del Rio formations are thin, and also somewhat less in the north edge along the belt characterized by the sandy and red-bed facies of the Woodbine sand along the old shorelines. An inspection of the organic material in the strata adjacent to the Woodbine sand from a large number of well samples indicates that the distribution of organic particles is widespread. Eagle Ford shales and certain clay lentils in the Woodbine formation contain organic detritus. The organic material is found abundant not only in certain spots close to the oil pools but distributed throughout the province. The organic content of the strata is much too widespread and the sediments too uniform to allow the conclusion that oil occurs only where source material is rich or that certain structures are barren because no adjacent source material is available. Traces of plant and animal remains and slight traces of oil are found in every well section. Deep-seated diastrophic forces, such as have produced salt plugs, domes, and reverse faults, are pointed out by some geologists[50] as evidence that petroleum occurs where pressure and heat are sufficient to generate oil, and that unless such heat and pressure occur oil will not form out of the source beds. In east Texas spots indicative of compressional earth movements are not confined to the vicinity of the oil pools. In fact, little evidence of diastrophism is found in the extensive Henderson-Kilgore producing area, and much evidence is found in Anderson County, where much less oil is produced. Diastrophism seems inadequate to explain why oil is generated in greater abundance in the eastern part of the sand sheet than in any other part. In seeking an explanation for the positions of the pools it seems necessary to consider, therefore, other agents, especially those that have to do with the migration of oil.

The propelling force that moves the oil seems to be the dominant factor in the distribution of pools in east Texas. Oil moves into wells and is propelled through pipes by two propelling forces, gas pressure and hydrostatic pressure. These two propellants are called upon by many geologists[51]

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[50]Daly, M. R., The diastrophic theory: Am. Inst. Min. Eng. Bull., pp. 1137–1151, 2205–2211, 1916; Am. Inst. Min. Eng. Trans. vol. 56, pp. 733–753, 1914.

[51]Munn, M. J., The anticlinal and hydraulic theories of oil and gas accumulation: Econ. Geol., vol. 4, pp. 509–529, 1909. Studies in the application of the anticlinal theory of oil and gas accumulation: Econ. Geol., vol. 4, pp. 141–157, 1909.

Rich, J. M., Moving underground water as a primary cause of the migration and accumulation of oil and gas: Econ. Geol., vol. 16, pp. 347–371, 1921.

Ziegler, Victor, The movement of oil and gas through rocks: Econ. Geol. vol. 13, pp. 335–348, 550–551, 1918.

to explain the migration of oil into pools. Another force, capillary action, is added as a cause of oil movement by a few investigators.[52] Of these three propellant forces capillary pressure is effective only over short distances, differential gas pressure over moderate distances, and hydrostatic pressure over long distances. The resistance of small spaces to fluid movement is so great that when a high-pressure well is opened wide, oil will not move to it from a distance of much over 600 feet.[53] Oil will move, however, in a series of short stages propelled by a series of differential pressures, in which the pressure is great enough at each stage to overcome the resistance of the sand pores to fluid movement. The differential pressures that exist in a sand layer between the crest of an anticline and the adjacent syncline is great enough to move oil from the surrounding drainage area up into the anticline. In other words, differential pressure may explain oil movement over moderate distances and be efficacious in transporting it into abnormal structures. Differential pressures do not explain, however, the concentration of oil in only a few small areas throughout a large sand sheet that extends over hundreds of square miles.

Water moves down dip by gravity long distances through a porous sand. In east Texas fresh water has moved downward for a distance of at least forty miles. The water carries with it all substances in solution or suspension fine enough to pass through the sand pores. All larger particles

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Parks, E. M., Migration of oil and water, a further discussion: Am. Assoc. Pet. Geol. Bull., vol. 8, pp. 697–715, 1924.

Russell, W. L., Some experiments on capillarity and oil migration: Econ. Geol., vol. 19, pp. 35–61, 1924.

Thiel, George A., Gas, an important factor in oil occurrence: Eng. and Min. Jour., vol. 109, p. 888, 1920.

[52]McCoy, A. W., Some effects of capillarity on migration: Jour. Geol., vol. 24, pp. 788–805, 1916. On the migration of petroleum through sedimentary rocks: Am. Assoc. Pet. Geol. Bull., vol. 2, pp. 168–171, 1917.

Cook, C. W., Study of capillary relationships of oil and water: Econ. Geol. vol. 18, pp. 167–172, 1923.

[53]Uren, L. C., An experimental study of the pressure gradient within the oil sand about a high pressure producing well: manuscript presented at fall meeting of Am. Inst. Min. & Met. Eng., Pet. Div., Houston, Oct. 2, 1931.

not in solution are filtered out and left behind. Oil in suspension has less surface tension than water and does not dissolve in it. If the oil droplets are larger than the spaces between the sand grains, the water will move into the capillary spaces more easily than oil and leave the oil behind. If oil is already in the spaces, water will displace the oil. If oil is present in considerable mass and the sand is fine and the hydraulic pressure is sufficient, the water will drive the oil down dip. There will always be the tendency for the water to move faster through the more porous channels and pass ahead of the oil. In experiments with many water drives in the laboratory, water has been found inadequate to propel oil in large quantities. In moderately coarse sand water by-passes much of the oil. If the oil particles are fine and dispersed, so small that they can be seen only with the aid of a high-power microscope, they exist in a permanent emulsified or colloidal state. If they are smaller than the passageways between the sand grains, they will travel with the water as if in solution. If oil in the buried sediments is produced by minute bacteria or by heat with pressure from very minute organic cells, it is conceivable that much of it travels downward in the colloidal state in minute suspension in the water, and thus it may move long distances, as far as the water moves. As soon as it reaches sufficient depth, or areas where temperature and pressure are sufficient, the minute hydrocarbon particle will "crack" into lighter hydrocarbon molecules that are partly gaseous and partly liquid. The newly formed gas bubbles are much more mobile than the original droplets of oil, and the newly formed light oil droplets are less viscous and merge readily to become drops that are moved upward by the propelling force of gas toward areas of less pressure into the tops of nearby domes and against fault planes. A gas drive, both in laboratory experiments and in the field, is an adequate motive force, as proved by the successful results of repressuring methods in producing oil fields.

Oil accumulation accordingly takes place in three stages:

1. Slow downward percolation of very minute particles of complex young hydrocarbons of large molecular weight.
2. "Cracking" of the minute hydrocarbon particles at depth and the resultant formation of lighter hydrocarbons consisting of gases and lighter oils.
3. Upward movement of the light oil droplets into structural traps under the propellant force of the gas bubbles.

The upward movement takes place wherever differential pressures are sufficient to overcome the resistance of the capillary spaces to movement of the gas bubbles. The "cracking" of the oil droplets to form gas takes place only in the deeper and warmer parts of the sand sheet in the belt of connate waters below the meteoric-connate contact. Since the water moves faster or farther through the coarse sand than through the finer, larger quantities of colloidal oil will be swept into the deeper portion of the basin fed by coarse-sand channels.

In east Texas the Woodbine sand is thickest, hydrostatic pressures are greatest, and temperatures in the sand are highest in the middle of the Van Zandt County trough. Liquids actuated by gravity move into this trough from the north, northwest, and northeast and percolate downward. In its lower levels the oil particles are "cracked," and the gas moves upward in the direction of least differential pressure and accumulates in the first trap encountered. If no trap lies in its path and gas pressure is sufficient, it will continue to the edge of the sand sheet, where the Henderson-Kilgore pool is located, and if the edge of the porous sand is not gas tight, some of the gas will move upward along the unconformity to the Bethany and Waskom (Louisiana) gas fields. Lesser quantities move upward to the west side of the trough and accumulate in the Van dome and along the Mexia-Powell faults and in yet undiscovered structures wherever spots of low pressure are set up by lines of structural weakness, such as faults.

The action may be likened to soda water under pressure in the familiar metal-capped bottle. If a small hole is punched in the cap, the gas rushes to the opening, carrying with it water which it sprays until the pressure inside the bottle is reduced to atmospheric pressure. If a tiny crack is formed in the glass before the pressure is relieved, gas and water will seep out of the crack and the hole at the same time. If the bottle contains oil, gas, and water, the gas and some of the water will escape, and oil will accumulate along the crack.[54]

The gas in the Woodbine sand in the lower part of the east Texas geosyncline is under pressure, and is sealed above and at its south end by Eagle Ford shales and dense marls, and at its north and west ends by the hydrostatic head of several thousand feet of water. Through the long periods of geologic time, it moves to low-pressure spots, just as gas in the bottle moves to the crack. The low-pressure spots in east Texas are: (a) high points along the east edge of the Woodbine sand on the flank of the Sabine uplift where the sand is not effectively sealed but thins out into an unconformity marked by a more or less porous old erosion surface; (b) faulted anticlines and other favorable abnormal structures near the gas supply.

LOCATION OF FAULTS AND SALT DOMES BY MEANS OF WATER ANALYSES

Chemical analyses of waters have been found helpful in locating faults and salt domes in deep soil or alluvium-covered area underlain at shallow depth by water sands. Certain areas in Kaufman, Hunt, and Hopkins counties are underlain at shallow depth by the Nacatoch sand—a persistent sand which furnishes water to many farms and towns. Geologists have found it difficult to map the structure of some parts of this area in detail because of lack of outcrops and absence of deep well records. A water-analysis survey, if systematically carried out and properly interpreted, will help to locate fault lines and to point out especially favorable areas for core drilling or seismographic investigation. Surveys made by Rycade Oil Company,

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54Mills, R. Van A., Natural gas as a factor in oil migration and accumulation in the vicinity of faults: Am. Assoc. Pet. Geol. Bull., vol. 7, p. 16, 1923 directed by D. C. Barton, and by Gulf Production Company,[55] and the detailed work of the American Petroleum Institute in east Texas have shown conclusively that the saline content and total solids of well waters close to faults and over salt domes is markedly higher than in areas of normal structure. Sampling and analyzing of all the well waters over favorable territory will show spots of abnormal salinity. If such areas are more or less elongate in the direction of strike of the known faults, and if the waters also have abnormally high total solids, a fault is indicated. If the area is small, the saline content especially high, and if some of the waters contain hydrogen sulphide which does not have its source in shallow organic debris, a salt dome is indicated.

The investigation is carried out in the field as follows: The exact locations of the water wells are plotted on a good base map of the area. The depth of the water well, its sand record, and casing record, if known, are carefully recorded, and one quart of the water is collected in a clean, well stoppered bottle. A good worker will collect twenty to thirty bottles of water a day and make a complete record of the location and depth of each sample on a map and in a notebook. The samples are taken to the nearest town and tested for chlorides, total solids, and total hardness with a simple portable field chemical outfit. The chlorides are determined by titrating with 0.1 normal silver nitrate according to the method given elsewhere in this bulletin. The total solids are calculated from the specific gravity or determined by evaporating 100 cc. of the sample to dryness on a small gas or electric water bath. Evaporation to dryness of a large number of water samples and weighing of the residues is a rather long and tedious process. Consequently chemists have suggested short methods for determining the relative amounts of total solids. Reistle and Lane[56] have found that the amount of total solids can be calculated

[55]Minor, H. E., Chemical relation of salt dome waters: Am. Assoc. Pet. Geol. Bull., vol. 9, pp. 38–41, 1925.

[56]Reistle, C. E., Jr., and Lane, E. C., A system of analysis for oil-field waters: U. S. Bur. Mines Tech. Paper 432, pp. 3–4, 1928.

accurately from the specific gravity of the water at room temperature made with either a Westphal balance or hydrometer. The following table will give the approximate relation between the specific gravity and total solids:

TABLE 4.—*Relationship between specific gravity of water and total solids.*

Specific gravity of sample at 15.6 C (60 F.)	Total solids *Parts per million*
1.020	27,500
1.030	41,400
1.040	55,400
1.050	69,400
1.060	83,700
1.070	98,400
1.080	113,200
1.090	128,300
1.100	143,500
1.110	159,500
1.120	175,800
1.130	192,400
1.140	210,000

If the specific gravity is below 1.025, it is necessary to determine the amount of solids by evaporation or to use the conductivity method.

Keyes[57] experimented successfully with a method of distinguishing differences in total solids of waters by electrical resistance or conductivity. Pure water is a poor conductor of electricity, whereas solutions of most inorganic salts in waters are good conductors. As the concentration of salt increases, the resistance decreases, so that the concentration of the solution is measured by its resistance. Disturbing factors in this method are changes in temperature and presence or carbon dioxide gas, which will affect the resistance. Also, the equipment is fairly complicated, and the time required is longer than the specific gravity method. Finally, the total hardness can be determined by the rapid soap-solution method, described elsewhere in this

[57]Keyes, R. L., An electrical apparatus for locating the source of water in oil wells: Summary of Operations California Oil Fields, vol. 10, No. 12, pp. 5–18, 1925.

bulletin. Since total hardness is a measure of the relative amounts of dissolved sulphates and bicarbonates in certain areas, especially where chlorides are low, determination of total hardness can be substituted for total solids.

It has been found unnecessary to calculate the percentage composition and chlorides and total solids or to compute the total hardness in terms of calcium carbonate in order to outline abnormal structural areas on a map. Each result is reported directly in milliliters and compared with distilled water or rain water and the result plotted on the base map by using an appropriate color for each class of water. The following example will make the procedure clear:

RECORD OF ANALYSIS

Water Samples	Silver Nitrate *Milliliters*	Total Solids *Grams*	Soap Solution *Milliliters*
Distilled Water	0.0	0.0	1.0
Well No. 1	0.5	1.0	2.0
Well No. 2	5.0	3.0	10.0
Well No. 3	10.0	6.0	20.0
Well No. 4	1.0	2.0	3.0
Well No. 5	6.0	2.8	10.0
Well No. 6	10.0	5.5	19.0
Well No. 7	8.0	1.2	2.0

CLASSIFICATION OF WATERS

Class	Chlorides	Total Solids	Hardness	Color
1	0– 5 ml.	0.5	0– 5	White
2	5–10	0.5–1.0	5–10	Blue
3	10–15	1.0–2.0	10–15	Green
4	15–20	2.0–3.0	15–20	Yellow
5	20–25	3.0–5.0	20–25	Red

A circle is drawn around each well on the map and divided into four quadrants. The northwest quadrant is used to indicate the amount of "hardness," the northeast quadrant to indicate the amount of total solids, and the southeast quadrant to indicate the amount of chlorides. Thus, if the water contains enough chloride to require from 5 to 10 milliliters of silver nitrate solution in the titration, the water belongs to class 2, and the southeast quadrant of the circle inclosing the well is colored blue. If the residue from total solids weighs .7 of a gram, the northeast quadrant is also colored blue. The amount of soap solution required is indicated on the map by placing the proper color in the northwest quadrant. In this way all the well locations on the field maps are colored with the colors to indicate the class of water found in each well. A survey of a

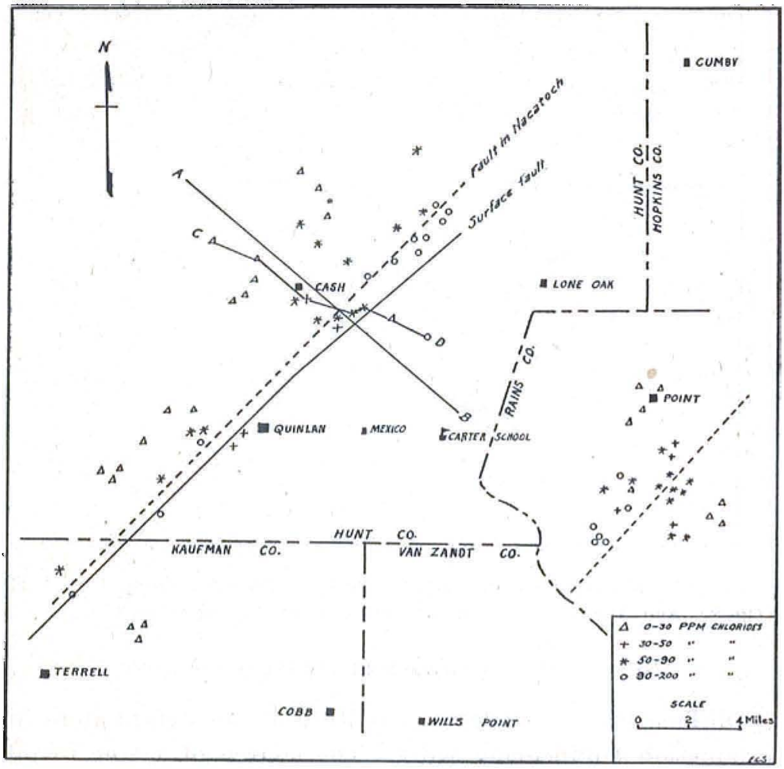

Fig. 9.—Map of Quinlan area showing chloride concentration in shallow-water wells.

series of wells along the Quinlan fault in Hunt County plotted according to this method is shown in figure 9. In this survey the analyses have been made in a little more detail and reported in parts per million and a different set of symbols are used, but the results are the same. Note that the wells close to the fault are high in chlorides. The wells on normal structure close to outcrop are low in chlorides and total solids (geologic section and curve, fig. 10).

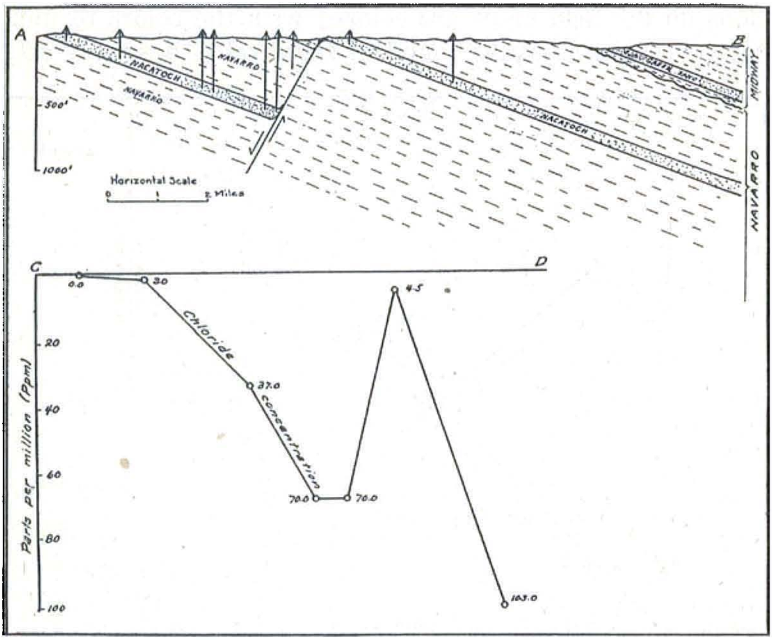

Fig. 10.—Geologic section across the Quinlan area along line A-B (fig. 9) and the chloride-concentration curve along line C-D.

USE OF WATER ANALYSES IN ENGINEERING WORK

Oil-field water problems constitute an important item in production engineering work. The source of water in oil wells, the rate of encroachment of edge water, the position of bottom water levels, the method of prevention of emulsification of water and oil, and the prevention of corrosion of casing by mineral waters are all every-day oil field problems, the solution of which often depends on a knowledge of the chemical composition of the underground waters. Ambrose,[58] Rogers,[59] Collom,[60] Nolan,[61] Ross and Swedenborg,[62] Reistle,[63] Parks,[64] Grizzle,[65] and others have shown that waters from different levels in oil wells located in Tertiary and Cretaceous oil fields have characteristic chemical analyses, which can be used in identifying unknown water infiltrating into a casing. The method of identifying underground waters consists of calculating from the chemical analysis of the water the reaction capacities of all the radicals found in the water solution by Palmer's[66] method, and then expressing the reacting values in percentages. The percentages of the reacting values are known as the "character formula." Waters from different horizons have characteristic character formulas which may be used to identify the water. These formulas may be expressed in figures or graphically by Tickell's[67] or Reistle's methods. The reacting values and reacting percentages of two hundred and seven underground water samples are included in this report. From these the character formula of the Woodbine waters in any part of the east Texas province can be calculated by the method given on a previous page. Typical graphic charts of the character formulae of the Trinity, Woodbine, Nacatoch, and shallow surface waters of east Texas are prepared

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[58] Ambrose, A. W., Water problems; U. S. Bur. Mines Bull. 195, Pet. Tech. 62, pp. 68–159, 1921.

[59] Rogers, G. S., The interpretation of water analyses by the geologist: Econ. Geol., vol. 12, pp. 56–88, 1917.

[60] Collom, R. E., Prospecting and testing for oil and gas: U. S. Bur. Mines Bull. 201, p. 143, 1922.

[61] Nolan, E. D., Water analyses and their use in the development of the Coalinga field: Unpublished manuscript, 1919.

[62] Ross, J. S., and Swedenborg, E. A., Analyses of waters of the Salt Creek field applied to underground problems: Am. Inst. Min. Eng. Trans., Pet. Div., pp. 207–220, 1929.

[63] Reistle, C. E., Jr., Identification of oil field waters by chemical analysis: U. S. Bur. Mines, Tech. Paper 404, pp. 1–25, 1927.

[64] Parks, E. M., Water analyses in oil production and some analyses from Poison Spider, Wyoming: Am. Assoc. Pet. Geol. Bull., vol. 9, pp. 927–946, 1925.

[65] Grizzle, M. A., Geochemical relationship of waters encountered in the Huntington Beach field: Summary of Operations California Oil Fields, vol. 9, No. 6, pp. 17–28, 1923.

[66] Ambrose, A. W., Water problems: U. S. Bur. Mines, Bull. 195, Pet. Tech. 62, p. 92, 1921.

[67] Tickell, F. G., A method for the graphical interpretation of water analyses: Summary of Operations California Oil Fields, vol. 6, No. 9, pp. 5–12, 1921.

easily and used in identifying unknown waters found in wells. The surface waters contain no chloride, but an abundance of bicarbonate, and some sulphate. The Nacatoch water contains a little chloride, some sulphate, and some bicarbonate. The Woodbine sand contains more chloride, a little bicarbonate and sulphates, and more total solids than the other two. The water from the chalk, if present, is high in bicarbonate, sulphate, and sulphide, and in addition has some chloride. Waters of the Glenrose sands beneath the oil-field areas in Texas have not been available for comparison, but they are known to have higher total solids and greater concentration of chloride where penetrated along the Mexia-Powell fault line. Samples of Trinity water obtained from water wells in Louisiana have been analyzed. They contain more chloride and more total solids than the Woodbine. Thus, it is generally not difficult to distinguish the various east Texas water sands if the chemical analyses are known.

PREVIOUS WORK ON SUBSURFACE TEMPERATURE MEASUREMENTS

Measurements of temperature have interested physicists and geologists for a long time. Geothermal data were mentioned in literature as early as 1664 by Kircher. Observations on temperature were made by Gensonne in mines in Alsace in 1746. Gensonne used rough instruments and the work was crude, yet it constituted a good beginning and aroused enough interest so that temperature measurements were continued with increasing accuracy. Precise systematic methods and the compilation and interpretation of geothermal data are comparatively recent accomplishments. Daubrée[68] measured the temperature in a hole seventy meters deep in the Pechelbronn oil region in 1852 and calculated the geothermic gradient to be 1° C. increase in 20 meters of depth, and in two other deeper oil wells he found the gradient to be 1° C. in 12.7 meters and 1° C. in 12.2 meters respectively. As far as known, these were the first temperature measurements made in an oil field. In 1858 the British Association for the Advancement of Science[69] appointed a committee to compile data on underground temperatures which were published in the reports of the society. With the exception of the records of Daubrée and the reports of the British Association, nearly all of the published records have appeared within the past fifty years. In 1889, Dunker[70] measured the temperature to a depth of 5630 feet in a well at Schladebach near Leipzig, Germany, and found a temperature increase of 1° F. with 67.1 feet of depth. This result stimulated members of the British Association for the Advancement of Science to make another compilation of earth temperature measurements,[71] which were published in 1892. Their records

[68]Daubrée, A., Descrip. géol. du Bas-Rhin, p. 360, 1852.

[69]Everett, J. D., Underground temperatures: Repts. of the Meeting of the British Assoc. for the Adv. of Sci., London, pp. 245–248, 1859.

[70]Dunker, E., Ueber die Temperature-Beobachtungen im Bohrloche zu Schladebach: Neues Jahrb. f. Min. etc., vol. 1, pp. 29–47, 1889.

[71]Everett, J. D., Report on underground temperature: Repts. of the Meeting of the British Assoc. for the Adv. of Sci., pp. 129–131, 1892.

showed that the temperature increases with depth ranged from 1° F. in less than 20 feet to 1° F. in 130 feet with an average of 1° in 50 to 60 feet. The first accurate measurements of temperatures in deep wells in America were made in the Ohio Valley near Wheeling, West Virginia, by W. Hallock[72] in 1897. The increase of temperature was 1° F. in 76 feet, taking the mean annual temperature at 51.3°. In another well drilled near West Elizabeth, Hallock found a temperature of 127° F. at 5380 feet, or an increase of 1° in 70 feet of depth. In 1904, T. C. Chamberlin[73] compiled a record of temperature measurements in deep borings, and found an average increase of 1° F. in 77 feet, taking the temperature of no variation at 50 feet below the surface at 40° F. His figures are as follows:

Well	Depth *Feet*	Rate of Temperature Increase
Sperenberg well, Germany	3492	1° in 51.5 feet
Schladebach well, Germany	5630	67.1
Cremorne well, N. S. Wales	2929	80.0
Paruschowitz well, Silesia	6408	62.2
Wheeling well, W. Virginia	4462	74.1
St. Gothard tunnel, Italy	5578	82.0
Mt. Cenis tunnel, France	5280	79.0
Tamarack mine, Michigan	4450	100.0
Calumet and Hecla mine, Michigan	4939	103.0

Chamberlin concluded that temperature gradients in the earth's crust varied greatly, that some of the differences could be explained on the basis of differences in conductivity of the rock, movement of underground water, degree of compression of the rock, and other factors, but that "the meaning of other temperature variations is yet to be found." Königsberger and Mühlberg[74] in 1910 suggested first the application of geothermal data to the location of oil pools. These workers established the fact, which was

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72Hallock, W., Subterranean temperatures at Wheeling, West Virginia and Pittsburgh, Pennsylvania: School of Mines Quarterly, vol. 18, pp. 148–154, Jan. 1897.

73Chamberlin, T. C., and Salisbury, R. D., Geology: vol. 1, p. 569, 1905.

74Königsberger, J., and Mühlberg, Max, Uber Messungen der Geothermischen Tiefenstufe, deren Technik und Verwertung zur geologischen Prognose und über Messungen in Mexico, Borneo, und Mitteleuropa: Neues Jahrb. f. Min. etc., vol. 31, pp. 107–157, 1911.

further demonstrated in 1911 by Hans von Höfer,[75] that oil regions have abnormally small temperature gradients, and that these gradients are higher than in adjacent areas of the same or similar structure where oil is absent. Königsberger and Mühlberg found that the temperature gradient in the Alsace oil fields is approximately 1° in twelve meters (1° in 39.3 feet). These workers as well as von Höfer suggested the possibility of using temperature data in prospecting for oil.

Recent investigators have developed greatly the precision and accuracy of the methods of making measurements. Johnson and Adams[76] in 1916 developed a technique of measuring temperatures in wells with mercury and electrical resistance thermometers and recommended electrical resistance thermometers in place of mercury thermometers on account of their greater accuracy. Van Orstrand[77] devised instruments and developed methods of technique for measuring temperatures in deep oil wells by means of maximum thermometers. His method is now generally used for temperature measurements in oil wells in America, and much credit is due Van Orstrand for his thorough, painstaking work. H. K. Arctowski[78] during 1926 and 1927 made about 1300 temperature measurements in about fifty wells in the Boryslaw oil district, Roumania. The subsurface structure is that of a syncline cut by faults to form a down-faulted block or graben. The wells near the center of the syncline have the largest temperature gradients. The water sands, the oil sands, and rocks of different heat conductivity show slight effect in the temperature measurements.

75Von Höfer, Hans, Temperature in oil regions: Econ. Geol., vol. 7, pp. 536–541, 1912.

76Johnson, J., and Adams, L. H., On the measurement of temperature in boreholes: Econ. Geol., vol. 11, pp. 741–762, 1916.

77Van Orstrand, C. E., Apparatus for the measurement of temperature in deep wells and temperature determinations in some deep wells in Pennsylvania and West Virginia: W. Va. Geol. Survey, Ann. Rept., Introduction pp. lxvi–ciii, 1918.

78Arctowski, H. K., Researches sur les relations geothermique de la region de Boryslaw: Intern. Geol. Congress, 14th Session, Spain Compt. Rend. 1926, vol. 4, pp. 1699–1706, 1928.

R. Hermann[79] the same year measured temperature gradients in the oil district near Hannover, Germany. He found the thermal gradient to be 1° in 16 to 18 meters (52 to 59 feet). At Oberg they were 1° in 26 meters (85 feet), and near Hamburg 1° in about 52 meters (170 feet). Hermann believes that the high gradient at Oberg is due to chemical reactions within the oil, especially to depolymerization. He cites the presence of carbon in the oil at Oberg as evidence of polymerization.

I. O. Hass and C. R. Hoffmann[80] in 1929 published results of a detailed survey of underground temperatures in the Pechelbronn oil-bearing region, Alsace, France. The temperature measurements show a definite relationship between the isogeotherms (lines of equal earth temperature) and the structural lines. The rate of temperature increase was found to be greatest near the center of the graben and least near the edge. An increase of temperature was noticeable at fault zones. Oil accumulations did not affect the earth temperatures. The authors regarded the higher temperatures in the center of the graben to be due to the greater thickness of fine sediments that act as a blanket or insolating covering.

In 1926, as a result of the interest developed in geothermal studies by the excellent work and publications of C. E. Van Orstrand, the American Petroleum Institute through its research committee chose an investigation of underground temperatures in oil wells as one of its research projects. Mr. Van Orstrand was assigned a fund to make observations in Wyoming and California; A. J. Carlson in California; A. L. Locke in Oklahoma; and E. M. Hawtof in Texas. Later, Mr. Locke was replaced by Mr. McCutchin and Mr. Hawtof by Mr. Sargent. The result of the first two years of these investigations[81] has been published by the

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[79]Hermann, D., Erdtemperaturen in hannoverschen Oelfeldern: Petroleum, vol. 24, pp. 241–243, 1928.

[80]Hass, I. O., and Hoffman, C. R., Temperature gradient in Pechelbronn oil-bearing region, lower Alsace; its determination and relation to oil reserves: Am. Assoc. Pet. Geol. Bull., vol. 13, pp. 1257–1273, 1929.

American Association of Petroleum Geologists and the American Petroleum Institute.[82]

Temperatures were measured in more than three hundred and thirty wells in Oklahoma, Texas, New Mexico, and California. Special study was made of the relation of earth temperatures to various types of structure, to unconformities, to water circulation, and to oil pools. Abnormally high geothermal gradients were found associated with most structures. Variations in gradients are ordinarily small but measurable and uniform. No definite evidence has indicated that oil in itself is a cause of the higher temperatures. The work by Hawtof around salt domes and by McCutchin on buried ridges suggests that the conductivity of rocks is a factor in subsurface temperature and that the higher temperatures over buried granite and salt plugs may be due to greater thermal conductivity of granite and salt. Many maps have been prepared showing local and regional isogeothermal lines in oil-field districts, and measurement of temperature in wells has continued in the mid-continent and California up to the present time.

TERMINOLOGY IN GEOTHERMAL LITERATURE

Literature dealing with earth temperature surveys contain certain technical terms not commonly employed in geologic publications. These terms adapted from Wilson[83] are defined below to make subject matter which follows a little clearer for those not familiar with geophysical literature.

Temperature gradient is the number of degrees of temperature increase per unit of distance.

Geothermal gradient is the number of degrees of temperature increase per unit of distance of depth through the earth's strata.

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[81] McCutchin, John A., Determination of geothermal gradients in Oklahoma: Am. Assoc. Pet. Geol. Bull., vol. 14, pp. 535–557, 1930.

[82] Heald, K. C., Van Orstrand, C. E., McCutchin, J. A., Hawtof, E. M., and Carlson, A. J., Earth temperatures in oil fields: Am. Pet. Inst. Prod. Bull. No. 205, 1930.

[83] Wilson, J. H., Geophysical prospecting, pt. 10: Geothermal methods: Colorado School of Mines Mag., vol. 19, p. 13, Aug. 1929.

Reciprocal geothermal gradient or *reciprocal gradient* is the depth per degree increase in temperature. It is calculated between the 100-foot depth and the bottom of the hole, as follows:

$$\frac{c - 100 \text{ feet}}{b - a} = \text{reciprocal gradient}$$

a = temperature at 100-foot depth

b = bottom temperature

c = bottom depth

Coefficient of thermal conductivity is the amount of heat in gram-calories which will flow in one second through a cube with a volume of one cubic centimeter when the faces of the cube are perpendicular to the heat current and have a difference of temperature of one degree centigrade.

Isotherm is a line drawn through points of equal temperature.

Isothermal surface is a surface on which the temperature is everywhere the same.

Isogeotherm is a line connecting points of equal temperature on the surface or in the earth.

Isogeothermal surface is an isothermal surface within the earth.

PLAN OF SUBSURFACE TEMPERATURE SURVEY IN NORTHEAST TEXAS

Northeast Texas was selected for the subsurface temperature survey undertaken by the American Petroleum Institute during 1929 and 1930. The large number of water wells, the numerous oil pools, and extent of wild-cat drilling offered a wider diversity of conditions for temperature study than did other areas in Texas, whereas the uniformity and continuity of the geological formations make the interpretation of abnormal earth temperatures simpler and results of the investigation more definite.

A detailed systematic temperature survey was planned to determine the temperature gradients in wells throughout the entire area underlain by the Woodbine sand. Such a compilation of data enables a comparison of geothermal gradients to be made in areas of normal structure, in areas of anticlines, faults, and domes, and in areas where oil pools occur.

With this plan in view, suitable shallow wells were selected near the outcrop of the sand, the temperatures in them were measured at intervals of two hundred and fifty feet from the surface down to the bottom of the hole. Other deeper wells farther from the outcrop were surveyed, and the work extended until the fresh-water area was completely studied. South of the area of water wells every available oil well was measured, in which it was possible to get permission to lower the thermometers. It is more difficult than one would suppose to find satisfactory deep wells to test. After drilling, a well must be allowed to stand at least thirty days in order that the heat generated by the friction of the drill may be dissipated. It must not be producing gas, because expanding gas cools the hole. It must not be producing much oil, for of course, a company will not be willing to shut down a producing well for a day or more and wait for the survey to be made. Since most dry holes are abandoned and plugged as soon as the drilling is finished, the most available wells for obtaining temperature measurements are former producing wells that are standing idle. A few such wells are to be found along the fault-line fields and around some of the salt domes. According to this plan, temperature measurements were made in water wells in the area where the Woodbine sand is at shallow depths; in the old, partially abandoned wells in oil fields; and in a few dry holes that had stood long enough to allow the walls to cool sufficiently to permit accurate earth temperature measurements. Table 5 is a record of temperatures at various depths in several east Texas wells.

APPARATUS AND METHOD OF MEASURING TEMPERATURES IN WELLS

The apparatus used in making temperature tests of drill holes in east Texas was designed by C. E. Van Orstrand of the United States Geological Survey.[84] The complete apparatus set up and ready for operation is shown in figure 11. The instrument consists of a reel for lowering a set of maximum thermometers a measured distance into the

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[84]Van Orstrand, C. E., Apparatus for the measurement of temperatures in deep wells by means of maximum thermometers: Econ. Geology, vol. 19, pp. 229–248; Description of apparatus for measurement of temperatures in deep wells; Am. Pet. Inst. Prod. Bull. 205, pp. 9–18, 1930.

