THE BROOKS, STEEN, AND GRAND SALINE SALT DOMES, SMITH AND VAN ZANDT COUNTIES, TEXAS.

By SIDNEY POWERS and OLIVER B. HOPKINS.

An investigation of three salt domes in Texas in February, 1917, has formed the basis for this contribution to the study of salt domes. Both the writers have visited these domes, and the mapping was done jointly. The material was compiled and the manuscript prepared by Mr. Powers. One of the topographic maps and parts of another were kindly furnished by the Roxana Petroleum Corporation. L. W. Stephenson, of the Geological Survey, has identified fossils and otherwise assisted in the preparation of the report. M. I. Goldman, also of the Survey, examined samples of cap rock and made a detailed report on them.

GENERAL FEATURES OF SALT DOMES.

LOCATION.

The known salt domes in the United States are confined to the Coastal Plain in Texas and Louisiana (Pl. XX). For reasons that are not understood there are none east of Mississippi River. Several salt domes occur in Mexico near the Rio Grande, and there are many in the Isthmus of Tehuantepec. The asphaltic material cast upon the shore and the reported seepages suggest that the present coast does not bound the salt-dome area on the south and east.

Geographically and geologically the domes in the United States are divisible into two classes, interior and coastal, separated by a belt of country that happens to coincide with the outcrop of formations of Oligocene age. The interior domes are naturally divisible into two groups, a group of six in eastern Texas and one of nine or more in northwestern Louisiana.[1] The location of the

[1] Three of the interior salt domes in Texas are described in this paper. The other three are the Butler (West Point), Palestine, and Keechi domes. The nine in Louisiana are the Bistineau, Rayburn, Drake, Price, King, Winnfield Marble Quarry, Cedar Saline, Arcadia, and Bashawa. The Texas domes are described in the following publications: DeGolyer, E., The West Point salt dome, Freestone County, Tex.: Jour. Geology, vol. 27, pp. 647–663, 1919; Powers, Sidney, The Butler salt dome, Freestone County, Tex.: Am. Jour. Sci., 4th ser., vol. 49, pp. 127–142, 1920; Hopkins, O. B., The Palestine salt dome, Anderson County, Tex.: U. S. Geol. Survey Bull. 661, pp. 253–280, 1917. Those in Louisiana are described by A. C. Veatch (The salines of north Louisiana: Louisiana Geol. Survey Ann. Rept. for 1902, pp. 40–100, 1903) and G. D. Harris (Oil and gas in Louisiana: U. S. Geol. Survey Bull. 429, pp. 12–25, 1910).

domes is dependent on factors of sedimentation, folding, and isostasy that are but little understood. It can not be inferred with certainty from their location that they are of different origin or that they have not been formed in part contemporaneously.