TABLE 5.—*Comparison of underground temperatures (Fahrenheit) in east Texas wells.*

TEXT FIGURE	WELL	DEPTH IN FEET								
		100	250	500	1000	1500	2000	2500	3000	3500
	Boggy Creek oil field (Anderson and Cherokee counties)									
17	Humble O. & Rfg. Co., A. E. Todd No. A–3	70.81	----	----	91.21	----	118.17	----	----	168.05
18	Do Tom Jones, Jr., No. 2	83.63	----	95.41	106.68	122.74	134.40	145.83	152.36	158.37
19	Do W. T. Todd No. B–1	70.16	----	80.05	92.99	104.95	118.39	134.78	150.77	172.69
20	Do Elliott & Clark No. B–2	69.92	----	86.99	96.68	108.48	122.36	134.28	143.96	151.85
	Mexia oil field (Limestone county)									
29	Pure Oil Co., Joe Ross No. 4	----	----	----	112.36	----	125.12	----	136.68	----
30	Do B. H. Speer No. 2	69.15	----	76.84	88.76	100 70	112.51	123.56	134.91	----
31	Do H. Bluitt No. 2	75.50	----	85.73	95.83	106 50	116.62	126.61	----	----
†36	Do W. D. Pittman No. 2	70.16	----	77.76	89.46		113.20	----	136.58	----
33	Moss & Urschel, Lyles No. 1	76.06	----	79.46	92.27	103.35	114.00	124.74	136.17	----
34	Magnolia Pet. Co., J. L. Thompson No. 8–A	78.21	----	83 01	94.35	105.68	116.39	126.44	----	----
	Nigger Creek oil field (Limestone county)									
35	Moss & Urschel, Rosson No. 4	70.90	----	77.00	88.16	99.18	107.90	119.53	127.98	----
	Powell oil field (Navarro county)									
*38	Humble O. & Rfg. Co., W. J. McKie No. C–4	94.40	95.50	97.81	104.40	113.11	118.95	130.47	----	----
47	Do W. J. McKie No. B–3	87.32	88.36	93.51	103.49	111.22	118.69	125.52	----	----
*42	Do J. K. Hughes-Hill No. A–1	88.46	88.94	94.62	104.26	111.72	118.92	127.14	----	----
*46	Do J. K. Hughes-Hill No. C–1	89.17	91.46	93.13	102.71	110.74	118.55	126.23	----	----
*44	Do J. W. Pugh No. 2	89.30	90.25	94.62	104.76	112.40	119.73	129.56	----	----
52	Do J. W. Pugh No. 5	81.90	84.09	89.17	100.21	109.27	114.35	127.32	----	----
43	Do J. W. Pugh No. 6	72.03	75.12	80.69	92.19	102.78	113.17	122.60	----	----
*49	Do J. W. Pugh No. 8	88.03	----	----	103.85	----	119.97	133.37	----	----
*50	Do G. C. Kent No. 9	88.59	89.88	94.80	106.15	113.54	119.74	126.84	----	----
51	Do W. C. Humphries No. 20	85.13	88.23	92.12	102.61	111.38	117.33	129.15	----	----
37	Magnolia Pet. Co., I. T. Kent No. 7	77.64	80.12	84.20	96.85	106.73	116.62	125.24	----	----
*41	Pure Oil Co., W. J. McKie No. 7	90.11	91.26	96.21	104.46	112.53	120.00	125.65	----	----
†48	Sun Oil Co., G. H. Kent No. 2	67.75	70.74	77.22	90.14	100.57	112.48	121.53	----	----
45	Witherspoon Oil Co., J. O. Burke No. 1	----	71.87	78.60	91.08	101.93	112.57	122.46	----	----

	Wortham oil field (Freestone County)									
40	Magnolia Pet. Co., N. B. Boyd No. 10	79.09	----	86.54	96.98	106.22	116.56	125.73	----	----
39	Simms Oil Co., Will Calame No. 3	77.85	----	85.03	97.07	106.43	118.21	127.24	----	----
	Wildcat wells									
53	Amerada Pet. Co., Wade No. 1, Upshur County	71.76	----	----	89.27	100.35	----	----	----	----
22	Aswastika Oil Co., Owens No. 1, Fannin County	69.09	70.09	73.13	84.70	91.06	98.26	103.32	----	----
27	F. H. E. Oil Co., Bryant No. 1, Grayson County	67.00	68.08	71.96	79.16	----	----	----	----	----
25	Wolfe City Pet. Co., Kennedy No. 1, Hunt County	66.00	67.71	73.14	82.84	93.92	103.62	----	----	----
	Salt and water wells									
21	Bonham city well, Fannin County	68.60	71.10	77.20	88.49	----	----	----	----	----
24	Ennis city well, Ellis County	----	74.52	80.02	87.35	----	----	----	----	----
23	Ferris Brick Co. well, Ellis County	-	72.33	75.63	87.18	----	----	----	----	----
32	Greenville city well, Hunt County	69.00	-	75.86	86.53	94.94	----	----	----	----
26	Kimbell Flour Mill well, Hunt County	67.08	69.02	74.12	83.19	93.78	----	----	----	----
†54	Morton Salt Co., A. J. Eason No. 1, Van Zandt County	69.15	73.99	77.08	----	----	----	----	----	----
55	Do A. J. Eason No. 2 Do	69.56	74.16	77.45	----	----	----	----	----	----
†56	Do A. J. Eason No. 3 Do	68.08	70.87	76.88	----	----	----	----	----	----
28	Sherman city well No. 5, Grayson County	67.08	68.08	74.12	----	----	----	----	----	----

*Temperatures measured after well had stood idle only two days.
†Temperatures measured by E. M. Hawtof.

ground. The reel is set in a steel frame and has a capacity of approximately 8,000 feet of number 20 B and S gauge polished steel piano wire. The reel is mounted on the machine at one end; the other end is attached to a brass measuring wheel carrying a counter that records the depth to which the thermometers are raised or lowered. Between the reel and measuring wheel there is a spooler by which the wire is wound on the drum in coming out of the hole. The reel is equipped with two handles to enable the operator to revolve the drum evenly, and a brake to facilitate lowering the thermometers into the well. The machine is mounted on a four-legged stand, placed over the well and guyed to

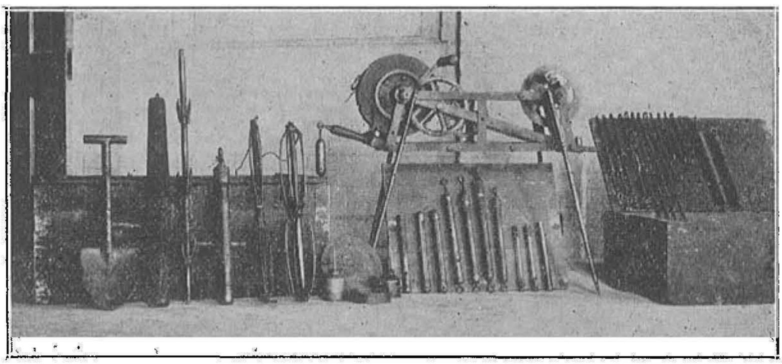

Fig. 11.—Temperature apparatus in position for making measurements.

the derrick floor by means of turnbuckles to prevent vibrations as the instruments are raised and lowered (fig. 11). The total weight of the machine including wire is approximately seventy-five pounds.

A set of three maximum thermometers is used for the temperature measurements. The maximum thermometers[85] are graduated at intervals of one degree to 213 degrees Fahrenheit over a length of about 18 centimeters. The diameter of the stem of the thermometer is 6 to 7 millimeters. The accuracy is within 0.2 to 0.3 of a degree. A

85Manufactured by H. J. Green, 1191 Bedford Ave., Brooklyn, N. Y., The Taylor Instrument Co., Rochester, N. Y.; and other firms.

thermometer graduated from 100 to 212 degrees Fahrenheit over a length of about 10 centimeters is used for measuring temperatures above 100 degrees. The bulb is placed just beneath the constriction to obtain a mercury column of minimum length. Three thermometers each with a different sized constriction are placed in a suitable container, fastened to the wire of the reel, and lowered by hand to the proper level in the well. The thermometer containers are shown in figure 12.

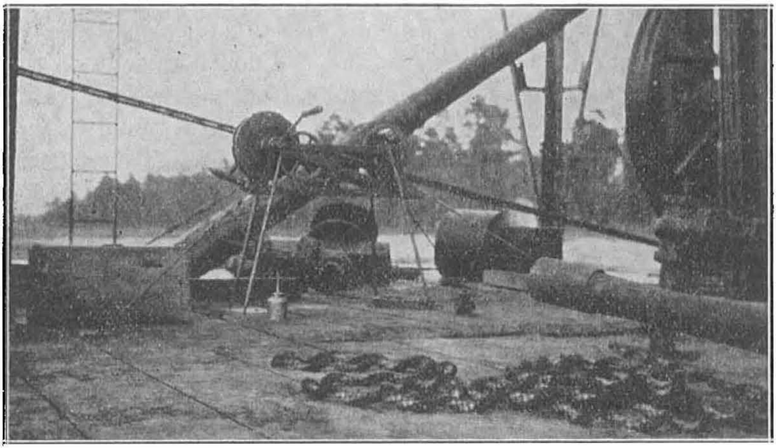

Fig. 12.—Near view of apparatus showing thermometer cases and accessory equipment.

The time required for the thermometers to remain in the hole in order to record the true temperature, if there is no liquid in the hole, is one hour and fifteen minutes. In fluid the time is one hour. Observations are made at a depth of 100 feet, and every 250 feet thereafter nearly to the bottom, in order to enable the observer to calculate the temperature gradient of each well. It is possible to measure temperatures with this apparatus down to a depth of 4,500 feet, if the holes are straight and the casing free from mud or other obstructions. Below 4,500 feet a heavier apparatus is required or the thermometers may be lowered on the bailer and sand line of the oil well rig. The average time for measuring temperatures in a 3,000-foot hole is eighteen hours. The thermometers are placed in a bath in ice water immediately after they are raised from the well. The maximum temperature is read by holding the mercury column still in the ice water exactly level with the eye. A small correction known as the "stem correction," K, is calculated[86] and added to the observed reading.

GRAPHIC REPRESENTATION OF TEMPERATURE MEASUREMENTS

The temperature readings at various depths from the surface downward are illustrated best graphically by means of temperature curves. The degrees of temperature are plotted on the horizontal lines and the depth in feet on the vertical lines of cross-section paper, and a curve is drawn through the plotted points. Curves have been made in this way for all wells that have been tested in east Texas (figs. 17 to 56).

Variations in reciprocal gradients or rate of increase in temperature per foot of depth in different parts of the area are shown by means of reciprocal-gradient maps. These are constructed by plotting the temperature increase per 100 feet of depth on the map at the location of the well, whose temperature has been measured, and by drawing lines through points of equal reciprocal gradients, just as contour lines are drawn through points of equal elevation. In this way all the reciprocal gradients of the wells tested have been plotted on a map and the equal reciprocal gradient lines drawn (Pl. IX). Bends, curves, and closures in the lines indicate areas of abnormal temperature gradients. A comparison of this map with the structure map of east Texas shows the relationship of temperature gradients to abnormal structure.

A diagram representing the altitude of the subsurface isogeothermal or equal temperature surface is another useful way of illustrating underground temperatures. The isogeotherms are illustrated either by subsurface cross sections

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[86] $K = 0.00009$ $(T-X)$ $(T-t)$. T = the observed thermomter reading (Fahrenheit); t = observed temperature of the air (Fahrenheit); X = degrees (F.) of constriction above zero (F.).

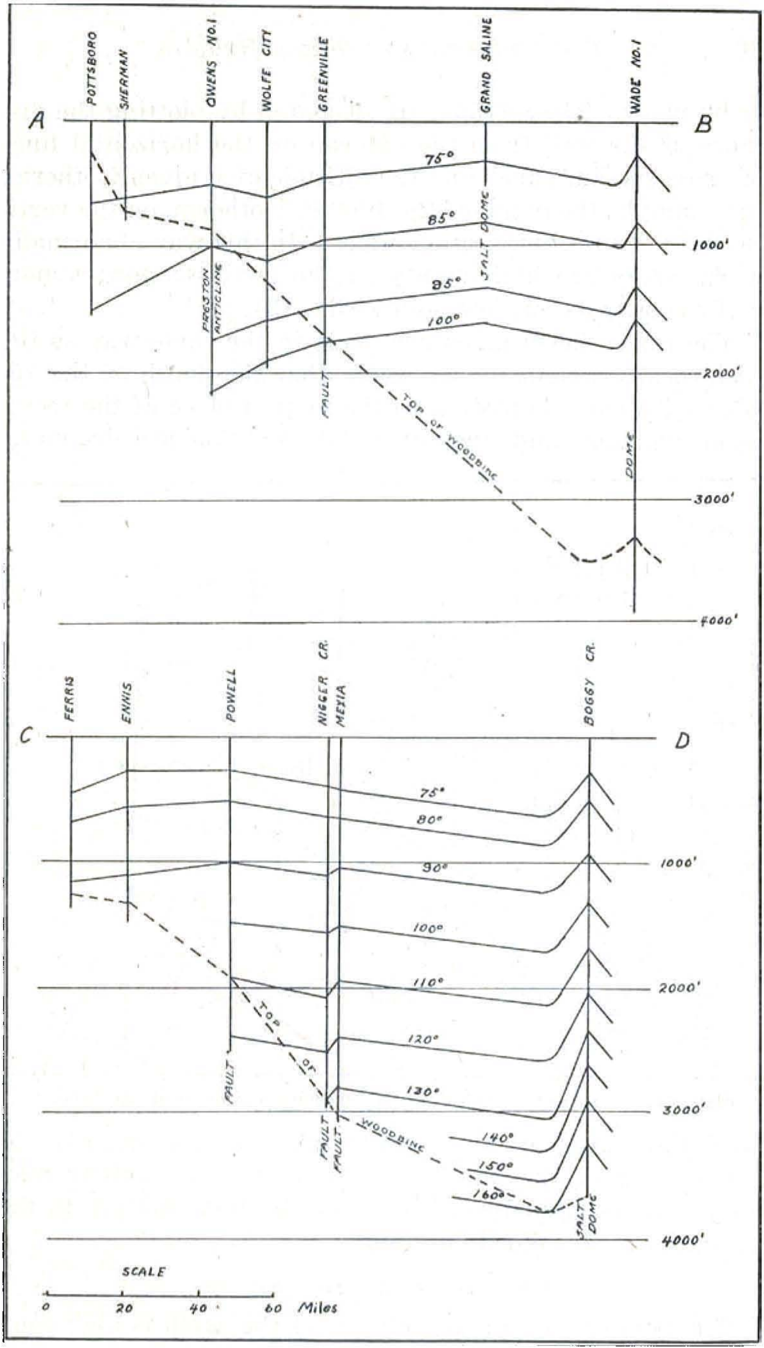

Fig. 13.—Profiles along lines A-B and C-D (Pl. IX) showing dip of Woodbine sand compared with the slope of the isothermal surface.

or by maps. The sections are prepared by plotting the distance of the well from the outcrop on the horizontal lines of cross section paper and the altitude of a given isotherm, for example, the depth of the 100° F. isotherm, on the vertical lines of the cross section paper. In this way abnormally warm spots are high points on the cross section; abnormally cool spots are low points (fig. 13).

The isogeotherm maps are made in the same way as the reciprocal gradient maps, except that the depth of the 75-degree isotherm is plotted on the map in place of the reciprocal gradient, and lines of equal elevation are drawn to

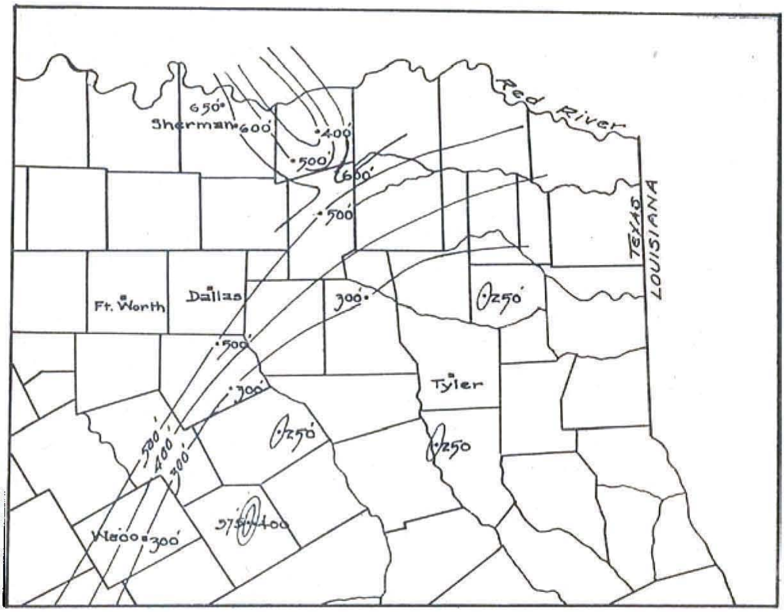

Fig. 14.—Contours drawn on 75-degree isothermal surface.

show the contour of the isogeothermal surface (fig. 14). A comparison of the map with the structural contour map shows the relationship of the isogeothermal surface to the structure of the Woodbine sand.

EARTH INTERIOR TEMPERATURES

The temperature of the interior of the earth is high compared with that at the surface. The degree of the temperature at the center is not known, but estimates by various authorities range from 2000° to 4000° Centigrade, although some believe the temperature may be as high as 20,000° C. Thus Gutenberg[87] estimated 2000° C. or less, Königsberger[88] 3000° C., Wiechert [89] 3300° C., Mohorovicic[90] 3000° C. to 4000° C., and Lunn[91] 20,000° C.

Heat is transferred outward from the warmer interior to the surface, and internal heat in the interior is constantly regenerated, otherwise the interior temperature would decrease. The rate of flow of heat from interior outward depends upon the difference of heat potentials of the interior and surface and upon the conductivity of the strata through which the heat travels. If the interior heat is more or less constant in amount, as is supposed, then the temperature gradients depend largely upon the conductivity of the strata through which the heat migrates. Thorton[92] has shown that the heat conductivity of rocks (λ) measured in gram calories per centimeter degree second depends upon the density and elasticity as expressed by the following formulae:

$$\lambda \times 10^{-3} = \nu^2 \times \rho^2 \times 10^{-11}$$
$$\lambda \times 10^{-3} = \epsilon \times \rho \times 10^{-3}$$

in which:

$\nu = \sqrt{\epsilon/\rho}$
ρ = density of the rock
ϵ = modulus of elasticity
λ = conductivity

The heat conductivity of some of the common rocks at the surface of the earth has been determined by a number

87Gutenberg, Benno, Der Aufbau der Erde, Berlin, 1925.

88Königsberger, J., Physikalische Zeitschrift, vol. 7, pp. 297–300, Leipzig, 1906.

89Wiechert, Lehrbuch der Geologie by E. Kayser, vol. 1, Allg. Geologie, Aufl. 5, pp. et seq., Stuttgart, 1918.

90Mohorovicic, S., Zeitschrift für angewandte Geophysik, vol. 1, pp. 330–383, Berlin, 1924.

91Lunn, A. C., Textbook of Geology by T. C. Chamberlin and R. D. Salisbury, vol. 1, 2nd edition, p. 566, 1905.

92Quoted by Richard Ambronn, Elements of Geophysics, p. 268, McGraw-Hill Book Co., 1928.

of investigators and compiled by Wilson,[93] Ambronn,[94] and Strong.[95] Conductivity of the more common rocks is as follows:

THERMAL CONDUCTIVITY

	Gram calories
Rock salt	.0034
Quartz	.0062
Slate	.0061
Sandstone, wet	.0060
Sandstone, dry	.0025
Quartz sand, wet	.0082
Quartz sand, dry	.00105
Very fine sand	.0003
Phyllite	.0059
Porphyry	.0055
Gneiss	.0054
Limestone	.0052
Granite	.0040–.0081
Andesite	.0031
Clay, dry	.0025
Clay, wet	.0035
Sandy clay	.0022
Slate, parallel to bedding	.0060
Slate, perpendicular to bedding	.0034
Soil	.0037
Petroleum	.0003
Water	.0014

In general the conductivity is greater along bedding planes than at right angles to them, and the more pronounced the stratification the greater is the difference between the two heat conductivities. In stratified rocks the amount of heat conductivity varies with the dip and extent of folding of the rocks. Ambronn[96] states that in most

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93Wilson, J. H., Geophysical prospecting, pt. 10; Geothermal methods: Colorado School of Mines Mag., vol. 19, pp. 13–16, Aug. 1929. (Contains bibliography.)

94Ambronn, R., The distribution of temperature in the earth's interior and the use of temperature measurements in applied geophysics: Elements of Geophysics, Trans. by M. C. Cobb, Chap. 8, pp. 266–284, New York, 1928.

95Strong, M. W., Geothermal phenomena and geological history with special reference to old structures in geothermal equilibrium: Inst. Pet. Tech., vol. 16, pp. 889–901, London, 1930 and 1931.

96Ambronn, R., The distribution of temperature in the earth's interior and the use of temperature measurements in applied geophysics: Elements of Geophysics. Trans. by M. C. Cobb, Chap. 8, pp. 266–284, McGraw-Hill Book Co., 1928.

rocks which are horizontal the temperature gradient is 8 per cent higher than in those having dips of more than 45 per cent. Thus there may be a slight change in the reciprocal gradient along marked unconformities, and also along faults where the strata on one side are much more tilted than on the other.

Since the heat conductivity of rocks and consequently the geothermal gradient depends upon the density of strata and arrangement of the grains in the rock, areas on the surface of the earth may be considered to have two classes of temperature gradient: regional or normal gradient and local or abnormal gradient. The regional gradient is dependent upon the density and nature of the rock of the region. Thus

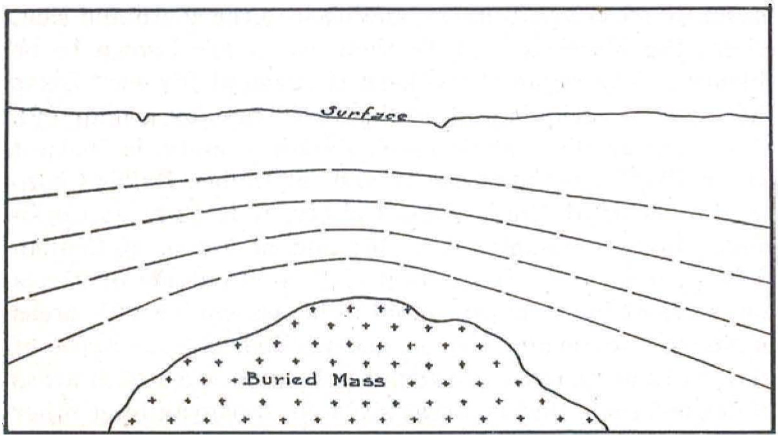

Fig. 15.—Isotherms in neighborhood of a buried salt plug or granite mass.

according to Königsberger[97] it is about 1° for 30 meters (98.4 feet) in dry gneiss, 1° for 32 meters (105.0 feet) in phyllite and 1° for 28 or 29 meters (92.0 to 95.0 feet) in mica schist. For alternating stratified sandstone and shale it is about 1° in 13.1 meters (43 feet). The local or abnormal gradient is due to local structural features which interrupt locally the continuity of the strata, and which have a different density and hence a different geothermal conductivity. The presence of a volcanic plug, salt dome,

97Königsberger, J., Eclogae geologicae Helvetiae, vol. 10, pp. 506–525, 1908.

or sharply folded anticline sets up local areas of abnormal temperature gradients (fig. 15), not only by changing conductivity but also by introducing other factors such as opening up channels for upward migration of warm waters, or retarding downward movement of fresh water and by producing increased chemical activity locally.

REGIONAL TEMPERATURE GRADIENTS IN EAST TEXAS

The average reciprocal gradient for east Texas is about 1° increase per 50 feet of depth. This average rate of increase, however, is not uniform for all parts of the province, even where there is no abnormal structure. The geothermal gradient is greatest on the north and west sides, where the Mesozoic rocks are thinnest, and least to the south and east, where the Mesozoic and Tertiary rocks are known to be thickest. The regional geothermal gradient for east Texas therefore is variable and is illustrated best by a map (Pl. IX). The gradient at Bonham, Fannin County, is 50.0; at Greenville, Hunt County, it is 55.0; at Dallas, Dallas County, it is 65.0; at Ennis, Ellis County, it is 52.9; at Corsicana, Navarro County, it is 46; and at Waco, McLennan County, it is 48.5. In areas investigated outside of Texas low rates of increase are found to be associated with areas of thickest sediments, that is, geosynclinal areas. Areas of high rates of increase are found to be associated with areas of densest rock, that is, areas situated over granite or other dense rock near the surface. A slight temperature factor must also be considered in going from geologically older to geologically younger formations. The younger Tertiary beds contain more unaltered organic matter, the freshest most unaltered least dense sediments. In them there is more chemical activity going on and more chemical changes taking place. Most of these chemical reactions are exothermic, and heat due to chemical reactions becomes possibly a factor. It is well known, for example, that spontaneous combustion sometimes takes place in lignite beds at shallow depths.[98] The presence of sulphide minerals par-

[98]Bowers, Paul C., An interesting case of spontaneous combustion: The Resources of Tennessee, vol. 6, No. 1, pp. 37–40, Jan., 1916.

tially or wholly oxidized to limonites, hematites, and other minerals is more proof of such reactions. Measurements of temperatures in wells situated along a north-south line from Oklahoma to the Gulf Coast show a decreasing reciprocal gradient until the Tertiary beds are reached, and then an increasing reciprocal gradient toward the Gulf. The Tertiary beds have the same structure as the Cretaceous below, are no better conductors of heat, as far as known, but probably are the source of more heat due to exothermic chemical reactions. Whatever the cause, the rate of increase appears to be slightly greater in areas of Oligocene rocks at the south edge of the province than in the Comanchean rocks at the north end. It is greater in the Gulf Coast and in California than in north Texas and Oklahoma. Such geothermal gradient changes, however, are slight and gradual and are represented by gentle curves, that are easily distinguished from the abrupt gradient changes due to the presence of a salt dome or buried granite ridge.

The isogeothermal surface in different parts of the province dips in about the same way as the surface of the Woodbine sand. In general the inclination of the isogeothermal surface is toward the southeast. The surface dips downward toward the east Texas geosyncline and is elevated abruptly in the vicinity of faults and salt domes (fig. 12 and Pl. 1).

ABNORMAL TEMPERATURE GRADIENTS IN EAST TEXAS

The reciprocal geothermal gradient in all wells located close to faults is less than normal (Pl. IX). The normal reciprocal gradient is about 1° in 50 feet. The reciprocal gradient at Powell oil field is 1° in 43 to 46 feet; at Mexia it is 1° in 46 feet. In the vicinity of salt domes the gradient is slightly higher; at Boggy Creek the rate of increase is 1° in 36 feet. At Grand Saline in Van Zandt County it is 1° in 41 feet, and at Pierce Junction it is 1° in 43.4 feet. The relationship of the structure of the sand to the isogeothermal surface in the Powell field is interesting. On the map, figure 16, the solid contours are drawn

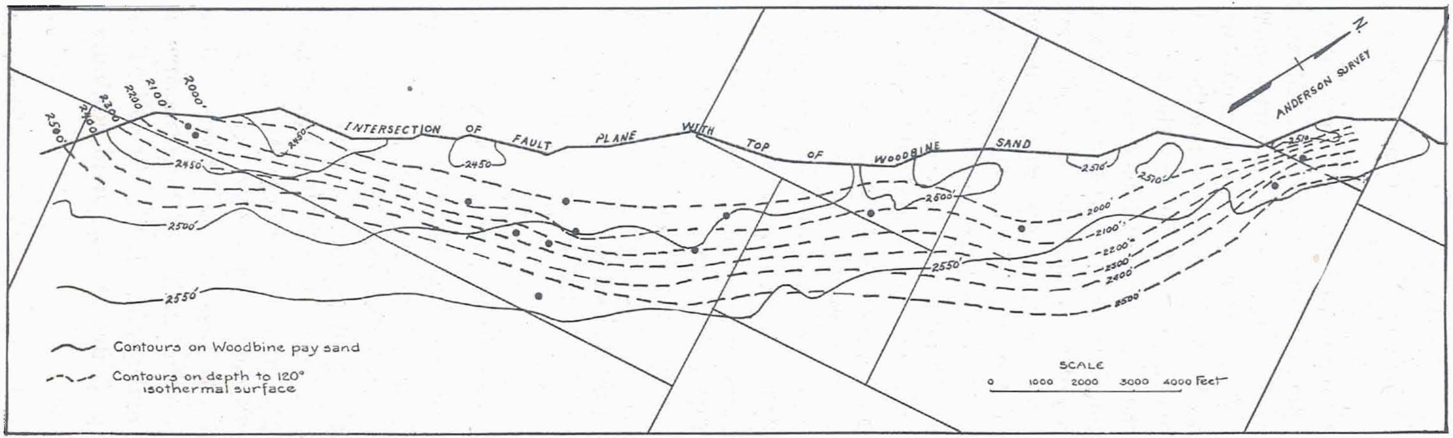

Fig. 16.—Map of Powell oil field, Navarro County, showing the structural contours on the top of the Woodbine sand and the 120-degree isothermal surface.

on the top of the oil sand.[99] The broken lines are drawn on the 120-degree isothermal surface. A 100-foot depth interval is used. The difference in the depth to the oil sand in the wells whose temperatures were measured amounted to 90 feet. The difference in the depth of the same wells to the 120-degree isothermal surface is about 350 feet. The result of the temperature measurements at Powell show that the area along the fault has abnormal temperature gradients and that the lines drawn through points of equal temperatures trend in the same general direction as the structural contour lines. The isogeothermal surface is warped more than the sand layer is bent by the deformation. A total of twenty-four wells were tested along the fault line and all showed abnormally high temperature gradients.

In all wells tested that actually crossed the fault close observations were made on each side of the fracture zone to see whether there was a noticeable increase of temperature at the fault itself. The temperature reading at the plane of displacement was found to follow the normal geothermal gradient for the wells of the field. It appears that there is no increased temperature in the fault plane due to upward migration of warm water or to abnormal heat conduction along mineral veins at the fault contact. The abnormal geothermal gradients are confined to a zone or belt along the fault and are not further exaggerated along the actual plane of faulting. The temperature survey in the Mexia and Wortham fields furnished the same geothermal gradients as those described at Powell.

Another area that has markedly abnormal geothermal gradients correlated with abnormal structure is the Boggy Creek salt dome located in Anderson and Cherokee counties. The wells in this field flow when brought in but decline fairly rapidly, and they are put on the pump in a short time. Some of the wells are yielding salt water. Four wells were tested in this field located along a north-south line on the east side of the dome and on top of the salt plug as

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99Hill, H. B., and Sutton, Chase E., Production and development problems in the Powell oil field, Navarro County, Texas: U. S. Bur. Mines Bull. 284, 1928.

shown in figure 7. The wells located on the salt core have a much higher geothermal gradient than those away from the salt plug. The lower diagram, figure 7, shows the iso-geothermal surface through the wells tested at Boggy Creek and indicates the amount that the surface is warped upward. The temperature at the 3,000-foot depth at Boggy Creek is 36 degrees Fahrenheit higher than at the same depth in the Powell field and 43 degrees higher than the normal temperature for a depth of 3,000 feet in east Texas. In the diagram the high isothermal surface in the Tom Jones, Jr., No. 2 is due partially to the large amount of salt water that this well yields. The other wells are producing more oil and less water. The gradients obtained at Boggy Creek indicate that temperatures in east Texas salt domes are much higher than the temperatures in normal areas and much higher even than the temperatures found close to the faults. Wells making most water on the domes have highest temperatures.

CAUSES OF TEMPERATURE ANOMALIES

The following factors have been suggested by physicists to explain abnormal temperature gradients:

1. Proximity to igenous intrusion still radiating heat.
2. Heat generated by compressional folding or faulting.
3. Exothermal chemical reactions in the underground water.
4. Upper migration of warmer liquids (water or oil).
5. Conduction of heat from below upward through a denser stratum.
6. Presence of radio-active minerals.
7. Presence of liquids having high conductivity in contact with those of low conductivity.

1. The proximity to warm igneous intrusions is probably the most obvious cause of high gradients. Though there is no known igneous intrusion beneath the Woodbine area, there are volcanic rocks along the fault zone both to the south and to the north of this province. There is the possibility that there is deeply buried igneous material in the form of sills or dikes associated with some of the faults. It is hardly conceivable, however, that there would be a fairly even distribution of this heat generating material all along

the fault zone where temperature measurements have been made, or that there is an igneous plug beneath the salt domes. The igneous plugs near Uvalde appear to have cooled completely and do not furnish a source of heat. Igneous material is probably not the cause of the temperature anomalies in east Texas.

2. Heat generated by compressional folding or faulting might be an important factor in certain spots of very recent deformation. Tanasescu[100] suggests that as petroleum is compressible it may suffer considerable reduction in volume through orogenic movement, and that this reduction in volume would be transformed into heat, in other words, that the heating of the rocks by earth movements is accentuated if petroleum is present. Rogers suggests that such effects may in part explain the fact that the gradient in the Appalachian fields, which are in Paleozoic rocks that have undergone no recent deformation, is unusually low, whereas the gradient in the other oil fields, which are in more or less deformed Tertiary or Cretaceous rocks, is unusually high. In east Texas, however, the faults are normal, and compressional forces are slight. It is hard to conceive that the heat which was produced by the slipping has not long ago been dissipated. If a rotary hole can cool completely in 60 days, it would seem that the heat generated by faulting must have cooled long ago.

3. One of the causes most often mentioned to explain abnormal temperatures in east Texas is the heat of chemical reaction. Some chemical reactions are endothermic, absorbing heat; others are exothermic, generating heat. The series of reactions in oil field sediments as a whole is exothermic. Among the chief reactions involved are: (1) Reduction of sulphate to sulphide and oxidation of hydrocarbons. As the exact course of this reaction is unknown its thermal value has not been determined, but it is known to be high. (2) Oxidation of hydrogen sulphide to sulphur.

100Tanasescu, I., Etudes préliminaires sur le régime thermique: Inst. Geol. Romanel Annural, vol. 5, p. 111, 1912—cited by Rogers, G. S., Sunset-Midway oil field, California, pt. 2, Geochemical relations of oil, gas, and water: U. S. Geol. Survey Prof. Paper 117, p. 41, 1919.

This reaction is strongly exothermic, yielding 59,100 calories.[101] (3) Reaction of oil with sulphur, leading to the formation of sulphur compounds. The thermal character of this reaction is unknown. (4) Oxidation of oil by oxygen-bearing waters, probably a rather strongly exothermic reaction. (5) Condensation or polymerization of hydrocarbon molecule through the action of sulphur or oxygen, or in other ways. According to Berthelot[102] the polymerization of acetylene to benzene produces 163 calories. Other similar changes are also known to be exothermic. Stremme[103] has pointed out that such reactions may account easily for the higher geothermal gradient in oil fields.

In east Texas the gradients are as high on faults which have yielded no oil as on those which have large pools. If chemical activity is a cause, the thermal effects are due to chemical action brought about by a concentration of soluble mineral matter along the fault line and not to reactions between oil and salt water alone.

4. The upward migration of warmer liquids has an effect on the geothermal gradients. At Boggy Creek the highest temperature was found in a well producing the most salt water. In many cases there is a definite relationship between the temperature and the amount of salt water that a well is making. It has been observed many times that when a well has been flowing or pumping oil only for some time and the temperature starts to rise, that the well will soon start producing salt water. Water around a structure that rises along a steeply dipping sand from a depth below the bottom of the hole is warmer than the normal bottom hole temperature. The temperature gradient is increased by the warmer water coming into the hole from below. It is not proven that there is an upward migration of warm water around salt domes. Domes which are producing oil probably support a slow upward movement.

101Becker, G. F., Geology of the quicksilver deposits of the Pacific slope: U. S. Geol. Survey Mon. 13, p. 255, 1888.

102Berthelot, M., Thermo-chemie, vol. 1, pp. 486–492, 1897.

103Stremme, H., Das polymerisierende Erdol als Warmquelle im Erdboden: Zentralblatt für Mineralogie, etc., p. 271, Stuttgart, 1908.

5. Conduction of heat from below may be effective in increasing temperature, if there is a good conductor. Salt domes provide a heat conductor in the salt itself which is believed to cause the higher geothermal gradients on salt domes. Mineral veins in faults might also conduct heat upward. If, however, conduction through mineral veins in the fractured zones is much of a factor, there would be a sudden rise in the temperature curve right at the contact of the fault or mineral vein. Such is not the case in the holes that cross faults in east Texas. Salt water is a better conductor than oil. This difference in conductivity may explain why salt-water wells are warmer than oil wells in the same field.

If the rocks along the fault are squeezed as a result of the drag and made more compact and denser, their conductivity would be increased. A measure of the specific gravity of surface samples of clay close to and away from the fault shows very little difference in density. It does not appear that the difference in density is enough to explain the difference in the reciprocal gradients in the wells in fault-line fields and in wells away from them. However, the rocks are more strongly tilted close to the faults and the thermal conductivity is slightly greater in the direction of the bedding planes than at right angles to the bedding. The change in dip might be a small factor.

6. Radio-active minerals have been suggested as a cause of higher temperatures in oil fields. Boyle[104] has shown that radium emanation is about fifty times as soluble in crude oil as in water and that thorium emanation is also considerably more soluble. Oil may thus tend to concentrate whatever radium and thorium emanation may be present in the rocks, and the heating effects of these substances might be sufficient possibly to cause a perceptible increase in the geothermal gradient. Coke residues from the distillation of oil in stills has been found to be radio active, and to contain traces of radio-active metals. Whitehead[105] has found that

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104Boyle, R. W., Note on the solubility of radium emanation in liquids: Roy. Soc. Canada Trans., 3rd ser., vol. 3, p. 75, 1919.

105Whitehead, R. B., personal communication.

Woodbine waters in east Texas were radio active in some cases at least.

It is possible that the radio-active material is in some way concentrated in the structure, although this seems doubtful. It is more likely that there is not enough difference in radio activity off and on the structures to explain the differences in temperature observed.

7. It has been suggested also that the presence of salt water of higher conductivity in contact with oil or with porous strata of much lower conductivity would produce differential temperatures around an oil pool. This phenomenon might explain the higher temperatures observed in the water zone around the edge of an oil pool. Since, however, higher temperatures are observed also in structures which are not known to contain oil, temperature differences between water and oil or liquids and solids is not the sole cause of temperature anomalies but may be possibly a contributing factor.

The abnormal temperatures are probably not due to one or two factors alone, but to a number of contributing causes. Mineralized waters in which exothermic chemical actions are taking place is important. Upward migration of warm water is a factor in some cases. Greater conductivity of heat in salt, granite, and denser rocks is certainly the best explanation of high geothermal gradients in salt domes and buried granite ridges. Increased conductivity in solutions of greater salt concentration is another probable factor. In fact, it has been observed in one case at least that where water is absent the geothermal gradient is less. Since the geothermal gradient is greater in all areas where increased salinity and increased total solids occur in the underground water, it is thought that increased water density is a contributing cause of warm spots in the earth. Such spots are associated with fault lines and salt domes where there are ascending salty waters and where the strata have been tilted and compressed.

COMPARISON OF CHEMICAL AND THERMAL INVESTIGATIONS

By conducting chemical and thermal studies at the same time in east Texas an unusual opportunity has been furnished for making a comparison of the relative merits of the two very different types of underground investigations.

The temperature gradients furnish information regarding the distribution of subsurface temperature, the relation of temperature to depth, and the relation of temperature to various kinds of rock formation and to various kinds of structure. The temperature measurements offer a possibility of gaining additional information on the character of certain types of structure, especially concerning the presence or absence of igeneous rock or salt plugs beneath domes. The measurements furnish also data useful to the solution of problems concerning the origin of oil. From a more practical standpoint they offer a method for determining the subsurface limits of abnormal structure and data important to engineers in calculating the setting time of cement at different depths underground.

The study of the chemical composition of the underground waters furnishes a method of investigating the rate of movement and direction of flow of water in different parts of a basin. It throws light on the relationship of the composition of underground water to structure and to oil pools and furnishes new information on the interchange of liquids between different subsurface levels and on the problem of the movement of liquids along faults. These are all problems of fundamental importance in the migration and accumulation of oil. From the basis of economic value it offers opportunity of gaining information regarding the location of faults and salt domes. Further, a knowledge of the composition of underground water aids the geologist in choosing for oil exploration the favorable parts of a petroliferous province, since oil rarely occurs in fresh water areas, and since oil pools occur in largest number along the belt of contact between connate and meteoric waters. Most important of all, the character formulae derived from the chemical composition of underground waters enables one to distinguish between waters from different horizons and to identify the source of any unknown water found in a northeast Texas well.

Both the thermal and chemical methods are important and are certain to play a large rôle in subsurface research in the future. The two methods can well be carried on together, since without loss of time a water sample can be obtained at the same time a temperature measurement is being made. The analytical work can be completed while the investigator is waiting for the next well to be made available for temperature study or during the many periods of unfavorable weather for temperature work. The good deep wells that are available for temperature study in rotary areas are few. Some are full of cavings, many are plugged or completely junked before they are cool enough for accurate work. Others are flowing gas or oil, or the owner is unwilling to open the well. On the other hand, water samples are nearly always available in all wells drilled into a water sand. The time required to take a water sample is thirty minutes, and ten complete analyses can be made easily in a single day. The research is more rapid and the results, we believe, are more positive, and the data more available. On the whole, for the east Texas province the chemical method of investigation is preferable, but the two make an excellent combination.