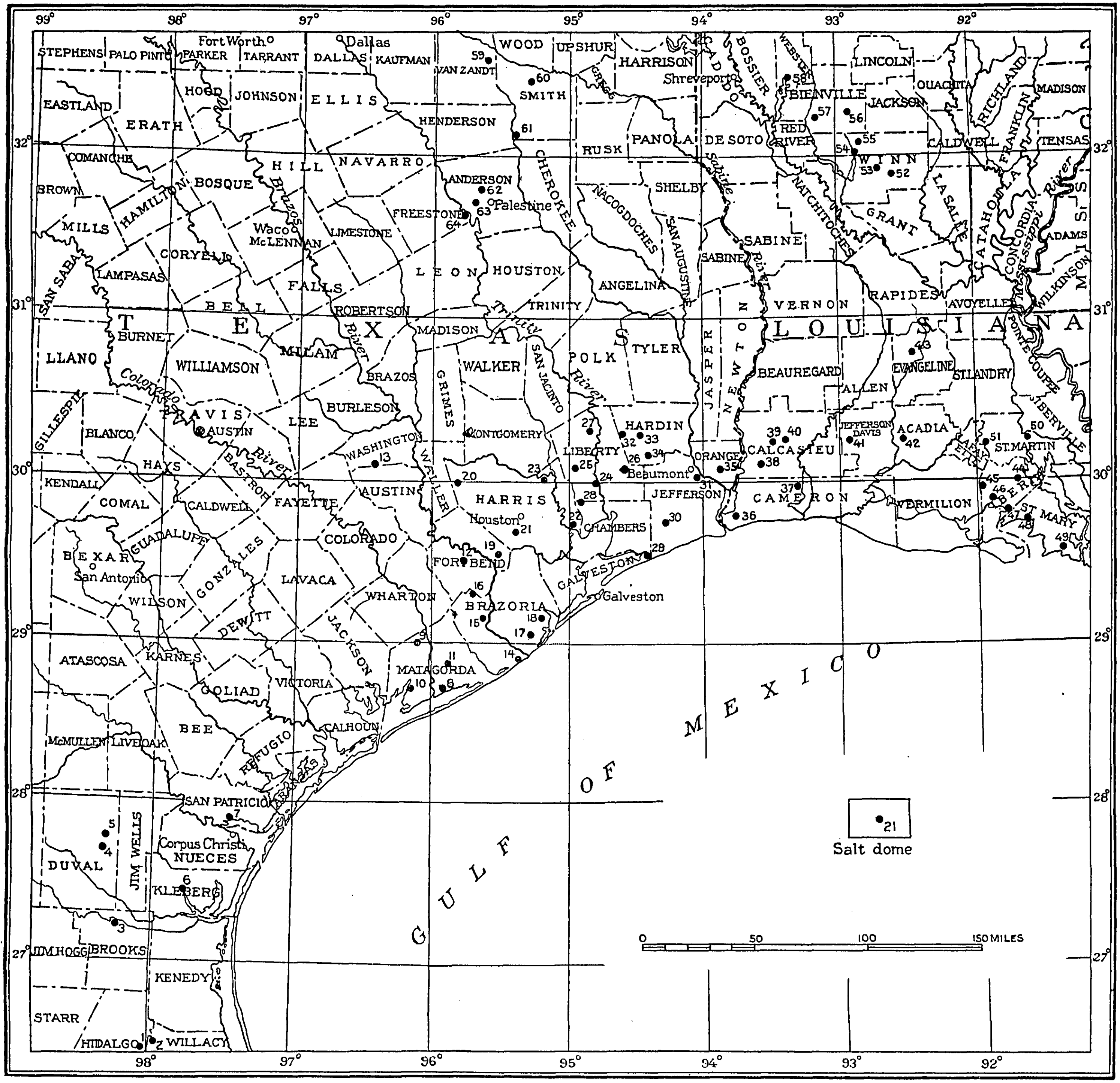
ORIGIN.

Comparatively little is generally known in the United States concerning the nature of salt domes, because commercial exploitation of salt, sulphur, and oil is of very recent date, and because a number of oil companies operating on these domes keep secret such information as they obtain. Underground workings are available for study in only two of the salt domes, those on Avery and Weeks islands, La. As a result many theories have been advanced for the origin of salt domes, but little information has been published. The theories have been reviewed by several authors [2] and will not be discussed here.

A contrast to the difficulties in studying salt domes in the United States is presented by the domes in Europe, which have been commercially exploited for a long time—some of them for more than 130 years. Underground workings and elaborate borings have revealed the structure and extent of the salt, and some of the borings have penetrated bedrock beneath the salt. The deepest test boring in the center of a salt dome in the United States is that of the Producers Oil Co. (Texas Co.) at Humble, Tex. (Wheeler & Pickens No. 17), which entered rock salt at 2,342 feet and stopped in salt at 5,410 feet, not reaching bedrock. Salt domes are known also in Egypt and western Asia, and oil is produced from those in Egypt.