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Fig. 17.—Humble Oil & Refining Co., A. E. Todd No. A-3, Boggy Creek field, Anderson County. Pumping well; little gas; fluid at 3400 feet; casing 6⅝ inches; idle two days. Temperatures measured at depths of 100, 1000, 2000, 3000, 3500, and 3703 feet.

Fig. 18.—Humble Oil & Refining Co., Tom Jones, Jr., No. 2, Boggy Creek field, Anderson County. Pumping well; little gas; fluid at 400 feet; casing 6⅝ inches; idle one day. Temperatures measured at depths of 100, 500, 1500, 2000, 2250, 2500, 3000, 3250, 3500, and 3652 feet.

Fig. 19.—Humble Oil & Refining Co., W. T. Todd No. B-1, Boggy Creek field, Anderson County. Pumping well; no gas; fluid at 2500 feet; casing 6⅝ inches; idle two days. Temperatures measured at depths of 100, 500, 1000, 1500, 2000, 2500, 3000, 3500, and 3679 feet.

Fig. 20.—Humble Oil & Refining Co., Elliott and Clark No. B-2, Boggy Creek field, Cherokee County. Pumping well; little gas; fluid at 2500 feet; casing 6⅝ inches; idle two days. Temperatures measured at depths of 100, 500, 1000, 1500, 2000, 2500, 3000, 3500, and 3590 feet.

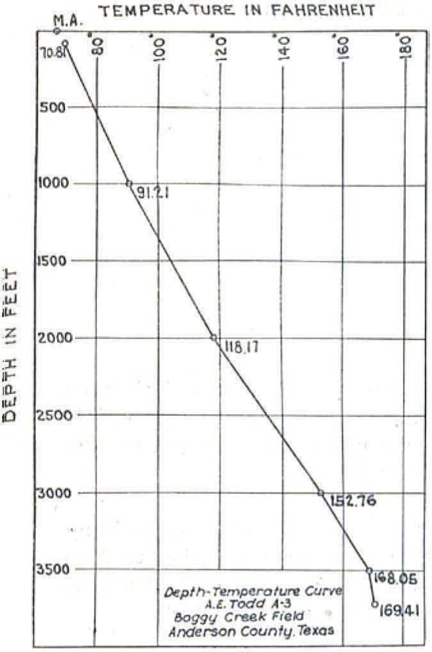
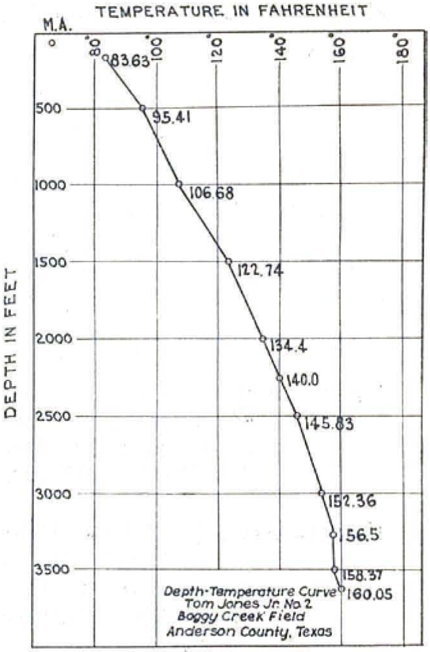


Fig. 17



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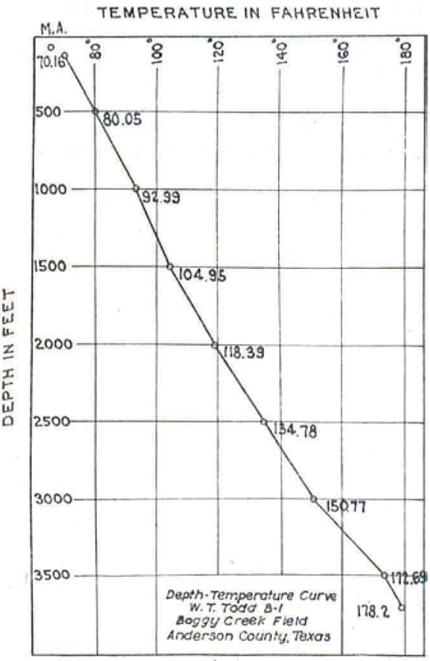

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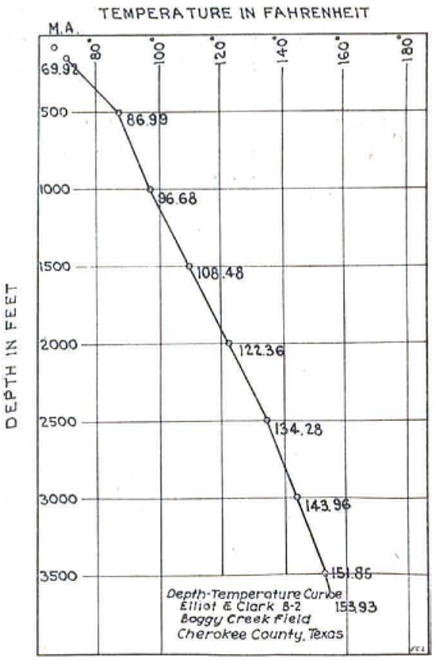


Fig. 20

Fig. 21.—Bonham city water well, Fannin County. Abandoned; no gas, fluid at 150 feet; casing 6⅝ inches to 1100 feet; idle several years. Temperatures measured at depths of 100, 250, 500, 750, 1000, and 1140 feet.

Fig. 22.—Aswastika Oil Co., Owens No. 1, Fannin County. Drilling well; no gas, fluid at 270 feet, casing 6⅝ inches to 2680 feet; idle two months. Temperatures measured at depths of 100, 250, 500, 1000, 1500, 2000, and 2500 feet.

Fig. 23.—Ferris Brick Co. water well, Ferris, Ellis County. Abandoned; no gas, fluid at 1100 feet; casing 6⅝ inches; idle several years. Temperatures measured at depths of 250, 500, 1000, and 1250 feet.

Fig. 24.—Ennis city water well at ice plant, Ellis County. Abandoned; no gas; fluid at 600 feet; casing 6⅝ inches; idle several years.

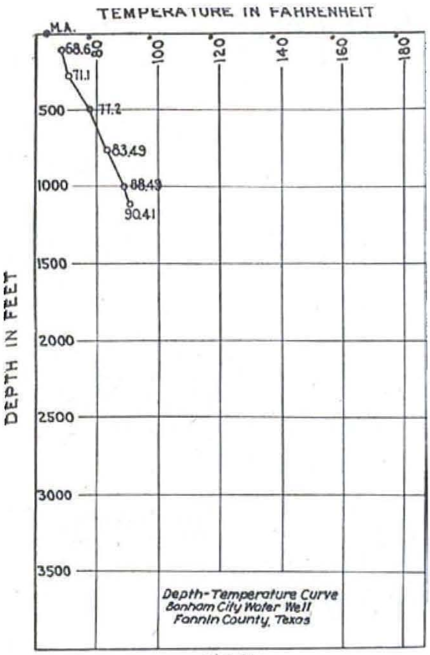


Fig. 21

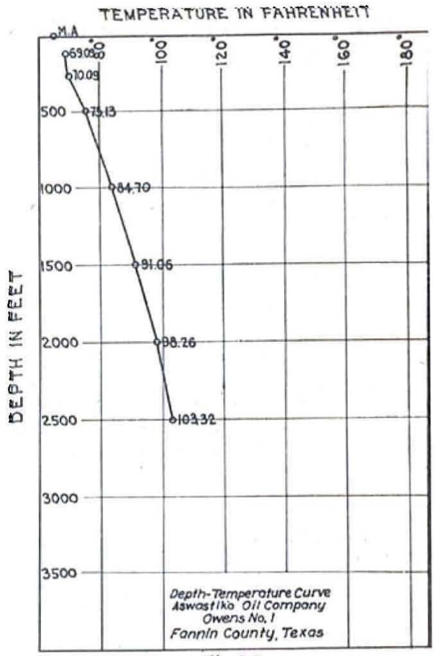


Fig. 22

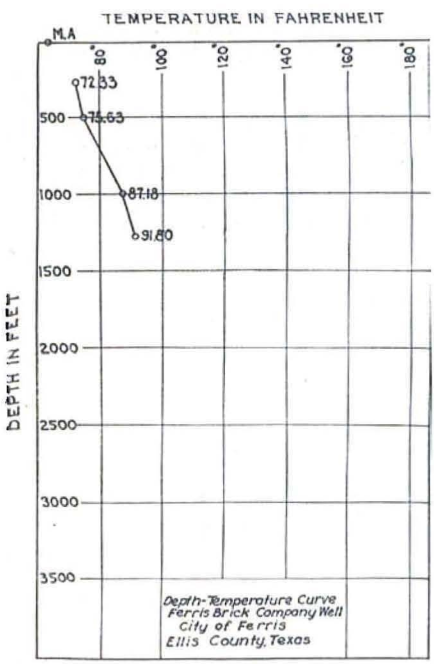


Fig. 23

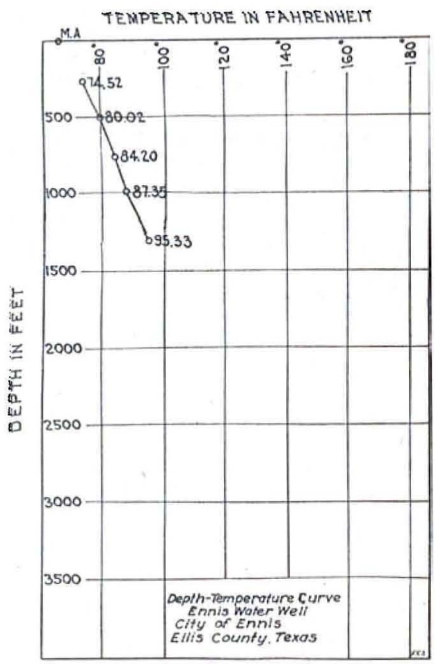


Fig. 24

Fig. 25.—Wolfe City Pet. Co., Kennedy No. 1, Hunt County. Abandoned; no gas; fluid at 55 feet; casing 8 inches to 2365 feet; idle several years. Temperatures measured at depths of 100, 250, 1000, 1500, and 2000 feet.

Fig. 26.—Kimbell Flour Mill water well, Wolfe City, Hunt County. Abandoned; no gas, fluid at 70 feet; casing 6¼ inches to 1716 feet; idle several years. Temperatures measured at depths of 100, 250, 500, 1000, 1500, and 1700 feet.

Fig. 27.—F. H. E. Oil Co., Bryant No. 1, Grayson County. Abandoned; no gas; fluid at 210 feet; casing 6⅝ inches to 1450 feet; idle two days after drilling ceased; standard rig. Temperatures measured at depths of 100, 250, 500, 750, 1000, and 1450 feet.

Fig. 28.—Sherman city water well, Woodbine No. 5, Grayson County. Abandoned temporarily; no gas, fluid at 500 feet; casing 6⅝ inches; idle several years. Temperatures measured at depths of 100, 250, 500, and 730 feet.

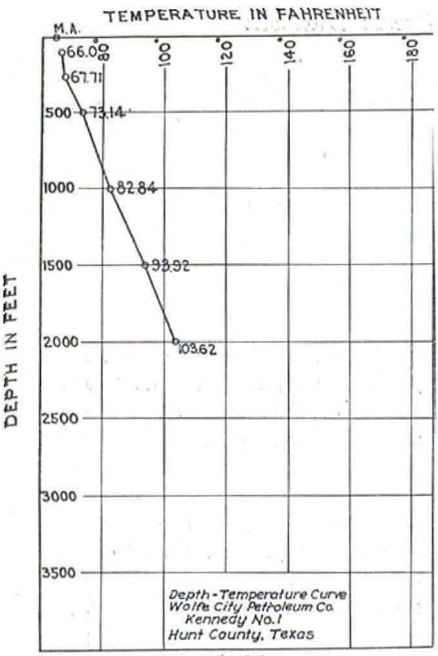


Fig. 25

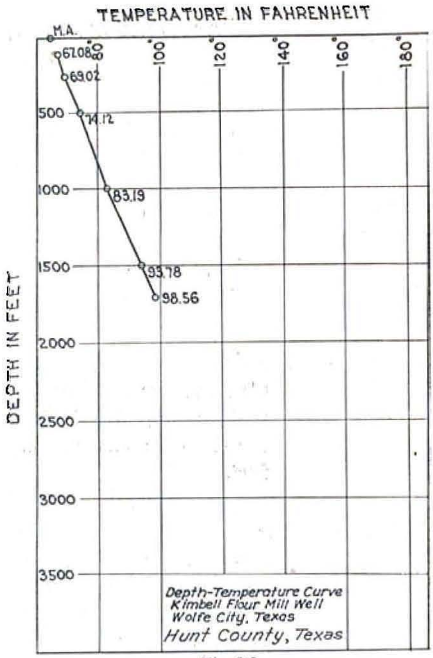


Fig. 26

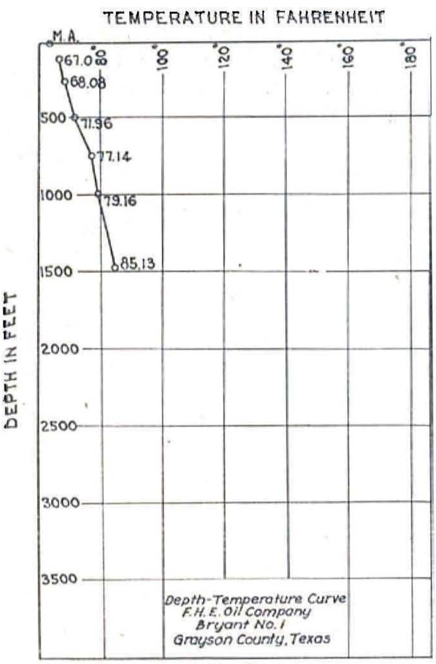


Fig. 27

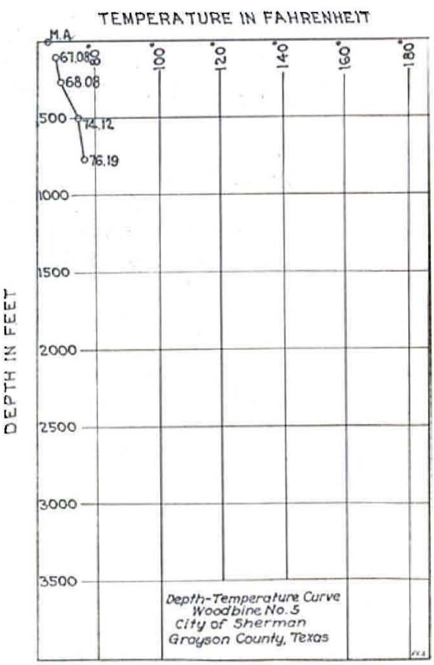


Fig. 28

Fig. 29.—Pure Oil Co., Joe Ross No. 4, Mexia oil field, Limestone County. Producing oil on pump; no gas; fluid at 300 feet; casing 5⅝ inches to 2933 feet; idle one day. Temperatures measured at depths of 1000, 2000, and 3000 feet.

Fig. 30.—Pure Oil Co., B. H. Speer No. 2, Mexia oil field, Limestone County. Producing oil on pump; no gas; fluid at 3000 feet; casing 6⅝ inches to 3084 feet; idle two days. Temperatures measured at depths of 100, 500, 1000, 1500, 2000, 2500, and 3000 feet.

Fig. 31.—Pure Oil Co., H. Bluitt No. 2, Mexia oil field, Limestone County. Producing oil and water on pump; no gas; fluid at 170 feet; casing 6⅝ inches to 2900 feet; idle several days. Temperatures measured at depths of 100, 500, 1000, 1500, 2000, 2500, and 2800 feet.

Fig. 32.—Greenville city water well, Hunt County. Abandoned; little gas; fluid at surface; casing 6⅝ innches to 1750 feet; idle several years. Temperatures measured at depths of 100, 500, 1000, 1500, and 1750 feet.

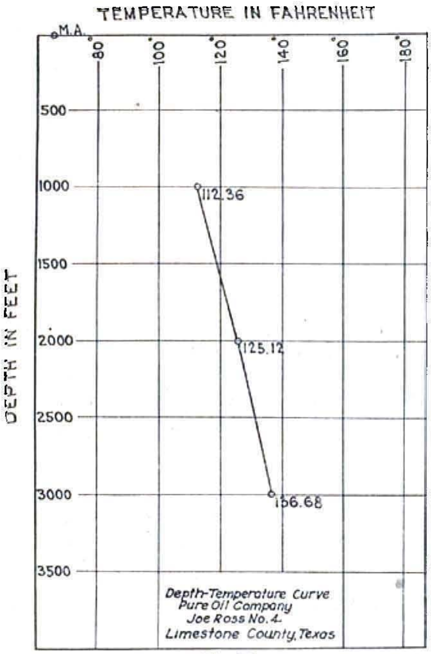


Fig. 29

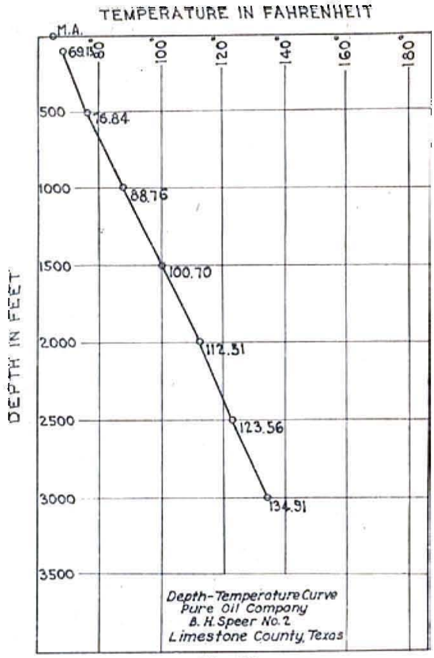


Fig. 30

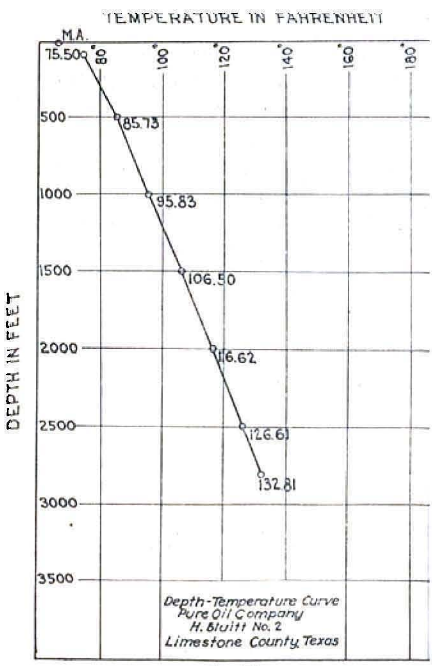


Fig. 31

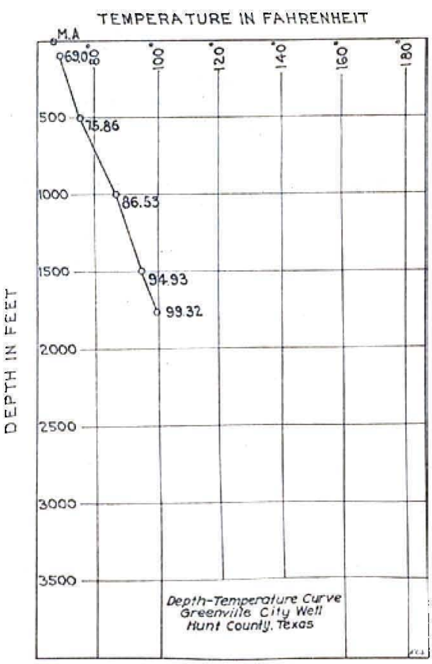


Fig. 32

Fig. 33.—Moss & Urschel, Lyles No. 1, Mexia oil field, Limestone County. Abandoned; no gas; fluid at 700 feet; casing 6⅝ inches to 3020 feet; idle several months. Temperatures measured at depths of 100, 500, 1000, 1500, 2000, 2500, and 3000 feet.

Fig. 34.—Magnolia Pet. Co., J. L. Thompson No. 8-A, Mexia oil field, Limestone County. Abandoned temporarily; no gas; fiuid at 260 feet; casing 6⅝ inches to 2800 feet; idle one month. Temperatures measured at depths of 100, 500, 1000, 1500, 2000, 2500, and 2900 feet.

Fig. 35.—Moss & Urschel, Rosson No. 4, Nigger Creek oil field, Limestone County. Abandoned; no gas; fluid at 7 feet; casing 6⅝ inches to 3025 feet; idle one and one-half years; located on down-throw side of fault. Temperatures measured at depths of 100, 500, 1000, 1500, 2000, 2500, and 3000 feet.

Fig. 36.—Pure Oil Co., W. D. Pittman No. 2, Mexia oil field, Limestone County. Abandoned; no gas; fluid at 2000 feet; casing 8¼ inches ot 2991 feet; idle five months. Temperatures measured by E. M. Hawtof at depths of 100, 500, 750, 1000, 1250, 2000, and 3000 feet.

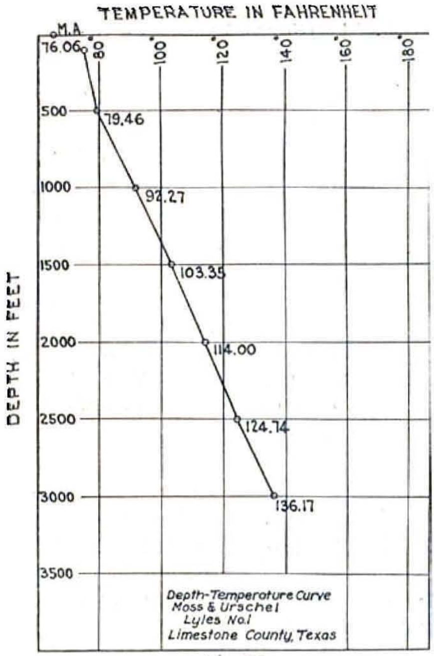


Fig. 33

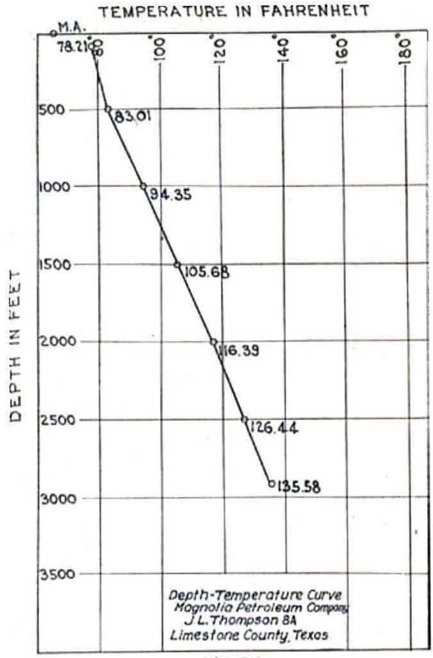


Fig. 34

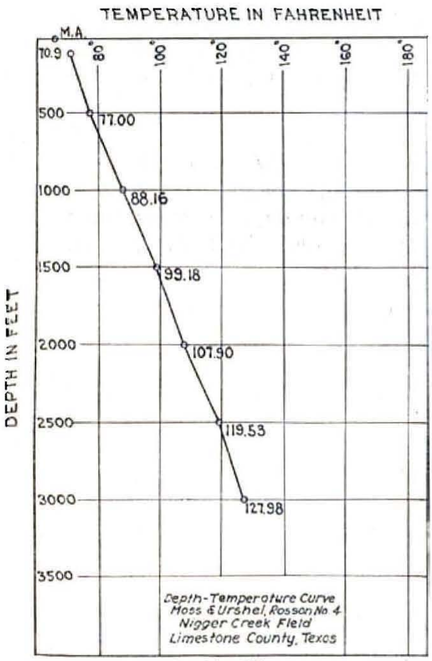


Fig. 35

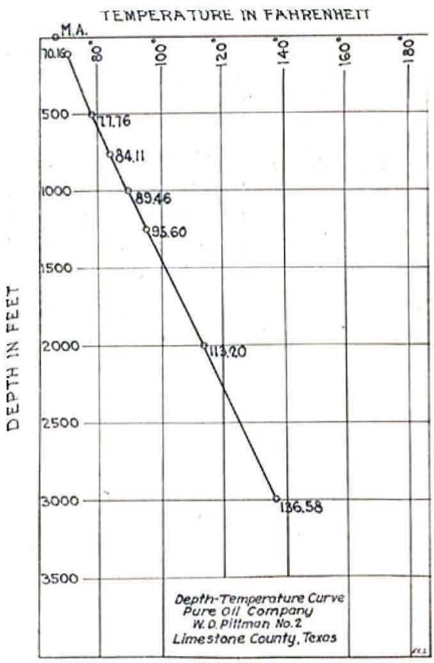


Fig. 36

Fig. 37.—Magnolia Pet. Co., I. T. Kent No. 7, Powell oil fied, Navarro County. Abandoned temporarily, no gas; fluid at 2550 feet; casing 6⅝ inches; idle two months. Temperatures measured at depths of 100, 250, 500, 750, 1000, 1500, 2000, 2500, 2700, and 2880 feet.

Fig. 38.—Humble Oil & Refining Co., W. J. McKie No. C-4, Powell oil field, Navarro County. Pumping well; no gas; fluid at 1968 feet; casing 6⅝ inches; idle two days. Temperatures measured at depths of 100, 250, 500, 750, 1000, 1500, 2000, 2500, 2700, and 2950 feet.

Fig. 39.—Simms Oil Co., Will Calame No. 3, Wortham oil field, Freestone County. Abandoned temporarily; no gas; fluid at 350 feet; casing 6⅝ inches; idle one month. Temperatures measured at 100, 500, 1000, 1500, 2000, and 2800 feet.

Fig. 40.—Magnolia Pet. Co., N. B. Boyd No. 10, Wortham oil field; Freestone County. Producing on pump; no gas; fluid at 500 feet; casing 6⅝ inches; idle two days. Temperatures measured at depths of 100, 500, 1000, 1500, 2000, 2500, and 2900 feet.

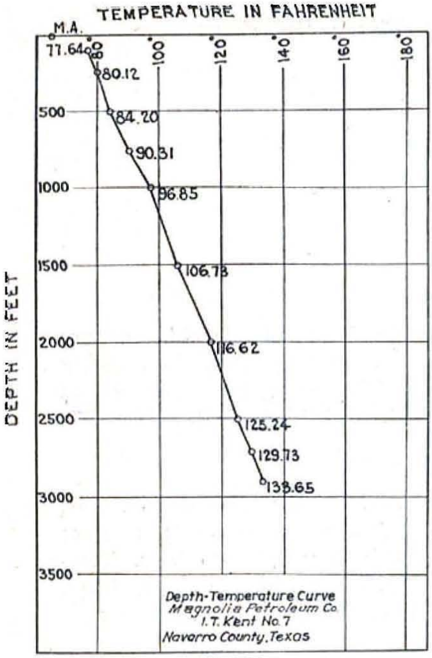
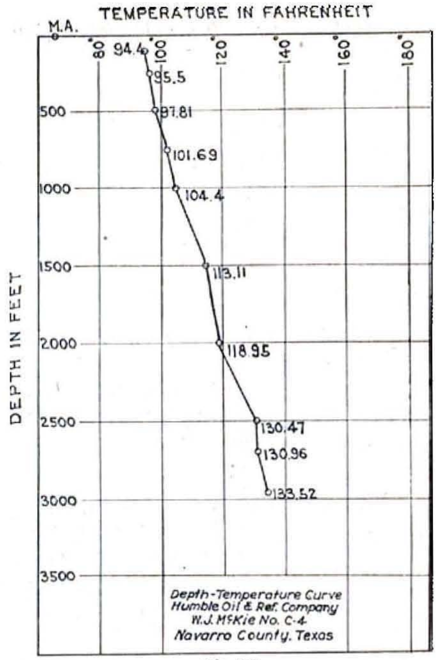


Fig. 37



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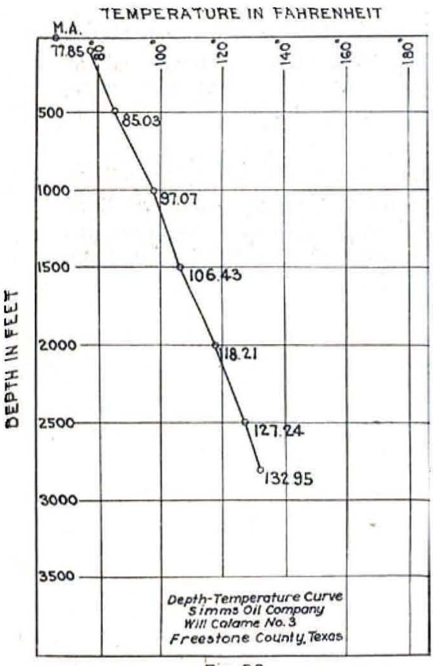

Fig. 39

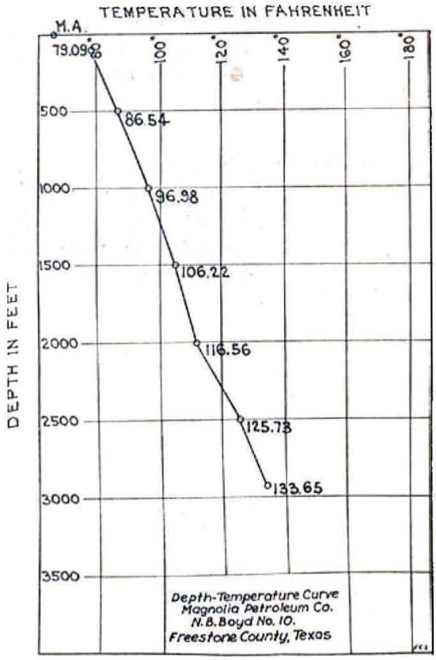

Fig. 40

Fig. 41.—Pure Oil Co., W. J. McKie No. 7, Powell oil field, Navarro County. Pumping; little gas; fluid at 2400 feet, casing 8 inches; idle two days. Temperatures measured at depths of 100, 250, 500, 750, 1000, 1500, 2000, 2500, 2700, 2885 feet.

Fig. 42.—Humble Oil & Refining Co., J. K. Hughes-Hill No. A-1, Powell oil field, Navarro County. Abandoned; no gas; fluid at 2500 feet; casing 8 inches; idle two days. Temperatures measured at depths of 100, 250, 500, 1000, 1500, 2000, 2380, 2500, 2550, 2650, 2750, and 2870 feet.

Fig. 43.—Humble Oil & Refining Co., J. W. Pugh No. 6, Powell oil field, Navarro County. Abandoned; fluid at 2523 feeet; casing 6⅝ inches; had been on 175 pounds air pressure two days before testing. Temperatures measured at depths of 100, 250, 500, 750, 1000, 1500, 2000, 2500, 2700, and 2890 feet.

Fig. 44.—Humble Oil & Refining Co., J. W. Pugh No. 2, Powell oil field, Navarro County. Pumping; no gas; fluid at 2385 feet; casing 6⅝ inches; idle two days. Temperatures measured at depths of 100, 250, 500, 750, 1000, 1250, 1500, 2000, 2500, 2700, and 2940 feet.

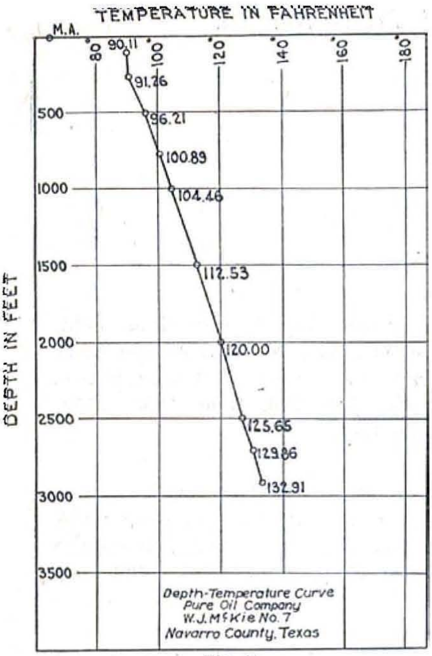

Fig. 41

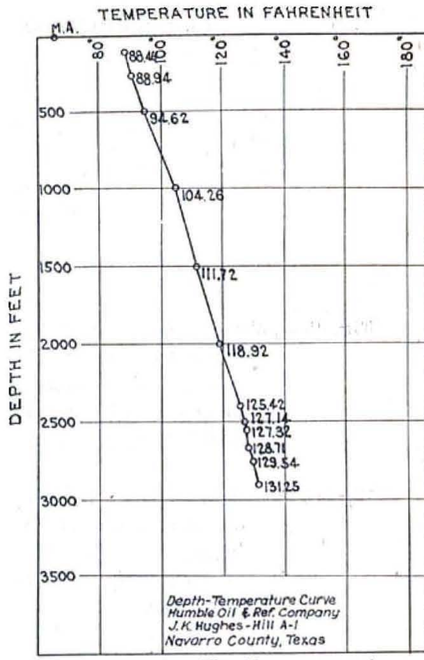

Fig. 42

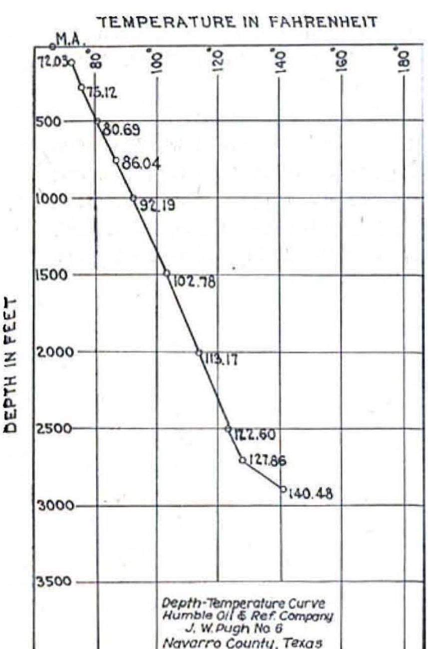

Fig. 43

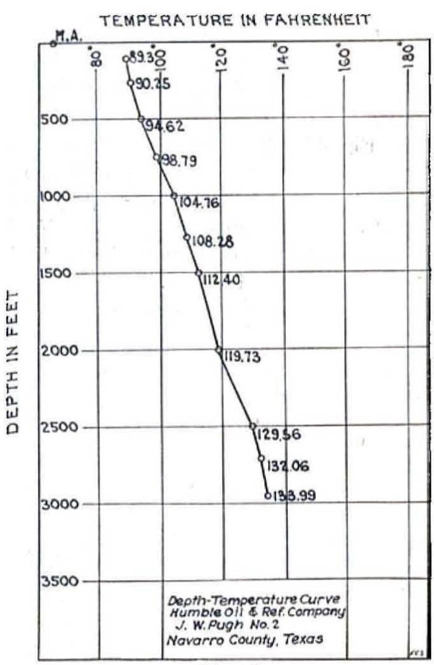

Fig. 44

Fig. 45.—Witherspoon Oil Co., J. O. Burke No. 1, Powell oil field, Navarro County. Abandoned; no gas; fluid at 700 feet; casing 6⅝ inches; idle two years. Temperatures measured at depths of 250, 500, 750, 1000, 1250, 1500, 1750, 2000, 2500, and 2750 feet.

Fig. 46.—Humble Oil & Refining Co., Hughes-Hill No. C-1, Powell oil field, Navarro County. Pumping; no gas; casing 6⅝ inches; idle two days. Temperatures measured at depths of 100, 250, 500, 750, 1000, 1500, 2000, 2500, 2700, and 2880 feet.

Fig. 47.—Humble Oil & Refining Co., W. J. McKie No. B-3, Powell oil field, Navarro County. Pumping; no gas; casing 6⅝ inches; idle eight days. Temperatures measured at depths of 100, 250, 500, 750, 1000, 1500, 2000, 2500, 2700, and 2900 feet.

Fig. 48.—Sun Oil Co., G. H. Kent No. 2, Powell oil field, Navarro County. Abandoned; no gas; fluid at 300 feet; casing 6⅝ inches to 2814 feet; idle over one year. Temperatures measured by E. M. Hawtoff at depths of 100, 250, 500, 750, 1000, 1250, 1500, 1750, 2000, 2250, 2500, and 2710 feet.

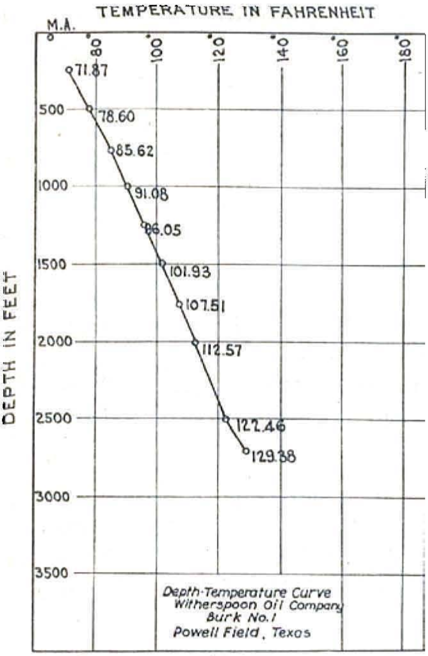

Fig 45

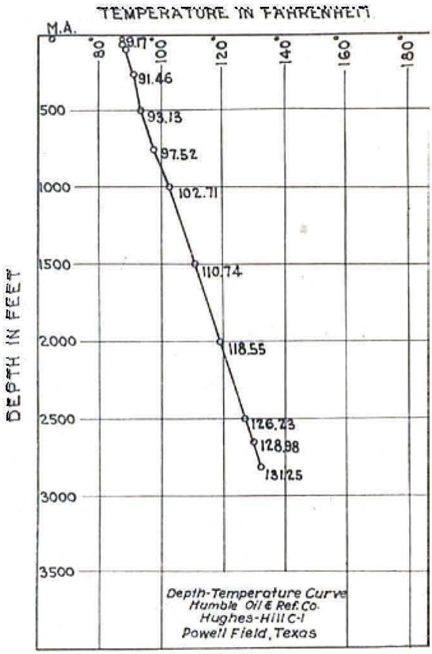

Fig 46

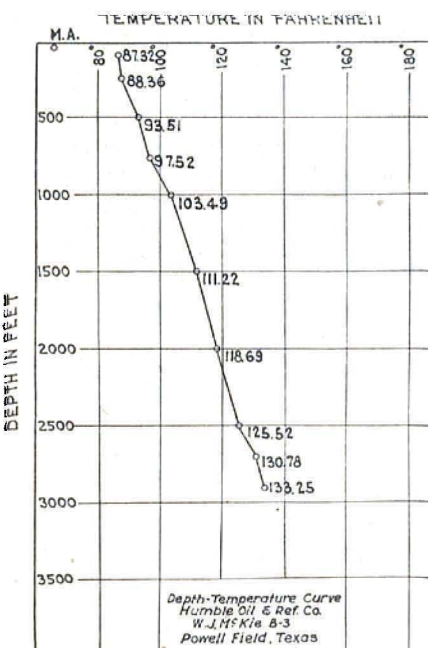

Fig 47

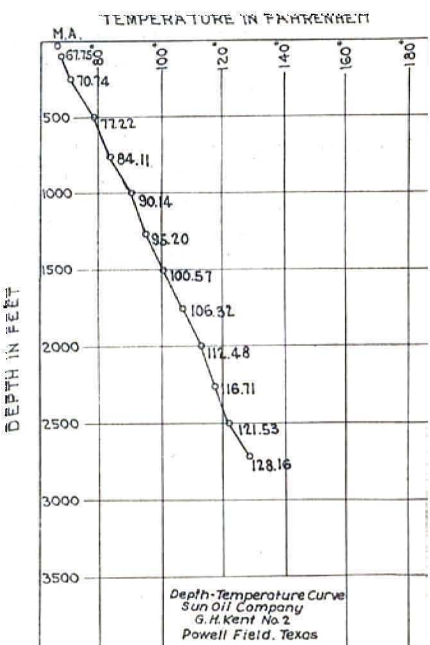

Fig 48

Fig. 49—Humble Oil & Refining Co., J. W. Pugh No. 8, Powell oil field, Navarro County. Pumping; little gas; fluid at 2400 feet; casing 6⅝ inches; idle two days. Temperatures measured at depths of 100, 1000, 2000, and 3000 feet.