The first question to be answered in determining the origin of salt domes is that concerning the origin of the salt. Salt deposits other than those in salt domes are of sedimentary origin. The salt in domes may have come from sedimentary beds or may have been crystallized from saline water ascending along fissures or other openings that have been enlarged as the salt accumulated. The water from which the salt was deposited, according to the second view, came from the water sands, which are fissured, the water being either connate—that is, buried with the sediments—or of surface origin, having descended from the outcrop in porous beds. If the first theory to account for the sources of the salt is accepted, the existence of salt beds under the Gulf coast must be postulated, though no field

[2] Harris, G. D., Rock salt: Louisiana Geol. Survey Bull. 7, pp. 59–83, 1907; Dumble, E. T., Origin of the Texas salt domes: Am. Inst. Min. Eng. Bull. 142, 1918; DeGolyer, E. L., The theory of the volcanic origin of salt domes: Am. Inst. Min. Eng. Bull. 137, 1918; Rogers, G. S., Intrusive origin of the Gulf coast salt domes: Econ. Geology, vol. 13, pp. 447–485, 1918; Hahn, F. F., The form of salt deposits: Econ. Geology, vol. 7, pp. 120–135, 1912; Hill, R. T., Salt domes: Alabama Geol. Survey Bull. 22, pp. 186–190, 1920.



INDEX MAP SHOWING THE LOCATION OF THE SALT DOMES OF THE GULF COASTAL PLAIN.

For explanation of numbers see table in text.

evidence of their existence is available; if the second theory is accepted an enormous supply of salt water, from which the salt was derived, must be postulated, though no satisfactory explanation of its origin can be offered.

The second question is, How did the salt accumulate in pluglike masses from half a mile to 1½ miles in diameter and more than 1 mile in thickness, with very steeply pitching sides. The uplift of the salt has flexed the adjacent strata upward over an area somewhat larger than the area of the salt core, and in some places at the periphery of the core the strata are tilted at angles of 50° to 70°. Tongues of the salt penetrate the adjacent strata here and there, but fragments of rock are very rarely found in the salt. Obviously the salt has forced its way upward, pressing the beds of rock aside but not engulfing them. On the tops of some of the Gulf coast domes the surface, the folds of the strata, and the undulations in the surface of the salt are parallel. Lines of weakness or stress are thought to connect the domes, but normal anticlinal folds seem to be in few places, if anywhere, associated with the salt domes of the Gulf coast.[3] In fact, the domes are confined to major synclinal areas.

Various hypotheses have been advanced to explain the rise of the salt. The force of growing crystals seems to be inadequate to account for the growth of salt cores, because crystals of salt near the tops of the domes show lack of crystal form, whereas those nearly a mile below the surface, where the force should be exerted, are perfectly cubical. The deposition of salt from solution in fissures or other openings seems to be a self-limited and inadequate process.

European views regarding the origin of salt domes have a notable degree of uniformity.[4] The salt deposits of domal type in Europe show gradation from the cores of true anticlinal folds to small domes

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[3] In several of the Gulf coast oil and gas fields, as Houma, La., no evidence of pronounced uplift or of steep dips has been found. It is believed that the accumulation of petroleum in these fields is controlled by sand conditions or by low anticlines or else by doming over deeply buried salt domes.

[4] Hahn, F. F., The form of salt deposits: Econ. Geology, vol. 7, pp. 120–135, 1912 (review of European literature); Von Waterschoot van der Gracht, W. A. J. M., Salt domes of northwestern Europe: Southwestern Assoc. Petroleum Geologists Bull., vol. 1, pp. 85–92, 1917; Mrazec, L., and Teisseyre, W., Aperçu géologique sur les formations salifères et les gisements de sel en Roumanie: Mon. des intérêts pét. Roumanie, Nos. 43–51, 1902; Mrazec, L., L'industrie du pétrole en Roumanie, Bucarest, 1910; Mrazec, L., Les plis à noyaux de percement: Soc. sci. Bucarest Bull., 1906; Harbort, E., Neu und Umbildungen im Nebengestein der norddeutschen Salzstöcke: Deutsch. geol. Gesell. Monatsber., vol. 65, pp. 6–16, 1913; Schuneman, F., Vorläufige Mitteilung über einzelne Ergebnisse meiner Untersuchungen auf den Kaliwerken des Stassfurter Sattels: Zeitschr. prakt. Geologie, vol. 21, p. 205, 1913; Stille, H., Das Aufsteigen des Salzgebirges: Idem, vol. 19, pp. 91–99, 1911; Kirschmann, W., Die Lagerungsverhältnisse des Oberen Allertales: Idem, vol. 21, pp. 1–23, 1913; Arrhenius, S., and Lachmann, R., Bildung der Salzlagerstätten: Geol. Rundschau, vol. 3, pp. 139–157, 1912; Beyschlag, F., Das Salzvorkommen von Hohensalza: K. preuss. geol. Landesanstalt Jahrb., vol. 34, pt. 11, pp. 225–241, 1913; Rogers, G. S., Intrusive origin of the Gulf coast salt domes: Econ. Geology, vol. 13, pp. 447–485, 1918.

such as occur in Texas and Louisiana. The regions in which these deposits occur are underlain by thick salt beds that were laid down in shallow seas or lakes. In the anticlinal folds the salt bodies have become thickened by compression due to folding and consequent flowage of plastic salt. The domes away from the anticlines show alinement and are believed to be caused by the flowage of salt induced by lateral compression and carried to completion because of lack of isostatic equilibrium between the salt (gravity 2.14) and the sediments (average gravity 2.4). The cylindrical core must represent the form of salt intrusion by which equilibrium is most readily established once the continuity of the strata immediately overlying the bedded salt deposit is broken.

This theory is supported by field evidence in the European domes, and it is therefore presented as a probable explanation of the origin of the domes of Louisiana and Texas, in the lack of information that would suggest any other explanation. According to this theory the wavy black bands seen in the Louisiana salt mines and also common in the European domes are original beds of salt colored by impurities which have become distorted by flowage. A sedimentary bed of salt at Malagash, Cumberland County, Nova Scotia, shows similar dark streaks of anhydrite colored with carbonaceous matter in the salt. These bands show the same intense folding, plication, and incipient faulting as the bands in the Louisiana salt domes.[5] Banded salt deposits in India are described by Murray Stuart.[6] The thin stringers of sandstone a few inches in thickness and several feet long in the Louisiana salt mines may represent original beds of sand deposited with the salt.

Many salt domes are covered by a cap rock composed generally of limestone, gypsum, anhydrite, and sulphur. This cap rock covers part or all of the top and may extend down the sides of the salt core for some distance. Here and there tongues of this rock project into the adjacent strata. The origin of the cap rock is unknown. If the cap had risen with the salt infolding might have resulted. If it represents, according to the European view, a concentration of the impurities in the salt left by solution of the more soluble salt as the mass rose, vast quantities of salt must have been dissolved from domes where the cap rock is 1,000 feet thick and where the impurities normally constitute only 1 to 4 per cent of the mass (average 1½ per cent). A third hypothesis would account for the cap rock by deposition from circulating waters after the core

[5] Canada Geol. Survey Mem. 121, 1920; also letter from W. C. Phalen to Sidney Powers.

[6] The potash salts of the Punjab Salt Range and Kohat, and suggestions regarding the origin and history of the rock-salt deposits of the Punjab and Kohat: India Geol. Survey Rec., vol. 50, pt. 1, 1919; Natural gas in bituminous salt from Kohat: Idem, vol. 50, pt. 4, 1919.

had practically attained its present height, the deposited material replacing the top of the salt rather than impregnating the overlying sedimentary deposits. A combination of the second and third hypotheses is probably necessary to explain the origin of the cap rock. Cap rocks may show doming parallel to the doming of the overlying rock. They also show the effect of slight compression, but this may be caused by crystallization, as many of these cap rocks are composed of bands of crystalline matter of different generations separated by cavities. As the present mineral constituents may be entirely secondary their arrangement is suggestive rather than conclusive. Either the formation or the alteration of the cap rock has produced the slight increase in sulphate content of the soil overlying salt domes.

Indirect evidence regarding the relative age of cap rocks is available. The absence of any cap over some of the domes where the salt comes within a short distance of the surface (35 feet at Avery Island, 96 feet at Jefferson Island, 103 feet at Belle Isle, La.) may be explained by the very recent growth of these domes. Some of them have grown during the final uplift of the coast to its present level, and others after this uplift. The Five Islands seem to show no evidence of elevated beaches, although they are at tide level on a coast line of recent emergence. Consequently they must have attained their present position since the most recent uplift of the Gulf coast. The fossils in the strata above the salt that rise above sea level are corroded shells of living species, and a log struck in a well drilled at Avery Island at a depth of 2,643 feet, beneath 2,263 feet of salt, is believed to be cypress of the same species as is now growing on the coast.