Fig. 50.—Humble Oil & Refining Co., G. C. Kent No. 9, Powell oil field, Navarro County. Pumping; no gas; fluid at 2500 feet; casing 8 inches; idle two days. Temperatures measured at depths of 100, 250, 500, 1000, 1400, 1500, 2000, 2500, 2750, and 2880 feet.

Fig. 51.—Humble Oil & Refining Co., W. C. Humphries No. 20, Powell oil field, Navarro County. Pumping; no gas; fluid at 2465 feet; casing 6⅝ inches; idle two days. Temperatures measured at depths of 100, 250, 500, 750, 1000, 1500, 2000, 2500, 2700, and 2925 feet.

Fig. 52.—Humble Oil & Refining Co., J. W. Pugh No. 5, Powell oil field, Navarro County. Pumping; no gas; fluid at 2382 feet; casing 6⅝ inches; idle six days. Temperatures measured at depths of 100, 250, 500, 750, 1000, 1500, 2000, 2500, 2700, and 2900 feet.

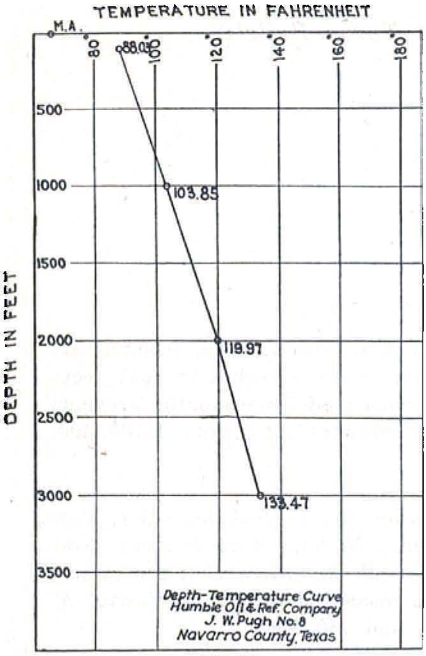

Fig. 49

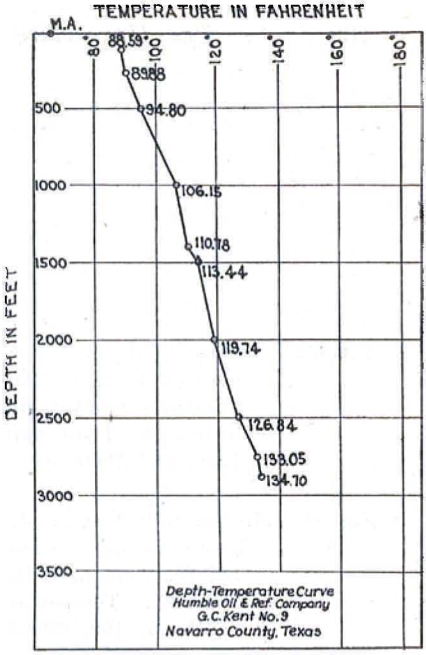

Fig. 50

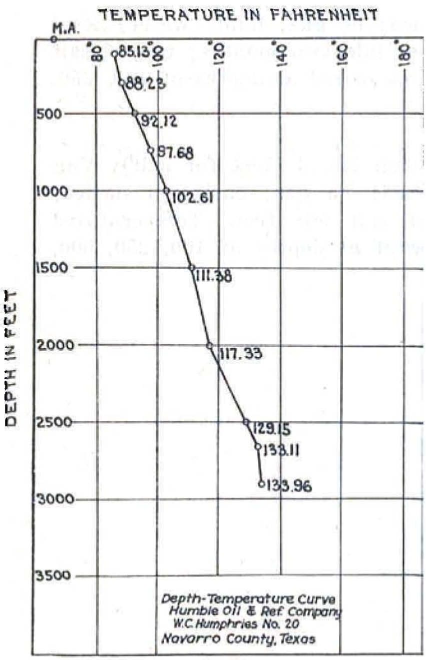

Fig 51

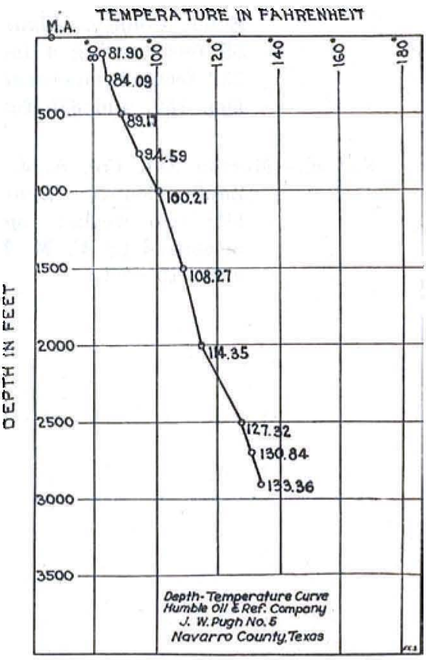

Fig. 52

Fig. 53.—Amerada Oil Co., Wade No. 1, Upshur County. Abandoned; no gas; fluid at 400 feet; casing 8 inches to 3947 feet; idle three months, filled with mud three months previous to testing. Temperatures measured at depths of 100, 400, 1000, and 1500 feet.

Fig. 54.—Morton Salt Co., A. J. Eason No. 1 (test for salt), Van Zandt County. Abandoned; no gas; fluid (water) level 165 feet; casing 3 inches; idle several weeks; top of salt 213 feet. Temperatures measured by E. M. Hawtof at depths of 100, 250, 500, and 750 feet.

Fig. 55.—Morton Salt Co., A. J. Eason No. 2 (test for salt), Van Zandt County. Abandoned; no gas; fluid (water) level 65 feet; casing 4 inches; idle two months; top of salt 232 feet. Temperatures measured at depths of 100, 250, 500, 750, and 875 feet.

Fig. 56.—Morton Salt Co., A. J. Eason No. 3 (test for salt), Van Zandt County. Abandoned; no gas; casing 3 inches; idle two weeks; top of salt 668 feet. Temperatures measured by E. M. Hawtof at depths of 100, 250, 500, and 715 feet.

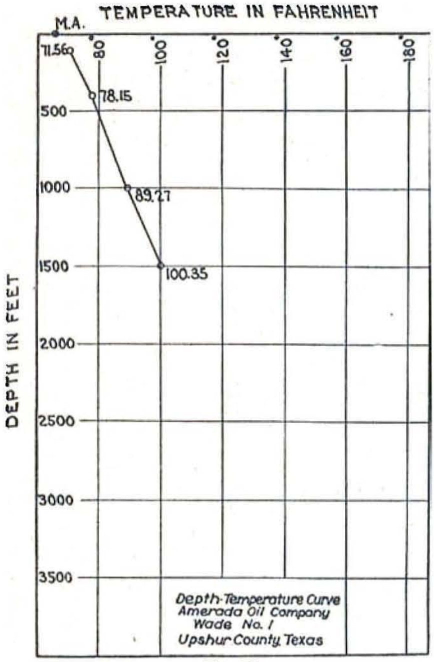

Fig. 53

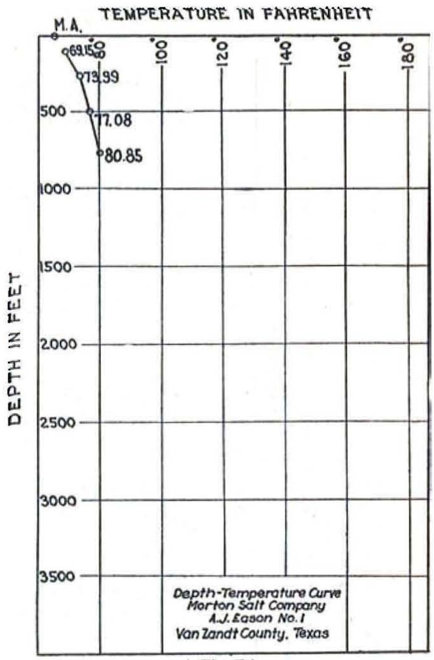

Fig. 54

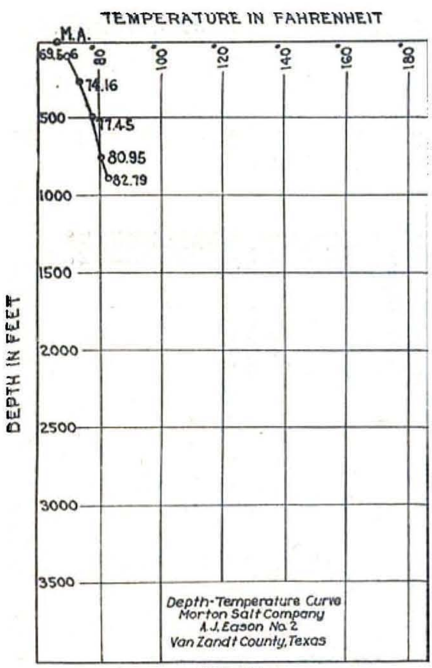

Fig. 55

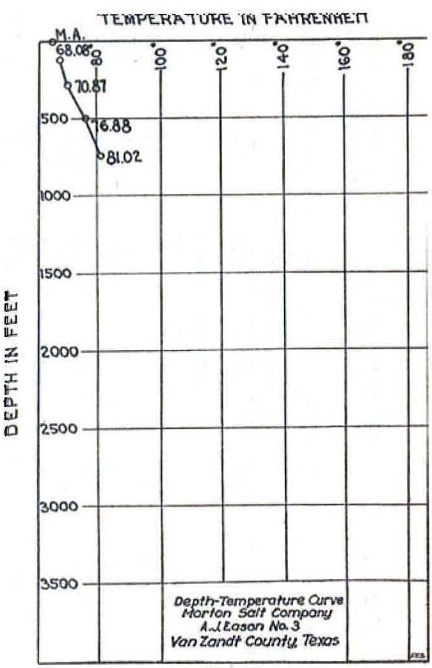

Fig. 56

TABLE 6.—*Reacting values and percentages of chemical constituents of Woodbine waters in east Texas wells.* (For names of wells indicated by sample numbers see Table 7.)

NOTE.—A blank space in the columns signifies no determination; 0.00 signifies the constituent was not present in the sample.

SAMPLE NO.	REACTING VALUES						PERCENTAGES					
	Ca	Mg	Na	HCO_3	SO_4	Cl	Ca	Mg	Na	HCO_3	SO_4	Cl
			Anderson County									
93	189.5	43.4	1398.0	3.80	5.14	1610.0	5.83	1.34	42.83	0.12	0.16	49.72
165	158.0	41.4	1700.0	4.33	5.95	1878.0	4.17	1.09	44.74	0.11	0.16	49.73
201	395.0	48.9	2738.0	2.18	6.14	3150.0	6.22	0.77	43.01	0.03	0.10	49.87
202	165.0	36.7	1540.0	6.43	5.80	1720.0	4.75	1.05	44.20	0.19	0.17	49.64
203	178.8	34.0	1590.0	6.75	6.24	1773.0	4.95	0.95	44.10	0.19	0.17	49.64
204	162.8	33.4	1566.0	4.36	6.32	1740.0	4.62	0.95	44.43	0.12	0.18	49.70
205	167.0	39.4	1554.0	3.71	5.80	1735.0	4.76	1.12	44.12	0.11	0.16	49.73
206	171.2	39.4	1535.0	5.23	6.08	1722.0	4.92	1.13	43.95	0.15	0.17	49.68
			Cherokee County									
163	174.6	45.3	1721.0	5.47	6.30	1920.0	4.51	1.14	44.35	0.14	0.16	49.70
164	154.5	38.8	1518.0	5.80	5.80	1685.0	4.54	1.14	44.32	0.17	0.17	49.66
166	187.6	43.3	1702.0	4.43	5.33	1910.0	4.86	1.12	44.02	0.11	0.14	49.75
200	168.5	30.6	1490.0	6.55	7.64	1660.0	5.02	0.91	44.07	0.20	0.23	49.57
			Collin County									
63	------	------	------	13.58	------	36.0	------	------	------	------	------	------
64	0.22	4.03	43.9	13.80	3.24	30.9	0.23	4.20	45.57	14.40	3.38	32.22
65	------	------	------	13.14	------	3.4	------	------	------	------	------	------
66	------	------	------	6.14	------	1.0	------	------	------	------	------	------
89	------	------	------	6.15	------	1.6	------	------	------	------	------	------
90	------	------	------	10.32	------	3.6	------	------	------	------	------	------
91	0.42	2.35	30.6	14.71	8.88	9.7	0.63	3.53	45.84	21.25	13.32	15.43
			Dallas County									
14	0.48	6.21	28.7	12.99	7.70	14.65	0.68	8.81	40.51	18.40	10.90	20.70
15	------	------	------	13.20	------	14.18	------	------	------	------	------	------
16	------	------	------	12.99	------	14.65						
17	------	------	------	12.89	------	11.22	------	------	------	------	------	------
18	------	------	------	12.89	------	4.06	------	------	------	------	------	------
19	------	------	------	12.65	------	7.65	------	------	------	------	------	------
20	------	------	------	11.67	------	4.74	------	------	------	------	------	------
21	------	------	------	11.22	------	2.16	------	------	------	------	------	------
22	------	------	------	10.10	------	1.63	------	------	------	------	------	------
23	------	------	------	8.57	------	0.81	------	------	------	------	------	------
24	------	------	------	12.90	------	5.55	------	------	------	------	------	------

25	------	------	------	13.08	------	5.55	------	------	------	------	------	------
26	------	------	------	10.61	------	3.08	------	------	------	------	------	------
27	------	------	------	10.22	------	2.88	------	------	------	------	------	------
28	------	------	------	13.30	------	15.60	------	------	------	------	------	------
29	0.50	7.63	35.82	14.45	9.75	18.75	0.58	8.90	40.52	16.85	11.35	21.80
30	------	------	------	9.94	------	0.78	------	------	------	------	------	------
31	0.28	4.87	21.5	11.87	9.06	5.66	0.53	9.15	40.32	22.30	17.00	10.70
32	0.34	------	25.37	9.85	11.93	3.93	0.66	------	49.34	19.10	23.00	7.90
33	------	------	------	8.05	------	1.91	------	------	------	------	------	------
34	------	------	------	10.18	------	5.16	------	------	------	------	------	------
35	------	------	------	9.12	------	4.10	------	------	------	------	------	------
36	------	------	------	9.73	------	5.33	------	------	------	------	------	------
108	0.79	1.03	24.40	16.15	3.82	6.25	1.51	1.96	46.53	30.80	7.28	11.92
145	0.55	0.24	40.50	16.42	8.00	16.80	0.68	0.29	49.03	19.90	9.70	20.40
147	0.20	0.08	30.00	9.95	14.30	6.00	0.33	0.13	49.54	16.60	23.60	9.80
148	0.30	0.08	25.40	9.55	12.80	3.61	0.58	0.15	49.27	18.42	24.80	6.78
149	0.20	0.08	34.15	14.72	7.10	12.80	0.29	0.12	49.59	21.35	10.10	18.55
150	0.70	0.66	26.90	14.82	8.65	4.80	1.17	1.17	47.66	26.12	15.28	8.60
151	0.80	0.74	19.40	13.95	4.38	2.60	1.77	1.77	46.46	33.40	10.50	6.10
			Denton County									
1	5.95	10.78	28.50	16.90	8.55	19.78	6.58	11.90	31.50	18.70	9.45	21.85
2	0.41	1.19	6.96	6.26	1.58	0.82	2.36	6.84	40.20	36.20	9.07	4.73
3	5.64	3.94	18.50	11.45	7.97	8.70	10.00	7.00	33.00	20.40	14.20	15.40
4	4.00	1.04	1.37	5.00	0.60	0.82	31.30	8.05	10.65	38.90	4.65	6.45
6	0.11	1.31	6.70	6.70	0.77	0.65	0.61	8.06	41.34	41.34	4.74	3.92
7	0.38	0.80	9.11	6.74	2.73	0.82	1.85	3.85	44.30	32.77	13.25	3.98
			Ellis County									
42	------	------	------	17.50	------	11.45	------	------	------	------	------	------
44	------	------	------	12.30	------	4.92	------	------	------	------	------	------
45	------	------	------	17.10	------	32.80	------	------	------	------	------	------
46	0.60	6.14	18.65	9.20	2.27	13.92	1.18	12.08	36.74	18.10	4.47	27.43
47	------	------	------	15.90	------	27.90	------	------	------	------	------	------
48	------	------	------	15.38	------	14.75	------	------	------	------	------	------
49	0.26	6.04	19.75	12.30	7.16	6.55	0.50	11.58	37.92	23.65	13.75	12.60
52	------	------	------	8.88	------	15.20	------	------	------	------	------	------
53	0.48	6.91	23.40	8.88	16.17	5.74	0.78	11.22	38.00	14.38	26.30	9.32
55	0.58	7.68	14.20	8.36	10.70	3.28	1.12	17.08	31.80	18.70	23.95	7.35
128	0.15	10.08	17.75	15.90	6.05	6.00	0.27	18.00	31.73	28.50	10.80	10.70
129	0.35	0.16	28.80	15.90	6.96	6.40	0.60	0.27	49.13	27.20	11.88	10.92
130	0.90	0.57	20.25	11.35	7.95	2.20	2.08	1.12	46.80	26.30	18.60	5.10
131	0.90	0.57	24.80	9.60	14.21	2.51	1.72	1.08	48.20	18.25	27.05	4.70
132	1.00	0.66	19.75	9.60	9.58	2.26	2.34	1.46	46.20	22.40	22.40	5.20
133	1.80	1.48	36.30	12.20	21.22	6.08	2.28	1.87	45.85	15.40	26.90	7.70
134	0.90	0.66	26.00	12.20	12.10	3.03	1.64	1.90	46.46	22.25	22.10	5.65
135	0.90	0.41	39.80	14.85	11.38	14.88	1.09	0.50	48.41	18.10	13.85	18.05
136	0.50	0.16	29.80	14.85	11.65	3.96	0.82	0.26	48.92	24.40	19.15	6.45

TABLE 6.—*Reacting values and percentages of chemical constituents of Woodbine waters in east Texas wells.*—(Continued.)

SAMPLE NO.	REACTING VALUES						PERCENTAGES					
	Ca	Mg	Na	HCO_3	SO_4	Cl	Ca	Mg	Na	HCO_3	SO_4	Cl
			Ellis County—Concluded									
137	0.70	0.25	34.14	16.50	12.65	5.94	0.98	0.35	48.67	23.60	18.05	8.35
138	1.05	0.88	43.77	15.70	15.32	14.68	1.14	0.96	37.90	17.20	16.80	16.00
144	0.15	0.08	24.58	12.70	7.80	4.40	0.30	0.20	49.50	25.55	15.60	8.85
			Fannin County									
72	------	------	------	7.70	------	1.97	------	------	------	------	------	------
73	------	------	------	10.98	------	20.20	------	------	------	------	------	------
75	------	------	------	14.26	------	29.05	------	------	------	------	------	------
76	0.16	3.94	11.68	8.75	4.57	2.46	0.51	12.49	37.00	27.75	14.45	7.80
77	------	------	------	8.32	------	2.46	------	------	------	------	------	------
			Freestone County									
162	7.18	0.0	248.2	5.98	2.40	247.0	1.45	0.00	48.55	1.20	0.47	48.33
209	13.6	8.5	366.8	10.20	0.17	379.5	1.7	1.1	47.10	1.3	0.02	48.8
210	12.0	6.5	356.6	8.52	------	369.0	1.6	0.9	47.38	1.1	------	49.0
211	12.4	7.4	351.0	9.30	0.17	363.6	1.7	1.0	47.21	1.2	0.02	48.9
212	11.0	7.2	355.2	7.70	0.25	367.6	1.5	1.0	47.44	1.0	0.03	49.1
213	12.0	7.0	323.8	7.95	0.21	335.8	1.7	1.0	47.18	1.2	0.03	48.9
215	12.6	7.0	345.0	9.42	------	357.5	1.7	1.0	47.20	1.3	------	48.8
216	14.4	8.5	382.0	8.51	------	400.0	1.8	1.0	47.00	1.0	------	49.2
217	13.2	7.4	359.8	9.10	------	374.0	1.7	1.0	47.15	1.2	------	48.9
218	12.9	6.9	351.4	9.60	------	364.0	1.7	0.9	47.20	1.3	------	48.9
219	11.1	6.8	356.0	7.81	------	368.0	1.5	0.9	47.55	1.0	------	49.0
220	12.0	6.8	375.0	9.01	------	384.0	1.5	0.9	47.65	1.1	------	48.8
221	11.8	6.9	355.5	8.41	0.21	368.0	1.6	0.9	47.36	1.1	0.03	48.7
222	13.1	6.9	318.6	9.70	------	344.0	1.9	1.0	46.08	1.4	------	49.7
223	15.0	8.8	349.0	8.51	------	382.0	2.0	1.2	47.38	1.1	------	48.3
224	12.3	7.5	357.0	9.10	0.17	368.0	1.6	1.0	47.38	1.2	0.02	48.8
225	12.0	7.0	354.5	9.60	0.19	364.0	1.6	0.9	47.40	1.3	0.02	48.8
226	11.1	6.7	348.4	8.00	0.17	358.0	1.5	0.9	47.60	1.1	0.02	48.9
227	11.7	7.1	348.5	9.30	0.23	358.0	1.6	1.0	47.48	1.3	0.03	48.6
228	11.9	7.0	346.5	9.30	0.23	356.0	1.6	1.0	47.42	1.3	0.03	48.7
229	11.9	7.8	364.0	7.89	0.21	376.0	1.5	1.0	47.40	1.0	0.03	49.1
			Grayson County									
5	0.85	0.80	2.25	2.82	0.60	0.48	10.90	10.30	28.80	36.20	7.70	6.10
59	------	------	------	3.40	------	0.65	------	------	------	------	------	------
60	0.14	3.74	3.78	5.58	1.42	0.66	1.00	24.40	24.60	36.40	9.25	4.35

61	——	——	——	12.28	——	1.15	——	——	——	——	——	——
62	——	——	——	9.95	——	9.50	——	——	——	——	——	——
67	——	——	——	11.85	——	0.65	——	——	——	——	——	——
68	——	——	——	9.10	——	8.52	——	——	——	——	——	——
69	0.16	5.32	7.45	8.24	2.66	2.03	0.62	20.60	28.78	31.85	10.60	7.55
			Henderson County									
152	165.52	33.40	490.00	117.42	177.50	394.00	12.00	2.42	35.58	8.53	12.90	28.57
			Hill County									
83	——	——	——	12.70	——	13.95	——	——	——	——	——	——
84	——	——	——	10.98	——	6.63	——	——	——	——	——	——
85	——	——	——	7.00	——	3.61	——	——	——	——	——	——
86	——	——	——	6.56	——	1.15	——	——	——	——	——	——
139	0.95	0.58	14.55	10.50	4.28	1.30	2.80	1.90	45.30	32.65	13.30	4.05
140	0.90	0.66	25.30	9.50	12.68	4.68	1.68	1.22	47.10	17.70	23.60	8.70
141	1.30	0.86	31.00	10.48	15.70	6.98	1.90	1.30	46.80	15.80	23.70	10.50
142	1.30	1.15	48.00	16.60	12.12	21.73	1.30	1.14	47.56	16.50	12.00	21.50
143	0.85	0.49	26.39	10.50	10.85	6.38	1.50	0.88	47.62	18.95	19.70	11.35
			Hopkins County									
155	42.80	13.60	806.24	4.60	0.04	860.00	2.48	0.78	46.75	0.27	——	49.73
156	45.00	18.30	845.00	4.56	0.74	903.00	2.48	1.00	46.52	0.25	0.04	49.71
			Hunt County									
74	——	——	——	11.22	——	50.50	——	——	——	——	——	——
88	24.00	8.55	460.00	2.85	27.70	462.00	2.44	0.87	46.69	0.29	2.78	46.93
			Johnson County									
87	——	——	——	6.36	——	0.82	——	——	——	——	——	——
			Kaufman County									
43	4.60	7.20	193.80	17.10	——	188.50	1.12	1.75	47.13	4.16	——	45.84
50	——	——	——	17.75	——	16.40	——	——	——	——	——	——
51	0.72	4.63	55.60	20.00	5.65	35.30	0.59	3.80	45.61	16.40	4.60	29.00
106	10.20	5.27	396.50	9.38	0.59	402.00	1.24	0.64	48.12	1.14	0.07	48.79
107	2.54	0.53	164.00	17.38	0.19	149.50	0.76	0.02	49.22	5.22	0.00	44.78
109	3.80	1.03	223.00	13.68	0.15	214.00	0.84	0.22	48.94	3.00	0.00	47.00
127	48.83	26.00	830.00	15.26	1.47	888.00	2.70	1.44	45.86	0.84	0.08	49.08
157	38.20	0.44	602.00	19.28	1.36	620.00	2.80	0.03	47.17	1.50	0.10	48.40
			Limestone County									
8	——	——	——	6.36	——	652.00	——	——	——	——	——	——
9	——	——	——	6.56	——	538.00	——	——	——	——	——	——
10	——	——	——	5.93	——	616.00	——	——	——	——	——	——
11	——	——	——	5.48	——	530.00	——	——	——	——	——	——
12	——	——	——	5.93	——	530.00	——	——	——	——	——	——
13	32.40	8.96	504.00	5.71	1.65	537.00	2.96	0.82	46.22	0.52	0.15	49.33
117	10.90	4.36	176.50	3.00	1.50	187.26	2.84	0.96	46.20	0.78	0.39	48.83

TABLE 6.—*Reacting values and percentages of chemical constituents of Woodbine waters in east Texas wells.*—(Concluded)

SAMPLE NO.	REACTING VALUES						PERCENTAGES					
	Ca	Mg	Na	HCO_3	SO_4	Cl	Ca	Mg	Na	HCO_3	SO_4	Cl
			Limestone County—Concluded									
120	26.38	15.20	477.00	6.26	0.82	511.50	2.54	1.46	46.00	0.60	0.08	49.32
121	27.10	13.90	496.00	5.32	0.50	531.18	2.52	1.29	46.19	0.49	0.05	49.46
122	28.60	15.95	495.00	10.60	0.95	528.00	2.64	1.48	45.88	0.91	0.09	49.00
123	42.20	16.82	647.78	4.80	4.00	700.00	2.96	1.19	45.85	0.34	0.28	49.38
153	38.40	20.00	491.35	2.72	1.03	546.00	3.50	1.82	44.68	0.25	0.09	49.66
161	24.60	13.30	478.97	4.87	------	512.00	2.38	1.28	46.34	0.55	0.00	49.45
167	26.32	13.30	456.13	5.75	------	490.00	2.65	1.34	46.01	0.58	0.00	49.42
168	65.60	12.00	395.56	5.26	------	468.00	6.94	1.27	41.79	0.56	0.00	49.44
169	24.15	11.90	511.06	5.16	------	542.00	2.21	1.09	46.70	0.47	0.00	49.53
170	4.85	12.40	485.00	7.35	------	494.90	0.48	1.23	48.29	0.73	0.00	49.27
171	22.20	12.25	434.30	5.75	------	464.00	2.37	1.31	46.32	0.61	0.00	49.39
208	15.50	8.30	388.20	6.91	0.48	435.00	1.80	1.00	45.40	0.80	0.10	50.90
			Navarro County									
79	1.02	2.66	89.27	15.95	------	77.00	0.55	1.43	48.02	8.60	0.00	41.40
80	------	------	------	18.42	------	12.60	------	------	------	------	------	------
81	------	------	------	17.92	------	19.35	------	------	------	------	------	------
82	------	------	------	13.40	------	4.24	------	------	------	------	------	------
94	4.40	2.87	208.33	17.40	0.20	198.00	1.02	0.66	48.32	4.03	0.00	45.97
95	7.38	4.68	281.12	25.18	------	270.00	1.25	0.79	47.96	4.26	0.00	45.74
96	3.00	1.97	181.00	18.28	------	167.69	0.81	0.53	48.66	4.92	0.00	45.08
97	3.70	2.46	200.92	18.00	3.08	186.00	0.89	0.59	48.52	4.35	0.75	44.90
98	3.50	2.87	185.31	29.72	0.46	161.50	0.91	0.75	48.34	7.75	0.00	42.25
99	4.00	4.60	279.57	18.00	0.17	270.00	0.69	0.80	48.51	3.12	0.00	46.88
100	2.70	4.76	159.50	22.00	------	144.96	0.81	1.42	47.77	6.60	0.00	43.40
101	7.20	5.42	308.68	15.30	------	306.00	1.12	0.84	48.04	2.38	0.00	47.62
102	10.85	6.82	366.53	8.20	------	376.00	1.41	0.89	47.70	1.08	0.00	48.92
103	3.35	2.79	190.81	15.76	1.19	180.00	0.85	0.71	48.44	4.00	0 30	45.70
104	1.10	0.75	92.50	22.80	------	69.92	0.59	0.04	49.37	12.86	0.00	37.14
105	12.70	7.70	424.35	10.66	0.09	434.00	1.43	0.86	47.71	1.20	0.00	48.80
110	9.64	3.36	284.31	6.80	0.51	290.00	1.62	0.56	47.84	1.14	0.09	48.77
111	14.90	6.26	291.00	8.00	0.14	304.02	2.39	1.00	46.61	1.28	0.02	48.70
112	11.10	5.74	309.00	9.30	0.54	316.00	1.70	0.88	47.42	1.43	0.08	48.49
118	6.40	5.88	227.72	10.90	0.60	228.50	1.33	1.22	47.45	2.27	0.01	47.72
119	10.20	6.68	334.00	6.63	0.15	344.00	1.44	0.95	47.61	0.94	0.00	49.06
124	6.55	3.58	255.51	11.30	0.34	254.00	1.23	0.67	48.10	2.13	0.06	47.81
125	9.08	6.35	267.43	10.50	0.36	272.00	1.61	1.12	47.27	1.86	0.06	48.08
126	9.80	6.10	322.00	8.00	0.49	329.35	1.45	0.90	47.65	1.19	0.07	48.74
158	12.80	6.48	378.12	7.40	------	390.00	1.62	0.82	47.56	0.93	0.00	49.07

159	10.20	4.60	204.00	9.80	—	209.00	2.34	1.05	46.61	2.24	0.00	47.76
160	11.00	5.34	217.80	10.70	0.44	223.00	2.35	1.14	46.51	2.28	0.01	47.71
172	26.90	1.48	216.36	11.52	—	231.50	5.52	0.30	44.18	2.38	0.00	47.62
173	25.22	4.03	218.50	11.15	—	235.60	5.12	0.81	44.07	2.23	0.00	47.77
174	15.45	6.48	294.88	7.05	—	308.00	2.45	1.03	46.52	1.10	0.00	48.90
175	5.55	1.81	218.00	10.52	—	214.84	1.24	0.40	48.36	2.33	0.00	47.67
176	6.45	5.00	288.00	6.93	—	292.52	1.08	0.83	48.09	1.15	0.00	48.85
230	2.6	0.8	178.3	22.90	0.58	158.6	0.7	0.2	49.10	6.3	0.16	43.5
231	5.8	1.5	233.5	5.80	—	236.0	1.2	0.3	48.40	1.2	—	48.9
232	3.1	1.8	181.8	18.70	0.94	224.8	0.7	0.4	42.15	4.3	0.22	52.2
233	16.2	3.9	233.0	2.71	0.60	260.00	3.1	0.8	45.15	0.5	0.12	50.3
234	3.4	7.2	231.2	33.05	0.17	220.0	0.7	1.5	46.68	6.7	0.03	44.4
235	6.1	4.4	218.6	19.67	0.87	209.2	1.2	0.9	47.70	4.3	0.18	45.7
236	3.4	2.0	192.0	11.00	—	186.0	0.9	0.5	48.70	2.8	—	52.9
237	2.9	1.9	161.2	23.91	—	142.0	0.9	0.6	48.60	7.2	—	42.7
238	2.7	3.5	250.0	37.75	0.17	215.8	0.5	0.5	49.05	7.4	0.03	42.5
240	2.6	3.9	253.0	11.0	—	246.0	0.5	0.8	48.90	2.0	—	48.8
241	4.0	29.9	116.2	20.32	0.24	244.0	1.0	7.2	28.00	4.9	0.10	58.8
242	3.2	4.8	241.0	39.25	—	210.0	0.6	1.0	48.40	7.9	—	42.1
243	2.6	1.5	190.6	13.91	—	181.0	0.7	0.4	49.00	3.6	—	46.3
244	6.2	162.8	178.5	15.34	0.96	331.0	0.9	23.4	25.70	2.2	0.10	47.7
245	8.0	2.9	198.5	17.34	—	191.8	1.9	0.7	47.50	4.1	—	45.8
246	3.5	2.4	200.0	12.86	0.35	173.8	0.9	0.6	51.00	3.3	0.10	44.1
247	7.9	4.7	281.8	15.11	—	270.0	1.4	0.8	48.60	2.6	—	46.6
248	4.8	4.8	219.2	18.90	—	210.0	1.0	1.0	47.90	4.1	—	46.0
249	12.0	18.3	126.0	24.22	0.37	215.8	3.0	4.6	31.80	6.1	0.10	54.4
250	—	3.7	149.3	18.48	0.60	139.8	—	1.2	47.9	5.9	0.20	44.8
251	2.7	4.8	159.5	22.00	—	142.0	0.8	1.4	48.2	6.6	—	43.0
252	3.8	2.6	204.9	20.25	0.46	192.2	0.9	0.6	48.3	4.8	0.10	45.3
253	3.5	2.9	184.8	29.78	0.46	161.5	0.9	0.8	48.3	7.8	0.10	42.1
254	4.7	1.4	190.0	24.60	3.93	169.0	1.2	0.4	48.3	6.2	1.00	42.9
255	3.2	2.4	190.2	23.00	0.06	173.0	0.8	0.6	48.5	5.9	—	44.2
256	2.8	2.1	167.5	21.70	—	150.4	0.8	0.6	48.7	6.3	—	43.6
257	2.8	1.9	160.0	22.40	0.17	143.0	0.8	0.6	48.5	6.8	0.10	43.2
258	6.8	4.7	286.0	15.80	—	282.0	1.1	0.8	48.0	2.7	—	47.4
			Rusk County									
207	58.8	16.2	959.0	6.0	8.0	1020.0	2.8	0.8	46.4	0.3	0.4	49.3
			Tarrant County									
37	1.06	3.65	3.73	5.26	—	3.18	6.28	21.70	22.02	31.20	0.00	18.80
38	1.06	3.65	3.39	4.88	2.09	1.13	6.53	22.50	20.97	30.10	12.80	7.10
39	0.28	7.30	2.79	8.34	1.31	0.82	1.34	34.85	13.81	39.80	6.30	3.90
40	—	—	—	5.26	—	3.88	—	—	—	—	—	—
41	—	—	—	5.15	—	0.82	—	—	—	—	—	—
			Titus County									
154	54.80	13.12	1108.00	3.19	2.73	1170.00	2.33	0.56	47.11	0.13	0.11	49.76
			Upshur County									
92	87.30	2.90	1643.00	8.20	5.00	1720.00	2.53	0.83	46.64	0.24	0.14	49.62

TABLE 7.—*Analyses of Woodbine water in east Texas wells.*

SAMPLE NO.	WELL DATA: Well	Depth taken	Date taken	WATER ANALYSES IN PARTS PER MILLION: Ca	Mg	Na	HCO_3	SO_4	Cl	Total solids	Chemist
	Anderson County	Feet									
93	Humble O. & Rfg. Co., J. Gouger No. 1, Boggy Cr. field	3955	6-25-29	3,790	528	32,100	232	247	57,500	94,279	R. J. Brewer
165	Do So. Pine No. 2, Boggy Cr. field	4446	8- 5-27	3,160	504	39,165	264	286	67,070	106,990	W. E. Winn
201	Do W. T. Todd No. B-1, Boggy Cr. field	3603	3- 3-30	7,930	595	62,900	133	295	112,500	184,285	E. C. Sargent
202	Do Mandlestam No. 4, Boggy Cr. field	3651	3- 3-30	3,300	446	35,400	392	279	61,450	101,078	Do
203	Do T. Jones, Jr., No. 3, Boggy Cr. field	3665	3- 3-30	3,580	414	36,500	412	300	63,350	104,346	Do
204	Do L. Smith No. 1, Boggy Cr. field	3732	3- 3-30	3,260	407	36,000	266	304	62,100	102,202	Do
205	Do L. Smith No. 4, Boggy Cr. field		3- 3-30	3,350	480	35,600	226	279	61,900	101,720	Do
206	Do T. H. Jones No. A-2, Boggy Cr. field	3728	3- 3-30	3,340	480	35,300	319	292	61,500	101,158	Do
	Cherokee County										
163	Humble O. & Rfg. Co., Elliott & Clarke No. 1, Boggy Cr. field	3844	8- 6-27	3,497	552	39,558	334	303	68,359	112,870	HumbleO.&R.Co.
164	Do Earl & Ragsdale No. 2, Boggy Cr. field	4281	8- 5-27	3,091	472	34,882	354	279	60,204	91,520	Do
166	Do	4234	7-25-27	3,758	527	39,150	270	256	68,185	112,980	Do
200	Do Elliott & Clarke No. B-2	----	3- 3-30	3,370	372	34,200	399	367	59,450	97,855	E. C. Sargent
	Collin County										
*63	Melisa city water well	1450	9-14-29	----	----	----	828	----	1,285	----	Do
64	McKinney city water well. No. 2	1050	9-14-29	4	49	1,010	842	156	1,105	2,739	Do
*65	Do No. 4	1275	9-14-29	----	----	----	801	----	122	----	Do
66	Celina city water well	700	9-14-29	----	----	----	374	----	38	----	Do
*89	S. O. Scott water well, 2 mi. S. of Anna	1550	12- 4-29	----	----	----	375	----	58	----	Do
*90	Allen city water well	1350	12- 4-29	----	----	----	630	----	130	----	Do
91	Plano city water well	940	12- 4-29	8	28	704	896	427	348	1,552	Do
	Dallas County										
14	A. P. Patterson water well, Sowers	156	7-23-29	9	75	660	791	370	524	2,028	Do
15	W. D. Wood water well, Sowers	156	7-23-29	----	----	----	804	----	506	----	Do
16	L. Brown water well	180	7-23-29	----	----	----	791	----	524	----	Do
*17	H. Steward water well	245	7-23-29	----	----	----	785	----	402	----	Do
18	L. A. Yager water well	171	7-23-29	----	----	----	785	----	145	----	Do
*19	W. E. Smallwood water well	260	7-24-29	----	----	----	772	----	273	----	Do
*20	W. P. Steward water well	310	7-24-29	----	----	----	711	----	169	----	Do
21	B. Roser water well	202	7-24-29	----	----	----	684	----	75	----	Do
22	F. Gallweging water well	260	7-24-29	----	----	----	618	----	60	----	Do
*23	Grand Prairie city water well	260	7-24-29	----	----	----	523	----	29	----	Do
24	E. M. Gebert water well	220	7-26-29	----	----	----	790	----	198	----	Do

25	W. E. Lindsey water well	220	7-26-29				800		198		Do
*26	T. Haley water well	180	7-26-29				650		110		Do
*27	R. W. Harrington water well	100	7-26-29				624		102		Do
28	Carrollton city water well	322	7-26-29				810		553		Do
29	Addison city water well	695	7-26-29	10	92	800	880	469	665	2,468	Do
*30	Richardson city water well	1940	7-26-29				606		27		Do
31	Vickory city water well	600	7-26-29	5	59	494	723	436	201	1,551	Do
32	Duncanville Gin Mill water well	648	7-27-29	6	59	271	600	573	129	1,544	Do
*33	H. E. White water well	1026	7-27-29				490		67		Do
34	DeSoto city water well	873	7-27-29				620		183		Do
35	Cedar Hill city water well	617	7-27-29				556		145		Do
36	Lancaster city water well	1100	7-27-29				593		189		Do
108	Dallas city water well	650		15	12	560	483	183	222	1,232	U.S.Bur.Mines
145	Seagoville Gin water well	1650		11	3	930	1,002	384	595	2,417	Gulf Prod. Co.
147	Houston water well	890		4	1	688	606	687	213	1,891	Do
148	Farm 1 mi. N. of Hutchins, water well	1000		6	1	584	582	615	128	1,619	Do
149	Mesquite city water well	1457		4	1	785	898	341	454	2,027	Do
*150	Valley View city water well	155		14	8	618	905	417	170	1,671	Do
151	Valley View city water well	416		16	9	446	850	210	92	1,191	Do
	Denton County										
1	W. Hager water well	297	6-23-29	119	131	655	1,030	412	700	2,515	E. C. Sargent
2	J. T. Talley water well	170	8-23-29	8	14	162	382	76	29	477	Do
3	B. E. Barron water well	130	6-23-29	113	48	425	698	383	309	1,621	Do
4	G. C. Turberville water well	218	6-23-29	80	12	31	305	28	29	322	Do
6	Crescent Oak water well	325	6-24-29	2	15	154	408	37	23	433	Do
7	E. F. Whitmore water well	229	6-24-29	7	9	210	411	131	29	489	Do
	Ellis County										
*42	Ennis city water well	1800	8-13-29				1,038		406		Do
*44	Waxahachie Ice Plant water well	1080	8-14-29				750		174		Do
45	Ennis Ice Plant water well	1580	8-15-29				1,042		1,162		Do
*46	K. Ferris water well	1112	8-15-29	12	74	428	562	109	404	1,393	Do
*47	Garrett Gin Mill water well	1372	8-17-29				970		988		Do
48	Palmer city water well	1154	8-17-29				936		523		Do
49	Bridgeport Brick Co. water well	1325	8-17-29	5	73	454	750	345	323	1,527	Do
*52	Wilson water well	237	8-22-29				542		538		Do
53	B. S. Spears water well	276	8-22-29	9	84	538	542	580	203	1,680	Do
55	Midlothian city water well	675	8-22-29	10	93	326	510	515	116	1,311	Do
128	Trumbull Gin Mill water well	1300		3	1	408	970	291	213	1,393	Gulf Prod. Co.
*129	India city water well	1470		7	2	660	970	335	227	1,708	Do
130	Red Oak city water well	1460		18	7	466	692	382	78	1,269	Do
131	Farm 1 mi. W. of Mountain Peak	485		18	7	570	585	681	89	1,653	Do
132	W. K. Ward water well	307		20	8	454	585	460	80	1,310	Do
133	Cunningham water well	700		36	18	835	745	1,020	213	2,497	Do

*Water of uncertain purity due to surface seepage, imperfect casing, or other causes; results not used in interpretations or on maps.
NOTE.—A blank space in the columns signifies no determination.