On the other hand, in the interior salt domes there is no relation between thickness of cap rock and age of the dome. In a few of them there is evidence that the top of the salt core has been lowered by solution contemporaneously with the development of the present topography and that a part of the cap rock, if it was originally thick, has also been removed.

SALT DOMES IN TEXAS AND LOUISIANA.

COASTAL DOMES.

As this paper is designed to form a contribution to the knowledge of the interior domes, the coastal domes are described only in the following table. The numbers refer to the map (Pl. XX). The table has been compiled with the assistance of D. C. Barton, W. E. Pratt, and D'A. M. Cashin, of Houston, Tex.

Coastal salt domes in Texas.

No. on map.	Name.	Salt.		Oil or gas.			Remarks.
		Found.	Depth (feet).	Present.	Depth (feet).	Production.	
	Hidalgo County:						
1	Sal del Rey (?)	......	......	Gas show.	2,416	....	Salt marsh; 2 wells drilled.
	Willacy County:						
2	Sal Vieja (?)	......	......	....	......	....	Salt marsh.
	Brooks County:						
3	Loma Blanca (Falfurrias, Alta, Colorado). (?)	......	......	Oil show..	2,660	....	Selenite cap rock (?) crops out.
	Duval County:						
4	Piedras Pintas	×	500	Oil	300-500	Small	Produces from above the cap rock; show of oil in deep test. Siliceous cap rock, deposited by fresh-water springs (?), crops out.
5	Palangana	×	500	....	......	....	Several wells drilled into salt.
	Kleberg County:						
6	Kingsville (?)	......	......	Gas	......	Small	Little evidence of salt dome except sour dirt. Gas and oil showings; not commercial.
	San Patricio County:						
7	White Point (?)	......	......	...do	1,508, 2,126, 3,140	....	Little evidence of salt dome except sour dirt and sulphur. Gas only; not commercial.
	Matagorda County:						
8	Big Hill (Matagorda).	×	1,200	Oil	800	....	Sulphur important.
9	Markham	×	2,710	...do	1,306-1,370	Small	Cap rock anhydrite and limestone. Initial wells large producers.
10	Collegeport (?)	......	......	....	......	....	Low rise in the prairie not yet known to be a salt dome.
11	Shepperd's Mott (?)	......	......	Oil	......	Show	Hill 40 feet high; no other evidence of a dome.
	Fort Bend County:						
12	Big Creek	×	750	...do	650	...do	New dome found in April, 1922; cap-rock production, not yet commercial.
19	Blue Ridge	×	400	...do	2,645-2,700 3,900-4,000	Small	Two small oil fields.
	Washington County:						
13	Brenham	×	1,400	...do	1,360	Little	Cap rock of anhydrite at 1,300 feet; oil from Cook Mountain formation (Eocene).
	Brazoria County:						
14	Bryan Heights	×	900	Gas	800, 1,300	Small	Mostly H_2S; sulphur mines.
15	West Columbia (Kisers Mound).	×	800	Oil	3,000, 3,400	Large field.	Production confined to 50 acres until summer, 1920. Fossils of Jackson formation (Eocene) from wells.
16	Damon Mound	×	500-3,400	...do	1,300, 2,308, 3,000	...do	Cap rock of imestone, anhydrite, and gypsum with sulphur at 140-500 feet; hill 82 feet high.
17	Stratton Ridge	×	1,300-2,300	...do	4,280	Shows	Cap rock of gypsum and anhydrite at 900-1,300 feet.
18	Hoskins Mound	×	1,250-1,700	Oil, gas..	670-730	Small	Principally sulphur, now being mined.
	Harris County:						
20	Hockley	×	1,000-3,400	Oil	300-500	Shows heavy oil.	Cap rock at 90-1,000 feet, anhydrite. Show of oil at 69 feet; 10-barrel production at 393 feet.

Coastal salt domes in Texas—Continued.

No. on map.	Name.	Salt.		Oil or gas.			Remarks.
		Found.	Depth (feet).	Present.	Depth (feet).	Production.	
	Harris County—Con.						
21	Pierce Junction	×	950	Oil, gas	3,720-4,300	A few large wells.	Cap rock 100-200 feet thick.
22	Goose Creek (?)	....	....	Oil	1,925, 2,500, 3,300	Large field.	Salt not encountered; if a salt dome it is deeply buried.
23	Humble	×	1,400-5,500	...do	950, 1,450, 2,700, 3,500, 4,193	...do	Cap rock at 50-250 feet containing oil of 20°-24° gravity; lateral sands produce oil of 22°-26° gravity; field covers 2,225 acres.
	Liberty County:						
24	South Dayton	×	600	...do	900, 1,200, 3,500	Very small.	Cap rock anhydrite; 30 wells drilled; one small pumper; no present production.
25	North Dayton (Myrtle Ridge).	×	674	...do	400, 740, 2,400	...do	Cap rock anhydrite.
26	Hull	×	600	...do	1,800, 3,500, 3,700	Large field.	Oil mostly 21°-27°; some 31°-37°. Fossils from wells at 3,300 feet, Jackson formation.
27	Davis Hill	×	1,385	Oil, gas	500, 3,700	Shows	Salt and anhydrite cap rock encountered; hill 140 feet high.
	Chambers County:						
28	Barbers Hill	×	600	Oil	850, 2,000	Small	Thick cap rock; sulphur.
	Galveston County:						
29	High Island	×	1,500-2,600	Gas, oil	155	...do	Cap rock at 300-1,300 feet; shows in cap.
	Jefferson County:						
30	Big Hill	....	....	Oil	2,200	Show	Cap rock thick, but no deep wells top of dome; 11 wells drilled; cap rock at 250 feet.
31	Spindletop	×	1,650	...do	1,120-1,139	Large field.	Discovery field for Gulf coast; discovery well drilled by Capt. A. F. Lucas in 1901; cap-rock production.
	Hardin County:						
32	Batson	×	....	...do	790	Small field.	Formerly large production, mainly from cap rock.
33	Saratoga	×	2,050	...do	740-1,500	Large field.	Now nearly exhausted; cap rock at 1,500 feet; production from sand in cap rock. Miocene fossils at 1,200 feet; also Jackson formation fossils.
34	Sour Lake	×	880	...do	700-1,900, 3,200	...do	Now nearly exhausted; cap rock outcrop reported; fossils, at 1,050 feet, of Jackson formation (Eocene); main production in cap rock.
	Orange County:						
35	Orange (Terry, Cow Bayou) (?).	....	....	...do	1,750, 3,120, 4,000 5,490	...do	Low rise in topography; no salt encountered; if a salt dome it is deeply buried. Pliocene fossils at 3,000-3,400 feet.

Coastal salt domes in Louisiana.

No. on map.	Name.	Salt.		Oil and gas.			Remarks.
		Found.	Depth (feet).	Present.	Depth (feet).	Production.	
	Cameron Parish:						
36	Johnson's Bayou(?).			Oil		Show	Large sulphur gas seepage; shallow "rock"; probably deeply buried.
37	Hackberry Island			do	1,860	do	Lenses of salt reported in one well; 17 wells drilled; cap rock at 1,580 feet.
	Calcasieu Parish:						
38	Vinton	×	1,000	Oil, gas	2,100-3,000	Large field.	Cap rock at 500 feet. Many pay sands in each well. Oil mostly 21°-29°.
39	Edgerly(?)			Oil	2,300, 2,700, 3,100	Small field.	No salt encountered and little evidence of a salt dome except paraffine dirt.[a] Pliocene fossils at 3,000 feet.
40	Sulphur	×	1,480				Sulphur mined; oil neglected; cap rock at 376 feet.
	Jefferson Davis Parish:						
41	Welsh(?)			Oil	930-1,100	Small field.	No domal structure shown in well logs; evidently not a salt dome.
	Acadia Parish:						
42	Jennings (Evangeline).			Oil, gas	1,800	Large field.	Low hill; greatest total production of all domes in Louisiana. Miocene fossils at 1,000 feet. Limestone cap rock at 2,100 feet.
	Evangeline Parish:						
43	Pine Prairie (St. Landry).	×	500	Oil	1,240	Good shows.	No present commercial production. Limestone cap rock crops out; cap 500 feet thick.
	Iberia Parish:						
44	New Iberia	×	800	do		Small field.	Located by presence of paraffine dirt[a]; no topographic expression; no cap rock.
45	Jefferson Island (Cote Caroline).	×	69-334				Salt mine; no cap rock.
46	Avery Island (Petite Anse)	×	15-35				Do.
47	Weeks Island (Grande Cote).	×	97				Do.
	St. Mary Parish:						
48	Cote Blanche	×	635				Tests for salt only.
49	Belle Isle	×	373	Oil	1,370-1,840	Shows	Salt mine; no cap rock.
	St. Martin Parish:						
50	Bayou Bouillon			Oil, gas	1,400	do	No topographic expression; gas seepage; paraffine dirt; no cap rock.
51	Anse la Butte	×	260	Oil	1,000-2,500	Small	Old field; did not hold up salt mine on top of dome.
	Catahoula Lake (sec. 28, T. 9 S., R. 7 E.)	×					One well drilled found; gypsum. Gas seepagee paraffine dirt.