TABLE 7.—*Analyses of Woodbine water in east Texas wells.*—(Continued)

SAMPLE NO.	WELL DATA			WATER ANALYSES IN PARTS PER MILLION							
	Well	Depth taken	Date taken	Ca	Mg	Na	HCO_3	SO_4	Cl	Total solids	Chemist
	Ellis County—Concluded										
*134	Italy city water well	970	......	18	8	598	745	581	107	1,687	Do
135	Avalon city water well	1016	......	18	5	915	905	541	527	2,451	Do
*136	Howard city water well	1197	......	10	2	680	905	538	149	1,824	Do
*137	Bardwell city water well	1470	......	14	3	768	1,013	607	210	2,095	Do
138	Reagor Springs water well	989	......	21	11	1,005	956	736	520	2,761	Do
*144	Ferris Brick Company, Ferris	1250	......	3	1	568	775	374	156	1,488	Do
	Fannin County										
72	Bonham city water well	1184	9-18-29	......	......	......	468	......	70	......	E. C. Sargent
73	Leonard city water well	1650	9-18-29	......	......	......	668	......	716	......	Do
75	Ladonia city water well	2513	9-21-29	......	......	......	870	......	1,060	......	Do
76	Honey Grove city water well	1720	9-21-29	3	48	268	534	219	87	888	Do
77	Dodd City Oil Mill water well	1680	9-21-29	......	......	......	507	......	87	......	Do
	Freestone County										
162	Orbit Oil Co., Coleman No. 1, Wortham field	......	7-25-27	144	......	5,716	365	115	8,772	16,060	Sun Oil Co.
209	Humble O. & Rfg. Co., Crouch No. A-6, Wortham field	......	6-15-25	272	103	8,439	622	8	13,475	22,974	U.S.Bur.Mines
210	Atlantic Rfg. Co., Williams No. 2, Wortham field	......	5-15-25	240	79	8,202	519	......	13,120	22,280	Do
211	Rio Bravo Oil Co., H. & T. C. No. 5, Wortham field	......	5-15-25	248	90	8,073	567	8	12,907	21,983	Do
212	Pure Oil Co., Manning No. 3, Wortham field	......	5-15-25	220	88	8,172	470	12	13,049	22,074	Do
213	Atlantic Rfg. Co., Edwards No. 1, Wortham field	......	5-15-25	240	85	7,445	585	10	11,915	20,367	Do
215	Humble O. & Rfg. Co., Simmons No. 1, Wortham field	......	5-14-25	252	85	7,939	574	......	12,695	21,660	Do
216	Pure Oil Co., Bounds No. 5, Wortham field	......	5-14-25	289	103	8,783	519	......	14,184	24,006	Do
217	E. L. Smith, Smith No. 1, Wortham field	......	5-14-25	264	90	8,268	555	......	13,259	22,573	Do
218	Humble O. & Rfg. Co., Ella Dodd No. 4, Wortham field	......	4-28-25	258	84	8,080	586	......	12,907	22,021	Do
219	The Texas Oil Co., Wright No. 2, Wortham field	......	4-28-25	222	83	8,191	476	......	13,049	22,121	Do
220	Do—Wright No. 2, Wortham field	......	2- 4-25	241	83	8,623	549	......	13,616	23,112	Do
221	Do—Bounds No. 2, Wortham field	......	4-28-25	236	84	8,176	513	10	13,049	22,186	Do
222	Atlantic Rfg. Co., McCorkle No. 3, Wortham field	......	2-10-25	262	84	7,327	592	......	12,198	20,942	Do
223	Pure Oil Co., Bounds No. 3, Wortham field	......	2-10-25	301	107	8,027	519	......	13,546	23,039	Do
224	Godley Oil Co., Manning No. 2, Wortham field	......	10-14-26	246	91	8,218	555	8	13,049	22,169	Do
225	Humble O. & Refg. Co., Lindley No. B-5, Wortham field	......	10-14-26	240	85	8,156	586	9	12,907	21,983	Do
226	Do—Crouch No. A-9, Wortham field	......	10-14-26	222	82	8,007	488	8	12,694	21,501	Do
227	Do—Crouch No. A-6, Wortham field	......	10-14-26	234	86	8,017	567	11	12,694	21,609	Do
228	Hughes, Berry No. A-1, Wortham field	......	10-14-26	238	85	7,969	567	11	12,624	21,494	Do
229	Simms Oil Co., Simmons No. 3, Wortham field	......	10-14-26	238	95	8,377	481	10	13,333	22,534	Do
	Grayson County										
5	J. F. Fries water well	217	6-23-29	16	9	51	171	28	17	295	E. C. Sargent
59	R. M. Wilson water well	232	9-12-29	......	......	......	207	......	23	......	Do

60	Sherman city water well	752	9-12-29	2	45	86	340	68	23	393	Do
61	Howe city water well	980	9-14-29				748		40		Do
62	Van Alstyne city water well	1188	9-14-29				600		337		Do
67	Gunter city water well	728	9-14-29				722		23		Do
*68	C. L. Owens water well	342	9-19-29				555		302		Do
69	Whitewright city water well	1150	9-17-29	3	64	171	502	128	72	687	Do
	Henderson County										
152	Penn & Boyd—T. P. C. & O., Murphy No. 1	3184	4-15-25	317	407	11,252		8,533	13,985	42,040	Atlantic Rfg. Co.
	Hill County										
83	Mertens city water well	782	11-20-29				775		495		E. C. Sargent
84	Brandon city water well	687	11-20-29				668		235		Do
85	Hillsboro city water well	900	11-21-29				427		128		Do
86	Itasca city water well	248	11-21-29				401		40		Do
139	J. H. Dearing water well	250		19	7	335	638	205	46	926	Gulf Prod. Co.
140	T. W. Berger water well	437		18	8	583	585	608	166	1,670	Do
141	W. N. Page water well	600		26	11	713	638	755	248	2,067	Do
*142	G. Eden water well	728		26	14	1,105	1,013	583	770	2,996	Do
*143	W. A. Rogers water well	602		17	6	605	640	521	226	1,690	Do
	Hopkins County										
155	The Texas Co., Wortham No. 1	3043	11-17-24	856	166	18,589	279	2	20,500	50,337	Atlantic Rfg. Co.
156	Noco Pet. Co., Smiddy No. 1	3327	7-29-22	925	223	19,434	272	36	32,000	52,853	Do
	Hunt County										
74	Celeste city water well	1550	12-10-29				682		1,790		E. C. Sargent
88	Greenville city water well	1750	12-10-29	480	104	10,580	174	125	16,380	27,754	Do
	Johnson County										
87	Venus city water well	400	11-21-29				388		29		Do
	Kaufman County										
43	Terrell Insane Asylum water well	3395	8-13-29	92	88	4,450	1,045		6,680	11,824	Do
*50	Forney Ice Plant water well	2037	8-20-29				1,082		582		Do
51	Grandall Gin water well	2140	8-20-29	14	56	1,280	1,218	275	1,250	3,475	Do
106	Humphrey Corp., Clarida No. 1	2968		204	64	9,105	573	8	14,250	23,959	U.S.Bur.Mines
107	Hedrick Oil Co., Woods No. 1	3019	1922	51	6	3,767	1,058	9	5,300	9,700	Do
109	Mexia-Reynolds, Cartwright No. 1	3080	1922	76	12	5,130	835	5	7,600	13,272	Do
127	Humphreys Corp., Barrow No. 1	3150		996	316	19,072	930	70	31,500	52,454	Humphreys Corp.
157	Boyd Oil Co., Rand No. 1	3441	5-25-24	765	5	13,831	1,035	65	22,000	37,262	Atlantic Rfg. Co.
	Limestone County										
8	Pure Oil Co., Hayter No. 2, Mexia field	3052	7-14-29				388		23,100		E. C. Sargent
9	Do Nussbaum No. 10, Mexia field	3077	7-14-29				400		19,100		Do
10	Do Kendricks No. 1-B, Mexia field	3040	7-14-29				361		21,820		Do
11	Do J. Ross No. 4, Mexia field	3058	7-14-29				334		18,800		Do
12	Do Thomas No. 8, Mexia field	3042	7-14-29				361		18,800		Do
13	Do Gamble No. 6, Mexia field	3048	7-14-29	648	109	11,540	348		19,050	31,448	Do

TABLE 7.—*Analyses of Woodbine water in east Texas wells.*—(Continued)

SAMPLE NO.	WELL DATA: Well	Depth taken	Date taken	WATER ANALYSES IN PARTS PER MILLION: Ca	Mg	Na	HCO_3	SO_4	Cl	Total solids	Chemist
	Limestone County—Concluded										
117	Humphreys Corp., Winn No. 1, Mexia field	3103		218	53	4,052	183	72	6,617	11,119	Humphreys Corp.
120	Do Clark No. 6, Mexia field	3059	1922	527	185	10,904	328	29	18,000	29,900	Do
121	Do Thomas No. 14, Mexia field	3039	1922	542	169	11,384	324	24	18,800	31,135	Do
122	Do Clark No. 4, Mexia field	3069	1922	573	194	11,350	442	44	18,750	21,211	Do
123	Jones Oil Co., Thompson No. 1, Mexia field	3032	1922	845	205	14,396	293	192	23,930	39,729	Do
153	Atlantic Rfg. Co., Eisenmeyer No. 3, Prairie Hill	1731		769	244	10,859	165	49	18,700	30,772	Atlantic Rfg.Co.
161	Pure Oil Co., Cockrum No. 6, Nigger Cr. field	2840	3- 1-27	492	162	10,612	297		17,529	29,092	Sun Oil Co.
167	Cranfill & Reynolds, Rosson No. 1, Nigger Cr. field	2846	3- 1-27	527	162	10,119	351		16,800	27,959	Do
168	Atlantic Rfg. Co., Rosson No. 2, Nigger Cr. field	2844	3- 1-27	1,329	146	8,723	321		16,038	26,557	Do
169	Barkley-Meadows, Rosson No. 2, Nigger Cr. field	2838	3- 1-27	483	143	9,959	315		17,534	29,376	Do
170	Pure Oil Co., Bertha-Atkins No. 3, Nigger Cr. field	2835	3- 1-27	97	151	11,146	448		16,440	27,340	Do
171	Do Bertha-Atkins No. 3, Nigger Cr. field	2844	3- 1-27	444	149	9,617	351		15,840	26,401	Do
208	Magnolia Pet. Co., Boyd No. 6, Wortham field		5-15-25	311	101	8,935	421	23	14,326	24,178	U.S.Bur.Mines
	Navarro County										
79	Dawson city water well	1473	11-20-29	30	32	2,000	975		2,640	5,172	E. C. Sargent
*80	Barry city water well	1741	11-20-29				1,122		447		Do
81	Blooming Grove city water well	1340	11-20-29				1,093		686		Do
*82	Frost city water well	1184	11-20-29				815		145		Do
94	Pure Oil Co., Fleming No. 1, Powell field	2979	5-25-24	88	35	4,771	1,061	10	7,021	13,141	U.S.Bur.Mines
95	Smith Oil Co., Cerf No. 5, Powell field	2990	10- 2-24	148	57	6,481	1,531		9,574	18,291	Do
96	Mills Bennett, Wolens, No. 3, Powell field	2986	10- 2-24	60	24	4,151	1,129		5,922	11,306	Do
97	J. K. Hughes, Hill No. A-1, Powell field	2984	4- 4-24	73	30	4,600	1,098	148	6,600	12,637	Do
98	Tidal Oil Co., Thompson No. 2, Powell field	2991	4- 4-24	70	35	4,250	1,815	22	5,730	11,939	Do
99	Pure Oil Co., Burke No. 1, Powell field	2963	5-11-26	80	56	6,417	1,098	8	9,573	17,232	Do
100	The Texas Co., Fleming No. 8, Powell field	2952	10- 2-24	54	58	3,670	1,342		5,035	10,174	Do
101	Roxana Corp., McKie No. A-9, Powell field	2878	11-19-24	144	66	7,063	933		10,851	19,057	Do
102	McMann Oil Co., Chapman No. 8, Powell field	3400	11-19-24	217	83	8,428	500		13,333	22,594	Do
103	Kent Co., Fleming No. 10, Powell field	3039	3-11-24	67	34	4,350	960	57	6,380	11,970	Do
104	Natatorium, Corsicana	2360		22	9	2,128	1,390		2,411	5,298	Do
105	Kerens city water well	3300		254	93	9,733	650	4	15,350	25,804	Do
110	Humble O. & Rfg. Co., McClelland No. 1, Powell field	3058	1922	193	41	6,542	414	25	10,300	17,332	Do
111	Sun Oil Co., Bound No. 1, Powell field	2968	1922	218	76	6,699	488	6	10,650	17,954	Do
112	Humble O. & Rfg. Co., Meador No. 3, Currie field	3006	1922	222	69	7,096	568	24	11,200	18,929	Do
118	Sun Oil Co., West No. 2, Currie field	2996	4- 5-22	128	71	5,236	666	28	8,100	13,932	Humphreys Corp.
119	Humphreys Corp., Cole No. 1, Currie field	3006	1922	203	80	7,675	404	7	12,200	20,432	Do
124	Livingston Milligan No. 1	3205	1922	131	43	5,872	688	16	9,000	15,442	Do
125	Panhandle Rfg. Co., West No. 1	3035	1922	182	77	6,147	640	17	9,650	16,425	Do
126	Travis, Bounds No. 1	2990	1922	196	74	7,403	492	23	11,650	19,656	Do
158	Sun Oil Co., Swink-Wilson No. 1, Currie field	2999	10-10-28	256	79	8,695	451		13,825	23,306	Sun Oil Co.
159	Do H. A. Swink No. 1, Richland field	3024	2-15-27	203	56	4,696			7,399	12,976	Do

160	Do........H. A. Swink No. B-2, Richland field	2983	2-15-27	220	65	4,999	613	20	7,913	13,830	Do
172	Humphreys Corp., Webb No. 3, Richland field	2960	3- 1-27	537	18	4,947	702		8,220	14,424	Do
173	Do........Webb No. 2, Richland field	2964	3- 1-27	505	49	5,008	679		8,361	14,602	Do
174	Sun Oil Co., Brown No. 13, Richland field	2951	3- 1-27	309	79	6,749	430		10,930	18,501	Do
175	Do........West No. 1-B, Richland field	2985	3- 1-27	111	22	4,971	642		7,550	13,296	Do
176	Do........E. L. Swink B-1, Richland field	2997	3- 1-27	129	61	6,620	424		10,360	17,594	Do
230	Derby Oil Co., Harvard No. 2, Powell field		4-12-24	52	10	4.100	1,396	28	5,633	11,329	U.S.Bur.Mines
231	Navarro Oil Co., Cerf No. A-3, Powell field		10- 2-24	116	18	5,370	360		8,368	14,272	Do
232	Gulf Prod. Co., Crews No. 17, Powell field		4-15-24	63	22	4,180	1,142	45	5,976	11,516	Do
233	J. K. Hughes, McKie No. 1, Powell field		8- ?-24	325	48	5,360	165	29	9,217	15,523	Do
234	Do........McKie No. 2, Powell field		4-29-24	69	87	5,320	2,016	8	7,804	15,344	Do
235	Do........McKie No. 9, Powell field		4-29-24	122	53	5,030	1,200	32	7,423	13,877	Do
236	Humble O. & Rfg. Co., Fleming No. A-2, Powell field		11-19-24	68	24	4,416	671		6,596	11,794	Do
237	Do........Fleming No. B-2, Powell field		11-19-24	58	23	3,704	1,458		5,035	10,303	Do
238	Do........McKie B-8, Powell field			54	43	5,752	2,302	8	7,659	16,090	Do
240	Pure Oil Co., Burke No. 1, Powell field		11-19-24	52	48	5,826	671		8,723	15,410	Do
241	Do........Burke No. 1, Powell field		5- 2-24	80	364	2,672	1,240	14	8,650	17,194	Do
242	Do........McKie No. 37, Powell field		11-19-24	64	59	5,544	2,392		7,446	15,535	Do
243	Do........Fleming No. 1, Powell field		6- 9-24	52	18	4,386	848		6,418	11,972	Do
244	Roxana Pet. Corp., McKie No. A-9, Powell field		6- 9-24	125	1,980	4,109	935	46	11,755	18,950	Do
245	Simms Oil Co., Rose No. 8, Powell field		10- 2-24	160	35	4,562	1,056		6,808	12,821	Do
246	Do........Kellum No. 4, Powell field		6-20-25	70	29	4,262	787	17	6,165	11,482	Do
247	Smith Oil Co., Cerf No. 5, Powell field		10- 2-24	148	57	6,481	1,531		9,574	18,291	Do
248	Sun Oil Co., Kent No. 2, Powell field		11-19-24	96	59	5,040	1,153		7,446	13,794	Do
249	Do........Kent No. 3, Powell field		5-17-24	240	223	2,900	1,478	18	7,657	15,747	Do
250	The Texas Co., Fleming No. 8, Powell field		8- ?-24		45	3,438	1,126	29	4,963	9,837	Do
251	Do........Fleming No. 8, Powell field		10- 2-24	54	58	3,670	1,342		5,035	10,174	Do
252	Tidal Oil Co., Cerf No. 8, Powell field		4-24-24	76	32	4,710	1,235	22	6,820	12,915	Do
253	Do........Thompson No. 2, Powell field		4-23-24	70	35	4,250	1,815	22	5,730	11,939	Do
254	U. S. Texas Oil Co., Ramsey No. 1, Powell field		4- 2-24	94	17	4,370	1,500	189	6,000	12,312	Do
255	Humble O. & Rfg. Co., Ramsey No. B-1, Powell field		6-30-26	65	29	4,378	1,403	3	6,135	12,013	Do
256	Do........Fleming No. 2, Powell field		6-30-26	57.	25	3,857	1,324		5,354	10,617	Do
257	Tidal Oil Co., Phillips No. 5, Powell field		6-30-26	56	23	3,699	1,367	8	5,071	10,224	Do
258	Humble O. & Rfg. Co., Ramsey No. B-21, Powell field		7- 8-26	136	57	6,582	964		10,000	17,739	Do
	Rusk County										
207	Magnolia Pet. Co., Flury No. 1	3650	5-30-31	1,176	197	22,050	366	384	36,400		E. C. Sargent
	Tarrant County										
37	Hardin Water well	75	7-29-29	21	44	71	322		113		Do
38	C. M. Milligan water well	280	7-29-29	21	44	71	298	74	49	406	Do
39	T. A. Roseburg water well	241	7-29-29	5	89		510	46	29	499	Do
40	J. E. Bloomer water well	200	7-29-29				322		137		Do
41	Webb city water well	200	7-29-29				315		29		Do
	Titus County										
154	Humphreys Corp., Corey No. 1, Ripley	3265		1,099	160	25,427	195		41,450	68,337	AtlanticRfg.Co.
	Upshur County			1,745	35	19,637	501	177	61,010	82,850	AmeradaPet.Corp.
92	Amerada Pet. Corp., Wade No. 1	3843									

TABLE 8.—*Well data*[a], *east Texas.*

COMPANY	FARM	LOCATION	CO-ORDINATE[c]	ELEVATION	TOTAL DEPTH	DEPTH TO TOP OF PECAN GAP	DEPTH TO TOP OF WOODBINE	DEPTH TO TOP OF WASHITA
				Feet above sea level	*Feet*	*Feet*	*Feet*	*Feet*
Anderson County								
Amerada Pet. Corp.	Barton No. 1	Richard Duty Surv.	M-18	—	1305	—	—	—
Do	J. L. Mayo	10 mi. E. of Palestine, nr. Still's Cr.	M-18	—	310	—	—	—
Do	B. McKinnon No. 2	J. S. Carson Surv.	M-18	—	4016	—	—	—
*Cosden & Co.	Adams No. 1	T. M. Carroll Surv.	K-17	430	4000	2502	3580	3780
J. S. Cosden, Inc.	R. S. Douglas No. 1	J. Simpson Surv.	K-17	400	4832	3540	—	—
*Cosden & Roeser	Brooks-Auld No. 2	Do	K-17	440	5211	3399	5201	—
* Do	Daniels No. 1	Chas. Gilmore Surv.	J-16	275	5011	2827	4992	—
Elkhart Prod. Co.	Lynn No. 1	R. Brown Surv.	L-19	370	2476	—	—	—
Frost Oil Co.	G. A. Botting No. 1	A. B. Patton Surv.	M-16	354	3858	2934	—	—
Humble Oil & Rfg. Co.	Beard No. 2	J. Trimmer Surv.	M-16	428	3692	—	—	—
Do	J. Beard No. 3	Do	M-16	326	3636	2440	3524	3570
Do	Birdwell No. 1	S. Bowlin Surv.	L-16	420	4119	3145	3955	4125
Do	S. Clemmans No. 1	H. C. Sassamon Surv.	M-16	313	2811	1925	—	—
Do	S. Clemmans No. 2	J. D. Beason Surv.	M-16	310	3715	—	—	—
Do	S. Clemmans No. 2-A	H. C. Sassamon Surv.	M-16	356	3790	2702	—	—
Do	G. Coleman No. 1	J. G. Kefting Surv.	M-16	351	3673	2885	—	—
Do	Collier No. 1	L. Roberts Surv.	L-16	362	3851	—	—	—
Do	Collier No. 1	J. Little Surv.	L-16	503	4400	3110	3901	4131
Do	Cooke No. 2	A. B. Patton Surv.	M-16	440	3698	2890	3680	—
Do	J. Gouger No. 1	J. Trimmer Surv.	M-16	417	3995	—	—	—
Do	B. L. Gammill	Nancy Cannon Surv.	M-17	417	4577	3145	4390	—
Do	Gouger No. 3	J. Trimmer Surv.	M-16	426	3761	2938	—	—
Do	Guaranty State Bank,							
Do	Palestine No. 1	John Albright Surv.	M-16	355	4345	3002	—	—
Do	J. C. Hall No. 1	Do	M-16	—	3625	—	—	—
Do	P. Holloway No. 1	David Roberts Surv.	M-16	349	3767	—	—	—
Do	P. Holloway No. 2	Do	M-16	—	4251	—	—	—
Do	P. Holloway No. 3	Do	M-16	349	3633	—	—	—
Do	Hurd No. 1	—	M-16	—	3335	—	—	—
Do	W. Johnson No. 1	James Hall Surv.	L-16	548	3582	2908	3384	—
Do	Tom Jones Jr. No. 1	David Roberts Surv.	M-16	348	3472	—	—	—
Do	Tom Jones Jr. No. 2	Do	M-16	344	3665	—	—	—
Do	Tom Jones Jr. No. 4	Do	M-16	—	—	2555	—	—
Do	T. H. Jones No. 1	Do	M-16	292	3650	2492	—	—
Do	T. H. Jones No. 1-B	Do	M-16	351	3599	—	—	—
Do	T. H. Jones No. 2	Do	M-16	336	3728	—	—	—

Do	T. H. Jones No. 4	Do	M-16	336	3723	2633	3705	
Do	Mandlestam No. 1	Do	M-16		3934			
Do	Mandlestam No. 2	Do	M-16	345	3814			
Do	Mandlestam No. 3	Do	M-16	336	3727			
Do	Mandlestam No. 4	Do	M-16	286	3561			
Do	Mandlestam No. 5	H. C. Sassamon Surv.	M-16			2525		
Do	McCaffrey No. 1	I. & G. N. Surv.	J-16	365	5419	2938	4829	
Do	Neches R. Bed No. 1	Boggy Creek field	M-16	400	3791			
Do	Neches R. Bed No. 2	Do	M-16	400	3831			
Do	A. Purvey No. 1	D. Clark Surv.	M-16	472	3688			
Do	A. Purvey No. 2	D. C. Clark Surv.	M-16	477	3503			
Do	J. F. Roberts No. 1	David Roberts Surv.	M-16	343	3891			
Do	J. F. Roberts No. 2	Do	M-16	399	3602			
Do	Russell No. 1	Nancy Cannon Surv.	L-17	360	4043			
Do	L. Smith No. 1	David Roberts Surv.	M-16	338	3722		3632	
Do	L. Smith No. 2	Do	M-16	339	3814			
Do	So. Pine Lumber No. 1	Anderson Co. Sch. Surv.	M-17	270	3506			
Do	So. Pine Lumber No. 1-A	Do	M-17	331	4314	3686		
Do	So. Pine Lumber No. 1-B		M-17	348	5080		4810	
* Do	So. Pine Lumber No. 2-A		M-17	309	5012		4391	4929
Do	So. Pine Lumber No. 3-A		M-17	332	4427	3390	4344	
Do	Dan Stevenson No. 1	M. Roberts Surv.	L-16		3742	2807		3650
Do	Todd No. 1	Do	M-16	303	3257			
Do	W. T. Todd No. B-1	J. Mancha Surv.	M-16	392	3603			
Do	A. E. Todd No. A-1	David Clark Surv.	M-16	438	3736			
Do	A. E. Todd No. A-3	Do	M-16	457				
Do	A. E. Todd No. A-4	Do	M-16			2968	3678	
Do	A. E. Todd No. A-5	Do	M-16	465	2887			
Magnolia Pet. Co.	H. B. Williams No. 1	Wm. Bledsoe Surv.	L-17		3920	3840		
Do	H. B. Williams No. 2	Do	L-17	384	4685	3880		
Do	So. Pine Lumber No. 1	R. Duty Surv.	M-18		3565			
Winans Pet. Co.	Parker No. 1	W. M. Frost, nr. Elkhart	L-19	455	3575	4148[b]		
Navarro Pet. Co.	Barrett No. 1	W. A. Cook Surv.	K-17	389	3511	1309	1982	
Navarro-Sun-Humble	A. Gardner No. 1	May Salisar Surv.	K-17	406	3365	1866	3600	
Navarro Pet. Co.	Greenwood No. 1	W. A. Cook Surv.	K-17	380	1363			
Do	Greenwood No. 2	Do	K-17	350	435			
Do	Greenwood No. 3	Do	K-17	384	1371			
Do	Greenwood No. 4	Do	K-17	422	2585	1965		
Producers Oil Co.	David Hassel No. 1	L. H. Catlett Surv.	M-18		1279			
Do	Barrett & Greenwood No. 1	W. A. Cook Surv.	K-17	389	3170	952		

*Wells plotted in sections A-B to K-L (Pls. II to VII).

[a]This table represents a compilation of data from well logs and elevation tables made available to the Bureau of Economic Geology and used in the preparation of this report. The list of wells is by no means complete, nor can the accuracy of the figures be guaranteed, since it has been impossible to check the sand and chalk depths against formation samples. The data have, however, been checked against two different collections of well logs, and it is believed that the list is representative and includes most wildcat wells drilled before March, 1931.

[b]Estimated figures.

[c]Coordinates used are shown on Plate I.

TABLE 8.—*Well data*[a], *east Texas.*—(Concluded)

COMPANY	FARM	LOCATION	CO-ORDINATE	ELEVATION	TOTAL DEPTH	DEPTH TO TOP OF PECAN GAP	DEPTH TO TOP OF WOODBINE	DEPTH TO TOP OF WASHITA
				Feet above sea level	*Feet*	*Feet*	*Feet*	*Feet*
Anderson County— Concluded								
Producers Oil Co.	Barrett & Greenwood No. 2	R. R. Powers Surv.	K-17	384	2297	1850	—	—
Do	Barrett & Greenwood No. 3	Do	K-17	387	2655	—	—	—
Do	Barrett & Greenwood No. 4	Do	K-17	380	2447	1535	—	—
Do	Barrett & Greenwood No. 5	Do	K-17	390	3048	—	—	—
* Do	Royal & Davey	—	M-18	387	4034	3825	—	—
Do	So. Pine Lumber Co. No. 1	Richard Duty Surv.	M-18	264	4346	3389	—	—
Pure Oil Co.	Bruce No. 1	A. M. Lewis Surv.	J-17	348	4007	3018	—	—
Do	Bruce No. 2	Do	J-17	355	4306	—	—	—
Do	Cooke No. 1	A. Lewellen Surv.	J-17	304	1610	—	—	—
Do	I. E. Jackson	T. H. Kinley Surv.	J-17	342	5836	3468	5610	—
Roeser Pet. Co.	Brooks-Auld No. 1	I. Simpson Surv.	K-17	430	4165	3376	—	4165
Do	Via No. 1	Do	K-17	440	4331	3482	—	4960
*Roeser & Pendleton, Inc.	W. L. Moody No. 1	J. Welch Surv.	K-17	349	4998	2975	4744	—
Sun Oil Co.	Bowers & Maiers No. 1	E. G. Meyers Surv.	J-18	320	1656	990	—	—
Bowie County								
Arkansas Nat. Gas Co.	So. Realty & Trust	W. H. Boyce Surv.	R- 4	360	2443	—	—	—
Boyd Oil Co.	Thompson No. 1	J. Barkman Surv.	R- 5	340	2775	—	—	—
Citizens O. & G. Co.	Burnett No. 1	M. H. Janes Surv.	U- 6	—	3150	—	—	—
Dalby Springs O. Co.	Pirkey No. 1	Bowie Co. Sch. Ld. Surv.	R- 5	370	2905	—	—	—
DeKalb O. & G. Co.	McBeth No. 1	W. L. Browning Surv.	Q- 4	367	2775	—	—	—
Delaney et al	Rochelle Bros. No. 1	W. C. McKinney Surv.	U- 4	285	2295	—	—	—
Devore et al	Cooper No. 1	W. Ward Surv.	R- 5	360	3000	—	—	—
Hindman & Bell	Merritt No. 1	Y. S. McKinney Surv.	T- 6	—	2650	—	—	—
Hooks Oil Co.	Lewis Fort	J. Barkman Surv.	R- 5	314	2444	—	—	—
Hooks O. & G. Co.	Ball No. 1	Mary Morris Surv.	U- 5	319	2000	—	—	—
Do	T. Hooks No. 1	J. Barkman Surv.	T- 4	317[b]	2160	—	—	—
Do	A. Hooks No. 1	Do	T- 4	—	—	—	—	—
Do	A. Hooks No. 2	Do	T- 4	317[b]	2018	—	—	—
Mission Oil Co.	Nelson No. 2	N. Dycus Surv.	U- 5	—	2860	—	—	—
Do	Nelson No. 1-A	—	U- 5	400	2900	1450	2600	—
Morgan Oil Co.	Freeze No. 1	P. S. Wyatt Surv.	S- 4	350	2505	—	—	—
Nash Oil Co.	Gholston No. 1	Geo. Brinbee Surv.	U- 5	345	2305	—	—	—
New Boston Oil Co.	Williams No. 1	Levi M. Rice Surv.	S- 5	341	3000	—	—	—
Parkington & Jones	Whybrook No. 1	—	R- 4	—	—	—	—	—
Postal Employees Oil Co.	Obenchain No. 1	W. J. Self Surv.	T- 6	250	2940	—	—	—
Redwater O. & Min. Co.	J. M. Tull No. 1	D. Morris Surv.	T- 6	287	2000	—	—	—

Sulphur O. & G. Co.	Morse No. 1	Nancy McCarter Surv.	U- 6	250[b]	3000	—	—	—
Texarkana Water Corp.	F. A. Dreyer No. 1	M. E. P. & P. RR. Surv.	V- 5	270	691	—	—	—
Texport Oil Co.	Gilley No. 1	Geo. Brinbee Surv.	U- 5	345	3034	—	—	—
Lee Timberlake	Tidwell No. 1	Joseph Eskell Surv.	S- 5	—	3000	—	—	—
Do	Tidwell No. 2	Levi M. Rice Surv.	S- 5	290	3000	—	—	—
Tri-State Oil Co.	Taylor No. 1	Chas. Collum Surv.	T- 5	364	2862	—	—	—
Camp County								
Benedum-Trees	Browning No. 1	Harrison Co. Sch. Land, Blk. 4	O- 8	432	3854	2463	3452	—
T. B. MacDonald	Tillery No. 1	J. H. Murphy Surv.	O- 8	440	4314	2413	—	—
J. C. Rogers	Enfeldt No. 1	R. M. Montgomery Surv.	P- 8	410	3045	2490	—	—
Cass County								
Atlas Oil Co.	Marshall Lenoir No. 1	Kitchens Surv.	—	210	2780	—	—	—
Bowie Hill	Yoke No. 2	½ mi. from Harton well	—	300	2725	—	—	—
Carlson Price Oil (Home Oil)	Spear No. 2		—	300	3496	—	—	—
Do	Spear No. 3	Needham Boone Surv.	—	300	2530	—	—	—
Daniels-Daniels	Lanier No. 1	A. Douthit Hrs. Surv.	T- 9	—	3322	—	—	2960
Gladys Bell Oil Co.	Lyster No. 1	Kinchloe Surv.	R- 8	337	3990	—	—	—
F. M. Green	O'Neal No. 1	½ mi. W. of Atlanta	—	250	1995	—	—	—
Home Pet. Co.	George No. 1	John Collum Surv.	—	244	2880	—	—	—
Hughe Spring	Stovall No. 2	O. King Surv.	—	342	2705	—	—	—
S. D. Hunter et al	Folkner No. 1	J. L. Chambers Surv.	—	248	3708	2373	—	—
James & O'Hara	Lodi No. 1	James Harris Surv.	—	236	3202	—	—	—
Midcontinent Oil Lease Co.	Marietta St. Bk. No. 1	E. Stalcup Surv.	—	420	3207	—	—	—
Mid-Kansas Oil & Gas Co.	Land No. 1	Potter Surv.	U- 8	248	3022	—	—	2874
Phillips Pet. Co.	J. R. Olds No. 1	J. A. Stephenson Surv.	R- 7	245	4100	1959	—	—
E. H. Pigg	Lambert No. 1	James Frazier Surv.	S- 7	—	4060	—	—	—
Producers Oil Co.	Green	J. N. Jackson Surv.	T- 6	—	2971	—	—	—
Do	Texas Iron Assoc.	Jas. Horton Surv.	U- 7	360	2450	—	—	—
Queen City Oil Co.	Howe No. 1		—	300	3131	—	—	—
Queen City (Snap & Sharp)	Jones Bros No. 1	James Wilson Surv.	U- 6	285	3208	—	—	—
Rogers	Lanier No. 1	K. A. Welborn Surv.	—	366	—	2144	—	—
Simms Oil Co.	Toughill No. 1	G. S. Young Surv.	T- 8	368	3605	2198	—	3508
Siosi Oil Co.	Kennedy No. 1	Ambrose Douthey Surv.	—	250	2426	—	—	—
J. E. Smitherman	A. S. Fall No. 1	Farrell Surv.	—	295	3783	2405	—	3765
Southwestern Gas & Electric	Gibson No. 1		—	210	2780	—	—	—
The Texas Co.	Citizens St. Bk. No. 1	Jos. Watkins Surv.	S- 8	339	3905	2860	—	3870
Cherokee County								
Atlantic Oil Prod. Co.	Marshall No. 1	P. R. & C. D. Nash Hrs.	M-16	375	3861	—	—	—
Alto Oil Co.	McCarty No. 1		M-17	—	2557	—	—	—
Arcadia Refining Co.	Jones No. 1	Edson Gee Surv.	—	481	3998	2978	—	—
Arkansas Fuel Oil Co.	Deaton No. 1	F. Coleman Hrs.	N-17	368	4705	3493	4601	—
Roy Baker et al	M. M. Tommel	Wm. George Surv.	—	442	4003	3054	—	—
Ben Banner et al	A. S. Lacey-Williams No. 1	J. L. Hogg Surv.	—	317	4476	3450	—	—

TABLE 8.—*Well data*[a], *east Texas*.—(Continued)

COMPANY	FARM	LOCATION	CO-ORDINATE	ELEVATION	TOTAL DEPTH	DEPTH TO TOP OF PECAN GAP	DEPTH TO TOP OF WOODBINE	DEPTH TO TOP OF WASHITA
				Feet above sea level	*Feet*	*Feet*	*Feet*	*Feet*
Cherokee County— Concluded								
D. H. Byrd et al	Dixie Farms No. 1	J. W. Foreman Surv.	O-19	—	4254	—	3996	—
Cherokee O. & Dev. Co.-J. A. Collitton	Clapp No. 1	12 mi. SE. of Jacksonville	O-16	—	2399	—	—	—
Cherokee O. & Dev. Co.	Tipton	Robert Stewart Surv.	O-16	—	2340	—	—	—
J. A. Collitton et al	Clapp No. 1	R. R. Lowell Surv.	O-16	305	3046	—	—	—
Do	Clapp No. 2	Do	O-16	305	4295	3188	—	—
Fain-McGaha Oil Corp. & Sinclair Oil & Gas Co.	W. A. Shaw No. 1	I. Reed Surv.	O-16	410	4017	3217	—	—
Giant Oil & Gas Co.	D. Pierce No. 1	C. Burnett Surv.	N-16	345	4183	3262	—	—
Humble Oil & Rfg. Co.	Earle & Ragsdale No. 1	T. A. Smith Surv.	M-16	290	2612	—	—	—
Do	Earle & Ragsdale No. 2	N. Johnson Surv.	M-16	296	4566	2693	4342	—
Do	Earle & Ragsdale No. 3	Do	M-16	—	3916	—	—	—
Do	Earle & Ragsdale No. 4	Do	M-16	296	3564	2545	—	—
Do	Elliott & Clark No. 1	M. Windsor Surv.	M-16	390	3847	—	—	—
Do	Elliott & Clark No. A-3	Do	M-16	299	2934	2635	3620	—
Do	Elliott & Clark No. B-2	M. Garcia Surv.	M-16	302	3647	2575	—	—
Do	Holt No. 1	A. D. Oliphant Surv.	M-16	326	3778	2568	—	—
Do	Reynolds-Mortgage No. 1	Isaac Durst Surv.	M-16	—	3774	—	—	—
* Do	Reynolds-Mortgage No. 2	Do	M-16	370	4648	2960	—	—
Do	J. A. Templeton No. 1	A. D. Oliphant Surv.	M-16	329	3447	—	—	—
Do	Weinberg No. 1	T. L. Trimble Surv.	M-16	409	3983	3112	—	—
Do	Weinberg No. 2	Do	M-16	—	3174	2325	—	—
Do	Weinberg No. 3	Do	M-16	475	3434	—	—	—
Do	Weinberg No. 4	Do	M-16	469	3983	3117	—	—
Humphreys Bros., Inc.	Bowling No. 1	W. H. Walters Surv.	O-16	400	3916	3000	—	—
Do	Clapp No. 2	R. R. Towell Surv.	O-16	352	4412	3210	4312	—
Do	Clapp No. 3	Do	O-16	—	3385	—	—	—
Do	Clapp No. 4	Do	O-16	—	4026	—	—	—
Do	Ousley No. 2	Culp Surv.	O-16	281	4135	3125	—	—
Do	Stafford No. 1	W. H. Walters Surv.	O-16	388	5124	3013	4085	4325
Do	Thomson No. 1	—	—	466	2215	—	—	—
H. M. Jones et al	T. McLee No. 1	Jas. McKnight Surv.	—	302	4154	3164	4109	—
O. W. Killam et al	W. A. Newton No. 1	Thos. Quevado Surv.	—	509	4521	3519	—	—
Kirby Pet. Co.	Comer Sessions No. 1	Jose Maria Masquez Surv.	O-17	361	4505	3375	4472	—
*Magnolia Pet. Co.	J. H. Summers No. 1	Wm. Brewer Surv.	O-17	317	4375	3515	—	—
Roy Nichols	J. L. Kennedy No. 1	Do	O-17	316	4550	3312	4325	—

Rowan Nichols & Tidal Oil Co.	W. T. Norman No. 1	Irby Large Surv.	—	—	4389	3240	4380	—
Rowan Nichols & Tidal Oil Co.	Ousley No. 1	T. L. Smith Surv.	O-16	279	4225	3138	4216	—
Rowan Nichols	Schleicher No. 1	A. C. Walter Surv.	O-16	282	4305	3128	4302	—
Orleander et al	Orleander No. 1	L. Hotchkiss Surv.	O-17	—	3265	—	—	—
Security Prod. Co.	No. 1	2 mi. E. Bullard	N-15	—	192	—	—	—
Sinclair Oil & Gas Co.	Martin No. 1	Larkin Baker Surv.	O-15	441	3999	2972	3966	—
Do	McRae No. 1	F. Vallanova Surv.	P-16	335	3976	2918	3874	—
Texas-New Orleans Prod. Co.	—	Near Jacksonville	P-16	—	423	—	—	—
Dallas County								
Buckner's Orphans Home	(water well)	7 mi. E. of Dallas	E-10	—	3368	—	—	—
Carnahan Newblock	—	Vicinity of Lancaster	D-11	—	1090	—	—	—
City of Dallas	(water well)	Negro Park, Oak Cliff, Dallas	D-10	—	2472	—	510	995
*De Soto city well	(water well)	Town of De Soto	D-11	610	925	—	760	—
First State Bank of Carrollton	Alford No. 1	Mary Kennedy Surv.	D- 9	—	1662	—	—	—
Garland city well	(water well)	Town of Garland	E-10	—	1350	—	1182	—
Mesquite city well	(water well)	Town of Mesquite	E-10	500	1725	—	1500	—
Southern Methodist Univ.	(water well)	Dallas	D-10	540	2850	—	670	1060
*Union Terminal Station	(water well)	Dallas	D-10	417	2745	—	550	970
*Vickory city well	(water well)	Town of Vickory	D- 9	500	750	—	500	—
Delta County								
Delta Dev. Co.	H. McKinney No. 1	J. Turner Surv. in B. B. Henderson Surv.	—	505	—	421	—	—
Evertts	Smith No. 1	J. A. Renfro Surv.	K- 5	525	—	355	—	—
*Thirteen Oil Co.	—	1 mi. E. Cooper	K- 5	495	2715	475	1920	—
Ellis County								
Avalon city well	(water well)	Town of Avalon	D-14	—	1016	—	—	—
Big State Oil Co.	Pritchett No. 1	Rafel de la Pena Surv.	—	485	1635	—	—	—
Boyce city well	—	Town of Boyce	D-13	519	975	—	—	—
Bridgeport Brick Co.	(water well)	1 mi. N. Ferr's	E-12	—	1325	—	—	—
*T. E. Caldwell	(water well)	H. H. Swisher Surv.	E-13	548	1210	—	1160	—
Dallas Oil Co.	Garvin No. 1	Coleman Jenkins Surv.	C-12	—	5220	—	—	—
Eason Gin well	(water well)	Town of Garrett	E-13	558	1372	—	1310	—
*Ennis deep well	(water well)	Town of Ennis	E-13	528	3560	—	1445	1835
Ennis Ice Plant well	(water well)	Town of Ennis	E-13	528	1580	—	—	—
Farmers Gin Co.	(water well)	Town of Waxahachie	D-13	—	952	—	—	—
Farrish-Watt-Collin Co.	Rachal No. 1	Town of Ennis	E-13	501	3566	—	1410	1760
Ferris Brick Co. old well	(water well)	Town of Ferris	E-12	467	1250	—	—	—
K. Ferris Farm	(water well)	Thos. S. Norrell Surv.	D-13	—	1112	—	—	—
Flannigan et al	Griffith No. 1	2½ mi. E. Palmer	E-12	510	1300	—	—	—
Foster & Richardson	Moise-Cerf No. 1	La Pena Surv.	—	440	—	—	1430	—
Henry Gin Co.	(water well)	Town of Henry	—	500	1197	—	—	—

TABLE 8.—*Well data*[a], *east Texas.*—(Continued)

COMPANY	FARM	LOCATION	CO-ORDINATE	ELEVATION	TOTAL DEPTH	DEPTH TO TOP OF PECAN GAP	DEPTH TO TOP OF WOODBINE	DEPTH TO TOP OF WASHITA
				Feet above sea level	*Feet*	*Feet*	*Feet*	*Feet*
Ellis County— Concluded								
F. B. Gentry	Triggs No. 1	5 mi. SE. Italy	D-15	—	1502	—	—	—
Green Press Brick Co.	(water well)	Town of Ferris	E-12	468	1325	—	—	—
Hartson Co.	F. Vaughn	18 mi. W. Waxahachie	C-13	—	257	—	—	—
*Italy city well	(water well)	Town of Italy	D-14	576	881	—	720	—
*Lewis Water Assoc.	Bardwell No. 1	Near Bardwell	E-14	478	1234	—	1040	—
Magnolia Pet. Co.	Getzendancer No. 1	S. Mayfield Surv.	E-13	—	2940	—	—	—
*Midlothian well	(water well)	Town of Midlothian	C-12	749	675	—	485	—
*Milford city well	(water well)	Town of Milford	D-15	601	2588	—	—	—
Mutz & Cassidy	(water well)	Town of Ferris	E-12	601	1350	—	—	—
Navarro O. & G. Dev. Co.	—	6.5 mi. SE. Ennis	F-14		1100	—	—	—
Palmer Gin & Compress Co.	(water well)	Town of Palmer	E-13	—	1154	—	1102	—
Palmer city well	(water well)	Do	E-13	471	1166	—	1140	—
Triangle Corp.	W. Hull No. 1	B. Smith Surv.	D-14	455	—	—	786	—
Waxahachie well	(water well)	Town of Waxahachie	D-13	560	—	—	700	978
Waxahachie Ice Plant well	(water well)	Do	D-13	550	1080	—	—	—
*Waxahachie Trinity well	(deep water well)	Do	D-13	550	2907	—	690	—
Fannin County								
Aswastika Oil Co.	Owens No. 1	Dav. Quinchaw Surv.	G- 5	750	2771	—	865	—
Bonham Water Plant	Well No. 2	Town of Bonham	H- 4	568	1156	—	950	—
Danciger Dev. Synd.	Kent No. 1	5 mi. NW. of Leonard	G- 5	—	2000	—	—	—
Elkay Oil & Gas Co.	Lane No. 1	James Bourland Surv.		—	1475	—	167	610
Ladonia city well	(water well)	Town of Ladonia	I- 5	670	2513	—	1970	—
Leonard city well	(water well)	Town of Leonard	H- 5	712	1219	—	1168	—
Ed. V. Parson-Peck	Morgan No. 1	J. E. English Surv.	H- 3	668	—	—	—	—
R. C. Sanders	Broadfoot No. 1	H. Williams Surv.	H- 3	511	2255	—	—	—
Telephone O. & G. Co.	Moore No. 1	N. of Bonham	H- 3	—	728	—	—	—
Franklin County								
Arkansas Fuel & Oil Co.	Dickson No. 1	Dan Field Surv.	N- 6	333	6261	1466	3300[b]	—
Do	Tittle No. 1	Thos. Willison Surv.	—	379	1550	1546	—	—
Cypress Glade Oil Co.	Gordon No. 1	John P. Moseley Surv.	N- 8	—	1952	—	—	—
Mahlstedt-Mook Co.	French No. 1	J. T. Pierson Surv.	N- 7	502	3176	2045	—	—
J. C. McNeill	Harper No. 1	J. S. Cliff Surv.	N- 6	383	3020	1485	3320[b]	—
Mt. Vernon Pet. Co.	Stanton No. 1	John Plunk Surv.	N- 7	—	2920	—	—	—
Trout et al	Gandy No. 1	James Truitt Surv.	N- 7	464	3309	1851	3850[b]	—

Freestone County

Abernathy et al	Gillam No. 1	J. B. McElrey Hrs. Surv.	G-19	458	4400	—	—	—
Abner Davis	Adamson No. 1	—	—	—	3112	—	—	—
Alexander & Lyles	Edwards No. 1	Simon Sanchez League	J-18	—	2010	—	—	—
Bentley & Malone	I. B. Kirven No. 1	Henry Awalt Surv.	H-17	—	3501	—	—	—
Bison Oil Co.	Thomson No. 1	M. Casillas Surv.	G-19	—	1510	—	—	—
Boyd Oil Co.	Simmons No. 1	R. B. Longbotham Surv.	F-17	431	2903	—	—	—
Brothers Oil Co.	Bounds No. 1	W. Richie Surv.	G-17	460	2721	—	—	—
Burke Texas Co.	G. Bonner No. 1	Sidney Sweet Surv.	G-17	—	3219	—	—	—
Carter & Lytle	Hackney No. 1	Sarah McAnulty Surv.	F-18	—	3132	—	—	—
Do	W. Lee No. 1	B. Longbotham Surv.	F-18	470	3501	—	—	—
Do	Manning No. 1	Sarah McAnulty Surv.	F-18	—	1681	—	—	—
J. S. Cosden	Woods No. 1	Maria de Cantona League	G-18	503	4226	2430	4092	—
*Cranfill & Reynolds	W. E. Bonner No. 1	S. T. Ballour Surv.	G-18	330	3868	2680	3730	—
Dillon & Richard	Stubbs No. 1	2½ mi. SE. Wortham	G-17	404	2736	—	—	—
Dorado Oil Co.	Edwards-Langley No. 1	J. Robbins Surv.	I-19	—	2834	—	—	—
Emerald Oil Co.	Tacker No. 1	G. Luna League	H-20	—	3150	—	—	—
Do	R. A. Tacker No. 4	Do	H-20	—	2981	—	—	—
Freeman Oil Co.	D. A. Haddick No 1	A. L. Stone Surv.	G-18	—	3010	—	—	—
Freestone Synd.	R. A. Tacker No. 1	G. Luna League	H-20	—	2340	—	—	—
T. L. Freiley	Purfoy No. 4	Wm. Richie Surv.	G-17	470	3100	—	—	—
Greenwood et al (Ligon Johnson)	Pitts No. 1	E. P. Cabler Surv.	G-18	535	3500	—	—	—
Hamil et al	Hackey & Weaver No. 1	Maria de Canton Surv.	G-18	590	3270	—	—	—
*J. W. Hoosier	McGeorge No. 1	S. A. Sweet Surv.	G-17	418	3340	—	3280	—
Do	Mussbaum No. 1	Do	G-17	368	3269	—	3237	—
Humble O. & Rfg. Co.	McCelland No. 1	W. Richie Surv.	G-17	460	2680	—	—	—
Do	W. E. MacDaniel No. 1	Simon Sanchez Surv.	J-18	331	4001	2830	—	—
*Keechi Pet. Co.	Perkins No. 1	J. A. Prewitt Surv.	J-19	490	3803	3703	—	—
Killam-Phillips Co.	R. H. Edwards No. 1	A. Sanchez Surv.	I-19	402	3854	3470	—	—
Lent et al	McFall No. 1	Sarah McAnulty Surv.	F-18	—	3500	—	—	—
C. F. Lytle et al	Holt No. 1	D. Avent Surv.	H-19	469	4380	—	4594	—
Thad McClain Co.	Green No. 1	John Lawrence Surv.	H-19	385	4055	2400	—	—
Magnolia Pet. Co.	N. B. Boyd No. 10	Sarah McAnulty Surv.	F-17	—	3000	—	—	—
Mexia Chief Oil Synd.	Tyner No. 1	A. L. Stone Surv.	G-18	—	3309	—	—	—
Mid-Kansas O. & G. Co.	Bounds No. 1	W. Richie Surv.	F-17	—	3157	—	—	—
National Consolidated	Coleman No. 1	Howard Surv.	G-17	369	3559	1950	3345	—
O. K. Oil & Gas (Haley & Pound)	H. Knight No. 1	David Bullock Surv.	G-18	—	3540	—	—	—
Orbit Oil Co.	Coleman No. 1	H. Howard Surv.	G-17	369	3360	1945	3345	—
Pathfinder Oil Co.	Holt No. 1	Do	G-17	—	2903	—	—	—
*Penn Oil Co.	Burgher No. 1	C. Chamer Surv.	I-18	401	—	2971	—	—
F. E. Pope	J. Smith No. 1	M. C. McGrew Surv.	H-19	—	3504	—	—	—
Pure Oil Co.	Couch No. 2	R. B. Longbotham Surv.	F-17	403	3250	—	—	—
*Riley et al	Couch No. 1	Do	F-17	432	3140	—	3120	—
Rio Bravo Oil Co.	H. & T. C. Fee No. 14	Wortham town site	F-17	—	4830	—	—	—

TABLE 8.—*Well data*[a], *east Texas*.—(Continued)

COMPANY	FARM	LOCATION	CO-ORDINATE	ELEVATION	TOTAL DEPTH	DEPTH TO TOP OF PECAN GAP	DEPTH TO TOP OF WOODBINE	DEPTH TO TOP OF WASHITA
				Feet above sea level	*Feet*	*Feet*	*Feet*	*Feet*
Freestone County— Concluded								
Roxana Pet. Co.	Thiele No. 1	T. C. Ry. Surv.	J-19	—	3955	—	—	—
Sewell & Baer	Smith No. 1	Sarah McAnulty Surv.	F-18	450	2107	—	—	—
Shirley et al	Hackmeyer & Weaver No. 1	Maria de Canton Surv.	G-18	—	3580	—	—	—
Simms Oil Co.	W. Calame No. 3	Longbotham Surv.	F-17	—	2832	—	—	—
Smith & Swift	J. Bounds	W. Richie Surv.	F-17	—	3108	—	—	—
Southern Oil Co.	Young No. 1	Do	G-17	425	3198	—	—	—
Southern Pet. Co.	Gaddy No. 1	H. Howard Surv.	—	—	3440	—	—	—
St. Louis Synd.	Red Horseshoe No. 1	James Stricklen Surv.	G-17	422	3210	—	—	—
Sun Oil Co.	Worthy No. 1	M. Cassillas Surv.	H-20	—	3906	—	—	—
The Texas Co.	W. S. Evans-Bounds	J. M. Davis Surv.	G-17	414	2952	—	—	—
Texiana	Wright No. 1	—	—	438	3233	—	—	—
Trapshooter Dev. Co.	J. Bounds No. 1	Ritchie Surv.	F-17	405	3260	—	—	—
Do	M. Couch No. 1	Longbotham Surv.	F-17	403	3195	—	—	—
Grayson County								
F. H. E. Oil Co.	Bryant No. 1	Pottsboro Field	E- 3	—	1510	—	—	—
Do	Dalton No. 1	G. R. Reeves Surv.	E- 3	—	840	—	—	—
Do	Dalton No. 2	Do	E- 3	—	897	—	—	—
Do	Finke No. 1	John Hull Surv.	E- 3	685	858	—	—	—
Do	Henderson No 1	B. Holder Surv.	E- 3	675	—	—	—	—
Do	Mauldin No. 1	—	—	647	859	—	—	—
*Gunter city well	(water well)	Town of Gunter	E- 5	697	600	—	485	—
*Howe city well	(water well)	Town of Howe	E- 4	640	980	—	752	—
*Sherman city well	(water well)	City of Sherman	E- 4	745	2366	—	965	—
Do	(water well)	Do	E- 4	745	752	—	—	—
Simpson-Felk Co.	Wall No. 1	J. Ingram Surv.	E- 3	—	2515	—	—	—
Sowell Bros.	Cannon No. 1	—	—	—	2800	—	—	—
Texas Tong & Tool Co.	Trinity well	J. B. McAnair	E- 4	—	2132	—	—	—
Tucker & Everett	Handy & Thorn No. 1	—	—	—	3032	—	—	—
Van Alstyne city well	Town of Van Alstyne	James McKinney	F- 5	—	1188	—	—	—
Gregg County								
Alco Royalty Co.	J. R. Castleberry No. 1	J. R. Castlebury Surv.	Q-12	268	3519	2274	—	3492
Arkansas Fuel Oil Co.	P. D. Harrison No. 1	—	—	—	3560	2455	3540	—
Do	W. L. Hestland No. 1	—	—	413	3608	2400	3608	—
Do	Lathrop No. 1-A	Wm. Robinson Surv. A-177	Q-12	401	3587	2458	3568	—
Do	F. K. Lathrop No. 1-B	Do	Q-12	414	3608	2578	3588	—
Do	F. K. Lathrop No. 1-C	Do	Q-12	—	3678	2414	3600	—

Do	F. K. Lathrop No. 2-A	Do	Q-12	420	3613	2488	3590	
Do	F. K. Lathrop No. 3-A	Do	Q-12	415	3605	2415	3583	
Do	R. S. McKinley No. 1			395	3600	2446	3578	
Blackwell O. & G. Co.	M. Magrill No. 1			446	3674	2390	3661	
W. L. Brandon-Geo. McCamey et al	Richards No. 1	M. Van W'nkle Surv.	P-13	339	3574	2541		3562
D. H. Byrd-Gulf Prod. Co.	Camorras No. 1	Haden-Edwards Surv.	Q-13	373	3518	2405		3480
Do	Frank Elder No. 1	Wm. J. McCurry Surv.	Q-13	341	4012	2418		
Capitol Drilling Co. et al	L. Osborne No. 1	Bobbitt Surv.	P-13	361	4070	2648		
Daniel & Patten	L. C. Dudley No. 1	Henry Wade Surv.	Q-13	365	3530	2535		3530
Ernest E. Eslick & Little	Springhill Church No. 1	Dolores Sanchez Surv.	Q-11	411	3623	2441	3597	
F. R. Foster-East Texas Refining Co.	Fisher Rodden No. 1	John Ruddle Surv.	Q-12	333	3542	2320		
Do	Fisher Rodden No. 2	Do	Q-12		3545	2325	3513	
General Pet. Co.	P. T. Morgan No. 1	Steve Simonds Surv.	Q-11	307	3345			
Hammond	Hamby No. 1	John Lout Surv.	Q-11	376	3724	2507		3685
O. L. Hickman et al	Maude Smith No. 1	Skillern Surv.		373	3580	2327		3555
T. D. Humphrey et al	A. F. McAfee No. 1	Wm. Engle Surv.	Q-12	349	3578	2370		3538
S. F. Hurlburt & Burton.	A. J. Page No. 1	J. F. Dixon Surv.	Q-11	438	3690	2610		3667
S. F. Hurlburt et al	L. L. Mackey No. 1	G. Y. Chambliss Surv.	Q-11	311	3651	2440		3640
Magnolia Pet. Co.	B. E. Rodden No. 1	J. Ruddle Surv.	Q-12	417	3616	2411	3597	
Do	B. E. Rodden No. 2	Do	Q-12	409	3603	2485	3587	
Do	B. E. Rodden No. 3	Do	Q-12		3568	2512	3546	
Do	B. E. Rodden No. 4	Do	Q-12		3595	2515	3568	
Do	B. E. Rodden No. 5	Do	Q-12		3616	2411	3596	
K. E. Merren-Miller-Van Horn	Maude Smith No. 1	I. Skilkern Surv.	Q-12	377	3605	2373		3550
National Securities Oil Corp.	C. Vernon No. 1	W. W. Avery Surv.	P-12	291	3627	2575	3621	
Natural Crude Oil Co.	Williams No. 1				2120			
Navarro Oil Co et al	G. B. Tenery No. 1			419	3603	2585	3587	
Geo. L. Pace et al	C. Harrell No. 1	A. M. Coleman Surv.	P-13	468	3875	2760	3870	
R. W. Perkins et al	Walter McCreede No. 1				3703	3703		
Pilot Oil Co.	McGrede No. 1			413	3681	2412	3592	
Producers Oil Co.	Sessume No. 1	W. M. Hewitt Surv.	Q-12		2685			
W. C. Ray Drilling Co.	Maude Smith No. 1	I. Skilkern Surv.	Q-12	374	3570	2339		3546
Roeser-Pendleton et al	B. E. Rodden No. 1			408	3592	2405	3575	
Do	B. E. Rodden No. 2				3581	2370	3558	
Rush, G. E. Hubbard & Simms Oil Co.	Tenery No. 1			413	3594	2462	3574	
Sabine Oil & Devel. Co.	J. F. Harris No. 1	M. Van Winkle Surv.	P-13		3666	2898		
Sabine Pet. Co.	Morgan No. 2	D. Simpson Surv.	Q-13	307	3345	2030		3175
Selby Oil Co.	P. J. Snavely No. 1	Wm. Tynedale	P-12	273	3583	2488	3528	
Skipper Oil Co.	Thadd Snoddy No. 1			387	3612	2400	3573	
Skipper Oil Co. & Lacy	Maggie Magrill No. 1			419	3658	2448	3644	
Stanolind Oil & Gas Co.-Simms Oil Co.	G. B. Tenery No. 1			398	3580	2550	3560	

TABLE 8.—*Well data*[a], *east Texas*.—(Continued)

COMPANY	FARM	LOCATION	CO-ORDINATE	ELEVATION	TOTAL DEPTH	DEPTH TO TOP OF PECAN GAP	DEPTH TO TOP OF WOODBINE	DEPTH TO TOP OF WASHITA
				Feet above sea level	*Feet*	*Feet*	*Feet*	*Feet*
Gregg County— Concluded								
Sultan Oil Co.	S. F. Thrasher No. 1	—	—	328	3564	2304	3524	—
Tidal-J. K. Wadely & Jim Evan	A. A. Castleberry No. 1	William Robinson Surv.	Q-12	416	3614	2430	—	3612
Tidal Oil Co.	F. K. Lathrop No. 1	Do	Q-12	430	3656	2465	3603	—
Tidal-J. K. Wadely & Jim Evan	A. G. Morton No. 1	W. McCurry Surv.	Q-13	—	3700	2490	—	3533
J. R. Travis et al	A. G. Morton No. 1	Do	Q-13	319	3700	2490	—	—
Vitek et al	Louis Osborne No. 1	R. R. Bobbitt Surv.	P-13	386	4005	2768	3785	3569
P. F. White	Clara Williams No. 1	David Hill Surv.	Q-12	407	3590	2244	—	—
Ben Youngblood et al	Wm. Lamb No. 1	David Ferguson Surv.	Q-12	401	3619	2417	—	3534
Yount-Lee Oil Co.	J. P. Davis No. 1	Near Gladewater	P-12	404	3530	2359	3596	—
Do	J. C. McKinley No. 1	Do	P-12	—	3600	2411	3573	—
Harrison County								
W. M. Atkinson	O. D. Hays No. 1	J. C. Chappin Surv.	—	307	2875	1770	—	2850
Ben Banner	J. C. Lowery No. 1	W. O. Stanfield Surv.	S-12	—	4016	—	—	—
Nick Barbare	J. W. Furrh No. 10	Jas. Short Surv.		—	2380	—	—	—
Crump & Hannagan	Dunn No. 1	Bettie Humphries Surv.	R-11	330	4006	—	—	3555
Eureka Nat. Gas Co.	Vaughn No. 2	W. R. Anderson Surv.	—	—	2352	—	—	—
Everett Drilling Co.	R. L. Syport No. 1	Richard Hooper Surv.	—	311	4007	2154	—	3995
Gulf Prod. Co.	Waterman Lbr. No. 1	E. Pollock Surv.	U-12	245	2804	—	—	2312
W. H. Hobson	Taylor No. 1	Henry Vardeman Surv.	—	284	3540	—	—	3183
Karona Pet. Co.	A. J. Bohler No. 1	S. F. Sparks Surv.	—	310	3161	1935	—	2812
Lyons Gas Co.	O'Bannon No. 1	W. H. Adams Surv.	—	—	2398	—	—	—
Do	Furrh No. 2	J. Lipscomb Surv.	—	253	2366	—	—	—
McRitchie	Dean	J. W. Croft Hrs.	V-11	229	2804	—	—	—
Geo. L. Pace	Barker No. 1	Victor Pedraso Surv.	—	349	4018	2237	—	2327
W. G. Ray Drilling Co.	M. J. Hall No. 1	D. Davis Surv.	—	591	3752	2257	—	3472
Shell Rock Oil Co.	O. Dougherty No. 1	W. B. Burress Surv.	R-12	388	3568	1900	—	3346
Sinclair Oil & Gas Co.	Davenport No. 1	John V. Morton Surv.	R-10	396	3735	2420	—	3712
Do	Gwynne No. 1	George Morgan Surv.	S-12	—	3000	—	—	—
Standard Orchard Oil Co.	—	½ mi. S. of Scottsville	—	—	3078	—	—	—
U. S. Drilling Corp.	Harris No. 1	J. Harris Surv.	T-12	410	4050	—	—	2930
Henderson County								
Arcadia Refining Co.	Dean No. 1	Simon Boon Surv.	—	—	4206	2432	3893	—
H. B. Ashburn	T. E. Barry No. 1	Jas. Duncan Surv.	K-14	397	3993	2810	—	—

Atlantic Oil Prod. Co.	Gamble No. 1	D. O. Williams Surv.	—	384	3103	—	—	—
Barkley & Meadow	McCluney No. 1	Amand Carroll Surv.	H-14	277	3395	—	3349	—
Bengrew Petrol. Co.	Cade Bros. No. 1	J. B. Dorsey Surv.		—	2015	—	—	—
Billings Oil Co.	J. M. Dansby No. 1	J. J. Martinez Surv.	L-15	480	4750	3177	4562	—
Billings et al	Tucker No. 1	Do	L-15	507	4484	—	—	—
Boston Fincastle Oil Co.	Tucker No. 1	Do	L-15	507	4484	3200	—	—
L. G. Bradstreet	Schaunnessy No. 1	John Izard Surv., 3½ mi. SW. Athens	J-14	548	4585	2560	4381	—
E. L. Chapman	Cade Bros. No. 1	Simon Wiess Surv.	M-13	340	3189	3170	—	—
Do	Cade No. 2	J. B. Dorsey Surv.	M-14	—	944	—	—	—
Do	Cade No. 3	Do	M-14	—	5090	3073	5051	—
Cranfill Bros.	J. W. Springer No. 1	J. M. Gardner Surv.	H-13	312	3300	—	3165	—
Cranfill & Reynolds	J. W. Broome No. 1	Samuel Cheap Surv.	J-15	457	4700	2695	4230	—
*Cranfill & Germany	Starr No. 1	Guadalupe Acosta Surv., 2½ mi. NE. Murchinson	K-13	434	4503	2543	4463	—
Foster et al	T. M. Richardson No. 1	I. W. Burton Surv.	L-15	403	3843	3234	—	—
Fred Haynes	Bounds No. 1	Henry Jeffrey Surv.	H-14	313	1733	—	—	—
Do	Bounds No. 2	Do	H-14	—	1831	—	—	—
Do	Bounds No. 3	Do	H-14	—	3053	—	—	—
Do	Wood No. 1	N. G. Russell Surv.	H-14	379	2607	—	—	—
Do	Pippin No. 1	G. W. Walters Surv.	I-13	—	2310	—	—	—
F. Heine	F. C. Cox No. 1	J. P. Brown Surv., Blk. 28	I-13	349	3657	1950	3629	—
Do	Tittle No. 1	G. T. Walters Surv.	I-13	—	3108	—	—	—
Do	Sterrett No. 2	I. Marshall Surv.	I-13	—	3110	—	—	—
Henderson Oil Co.	G. Perry No. 1	Susan B. Jones Surv.	J-15	—	3221	2827	—	—
Kim-Mill Oil Co.	Dobbs No. 1	Samuel Weiss Hrs. Surv.	M-13	307	—	—	—	—
Mutual Security Oil Co.	Browning No. 1	Murchinson	K-14	470	3946	2700	—	—
Geo. Pace	S. Anthony No. 1	J. M. Bettram Surv.	I-13	410	4039	2252	3979	—
Penn & Byrd & T. P. C. & O. Co.	Murphy No. 1	J. M. Gardner Surv.	H-13	323	3263	1885	3165	—
Pine Grove Oil Co.	Johnson No. 1	W. M. Brown Surv.	K-15	—	2911	—	—	—
Do	Brown No. 1	Samuel Chears Surv.	K-15	—	1180	—	—	—
Richardson Bros.	Cade No. 1	E. C. Sutherland Surv.	M-14	—	3501	—	—	—
Sid Richardson	Richardson No. 1	W. D. Ratcliff Surv.	I-14	430	3625	2380	—	—
*Shell Corp.	S. T. Stephens No. 1	I. D. Owen Surv.	K-15	510	4815	2050	3175	3600
Sun Oil Co.	Purfey No. 1	—	—	—	3033	—	—	—
Sunray Oil Co.	Davis No. 1	E. Harris Surv.	J-13	483	4721	2536	4496	—
Texas State Oil Co.	T. H. Skinner No. 1	J. Hinshaw Surv.	J-14	453	4581	2500	4396	4405
J. L. Thompson	Brown No. 1	Samuel Chears Surv.	K-15	—	1980	—	—	—
Tidal Oil Co.	Moore No. 1	J. N. Selley Surv.	I-14	458	3562	2500	—	—
Twin Creek Oil Co.	Sterrett No. 1	3 mi. SE. Maybank	I-13	370	1200	—	—	—
Union Pet. Co.	Kook Keek No. 1	John Morgan Surv.	K-15	—	2658	—	—	—
Hill County								
Advance Oil Co.	T. Speaker No. 1	G. H. Ussary Surv.	—	550	2998	—	—	—
* Do	Wood No. 1	James Harper Surv.	—	552	2574	—	1030	—
*T. W. Berger	(water well)		C-14	675	560	—	372	—

TABLE 8.—*Well data*[a], *east Texas*.—(Continued)

COMPANY	FARM	LOCATION	CO-ORDINATE	ELEVATION	TOTAL DEPTH	DEPTH TO TOP OF PECAN GAP	DEPTH TO TOP OF WOODBINE	DEPTH TO TOP OF WASHITA
				Feet above sea level	*Feet*	*Feet*	*Feet*	*Feet*
Hill County— Concluded								
*Bynum city well	(water well)	Town of Bynum	----	678	765	----	635	----
Cal-Tex Oil Co.	Mastin No. 1	3½ mi. SW. of Grandview	----	750	----	----	----	----
A. L. Edington	Jones No. 2	B. B. E. Ry. Co.	D-18	601	1500	----	----	----
Ed Hewitt	Banks No. 1	----	----	582	1505	----	----	----
*Hillsboro city well	(water well)	W. Houston Surv.	B-16	634	2200	----	117	----
Hub Oil Co.	Nathan Land No. 1	Copeland Surv.	D-17	621	1524	----	1238	----
*Hubbard city well	(water well)	W. Beasley Surv.	D-17	647	3166	----	1350	1480
Irene city well	(water well)	T. R. Nunn Surv.	D-16	----	915	----	894	----
Johnson & Phillips	Rose No. 1	Francis Blades Surv.	A-17	----	3349	----	----	----
J. S. Lee	Rogers No. 1	J. Tumblinson Surv.	D-17	540	1495	----	----	----
*Malone city well	(Trinity water well)	E. Hall Surv.	D-16	500	2471	----	856	1061
J. Meers et al	C. Rodgers No. 1	J. Tumblinson Surv.	D-17	540	1398	----	----	----
*Mertens city well	(water well)	Town of Mertens	D-15	533	850	----	780	----
Mid-Kansas Oil Co.	W. Patterson No. 1	Hardy Martin Surv.	C-16	621	2244	----	630	823
Penelope city well	(water well)	Tyler Co. School Land	C-17	627	2368	----	980	1199
J. C. Pool	Hammer No. 1	Ratcliff Surv.	D-17	624	2175	----	----	----
Pure Oil Co.	Barton No. 1	Tyler Co. School Land	C-17	693	1723	----	----	----
Hugh Smith	Jones No. 2	B. B. B. & C. Ry. Surv.	D-18	677	1228	----	----	----
Smith & Latson	Jones No. 1	Do	D-18	658	1500	----	----	----
Hopkins County								
Alcorn Oil Co.	Coppage No. 1	H. Hamilton Surv.	J- 8	464	4033	1855	3500	----
Amerada Pet. Corp.	Jackson & Maloney No. 1	W. Ewing Surv.	K- 6	474	3393	1465	2845	----
Atlantic Oil Prod. Co.	S McMilholland No. 1	J. H. Simpson Surv.	K- 6	525	3501	1408	3247	----
S. I. Borden et al	Smith No. 1	Eliz. Mitchell Surv.	L- 7	428	3430	1740	3280	3780
*Cousin & Hall	Brant No. 1	J. A. Winn Surv.	M- 7	445	3421	1770	3810[b]	----
E. A. Dreeben et al	Patterson No. 1	H. Russell Surv.	K- 7	595	3217	1555	3650	----
*Gulf Prod. Co.	Davis No. 1	Dan Fuller Surv.	L- 6	460	3366	1450	3310[b]	----
Do	Pierce No. 1	Alex. O. Wetmore Surv.	M- 6	420	3360	1150	3150	----
Kelsey et al	Addie Brooks	D. Dan Dawdell Surv.	K- 7	564	1807	----	----	----
National Oil Co.	Smiddy No. 1	Elisha Simmons Surv.	K- 6	497	3435	1470	3070	----
*Okla-Texas Oil Co.	Hamilton No. 1	E. Deacon Surv.	M- 7	501	3766	----	4081[b]	----
*Panhandle O. & Rfg. Co.	Davis No. 1	Robinson Surv.	L- 6	457	3506	1310	2870	----
Parks & Witherspoon	Smith No. 1	Camelo Cain Surv.	M- 6	403	2718	1440	3000	----
Do	Smith No. 2	Allen McLendon Surv.	M- 6	440	1631	----	----	----
Roxana Pet. Co.	Dolly Cork No. 1	R. C. Mathews Surv.	M- 7	425	3506	1740	3800	----
Rycade Oil Corp.	Gatex No. 1	F. Robinson Surv.	----	----	2877	----	----	----