[a] Paraffine dirt is an earthy material resembling art gum in color and "rubbery" quality. The paraffin dirt at Anse la Butte overlies strong gas seepages, and all gradations may be found from ordinary clay 1½ feet below the surface through joint blocks of clay coated with roots and with reddish-yellow "rubbery" dirt to solid beds of impure paraffine dirt. Black soil a few inches thick covers the dirt, and ordinary grass grows on the soil. The ground above the earth is springy. The origin of the dirt is believed to be connected with aeration and alteration of clay and humus material by gas. The origin of the dirt is discussed by A. D. Brokaw and others (Am. Inst. Min. Eng. Trans., vol. 61, pp. 482-500, 1920).

INTERIOR DOMES.

There are six known interior salt domes in eastern Texas, in Freestone, Anderson, Smith, and Van Zandt counties, and nine in northern Louisiana, in Webster, Bienville, Natchitoches, and

Winn parishes. Other domes may occur in northern Louisiana, but their existence has not been proved. Salt licks resembling those of salt domes are known in both States, but they have no connection with domes and are due to saline water ascending along joint planes or other openings. Smoothly curved lines may be drawn connecting the interior domes, and these lines are interpreted as representing lines of stress or joint planes on a grand scale rather than lines of upfolding. Faults or folds in rocks exposed at the surface between the domes have not been found. In general, each group of domes occupies an area of regional down-folding. It seems probable that the location of salt domes is controlled by the occurrence of small saline basins, which are now represented by major synclines.

Surface manifestations of interior salt domes are (1) saline prairies, either barren or sparsely covered with rushes and grasses that grow in brackish water; (2) springs of either fresh, slightly brackish, or mineralized water, usually containing sulphur or alum; (3) exposures of tilted rocks; (4) usually outcrops of older formations than those normally found in the region; (5) peculiar topographic forms consisting of a central depressed area surrounded by a ring of hills with steep slopes facing inward, or else of a central hill surrounded by stream courses that form a circle. In contrast with these features, those indicating the salt domes in the soft clays and sands of the coastal belt in advance of actual drilling are (1) topographic mounds or ridges a few feet (140 feet at Davis Hill) higher than the adjacent prairie; (2) gas or oil seepages (not including intermittent or occasional gas seepages); (3) sulphate content of the soil 1 or 2 per cent higher than normal; (4) paraffine dirt; (5) sour (alum), sulphur, or salty dirt or springs.

The following tables briefly describe these domes. The numbers refer to Plate XX.

Interior salt domes in northern Louisiana.

No. on map.	Name.	Salt.		Remarks.
		Found.	Depth (feet).	
	Winn Parish:			
52	Cedar saline (?), secs. 30-31, T. 11 N., R. 2 W.	(?)	....	Gas seepages and salt "licks"; 6 shallow wells, deepest 1,700 (?) feet. No known proof of a dome.
53	Winnfield marble quarry, secs. 19-24, T. 11 N., R. 3 W.	×	999	Limestone cap rock outcrop quarried for lime (99 per cent $CaCO_3$). Well on top of dome found 999 feet of limestone with only two beds of sand, 8 and 2 feet thick. Lower Claiborne (St. Maurice formation) limestone exposed on north side of dome. Old well near this outcrop 2,112 feet deep penetrated 3 lenses of cap rock, each over 40 feet thick. New well on northwest side of dome 3,252 feet deep did not find cap rock or salt.