G. J. Smith & Skelly O. Co.	McGowan No. 1	Shelby Tunnage Surv.	J- 8	509	3730	1930	3599	—
E. L. Smith et al	Pippin No. 1	Hawkins Surv.	K- 8	489	3618	2030	3700	—
Southwestern Oil Co.	Hardaway No. 1	Thos. Yates Surv.	K- 7	471	1421	—	—	—
Sulphur Springs city well	(water well)	Town of Sulphur Springs	L- 7	—	3045	1900	3850	—
Stough-King-Trotts	Fitzgerald No. 1	Jno. Binton Surv.	K- 8	513	2238	—	3850	—
The Texas Co.	Enix No. 1	J. Hulle Surv.	K- 7	533	3760	2045	3750	—
Do	J. Wortham No. 1	W. Hough Surv.	M- 7	375	3715	1550	3590	—
*Texas & Pacific O. Co.	McKay No. 1	Hayden Arnold Surv.	L- 8	500	4103	2520	4300[b]	—
Winnsboro Pet. Co.	Attoway No. 1	M. Ybarbo Surv.	M- 8	471	2535	—	—	—
Hunt County								
Amerada Pet. Corp.	Grainer No. 1	James Hamilton Surv.	H- 9	432	3262	—	3023	—
Branson	West No. 1	James Roads Surv.	H- 8	505	3239	1310	2525	—
Cash Oil Co.	Gibson No. 1	R. Mabry Surv.	H- 8	493	2665	—	—	—
Celeste city well	(water well)	Town of Celeste	H- 6	—	1554	—	—	—
Fensland Oil Co.	Greenwood No. 1	James Nicholson Surv.	—	660	3206	—	—	—
Greenville city well	(water well)	Town of Greenville	—	—	—	—	—	—
Gulf Prod. Co.	Alexander No. 1	E. Tedwell Surv.	I- 7	532	3205	—	2900	—
Do	Bell (Bonner) No. 1	John Bordine Surv.	I- 9	418	2167	—	—	—
Do	Bryan No. 1	Jas. Cole Surv.	I- 8	442	3314	—	2990	—
Do	Cannon No. 1	J. R. Ragsdale Surv.	I- 7	591	3297	—	2768	—
Do (Invincible)	Corley No. 1	John Finley Surv.	J- 8	523	3520	—	3400	—
Do	Hicks No. 1	J. Bordine Surv.	I- 9	461	4768	—	3350	—
Do	Harris (Rawton) No. 1	G. W. Schultz Surv.	I- 9	437	3430	—	3110	—
Gulf-Atlantic Cos.	Meadows No. 1	James Levins Surv.	I- 9	434	3512	—	—	—
Harlow Pettit et al	Cooper No. 1	Chas. Cole Surv.	I- 7	557	3140	—	2682	—
J. K. Hughes	Manley No. 1	John Mooney Surv.	J- 7	569	2997	—	—	—
Humble O. & Rfg. Co.	Knight No. 1	Richard Byrd Surv.	J- 6	—	1074	—	—	—
Hunt Oil Co.	Wolfe City	—	H- 5	—	1765	—	—	—
Kelsey et al	Barnett No. 1	A. Smith Surv.	J- 8	—	2070	—	—	—
Kimball Flour Mill	—	Jas. Merrick Surv.	I- 5	682	1716	—	—	—
Lone Oak Co. (Hog Creek-Carruth)	Neal No. 1	W. Lewis Surv.	I- 8	492	3500	—	—	—
Marland Oil Co.	Weathers No. 1	Jas. Hamilton Surv., Sec. 22	I- 9	487	3743	—	2700	—
Do	Paul Knight No. 1	Do	I- 9	—	3750	—	—	—
McPhail Co.	Maller No. 1	W. A. J. Brown Surv.	H- 8	—	2990	—	—	—
Mexia-Kaufman Co.	Dennis No. 1	Jose Santos Surv.	H- 9	489	3350	—	—	—
Rycade Oil Corp.	Holden	James McAdams Surv.	H- 9	496	75	—	—	—
Do	Dr. Lytal No. 1	Do	H- 9	520	3465	1785	3045	—
Do	Robinson No. 1	Jas. M. Rush Surv.	H- 9	510	2490	—	—	—
Sowell Bros.	Weathers No. 1	Jas. Hamilton Surv., Sec. 38	I- 9	437	3293	—	—	—
Tri-City	Ridley No. 1	McKinney & Williams Surv.	J- 7	558	3248	—	2920	—
Wolfe City Pet. Co.	Kennedy No. 1	1½ mi. NW. Wolfe City	I- 5	865	2365	—	—	—
Kaufman County								
Atlantic-Skinner	Becker No. 1	Thos. H. Easton Surv.	H-12	450	3144	—	3106	—
Barney Carter	D. Brown No. 1	M. Reynolds Surv.	G-12	[illegible]	2981	—	2654	—
Barney Carter et al	McMaster Hrs. No. 1	John Pyle Surv.	[illegible]-12	[illegible]	[illegible]	—	2660	—

TABLE 8.—*Well data*[a], *east Texas*.—(Continued)

COMPANY	FARM	LOCATION	CO-ORDINATE	ELEVATION	TOTAL DEPTH	DEPTH TO TOP OF PECAN GAP	DEPTH TO TOP OF WOODBINE	DEPTH TO TOP OF WASHITA
				Feet above sea level	*Feet*	*Feet*	*Feet*	*Feet*
Kaufman County— Concluded								
Boyd Oil Co.	B. R. Rand No. 1	J. M. Riveson Surv.	H-12	376	3441	1978	3441	-----
Boyd-Cranfill-Kirby	Tharp No. 1	Dikes Surv., E. Maybank	H-13	379	3350	1777	3292	-----
J. F. Carter	Cottonwood	-----	-----	374	1958	-----	-----	-----
Combine Gin Co.	(water well)	E. Crane Surv., S. Crandall	-----	415	2070	-----	-----	-----
Cranfill Bros.	Marland No. 1	G. Ybarbo Surv.	H-13	332	3280	-----	3060	-----
*Cranfill & Griffith	R. B. Monk No. 1	John Ables Surv.	H-11	499	3337	-----	3330	-----
Cranfill & Reynolds	Nicholson No. 1	A. Bennett Surv.	H-10	-----	3203	-----	-----	-----
Couch-Winfrey Synd.	Gibbard	Levi Pruitt Surv., 7 mi. SW. of Wills Point	I-10	-----	2360	-----	-----	-----
Farmers Gin well	Crandall	-----	F-11	-----	2140	-----	-----	-----
*Forney Ice Plant	(artesian well)	Town of Forney	F-10	461	2051	-----	1760	-----
Harty & Germany	Kirby No. 1	-----	-----	461	2790	1587	2770	-----
Hedrick Oil Corp.	Woods No. 1	J. Baker Surv.	H-13	400	3112	-----	3012	-----
Do	Woods No. 2	Do	H-13	-----	-----	-----	-----	-----
Humphreys Corp.	Ables No. 1	R. G. Cartwright Surv.	H-10	-----	-----	-----	-----	-----
Do	J. L. Fox	P. H. Pearson Surv.	H-12	-----	-----	-----	-----	-----
Do	Ables No. 1	Wm. Fulcher Surv.	H-10	547	3619	-----	3350	-----
Do	Barrow No. 1	S. R. Heath Surv.	H- 9	573	3510	-----	3181	-----
Do	Bynum No. 1	P. Tesia Surv.	G-11	-----	2910	-----	-----	-----
Do	Clarida No. 1	Juan Gonzales Surv.	H-12	520	3324	-----	3190	-----
*Insane Asylum	(water well)	Town of Terrell	G-10	530	2960	-----	2600	2950
Jackson & Cathcart	Watkins No. 1	C. Pearson Surv.	H-12	-----	2400	-----	-----	-----
*Lyles et al	Messengill No. 1	Phil Walker Surv.	H-11	463	2989	-----	2988	-----
Magnolia Pet. Co.	Carnack No. 1	J. Cassilas Surv.	G-10	522	3706	-----	2790	2965
Marland Prod. Co.	Kelly No. 1	B. S. Newman Surv.	H-12	401	3714	1905	3493	-----
Do	Kensale No. 1	Do	H-12	377	3403	1860	3390	-----
Mexia-Reynolds	Cartwright No. 1	W. Colwell Surv.	H-12	482	3080	-----	3082	-----
Panhandle Refining Co.	Grinnall No. 1	R. A. Bennett Surv.	H-10	577	3504	-----	3385	-----
Pioneer Oil Co.	Trinity	-----	-----	314	3530	-----	-----	-----
Nova Scotia Pet. Co.	Pyle No. 1	Maria Dolores Soto Surv.	-----	-----	-----	-----	-----	-----
Roscoe & Carlisle	M. Wilkerson No. 1	R. O. Brown Surv.	H-12	332	2344	-----	-----	-----
Ranger Oil & Gas	Harbin No. 1	A. Owens Surv.	H-13	330	3530	-----	3196	-----
Shaw-Alexander	Barrow No. 1	R. A. Terrell Surv.	-----	538	-----	1080	3232	-----
Skinner-Kelsey	Barrows No. 1	John Riverson Surv.	-----	527	2212	-----	-----	-----
Trapshooter Reilly	Porter No. 1	Isaac Surv.	I-13	406	2930	1915	-----	-----
W. B. Tucker et al	Bosher No. 1	T. Stokeley Surv.	H-11	520	3517	2004	3500	-----
Willis Point O. & G. Co.	Watson No. 1	J. Escalan Surv.	H-10	-----	1250	-----	-----	-----

Lamar County								
Bailey Dev. Co.	Ford No. 1	S. & P. S. Doss Surv.		565	605			
Laubenheim	S. D. Johnson No. 1	Wm. Drigger Surv., 1 mi. W. Paris	L- 3	667	3090			
*Paris city well	(water well)	Town of Paris	L- 3	601	1726		716	
Limestone County								
Atlantic Prod. Co.	Eisemeyer No. 3	D. C. Abbott Surv.	D-18	657	1953		1698	1912
Do	Gillette-Rosson No. 2	P. Varela Surv.	F-19	502	2847			
Do	A. E. Rosson No. 1	Do	F-18	509	2851		2843	
Do	A. E. Rosson No. 3	Do	F-18	501	2829		2826	
Barkley	Meadows-Rosson No. 2	Nigger Cr. field	F-18	509				
Barclay & Meadows	A. E. Rosson No. 1	P. Varela Surv.	F-18		2853		2837	2850
Co-operative Oil Co.	Everett No. 1		F-18	480	2750			
Cranfill & Reynolds Co.	Dugger No. 1	P. Varela Surv.	F-18	529	2928			
Dearing & Imperator	B. B. Baron No. 1	E. Mabry Surv.	F-20			1622		
Cayton et al	Thorton No. 1	J. Boyd Surv.	F-18		3128			
Dearing & Son	Stroud No. 1	P. Varela Surv.	F-19		4414			
Donoho & Smith	Oliver No. 1	Do	F-19	574	3306			
A. J. Eisenmeyer	Baker No. 1	Near Prairie Hill	D-18		1550			
Ewno Oil Corp.	Black No. 1	L. Norvell Surv.	F-18	552	2690			
Do	Sweatt & Bass No. 1	P. Varela Surv.	F-18		3588			
Flannigan	J. Presnall	A. Varella Surv.	F-18		3292			
Godley Oil Co.	A. E. Rosson No. 1	P. Varela Surv.	F-18	494	2844		2829	
Do	A. E. Rosson No. 2	Do	F-18	498	2842		2831	
Do	A. E. Rosson No. 3	Do	F-18		2842		2838	
Godley, Cranfill & Reynolds	A. E. Rosson No. 1-A	Do	F-18	480	2813		2809	
Do	A. E. Rosson No. 2-A	Do	F-18	479	2803		2795	
Do	A. E. Rosson No. 3-A	Do	F-18	478	2807		2796	
Green et al	Dies No. 1	S. Garrison Surv.	F-18	477	3756			
Haskell et al	Strange No. 1	S. Holloway Surv.	F-20	510	1275			
Hicks-Hunt-Hoover	Priddy No. 1	P. Varela Surv.	F-18	472	3300			
Hicks et al	J. R. Stroud No. 1	A. Varela Surv., nr. Groesbeck	F-19		4414		2951	
Humble Oil & Rfg. Co.	Stubenraugh No. 1	P. Varela Surv., Mexia field	F-18	529	5685			
Humphreys Oil Co.	S. Welch No. 2	A. Varela Surv., nr. Groesbeck	F-19		4420		3238	
Do	Clarke No. 8	Do Mexia field	F-18	513	3059			
Do	Collins No. 1	Do Mexia field	F-18	562	3082			
Do	Spear No. 1	Do Mexia field	F-18	580				
J. B. Jones et al	W. F. Batchelder No. 1	Do near Groesbeck	F-19		4410		3178	
Lucas & Lewis	Oliver No. 1	D. Sullivan Surv.	E-19	550	3177			
Do	Val de Long No. 1	P. Varela Surv.	E-18	514	2911			
C. F. Lytle	Thompson No. 5	Do	F-18	540	6092		3750	4080
Magnolia Pet. Co.	M. B. Boyd No. 10	S. McNulty Surv., Wortham field	F-18		3000			
Do	David No. 4	Mexia field	F-18	500	3010			

TABLE 8.—*Well data*[a], *east Texas.*—(Continued)

COMPANY	FARM	LOCATION	CO-ORDINATE	ELEVATION	TOTAL DEPTH	DEPTH TO TOP OF PECAN GAP	DEPTH TO TOP OF WOODBINE	DEPTH TO TOP OF WASHITA
				Feet above sea level	*Feet*	*Feet*	*Feet*	*Feet*
Limestone County—(Continued)								
Magnolia Pet. Co.	Thompson No. 8-A	Mexia field	F-18		2957			
Mexia Terrace Co.	Oliver No. 1	P. Varela Surv., 15 mi. SW. of Mexia	E-19	616	3500			
McKinney & Skinner	Carter No. 3	Do Mexia field	F-18	450	3050			
Moss & Keeling	A. E. Rosson No. 1	P. Varela Surv., Sec. 4	F-18	520	2853		2842	
Do	Do No. 2	Do	F-18	520	2852		2878	
Do	Do No. 3	Do	F-18	515	2846		2832	
Moss & Urschel	Lyles No. 1	Do Mexia field	F-18		3040			
Do	A. E. Rosson No. 4	Do Nigger Cr. field	F-18	523	3100			
Murchison & Fain	A. E. Rosson No. 2	Do		496	2843		2834	
Do	A. E. Rosson No. 1	Do		495	2846		2835	
Pandum Oil Co.	Bassett No. 1	J. Walker Surv., N. of Kosse	E-20		4826			
Pine Oak Oil & Gas Co.	M. Forrest No. 1			483	2848		2600	2848
Pure Oil Co.	Bertha Atkins No. 1	P. Varela Surv., Nigger Cr. field	F-19	492	2844			
Do	Bertha Atkins No. 2	Do	F-18		2844		2840	
Do	Bertha Atkins No. 3	Do	F-18		2835		2830	
Do	Bluitt No. 2	Do Mexia field	F-19		3070			
Do	Gamble No. 6	Do	F-19		3048			
Do	Hayter No. 2	Do	F-18		3052			
Do	Kendricks No. 1-B	Do	F-18		3040			
Do	J. J. Nussbaum No. 10	Do	F-18		3077			
Do	Pittman No. 2	Do	F-18		3062			
Do	Joe Ross No. 4	Do	F-18		3058			
Do	Speer No. 2	Do	F-18		3135			
Do	Thomas No. 8	Do	F-18		3042			
Do	Unfried No. 1	Near Bald Hill	F-17	487	2888		2610	2887
Do	Ward No. 1	P. Varela Surv., Cedar Cr. field	E-19		2790			
Do	S. & M. K. O'Deill No. 1		F-19	502	2882		2869	
Do	Do No. 2		F-19	501	3807			
Do	Do No. 3		F-19	502	1769			
Do	Do No. 4		F-19	485	2326			
Rycade Oil Corp.	Ward No. 1	P. Varela Surv., Cedar Cr. field	E-19	504	2897		2891	
Ranger Caldwell	Ward No. 1	Do	E-19		2790			
Reiter et al	Dugger No. 1	Do	E-19	521	2930			

Reiter & Lewis	Lewis No. 1	Do	E-19	510	2902			
Reiter et al	Lewis No. 2	Do	E-19	513	2906			
Do	Ward No. 1	Do	E-19	503	2879			
Reiter, Lewis & Moutray	Ward No. 2	Do	E-19	504	2888			
Ben Segal & Humdahl	A. E. Smith No. 1	M. N. Miller Surv.	E-19			1579		
Simms Oil Co.	A. E. Rosson No. 1	P. Varela Surv.		475	2819		2812	
Do	A. E. Rosson No. 1-A	Do		485	3110			
F. L. Smith	A. E. Rosson No. 1	Do		475	2818		2814	
Straube & Straube	Bertha Atkins	Do		512	2880			
Transcontinental Oil Co.	Amelia Medlock No. 1	Do			2805		2795	
Do	Amelia Medlock No. 2	Do		489	2810		2809	
Do	Amelia Medlock No. 3	Do		476	2809		2801	
Do	Amelia Medlock No. 4	Do		471	2807		2802	
Do	G. B. Echols & Amelia Medlock No. 1	Do		459	2831		2818	
Do	A. E. Rosson No. 1	P. Varela Surv., Nigger Cr. field	F-18	503	2842		2840	
Do	Do No. 2	Do	F-18	513	2849		2844	
Do	Do No. 3	Do	F-18		2841		2831	
Do	Do No. 4	Do	F-18	506	2842		2832	
Do	Do No. 5	Do	F-18	510	2846		2842	
Do	Do No. 6	Do	F-18		2838		2829	
Do	Do No. 7	Do	F-18	513	2839		2840	
Do	Do No. 8	Do	F-18	502	2845		2833	
Do	Do No. 9	Do	F-18		2841		2831	
Do	Do No. 10	Do	F-18	499	2841		2833	
Do	Do No. 11	Do	F-18	507	2835		2829	
Do	Do No. 12	Do	F-18	512	2836		2831	
Do	Do No. 13	Do	F-18	501	2849		2844	
Do	Do No. 14	Do	F-18	512	2844		2833	
Do	Do No. 1-A	Do	F-18	495	2847		2838	
Do	Do No. 2-A	Do	F-18	495	2841		2829	
Do	Do No. 4-A	Do	F-18		2843		2837	
Do	Do No. 5-A	Do	F-18		2843		2831	
Do	Do No. 6-A	Do	F-18	476	2826		2819	
Do	Do No. 7-A	Do	F-18	480	2823		2815	
Do	Do No. 8-A	Do	F-18		2833		2822	
Do	Do No. 9-A	Do	F-18	491	2840		2838	
Do	Do No. 10-A	Do	F-18	489	2832		2825	
Do	Do No. 11-A	Do	F-18	490	2832		2825	
Do	Do No. 12-A	Do	F-18	483	2837		2831	
Do	Do No. 13-A	Do	F-18	492	2845		2840	
Do	Do No. 14-A	Do	F-18	495	2848		2836	
Do	Do No. 15-A	Do	F-18		2850		2845	
Do	Douglas Cogdell No. 1	Do	F-18	517	2868		2856	
Do	Do No. 2	Do	F-18	513	2846		2837	
Do	Do No. 3	Do	F-18	498	2844		2837	

TABLE 8.—*Well data*[a], *east Texas.*—(Continued)

COMPANY	FARM	LOCATION	CO-ORDINATE	ELEVATION	TOTAL DEPTH	DEPTH TO TOP OF PECAN GAP	DEPTH TO TOP OF WOODBINE	DEPTH TO TOP OF WASHITA
				Feet above sea level	*Feet*	*Feet*	*Feet*	*Feet*
Limestone County—Concluded								
Transcontinental Oil Co.	Douglas Cogdell No. 4	P. Varela Surv., Nigger Cr. field	F-18	510	2834	----	2822	----
Do	Do No. 5	Do	F-18	482	2817	----	2811	----
Do	Do No. 6	Do	F-18	505	2848	----	2842	----
Do	Do No. 7	Do	F-18	507	2835	----	2833	----
Do	Bertha Atkins No. 1	Do	F-18	488	2828	----	2821	----
Do	Do No. 2	Do	F-18	488	2853	----	2844	----
Do	Do No. 3	Do	F-18	496	2846	----	2840	----
Do	Do No. 4	Do	F-18	422	2831	----	2825	----
Do	S. M. & K. O'Dell No. 1	Do	F-18	499	2877	----	----	----
Do	Do No. 2	Do	F-18	484	2276	----	----	----
Do	Do No. 3	Do	F-18	----	2910	----	----	----
Do	Do No. 4	Do	F-18	493	1946	----	----	----
Do	W. B & Mary Cochrum No. 1	Do	F-18	409	2855	----	2842	----
Do	Do No. 2	Do	F-18	503	2862	----	2860	----
Do	Do No. 3	Do	F-18	480	2830	----	2820	----
Do	T. D. & M. Ross No. 2	Do	F-18	488	2890	----	2880	----
Do	L. R Suttle No. 1	Do	F-18	487	2454	----	----	----
Do	W. R. & Lilliam Erskine No. 1	----	----	----	2828	----	2818	----
Do	Do No. 2	----	----	470	2825	----	2820	----
Do	Do No. 3	----		475	2831	----	2824	----
Do	Dugger No. 2	P. Varela Surv.	E-19	510	3046	----	----	----
Do	Lewis No. 1	Do	E-19	512	2900	----	----	----
Do	Lewis No. 2	Do Cedar Cr. field	E-19	----	2923	----	----	----
Do	Ward No 1	Do	E-19	507	2891	----	----	----
Do	Ward No. 2	Do	E-19	507	2903	----	----	----
Do	Ross No. 1	Do Nigger Cr. field	F-18	----	3057	----	2815	3051
Well et al	Richardson No. 1	Do Cedar Cr. field	E-19	479	2140	----	----	----
Why Not Oil Co.	Lewis No. 1	Do	E-19	510	2896	----	----	----
Do	Lewis No. 2	Do	E-19	516	2896	----	----	----
Do	Joe Rhea No. 1	Do	E 19	509	2902	----	----	----
Do	Joe Rhea No. 2	Do	E-19	----	2905	----	----	----
Marion County								
Ackerman	----	Daniel O. Dr'scol	V- 9	----	2720	----	----	----
W. D. Chew	Fee No. 1	Wm. Hamilton Surv.	V- 9	----	3426	----	----	----

Daniels		R. Hazelwood Surv.	T-10	—	2560	—	—	—
Davidson et al	Chatten No. 1	Jackson Grayson Hrs.	U- 9	260	3415	—	—	—
Eden Oil Co.	J. M. Deware No. 1	R. Hazelwood Surv.	T-10	208	3304	2105	—	3258
E. N. Gillespie	Turner No. 1	Caddo Lake Surv.	V-10	—	2315	—	—	—
Gulf Prod. Co.	Potter No. 5	Robert Potter Hrs.	U-10	183	2935	—	—	2290
Hindman	F. O. Lindsey No. 1	Alexander Allbright Surv.	R-10	—	—	—	—	—
Hunt	Chatten	Jackson Grayson	U- 9	300	—	—	—	—
Imperator Oil Co. & Paul Vitek	Luther No. 1		—	447	3025	1653	—	—
Irick Oil Co.	McGaughy	J. W. Wills Headright Surv.	R-10	357	3801	—	3200	—
Kraft & Kelsey et al	Wiley Enas No. 1	Prado Surv.	—	—	3003	1645	—	—
Marion Oil Co.	McCoy No. 1	W. J. Willis Hrs.	R-10	356	3801	—	—	—
Producers Oil Co.	Stallcup No. 2	Hamilton Surv.	T-10	200	3263	—	—	2948
Pure Oil Co.	I. W. Thompson No. 1		—	—	3313	—	—	—
Rondeau	McGaughey No. 1	Wm. J. Willis Surv.	R-10	—	—	—	—	—
Shelton & McNeil	McNeil No. 1	Robt. B. Fowler Surv.	R- 9	—	—	—	—	—
Sinclair Oil & Gas Co.	Coulter No. 1	Wm. Russell Surv.	S- 9	376	3906	2310	—	3905
Do	Wright-Braden No. 1	Jacob Grover Surv.	S-10	336	3463	2210	—	3451
Sun Oil Co.	Fischer No. 1	Miles Reed Hrs.	S-10	212	3181	—	—	3114
Do	Rowell & Armstead No. 1		—	—	2253	—	—	—
S. W. Gas & Electric Co.	Gibson No. 1	West side of Vivian	—	—	2780	—	—	—
Texas Caddo Oil Co.	No. 1	Thomas Regsdale Surv.	V- 9	—	1353	—	—	—
Do	W. D. Chow	Clinton Landing	—	175	1041	—	—	—
Trammell, Jr.	Husey No. 1	Chas. Lockhart	T-10	282	1878	1771	—	—
McLennan County								
W. Franklin	West No. 1	Tomas de la Vega Surv.	C-18	555	1173	—	972	1095
*Tudor Oil Co.	Shelton No. 1	Do	C-18	531	2100	—	—	1680
Navarro County								
Admiral Oil Co.	D. S. Brown No. 1	W. T. Turner Surv.	H-14	439	2984	—	—	—
Ashley Bros. et al	J. Pullen No. 1	A. Bond Surv. (?)	E-15	—	1534	—	1208	1530
Atlantic Oil Prod. Co.	Kenner No. 1	W. P. Lane Surv.	G-15	343	3005	—	—	—
Do	Goldman No. 1	J. Lockhart Surv.	G-16	—	3187	—	—	—
D. F. Baker	Davis No. 1	James B. Berry Surv.	G-16	—	2719	—	—	—
*Town of Barry	(water well)	J. McGowan Surv., Barry	E-15	502	1721	—	1570	—
Bateman et al	McGown No. 1	Morris Webb Surv.	H-14	397	3255	—	3235	—
Big Four Oil Co.	Akers No. 1	L. M. Cook Surv., 3 mi. SE. Dawson	E-16	—	3048	—	—	—
*Blooming Grove	(water well)	Town of Blooming Grove	E-15	599	1436	—	1290	1813
Boyd Oil Co.	Conner No. 1	R. D. Newman Surv., 2 mi. E. of Bazette	G-14	343	3190	—	—	—
* Do	McGowan No. 1	Morris Webb Surv., 2½ mi. E. Bazette	G-15	388	3288	—	3240	—
Do	McGowan No. 2	Morris Webb Surv.	G-15	363	3212	—	—	—
Do	Walthall No. 1	J. H. Millican Surv., 1 mi. SW. Bazette	G-15	—	3274	—	—	—

TABLE 8.—*Well data*[a], *east Texas.*—(Continued)

COMPANY	FARM	LOCATION	CO-ORDINATE	ELEVATION	TOTAL DEPTH	DEPTH TO TOP OF PECAN GAP	DEPTH TO TOP OF WOODBINE	DEPTH TO TOP OF WASHITA
				Feet above sea level	*Feet*	*Feet*	*Feet*	*Feet*
Navarro County—(Continued)								
Burt & Burt	Hamilton No. 1		—	—	3830	—	—	—
D. H. Byrd et al	C. S. Garrett No. 1	1 mi. E. of Currie	G-17	—	3224	—	—	—
Compass Oil Co.	R. P. Alexander	T. Morrow Surv.	G-15	349	3043	—	—	—
Corsicana Deep Well Co.	Springfield No. 1	W. P. Lane Surv.	G-15	366	2954	—	—	—
Do	Burke No. 3	Do	G-15	366	2963	—	2933	—
Corsicana Oil Co.	Kennen No. 1	Do	G-15	—	2961	—	—	—
*Corsicana-Mexia Oil Synd.	Allbritton No. 1	H. T. T. & B. Ry Surv., 5 mi. N. of Powell	G-14	418	3195	—	3110	—
Cor-Tex Oil Co.	Gray No. 1	J. P. Brown Surv.	F-15	417	3956	—	2463	—
*J. S. Cosden	Finch No. 1	W. H. Hardman Surv.	F-17	536	3106	—	2800	—
Cranfill Bros. & Penn	Barnett No. 1	H. S. Simonton Surv.	G-15	293	3060	—	—	—
Do	Reid No 1	J. H. Millican Surv.	G-15	365	3087	—	3030	—
Do	Tramel No. 1	H. S. Simonton Surv.	G-15	—	3082	—	—	—
M. Curtiss et al	Barrington No. 1	Powers Surv.	H-16	310	2890	—	—	—
*Dawson city well	(water well)	Town of Dawson	E-17	482	1816	—	1458	—
Corsicana Deep Well Co.	Springfield No. 1	W. P. Lane Surv.	G-15	361	2535	—	—	—
L. L. Doddwell	Wilson No. 1	J. Hunter Surv.	H-14	374	3497	—	—	—
Elliott & Nichols	Westbrook No. 1	H. H. Horn Surv.	H-15	—	3267	—	—	—
Finley et al	Champion No. 1	R. C. Doom Surv.	H-15	—	3150	—	—	—
*F. B. Foster & Co.	Daniels No. 1	W. H. Ottiwell Surv.	H-15	304	3522	2074	—	—
Do	Johnson No. 1	S. King Surv., 6 mi. NE. Streetman	H-16	330	2837	1961	—	—
*J. O. Galloway	McClung No. 1	Pedro Guero Surv.	H-15	342	3520	—	3360	—
Gilbert Johnson	Albritton No. 1	H. H. T. & B. Surv. 1327, 6 mi. NE. Powell	G-14	409	—	—	—	—
Gilbert-Johnson Co.	Greer No. 1	C. Bushian Surv.	G-15	401	3555	—	—	—
Gilbert-Hunter Co.	McLain No. 1		—	—	1864	—	—	—
Gilbert-Johnson Co.	Skiles No. 1	R. Mitchell Surv.	G-15	400	3210	—	—	—
Gray-Cranfill Co.	G. W. Hardy No. 1	M. Brown Surv.	—	—	2996	—	—	—
Gulf Prod. Co.	Blumrosen No. 1	W. P. Lane Surv., Powell	G-15	—	2874	—	—	—
Do	Christian No. 1	Do	G-15	—	2870	—	—	—
Do	M. Green No. 1	Bazette	G-14	365	3203	1975	3065	—
J. K. Hughes	Burke No. 1	W. P. Lane Surv., Powell	G-15	303	3358	—	—	—
Do	McKie No. 1-A	J. Broyles Surv.	G-15	427	2984	—	—	—
Do	C. R. McGowan No. 1	Morris Webb Surv.	H-14	397	3215	—	—	—
Do	McKie No. 1	J. Broyles Surv.	G-15	300	2046	—	—	—
Humble O. & Rfg. Co.	Blumrosen No. 2	W. P. Lane Surv.	G-15	—	2825	—	—	—

Do	Blumrosen No. 3	Do	G-15	—	2145	—	—	—
Do	T. A. Bounds	Eli Hillhouse Surv.	G-17	—	2707	—	—	—
Do	Hughes-Hill No. A-1	Jas. Smith Hrs. Surv.	G-15	427	2969	—	—	—
Do	Do No. C-1	Do	G-15	—	2899	—	—	—
Do	W. C. Humphries No. 20	Do	G-15	—	—	—	—	—
Do	Kent No. 1	J. Broyles Surv.	G-15	—	2856	—	—	—
Do	G. C. Kent No. 9	Jas. Smith Hrs. Surv.	G-15	—	2906	—	—	—
Do	McClelland No. 1	—	—	—	3058	—	—	—
Do	W. J. McKie No. B-3	A. Buffington Surv.	G-15	—	2949	—	—	—
Do	W. J. McKie No. C-4	Do	G-15	—	—	—	—	—
Do	J. W. Pugh No. 2	Jas. Smith Hrs. Surv.	G-15	—	—	—	—	—
Do	J. W. Pugh No. 5	Do	G-15	—	—	—	—	—
Do	J. W. Pugh No. 6	Do	G-15	—	—	—	—	—
Do	J. W. Pugh No. 8	Do	G-15	—	—	—	—	—
Humphreys Corporation	J. O. Burke No. 2	W. P. Lane Surv.	G-15	—	2915	—	—	—
Humphreys-Texas	English No. 1	M. Bowen Surv.	G-17	447	2924	—	—	—
Humphreys Corporation	Fair No. 1	W. W. McCanless Heirs	G-15	—	2888	—	—	—
* Do	M. S. Finish No. 1	W. Spicer Surv.	G-14	396	2702	—	2410	—
* Do	McKie No. 1	J. Broyles Surv.	G-15	425	2853	—	2830	—
Do	McKie No. 2	Do	G-15	335	2864	—	—	—
Humphreys-Texas	Meador No. 1	M. Boren Surv.	G-17	443	3007	—	—	—
Humphreys Corporation	Meador No. 3	Do	G-17	—	3006	—	—	—
Humphreys-Texas	Singleton No. 1	J. H. Dean Surv.	G-15	425	3682	—	3201	—
Humphreys Corporation	Webb No. 2	John White Surv.	G-16	—	2964	—	—	—
Do	Webb No. 3	Do	G-16	—	2960	—	—	—
Kent Co.	R. D. Fleming No. 10	John Harris Surv.	G-16	422	3039	—	—	—
Kent-Middletown Rfg. Co.	Fulwood No. 1		—	—	1733	—	—	—
*Town of Kerens	(water well)	Hyram Bush Surv.	H-15	370	3812	—	3540	—
Keyser Oil Int.	W. M. Warren No. 1	R. C. Doom Surv.	G-15	370	3150	—	—	—
Killiam-Phillip	Wilson No. 1	Wm. Bridges Surv.	F-14	391	3167	—	1991	—
Lenoir & Schnaufer	Edger No. 1	M. Meazel Surv.	G-17	397	3271	—	—	—
Livingston	Milligan No. 1	M. Latham Surv.	G-16	373	3205	—	—	—
Love Bros. et al	Townes No. 1	—	G-15	372	2990	—	—	—
Maderia Oil Co.	Farrald No. 1	J. M. Meredith Surv.	E-17	—	1470	—	—	—
Magnolia Pet. Co.	Baum No. 1	S. Everett Surv.	—	380	3076	—	—	—
* Do	R. L. Hodges No. 1	—	—	478	3016	—	2435	2968
Do	I. T. Kent No. 7	Jas. Smith Hrs. Surv.	G-15	—	2920	—	—	—
* Do	Kerr No. 1	—	—	405	3140	—	2801	—
* Do	Marshall No. 1	T. J. Chambers Surv., 3 mi. NE. Rice	F-14	450	4461	—	2050	2520
* Do	Refinery No. 1	J. M. Muse Surv.	F-15	410	2781	—	2380	—
Maxwell Bros.	Owens No. 1	—		—	3504	—	—	—
McCormick-Mexia	Swink No. 1	J. White Surv.	G-16	550	2503	—	—	—
McDonald Bros.	Brown No. 1	J. White Surv., 1½ mi. E. of Richland	G-16	355	2954	—	—	—
A. M. McIntyre	Richards No. 1	—	—	397	3002	—	—	—
McMann Oil Co.	Chapman No. 8	J. Broyles Surv.	G-15	—	4753	—	—	—

TABLE 8.—*Well data*[a], *east Texas*.—(Continued)

COMPANY	FARM	LOCATION	CO-ORDINATE	ELEVATION	TOTAL DEPTH	DEPTH TO TOP OF PECAN GAP	DEPTH TO TOP OF WOODBINE	DEPTH TO TOP OF WASHITA
				Feet above sea level	*Feet*	*Feet*	*Feet*	*Feet*
Navarro County—Concluded								
Mendell et al	Dies No. 1	H. C. Ridge Surv.	——	473	3450	——	——	——
Mexia Pet. Co.	Y. E. Hildreth No. 1	Near Pursley	E-16	——	2424	——	——	——
Mills-Bennett	Wolens No. 3	James Smith Surv.	G-16	425	2986	——	——	——
Morris Frazer et al	Lee No. 1	SE. cor. A. H. Hodge Surv.	G-17	——	3019	——	——	——
Mutual Oil Co.	Nowlin No. 1	Thomas B. Hardin Surv.	H-14	321	3470	——	3464	——
Mutual Oil Operators	Tucker No. 1	M. Boren Surv.	G-17	——	3068	——	——	——
Tom Nash	Laird No. 1	——	——	475	3132	——	2789	3076
Natatorium in Corsicana	(water well)	Town of Corsicana	F-15	——	2360	——	——	——
New Domain Oil Co.	Johnson No. 1	Sidney King Surv.	H-16	——	3000	——	——	——
Navarro Oil Co.	Mathews No. 2	——	——	——	1555	——	——	1552
Neway Lse. & Dev. Tr. Co.	F. Smith No. 1 (Known as Cheneyboro well)	J. White Surv.	G-16	335	3101	——	——	——
Nichol & Elliott	West Brook No. 1	H. H. Horn Surv., 2 mi. NE. of Kerens	H-15	——	3267	——	——	——
O. P. & G. Co.	Stubbs No. 1	Mathew Boren Headright Surv.	G-17	——	3215	——	——	——
Panhandle Refining Co.	West No. 1	M. Boren Surv.	G-16	424	2240	——	——	——
Penn et al	Absher No. 1	J. T. Jordan Surv.	H-14	——	2410	——	——	——
Do	White No. 1	——	——	——	3132	——	——	——
Penn-Windor Co.	Vinson No. 1	S. P. Bailey Surv.	G-15	375	2993	——	——	——
Perryman, Hicks, & Dearing	R. E. Price No. 1	Forrester Surv.	——	369	3208	——	——	——
*Priest et al	Albritton No. 1	H. T. & B. RR. Surv.	G-14	——	——	——	——	——
Pure Oil Co.	J. O. Burke No. 1	W. P. Lane Surv.	G-15	365	2973	——	——	——
Do	Fleming No. 1-A	J. Harris Surv.	G-16	423	2979	——	——	——
Do	W. J. McKie No. 7	Jos. Broyles Surv.	G-15	——	2910	——	——	——
*Ranger-Vindicator Oil Co.	Thornton No. 1	R Hazard Surv., 2 mi. W. Wortham	F-17	465	3200	——	2790	——
Richland-Powell Co.	Vinson No. 2	J. P. Hardin Surv., 2 mi. N. of Powell	G-15	405	3173	——	——	——
Roxana Pet. Corp.	McKie No. A-9	J. Broyles Surv.	G-15	386	2878	——	——	——
Rowan Edson et al	Warren No. 1	T. C. Doom Surv., 2 mi. NE. Powell	G-15	——	3004	——	——	——
Sanders-Wheelock	Barron No. 1	——	——	410	3042	——	——	——
Do	Bressie No. 1	Bragg Surv.	G-16	420	3309	——	——	——
Do	Eadons No. 1	——	——	——	3304	——	——	——

Seaport O. Co. (Vidler & Dean)	Vinson	J. P. Hardin Surv., 2 mi. N. Powell	G-15	403	2984	—	—	—
Simms Oil Co.	Clark No. 1	H. Wright Surv.	G-17	392	3542	—	—	—
Do	Gilbert No. 1	1 mi. N. Streetman	G-17	412	3508	1927	3486	—
Do	Smith No. 1	Micajah Autrey Surv.	G-16	—	3047	—	—	—
Smith	Cerf No. 5	James Smith Hrs. Surv.	G-16	423	2990	—	—	—
Snowden & McSweeney	Longbotham No. 14	T. C. Curry Surv.	G-17	—	2974	—	—	—
*State Orphans Home well	(water well)	NE. cor. J. M. Williams, 2 mi. W. Corsicana	F-15	480	3190	—	2170	—
Stagger Oil Co.	McClelland No. 1	T. C. Curry Surv.	G-17	—	3450	—	—	—
Sun Oil Co.	O. Bounds No. 1	Wm. H. Smith Heirs Surv.	G-17	—	—	—	—	—
Do	W. P. Brown No. 13	J. White Surv., Richland	G-16	—	—	—	—	—
Do	G. H. Kent No. 2	Jos. Broyles Surv.	G-15	—	—	—	—	—
Do	Swink No. 1	M. Boren Surv.	G-16	416	5415	1888	3398	—
Do	Swink No. 1	Do	G-16	425	2982	—	—	—
Do	E. Swink No. 1	Wm. Hudson Surv.	G-17	—	2960	—	—	—
Do	Swink-Wilson No. 1	Do	G-17	389	2985	—	—	—
Do	E. L. Swink No. B-2	Hudson Surv.	G-17	—	—	—	—	—
Do	H. A. Swink No. B-1	Thos. Ross Surv.	G-16	—	—	—	—	—
Do	West No. B-1	J. Choat Surv., Richland	G-16	—	—	—	—	—
The Texas Co.	Autry No. 1	Micajah Autrey Surv.	G-16	371	3048	—	—	—
Do	Fleming No. 8	I Harris Surv.	G-16	417	2952	—	—	—
J. L. Thompson Oil Co.	Springfield No. 1	W. P. Lane Surv.	G-15	—	2898	—	—	—
Tidal Oil Co.	Longbotham No. 1	T. Smith Surv.	G-15	—	—	—	—	—
Do	Thompson No. 2	—	G-15	420	2991	—	—	—
Transcontinental Oil Co.	Derden No. 1	J. C. Powell Surv.	—	—	3010	—	—	—
Trapshooters Dev. Co.	Warren No. 1	E. M. Adcock Surv.	G-15	—	3317	—	—	—
Do	O. Bounds	Eli Hillhouse Hrs. Surv.	—	407	2956	—	—	—
U. S. Texas Oil Co.	J. O. Burke	Anderson Surv.	G-15	—	2845	—	—	—
Wheelock & Collins	Castles No. 1	Abner-Mathews Surv., 1 mi. N. of Eureka	G-16	337	3235	—	3220	—
J. H. Wilder	Bradley No. 1	Robertson Co. Sch. Land League	—	—	790	—	—	—
Witherspoon et al	J. O. Burke No. 1	J. Smith Hrs. Surv.	G-15	—	2845	—	—	—
Young et al	J. H. Farmer No. 1	—	—	—	—	—	—	—
Panola County								
*Bell et al	Burnett Lbr. Co. No. 1	S. B. Hendrick Surv.	U-15	186	3335	—	—	—
* Do	Guill No. 1	Wm. English Surv.	U-14	315	2780	1296	—	2325
Do	Jernegan No. 1	½ mi. E. Tacona	U-14	367	2750	—	—	2375
Burk & Humphreys	Waterman No. 1	Cheairs Surv.	T-14	—	2450	—	—	—
Carthage Oil Co.	Adams No. 1	George Goodwin Surv.	T-15	—	2079	—	—	—
Do	Pool No. 1	Do	T-15	235	2880	—	—	—
Collinwood et al	W. A. Adams No. 1	Blankenship Surv.	S-14	—	2800	—	—	—
Commercial Drilling Co.	McLain No. 1	T. C. Carruth Surv.	T-14	197	2894	1545	—	—
Commercial Oil Co.	Pool No. 1	George Goodwin Surv.	T-15	235	2880	—	—	—

TABLE 8.—*Well data*[a], *east Texas*.—(Continued)

COMPANY	FARM	LOCATION	CO-ORDINATE	ELEVATION	TOTAL DEPTH	DEPTH TO TOP OF PECAN GAP	DEPTH TO TOP OF WOODBINE	DEPTH TO TOP OF WASHITA
				Feet above sea level	*Feet*	*Feet*	*Feet*	*Feet*
Panola County— Concluded								
Cranfill et al	Mays No. 1	Jane Thorpe Surv.	V-13	—	1992	—	—	—
Creichton & Hart	Greeny Kyle No. 1	Jas. Tippet Hrs. Surv.	U-15	332	3704	—	—	—
Everett Prod. Co.	McDaniel No. 1	Alamson Barr Surv.	U-16	—	410	—	—	—
Excelsior Oil Co.	Cook No. 1	George Goodwin Surv.	T-15	235	2340	—	—	—
S. H. Gardner	Lawless No. 1	J. L. Mathews Surv.	V-14	—	2805	—	—	—
Gulf Prod. Co.	Agurs No. 1	J. Shandon Surv.	V-13	352	1080	—	—	—
Do	Agurs No. 2	Do	V-13	353	2988	—	—	—
Do	Agurs No. 3	Do	V-13	—	2951	—	—	—
Do	T. Douglas No. 1	Lacy Surv.	V-13	288	2403	—	—	—
Do	A. Jeter No. 1	John Womack Surv.	V-13	342	2925	—	—	2360
Do	Trosper No. 1	Welligan Surv.	V-13	350	2473	—	—	—
Do	Werner No. B-2	W. A. Pope Surv.	U-16	—	3000	—	—	—
Do	Werner No. B-3	T. C. R. R. Surv. Abs. No. 13	U-16	—	3005	—	—	—
Do	E. L. Werner No. 1	E. Daniel Surv.	U-16	204	2935	—	—	—
Do	E. L. Werner No. 2	Do	U-16	—	2904	—	—	—
H. Hines	Jones No. 1	G. Goodwin Surv.	T-15	—	2514	—	—	—
Hog Bayou Oil Co.	Pierce No. 1	G. Roberts Surv., NE. of Carthage	T-14	261	2701	—	—	—
Do	Pool No. 1	Geo. Goodwin Hrs. Surv.	T-15	235	2111	—	—	—
Hope Oil Co.	Louis Werner Sawmill No. 1	D. B. Lewis Hrs. Surv.	U-14	262	1038	—	—	—
Humble Oil Co.	Christian No. 1	Duncan Surv.	T-14	312	2575	—	—	—
Littlejohn et al	Cromwell No. 1	Mann Surv.	U-14	—	2560	—	—	—
Magnolia Pet. Co.	Adams No. 2	E. Jones Surv.	V-14	—	1017	—	—	—
Do	Adams No. 3	James Mathew Surv.	V-14	—	2760	—	—	—
Do	Adams No. 4	Ezekiel Jones Surv.	V-14	—	2751	—	—	—
Do	Fletcher No. 2	B. C. Jordan Surv.	U-14	—	2560	—	—	—
Do	Steele No. 1	Do	U-14	—	1518	—	—	—
Do	Steele No. 2	Do	U-14	288	1926	1418	—	—
Do	Steele No. 15	Do	U-14	271	2649	—	—	2304
Natural Gas Prod. Co.	Floyd No. 1	Do	U-14	283	986	—	—	—
Do	Floyd No. 2	Do	U-14	266	939	—	—	—
Do	J. T. Roquemor No. 8	Do	U-14	267	2672	—	—	—
National Oil Co.	Nail No. 1	John Adams Hrs. Surv.	U-14	268	2489	1818	—	—
Newmours Corp.	C. E. Brumble No. 4	B. C. Jordan Surv.	U-14	275	2268	—	—	—
Old Colony Oil Co.	Edens No. 1	1½ mi. E. of Beckville	S-14	350	3275	2025	—	2725
Palmetto Oil Co.	Trosper No. 1	James Thorp Surv.	V-13	—	2434	—	—	—

Panola Oil Co.	Barksdale No. 1	Edw'n Smith Surv.	S-14	—	2559	—	—	—
Panola Pet. Co.	Flanagan No. 1	Antwine Duboise Surv.	T-13	225	2862	1835	—	—
Producers Oil Co.	Furrh No. 1	Thomas M. Alstone Surv.	U-13	351	3339	1537	—	—
Riverland Co.	J. H. Finch	Wm. Hartman Surv.	—	—	2752	—	—	—
Smith et al	Pool No. 1	George Goodwin Surv.	T-15	282	2157	—	—	—
Texas Co.	Adams No. 1	W. D. Thompson Surv.	T-15	350	2774	—	—	—
Do	Adams No. 2	J. Matthews Surv.	T-15	—	2663	—	—	—
Do	T. C. Adams No. B-2	Isom Hatcher Surv.	V-14	—	2749	—	—	—
Do	G. B. Brumble No. 1	E. F. Mitcheson Surv.	U-13	—	1966	—	—	—
Do	H. L. Brumble No. 1	Do	U-13	—	1914	—	—	—
Do	Brumble No. 6	Evans Bracken Surv.	U-14	—	2640	—	—	—
Do	Brumble No. 12	J. Womack Surv.	V-13	—	4751	—	—	—
Do	Waterman No. 1	Thomas Pratt Surv.	T-13	204	2703	1548	—	2400
Do	Waterman No. 2	J. W. Jones Surv.	T-13	205	3131	—	—	—
Do	Waterman No. 3	J. M. Jones Surv.	T-13	204	2605	—	—	—
Do	Waterman No. 4	J. F. Cheairs Surv.	T-13	201	2025	—	—	—
Do	Waterman No. 5	T. A. Pratt Surv.	T-13	201	2100	—	—	—
Do	Waterman No. 6	Do	T-13	205	2841	—	—	—
Do	Waterman No. 7	Do	T-13	—	2600	—	—	—
Do	Waterman No. 8	A. L. Birdsong	T-13	—	2080	—	—	—
Texas-Louisiana	Lawrence No. 1	Harrison Davis Hrs. Surv.	R-15	295	3016	—	—	—
Transcontinental Oil Co.	Lawrence No. 1	N. B. Thompson Surv.	S-15	354	3297	1795	—	2509
Rains County								
Atlantic Oil-McLaughlin & Lyles	Dowell No. 1	J. W. McMahan Surv.	J- 9	—	2566	—	—	—
Atlantic Oil-McLaughlin & Lyles	Dowell No. 2	O. S. Downing Surv.	J- 9	511	3475	—	—	—
D. H. Byrd	J. D. Hill No. 1	F. McMahan Surv.	K-10	410	4562	2348	4508	—
Emory Oil & Gas Co.	Windham No. 1	Bonifacao de O. Sinea Surv.	K-10	—	1427	—	—	—
Greer Coulton	W. P. Peeples No. 1	E. A. Tibbles Surv., 5 mi. NE. Emory	K- 9	—	2412	—	—	—
Marland Oil Co.	King No. 1	N. G. Crittenden Surv., 3 mi. S. of Point	J- 9	461	3865	2311	3822	—
Peter & Barnes	Jefferies No. 1	D. E. Lawton Surv.	J- 9	527	1479	—	—	—
Rains & Porter	Corley No. 1	Do	J- 9	—	1479	—	—	—
T. P. Coal & Oil Co.	A. A. Humphrey No. 1	J. H. Garrett Surv.	J- 9	541	3802	2285	3782	—
Do	J. W. Humphrey No. 1	J. A. Garrett Surv.	J- 9	540	3308	—	—	—
Yost et al	Lone Oak State Bank No. 1	M. Tollett Surv.	I- 9	460	3450	1990	3195	—
Rusk County								
Adkin & Dearing	C. Ashby No. 1	Juan Ximenes Surv.	P-14	447	3617	2610	3614	—
Anderson et al	Bradford No. 1	Do	P-14	396	3606	2500	3526	—
George Anderson-Cox et al	Frederick No. 1	Do	P-14	466	3570	2507	3564	—
Arkansas Fuel Oil Co.	J. A. Worrell No. 1	Do	P-14	412	3700	2510	—	3640
Ball Oil Corp. & Malone	D. Bradford	Do	P-14	448	3660	2615	3638	—
Ed Bateman	L. D. Crim No. 1	E. Sevier Surv. A. 697	P-13	403	3652	2608	3640	—

TABLE 8.—*Well data*[a], *east Texas*.—(Continued)

COMPANY	FARM	LOCATION	CO-ORDINATE	ELEVATION	TOTAL DEPTH	DEPTH TO TOP OF PECAN GAP	DEPTH TO TOP OF WOODBINE	DEPTH TO TOP OF WASHITA
				Feet above sea level	*Feet*	*Feet*	*Feet*	*Feet*
Rusk County—Concluded								
Big Indian Oil Co.	A. J. Deason No. 1	Juan Ximenes Surv.	P-14	—	3655	2710	—	—
Dan S. Brooks-Root Rfg. Co.	Alford No. 1	J. D. Reel Surv.	Q-16	—	3815	2625	—	3530
Burgorne et al	Alexander No. 1	T. Jones Surv.	Q-15	499	3757	2478	—	3588
Burton Drilling Co.	B. S. Florey No. 1	P. Holmes	P-13	354	3728	2650	3710	—
Burnham-Anderson	Nicely No. 1	Thomas Obar	R-13	339	3601	2210	—	3201
Capps-Smith	J. L. Cochran No. 1	J. Roth Survey	P-16	386	3802	2683	—	3769
Roy I. Carter et al	Mayfield Alford No. 1	Juan Ximenes Surv.	P-14	396	3638	2557	3604	—
Clem Clark	M. McCaffen No. 1	Eli Blackburn Surv.	R-15	385	3256	2189	—	3069
J. E. Coleman	A. K. Buckner No. 1	Do	R-15	443	2342	—	—	—
Consolidated Oil Co.	Camp No. 1	Juan Ximenes Surv.	P-14	—	3643	2593	3614	—
Cordova Union Oil Corp.	Christian No. 1	—	P-13	446	3684	2630	3679	—
Daniel-Patton	Mercer No. 1	M. A. Young Surv.	—	—	3595	2400	—	3551
Deep Rock Oil Co.	Mayfield Alford No. 1	Juan Ximenes Surv.	P-14	421	3630	2600	—	3613
Federated Oil Co.	Ben Laird No. 1	Do	P-14	400	3654	2607	3624	—
Do	Mayfield Alford No. 1	Do	P-14	418	3625	2615	3595	—
F. Foster-Jefferies-Kolp	M. Alford No. 1	Do	P-14	418	3630	2598	3602	—
George & Jones	Rogers or Pilgreen No. 1	N. R. Rhodes Surv.	—	507	2230	—	—	—
Hamilton-Consolidated	Jenkins & W. W. Camp	No. 1	—	442	3643	2593	3614	—
L. P. Hammond	Camp No. 1	—	—	—	—	2584	3530	—
Haynes Drilling Co.	Brown No. 1	M. J. Pru Surv.	P-14	486	3673	2740	3660	—
*Humble O. & Rfg. Co.	L. D. Crim No. 1	E. Sevier Surv., A. 697	P-13	403	3652	2608	3640	—
Do	L. D. Crim No. 2	Do	P-13	487	3724	2610	3699	—
Do	L. D. Crim No. 3	Do	P-13	466	—	2615	3653	—
H. L. Hunt et al	Claude Ashby No. 1	Juan Ximenes Surv.	P-14	391	3572	2545	3578	—
Do	Claude Ashby No. 2	Do	P-14	416	3630	2600	3588	—
Do	Claude Ashby No. 3	Do	P-14	409	—	2500	3591	—
Do	Claude Ashby No. 4	Do	P-14	440	3624	2620	3602	—
Do	Daisy Bradford No. 1	Do	P-14	391	3650	2500	3542	—
Do	Daisy Bradford No. 2	Do	P-14	394	3583	2560	3536	—
Joiner	D. Bradford	Juan Ximinez Headright	P-14	—	1094	—	—	—
Ed Jones & Houston Oil Co.	Crim No. 1	Winn Surv.	P-13	440	3695	2631	3675	—
Joiner et al	Bradford No. 3	Juan Ximinez Headright	P-14	395	3592	2403	3536	—
Karona Oil Co.	Peterson No. 1	—	—	360	—	2544	3601	
Laster Oil Co.	D. Bradford No. 1	Juan Ximenes Surv.	P-14	387	3582	2545	3582	—
Leonard Pet. Co.	Adams No. 1	S. C. George Surv.	Q-13	—	3334	2365	—	3269
Lewis & Goodman	Jones No. 1	W. Brown Surv.	P-14	507	—	2420	—	—

Lide-Taylor Oil Co.	Calvin Young No. 1	M. J. Pru Surv.	P-14	475	3888	2714	3677	
Louisiana Pet. Co.	Alford No. 1	E. B. Warren Surv.	Q-15	510	3500	2110		3275
Kimbro & Miller	D. Bradford No. 1	Juan Ximenes Surv.	P-14	396	3547	2500	3526	
Magnolia Pet. Co.	Della Crim No. 1	E. G. Sevier Surv.	P-13	434	3690	2616	3688	
Do	Duran-Wylie	A. Norris Surv.	R-15	436	3295	2053		3000
Do	N. Duran No. 1	John Zolland Surv.	R-15	437	4035	2078		3035
Do	Flurey No. 1	P. Holmes Surv.	P-13	330	3668		3647	
McCurry	Sparks No. 1	L. C. Rugg Surv.	S-16		2215			
Mildred Oil Co.	Chicken Feather No. 2	P. Chism Surv.	Q-14		2626			
Millville Oil Co.	No. 1	Do	Q-14		2628			
Do	No. 2	Do	Q-14		1588			
Morefield Drilling Co.	Ector No. 1	Daniel Clark Surv.	P-14	401	3700	2420		3594
Moss et al	Matthews No. 1	D. Cortinas Surv.	R-14	386		2296		
H. S. Moss-J. E. Urschel	Mayfield-Alford No. 1	Juan Ximenes Surv.	P-14	414	3630	2598	3602	
John W. Olvey & Sample	W. R. Crimm No. 1	Winn Surv.	P-13	458	3708	2645	3688	
Osborn et al	H. Mathews No. 1	Dolores Cartinez Surv.	R-14	386	2607			
Pear Oil Co.	Eaton No. 1	F. Cordova Surv.	P-14			2714		
W. R. Ramsey et al	M. Kangerga No. 1	W. J. Allen Surv.	P-15	430	3883	2806	3780	
Robert Oil Co.	Ashby No. 1	Juan Ximenes Surv.	P-14	417	3634	2600	3598	
Rosenfield	Pinkston No. 1	M. V. Pena Surv.	P-14	369	3605	2503		
Roxana Pet. Corp.	J. Johns No. 1	Elliott Surv.	R-17	515	3404			
Rucker Oil Co.	Wright No. 1	P. Chism Surv.	Q-14	375	3560	1950		
Do	Tate No. 1	Do	Q-14					
Rusco Oil Co.	Bradford No. 1	Juan Ximenes Surv., Lot B.	P-14	397	3626	2520	3530	
Rusk Dev. Co.	Chicken Feather No. 1	P. Chism Surv.	Q-14		1800			
*Sabine Pet. Co.	Bird No. 1	Bird Surv.	Q-13	331	3519	2010		
C. E. Sanford	Garrison and Sanford	W. A. Corder Surv., water well, 25 mi. SE. Henderson	S-16		300			
Bert Shaw Oil Co.	Andrade Ashby No. 1	Juan Ximenes Surv.	P-14	434	3638	2672	3609	
W. I. Simms-Roxana	Johns No. 1	W. Elliott Surv.	S-16	520	3404			
Sinclair Oil Co.	Bosworth No. 1	Eli Blackburn & John Howeth Surv.	R-15	500	3650	2010		3200
Sinclair Oil & Gas Co.	W. W. Holland			448	3649	2686	3627	
L. L. Smith et al	W. H. Worell No. 1	Juan Ximenes	P-14	412	3700	2490	3640	
H. R. Smith-Houston Oil Co.	D. M. Peterson No. 1			446	3698	2638	3660	
*Snowden & Roxana	Fambrough No. 1	I. & G. N. Ry. Surv., 2½ mi. S. of Kilgore	Q-13	425	3483	2485		
Southwestern Pet. Co.	Garrison No. 1	J. R. Clute Surv., 2½ mi. N. Garrison	R-17	380	3806	2390		3400
Stevens & Turner	Pickett No. 1	T. J. Roberts Surv.			3456	2354		3454
Stroube & Stroube	Frederick No. 1			415	3618	2488	3538	3614
Tate & Culp (S. W. Pet. Co.)	Garrison & Sandford No. 1	Wm. A. Corder Surv.	S-16		401			
The Texas Co.	Goodwin No. 1	James Smith Surv.	Q-15	476	4998	2350		3170
Do	Schultz No. 1	A. Lafton Surv.	P-17	206	3342			
Tex-Lloyd	Camp No. 1			408	3610		3541	

TABLE 8.—*Well data*[a], *east Texas*.—(Continued)

COMPANY	FARM	LOCATION	CO-ORDINATE	ELEVATION	TOTAL DEPTH	DEPTH TO TOP OF PECAN GAP	DEPTH TO TOP OF WOODBINE	DEPTH TO TOP OF WASHITA
				Feet above sea level	*Feet*	*Feet*	*Feet*	*Feet*
Smith County								
*Amerada Pet. Corp.	Christian No. 1	Felix Flores Surv.	N-12	517	5400	3220	5025	—
Apex Dome Co.	Phillips No. 1	S. M. Hager Surv.	N-13	—	2611	—	—	—
Arkansas Drilling Co.	L. A. Wallace No. 1	W. W. Avery Surv.	P-12	—	3859	2640	—	—
Benedum Trees Oil Co.	W. Rogers No. 1	6 mi. N. Walnut Springs	—	—	3625	—	—	—
Big Indian Oil Co.	Holland No. 1	T. Allen Surv.	O-14	509	4015	2860	3962	—
Brooks-Saline Oil Co.	Beauchamp No. 1	Pedro E. Bean Surv.	M-15	413	3193	—	3108	—
Do	Beauchamp No. 2	Do	M-15	—	2161	—	—	—
Do	Kimbell No. 1	Jose Marino Surv.	M-15	—	1864	—	—	—
Do	Meyer No. 1	Don Thos. Quevado Hrs. Surv.	M-15	—	528	—	—	—
Do	Meyer No. 2	Do	M-15	—	2769	—	—	—
Do	Woldert No. 1	Pedro E. Bean Surv.	M-15	—	249	—	—	—
Do	Woldert No. 2	Pedro E. Bean Surv.	M-15	505	850	—	—	—
E. L. Chapman et al	Alexander No. 1	J. K. Carson Surv.	O-13	—	4144	2700	—	—
Daniels, Adair & Slick	A. J. Poiret No. 1	David Wilson Surv.	L-11	375	4537	2857	—	—
*Deep Rock Oil Co.	J. R. Bowdoin No. 1	M. V. Lout Surv.	M-12	434	4220	3338	—	—
H. C. Dickey (Gather et al)	Parker No. 1	Don Thomas Sherwood Thadus Grant, Blk. 36	M-14	—	3240	—	—	—
*East Texas Pet. Corp.	Kadane-Peoples No. 1	J. McFadden Surv.	L-12	465	3375	2160	—	—
Elkton Oil Co.	Marsh No. 1	Marshall Univ. Surv., 5 mi. S. Tyler	M-14	—	2475	—	—	—
Gulf Prod. Co.	McCammond No. 1	V. Moore Surv.	N-15	516	3316	—	—	—
Do	McCammond No. 2	Do	N-15	—	2950	—	—	—
Do	McCammond No 3	V. Moore Surv.	N-15	510	4219	2903	4062	—
Howard Pet. Co.	Lee Holt No. 1	Barnes Clark Surv.	O-13	434	4050	2840	—	—
Humble O. & Rfg. Co.	J. J. Birdsong No. 1	Nancy Chiles Surv.	N-14	—	723	—	—	—
Do	H. E. Lassiter	Bryant Herring Surv.	N-13	—	905	—	—	—
Do	T. C. Williams No. 1	A. B. Keller Surv.	N-13	—	2719	—	—	—
*J. D. Kugle & Slick	M. Freeman No. 1	A. J. Lagrone Surv., 4 mi. S. Winona	O-13	503	3623	2680	—	—
G. Lewis et al	Cook & Green No. 1	Jas. Jordan	P-14	420	3696	2736	3675	—
Lindale Oil Co.	E. W. Winters No. 1	M. G. Estrada Hrs., nr. Lindale	M-12	400	2630	—	—	—
McElreath & Suggett	Gilliam No. 1	J. C. Robertson	L-12	623	4010	3430	—	—
Owen & Sloan	Starnes No. 1	J. W. Allen Surv.	O-12	397	4235	2738	3900	—
Do	Starnes No. 2	Samuel Epps Surv.	O-12	357	4204	2620	3879	—
Ruffin-Williams	H. Florence No. 1	Barnes Clark Surv.	O-13	—	4025	2775	4006	—

Sinclair Oil & Gas Co.	Brooks No. 1	NW. cor. Gabriel Cole Surv.	N-13	402	3310	3195	—	—
Slick & Adair	Smith No. 1	D. Wilson Surv.	L-11	375	3557	2857	—	—
Sun Oil Co.	McGehee No. 1	Thos. Quevedo Surv.	M-14	428	3844	3760	—	—
Sutton et al	J. M. Hammon No. 1	James Reid Surv.	L-11	380	4295	2680	—	—
Titus County								
Arkansas Natural Gas Co.	Hicks No. 1	S. N. Bullock Surv.	O- 7	400	3236	1880	3670b	—
Canadian Oil Co.	Wolcott No. 1	Wm. D. Smith Surv.	P- 7	280	3818	2600	3791	—
Deep Rock Oil Co.	Awtry No. 1	J. Ping Surv.	Q- 7	550	4000	2253	—	—
Do	First Nat. Bank No. 1	Henry Culp Surv., 7 mi. SE. Mt. Vernon	P- 8	413	4635	2406	4264	—
Do	E. L. McElroy No. 1	Kendall Lewis	P- 7	460	3858	2424	—	—
Humphreys Corp.	Corey No. 1	S. N. Bullock Surv.	O- 7	400	3265	1794	3580b	—
Magnolia Pet. Co.	Anthony No. 1	—	O- 6	390	3228	1435	3220	—
Texas-Iowa O. & G. Co.	Mason No. 1	F. Bolin Surv.	O- 7	383	2820	1835	3630b	—
Titus Co. O. & G. Co.	Hicks No. 1	J. H. Henley Surv.	P- 8	370	2431	2409		—
Do	Hicks No. 2	Do	P- 8	400	1746	—	—	—
Wainwright-West Oils Ltd.	Walcott Lott No. 1	W. D. Smith Surv.	P- 7	290	3818	2627	—	—
Western Oil Co.	Mitchell No. 1	Wm. Burk Surv.	P- 7	422	3652	2360	4160b	—
Upshur County								
Amerada Oil Corp.	C. W. Wade No. 1	John Henry Fields Surv.	O-10	422	6153	2250	3601	3887
Arcadia Rfg. Co. & Harper	T. S. Johnson No. 1	J. H. Mallory Surv.	—	—	3790	2461	—	—
E. L. Chapman & Wilburn	Hudspeth No. 1	J. C. Dearmore Surv.	Q-10	383	4114	—	—	—
Davis, Dunlap & Young	Minor No. 1	J. L. Lowery Surv.	Q- 9	345	3865	2145	—	—
De Armand et al	Chas. Cobb No. 1	M. Mann Surv.	Q-11	428	3864	2590	3771	—
McGinley Corp.	Stewart No. 1	L. B. Brown Surv.	P- 9	358	4004	2570	3889	—
Mudge Oil Co.	J. D. Richardson No. 1	D. Ferguson Surv.	P-11	451	—	2622	3725	—
Nichols et al	Cannon No. 1	M. H. Polvador Hrs.	O-11	422	3519	—	—	—
Penn Oil Co.	O. B. Gage No. 1	J. B. Davenport Surv.	P-11	377	4105	2574	3668	—
Roland Oil Co.	Mitchell No. 1	Sarah Powell Surv.	Q-10	369	3674	—	3625	—
Van Zandt County								
George Anderson	Sanger No. 1	J. Walling Surv.	L-12	550	2800	1590	2750	—
Barton	Wamble No. 1	P. Young Surv.	J-13	573	—	—	—	—
Broderick & Calvert	Shirley No. 1	J. Walling Surv.	L-12	477	—	—	2765	—
Brookins & Jenkins	Rose Hughes No. 1	E. Alvarado Surv.	I-10	491	3505	2150	3460	—
Byrd et al	Morrison No. 1	J. Piles Surv.	L-13	573	4737	3258	—	—
Central Oil Co.	J. West No. 1	A. C. Waters Surv.	K-12	564	4747	2743	4388	—
*Century Oil Co.	L. A. Stewart No. 1	A. J. Horseley Surv.	K-12	519	4478	2485	4238	—
E. L. Chapman et al	Wolverton No. 1	Wm. James Surv.	I-11	515	4150	2810	3996	—
Cranfill & Reynolds	C. M. Alexander No. 1	Burleson Surv.	K-11	395	3490	2695	—	—
Do	C. S. Coker No. 1	Wm. Daniels Surv.	L-12	451	3370	1840	3293	—
Dallas Oil & Prod. Co.	Hughes No. 1	E. Alvarado Surv.	I- 9	—	2030	—	—	—
Fore & Pace	Hand No. 1	Wm. Sherman Surv.	J-11	577	5160	2420	4451	—
Grand Saline Oil Co.	W. J. Carns No. 1	S. P. Ry. Surv.	K-10	359	3520	2336	—	—
*Gurley & Lee	Andrews No. 1	P. W. Anderson Surv.	J-12	495	4114	2445	—	—
Hallsville Oil & Gas Co.	McGrain No. 1	S. Bell Surv.	K-11	407	3847	2580	2600	—

TABLE 8.—*Well data*[a], *east Texas*.—(Concluded)

COMPANY	FARM	LOCATION	CO-ORDINATE	ELEVATION	TOTAL DEPTH	DEPTH TO TOP OF PECAN GAP	DEPTH TO TOP OF WOODBINE	DEPTH TO TOP OF WASHITA
				Feet above sea level	*Feet*	*Feet*	*Feet*	*Feet*
Van Zandt County— Concluded								
Hervey & Bethel Oil Co.	Foster No. 1	M. Neil Surv.	I-13	435	4815	2555	4583	------
Hughes et al	Giles No. 1	E. Alvarado Surv.	I-10	482	2030	------	------	------
Humble O. & Rfg. Co.	Blake No. 1	J. Walling Surv.	L-12	497	------	------	2375	------
Do	Blake No. 2	Do	L-12	472	------	1598	------	------
Do	Correll No. 1	Wm. Daniel Surv.	L-12	472	2932	1556	2819	------
Do	J. A. Fowler	Near Van	L-12	465	2529	1815	2918	------
Do	J. A. Freeman No. 1	John Walling Surv.	L-12	510	3505	1749	------	------
Do	W. Freeman No. 1	Do	L-12	------	3017	1580	2857	------
Imperator Oil Co.	Carter No. 1	W. Daniel Surv.	L-12	433	3504	1795	3356	------
Do	Luther No. 1	M. Gross Surv.	K-12	447	------	1653	2842	------
*Jewel & North Texas Oil Co.	Davis No. 1	G. B. Medlin Surv.	K-11	520	4093	2590	3938	------
W. H. Kerbow et al	J. A. Everett No. 1	A. Carlisle Surv.	J-12	410	3008	2918	------	------
Kolp et al	Mathew No. 1	W. H. Bruce Surv.	K-12	409	3736	2805	------	------
Kraft & Kelsey	Enas No. 1	Prado Surv., S. of Van	K-12	485	------	1645	2953	------
McElmurry	Peel No. 1	S. T. Meek Surv.	K-12	528	3008	2912	------	------
McNeill & Mathews	Jones No. 1	J. N. Holt Surv.	J-10	450	2400	------	------	------
Mills-Bennett Prod. Co.	Jones No. 1	J. N. Holt Surv.	J-10	465	3347	2152	------	------
Mill Creek Oil Synd.	Dunbar No. 1	E. Vansick Surv.	J-11	460	2400	------	------	------
Morton Salt Co.	Eason No. 1	S. Bell Surv., Grand Saline dome	K-11	------	804	------	------	------
Do	Eason No. 2	Do	K-11	------	904	------	------	------
Do	Eason No. 3	Do	K-11	------	724	------	------	------
Do	Eason No. 8	Do	K-11	------	204	------	------	------
George Pace	Kellam No. 1	Jesse Russell Surv.	------	------	4806	------	4468	------
Pandem Oil Corp.	Gibbard No. 1	R. Sumigas Surv.	K-11	391	3512	2950	------	------
*L. G. Priest	Blewitt No. 1	4 mi. S. of Canton	J-12	566	3212	2796	------	------
Pure Oil Co.	A. Crimm No. 1	Van field	K-12	483	3594	1745	2880	------
Do	B. E. Crimm No. 2	Do	K-12	------	3012	------	------	------
Do	Ellison No. 1	James Rose Surv.	K-12	507	2942	------	------	------
*Do	Jarmon No. 1	Nacogdoches Co. Sch. Land	K-12	497	2710	1500	2611	------
Do	Mager No. 1	Do	K-12	475	2863	------	2838	------
Do	Thompson No. 1	M. Gross Surv., Van field	K-12	492	2670	------	------	------
Do	Wells No. 1	Do	K-12	485	2678	------	------	------
Do	McMahan No. 1	J. Walling Surv.	K-12	492	------	1675	------	------
Schwedar	Jones No. 2	J. H. Holt Surv.	J-10	440	1437	------	------	------
T. G. Shaw & Fagg	W. F. Huddle No. 1	Richardson Surv.	K-12	545	3448	2593	------	------

Shell Pet. Corp.	Fowler No. 1	J. Walling Surv., Van field	K-12	501	2699	—	2460	—
Do	Tunnell No. 1	Do	K-12	492	2680	—	—	—
Do	Tunnell No. 2	Do	K-12	487	2666	—	—	—
Short et al	Andrews No. 1	M. Neil Surv.	J-12	536	—	2500	—	—
Sun Oil Co.	Thompson No. 1	Van field, J. Walling Surv.	K-12	505	2693	—	2461	—
Taubert & Thornton	Evans No. 1	A. Carlyle Surv.	J-12	—	—	—	—	—
The Texas Co.	Tunnell No. 1	Van field, J. Walling Surv.	K-12	490	2776	—	2751	—
Do	White No. 1-A	Do ... M. Gross Surv.	K-12	—	—	—	—	—
Transcontinental Oil Co.	Rice No. 1	J. A. Murray Surv.	I-13	398	4414	1990	3765	—
Upchurch et al.	School House No. 1	McKinney & Wittam Surv.	K-12	507	3073	2020	—	—
Van Zandt County Oil Co.	Jones No. 1	J. N. Holt Surv.	J-10	465	1371	—	—	—
Van Zandt O. & Dev. Co.	Sharp-Robinson No. 1	J. B. Yarbo Surv.	K-11	373	4802	2764	—	—
*Walker Consolidated Co.	Dawson No. 1	D. Chesher Surv.	I-12	495	3584	2146	—	—
A. W. Walker	Stewart No. 1	A. J. Horsley Surv.	—	519	4238	—	4238	—
Wittmer et al	Beggs No. 1	Raquet Surv.	K-13	560	3513	2950	—	—
A. Wray	Bailey No. 1	Nacogdoches Co. Sch. Land	K-12	546	3505	2591	—	—
Wood County								
Big Indian Oil & Devel. Co. & Tidal Oil Co.	N. P. Foster No. 1	Wm. Barnhill	M- 9	484	4907	2626	4535	—
L. B. Carter et al	Vance No. 1	A. Hamilton Surv.	L-11	378	3261	—	—	—
Consumers Lignite Co.	Everett No. 1	Jacob Crawford, Jr., Surv.	L-10	445	3505	2435	—	—
Golden Oil Co.	Adrian No. 2	2 mi. W. of Golden	L-10	458	3028	—	—	—
Do	J. D. Adrian No. 3	Hallmark Surv.	L-10	—	4168	—	—	—
* Do	Everett No. 1	Hagan Surv.	L-10	422	3903	2760	4560[b]	—
Gulf Prod. Co.	N. E. Carver No. 1	Wm. Kern Surv.	M-11	400	5430	2870	—	5000
Haynesville O. & G. Co.	Chappell No. 1	W. H. Patton Surv.	M-10	414	1890	—	—	—
Hoard Oil & Gas Co.	Hoard No. 1	Jas. Brewer Hrs. Surv.	M-11	392	3591	3278	—	—
Jones Oil Co.	Chappell No. 1	S. Yarbrough Surv.	L-11	—	1400	—	—	—
Mineola-Dixon O. & G. Co.	Nash-Bagan No. 1	A. Hamilton Surv.	L-11	434	1800	—	—	—
George L. Pace et al	B. G. Dickey No. 1	J. C. Clark Surv.	M- 9	461	4403	2849	—	—
Simpson Oil & Gas Co.	Owens No. 1	James B. Parker Surv.	M-11	345	3220	—	—	—
West Texas O. & G. Co.	Negro Orphanage No. 1	Charles E. Rivers Surv.	L-11	361	4610	3043	—	—
Winnsboro Pet. Co.	Morris No. 1	Mary Arocha Surv.	N- 8	523	2104	—	—	—

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