Interior salt domes in northern Louisiana—Continued.

No. on map.	Name.	Salt. Found.	Salt. Depth (feet).	Remarks.
	Winn Parish—Continued.			
54	Drake saline (Goldonna), sec. 21, T. 12 N., R. 5 W.[a]	×	910	Salt "licks"; deep well showed limestone cap rock from 303 to 910 feet and salt to 2,320 feet, with gypsum to bottom of hole at 2,342 feet.
55	Price saline (Dugdemona), sec. 30, T. 13 N., R. 4 W.	....	....	Central hill 90 feet high, surrounded by circular drainage and salt "licks." One shallow well.
	Bienville Parish:			
56	Rayburn saline, sec. 31, T. 15 N., R. 5 W.	....	....	Circular saline surrounded by hills. The Saratoga chalk member of the Marlbrook marl (Upper Cretaceous) crops out east of the saline and dips away from it at an angle of 67°.
57	King saline, sec. 35, T. 15 N., R. 8 W.	....	....	Broad flat area with several "licks." Saratoga (?) chalk in shallow wells. Recent test at Castor found gypsum cap rock at 2,088 feet and stopped at 2,225 feet.
	Acadia, sec. 29, T. 18 N., R. 5 W.	×	1,400	Discovered by the drill in August, 1922; well was located near Claiborne (?) exposure showing steep dip. Limestone cap rock 25 feet thick.
	Webster Parish:			
58	Bistineau, secs. 25, 26, 35, and 36, T. 18 N., R. 10 W.	....	....	Portion of old lake bottom with "licks" arranged in a circle. Outcrop of Saratoga (?) chalk.
	Bashawa, sec. 16, T. 17 N., R. 5 W.	×	799	Arkadelphia clay (Upper Cretaceous) crops out in center of dome; salt discovered in well drilled in August, 1922. Anhydrite cap rock 90 feet thick. (Wells at Pine Island find anhydrite in the Fort Worth limestone (?) about 400 feet above the Kiamitia-Duck Creek producing horizon.)

[a] Partly in Natchitoches Parish.

Interior salt domes in eastern Texas.

No. on map.	Name.	Salt. Found.	Salt. Depth (feet).	Remarks.
	Van Zandt County:			
59	Grand Saline........	×	212	Described in text.
	Smith County:			
60	Steen................	×	(?)300	Do.
61	Brooks...............	×	220	Do.
	Anderson County:			
62	Keechi...............	×	2,162	Saline surrounded by hills; outcrops of Navarro formation and Austin chalk. Five test wells located near together on south side of dome encountered formations as follows:

	Top of Austin chalk (feet).	Top of Woodbine sand (feet).	Total depth (feet).
1	951	1,647 (8° oil).................	3,170
2	(?)1,592	2,257 (salt water)............	2,297
3	1,566	2,221.........................	2,656
4	1,537	2,314 (gas)...................	2,447
5	2,091	2,912.........................	3,048

No. 1 found salt at 2,162–2,822 feet and a show of heavy oil at 3,091–3,170 feet.

No. on map.	Name.	Salt. Found.	Salt. Depth (feet).	Remarks.
63	Palestine............	×	140	Lake surrounded by hills and these in turn surrounded by circular drainage system; salt works; Navarro formation, Austin chalk, and Woodbine sand crop out.
	Freestone County:			
64	Butler...............	×	400	Low hills inside and high hills outside circular drainage system; Navarro (?) formation crops out.

STRATIGRAPHY.

The type stratigraphic section for this part of eastern Texas follows. A detailed discussion of the stratigraphy at each dome is given in the description of the dome.

Generalized section of formations in the region of the Brooks, Steen, and Grand Saline salt domes, Tex.[a]

System.	Series.	Group.	Formation.	Thickness (feet).	Character.
Quaternary.	Recent.				Alluvial deposits along streams.
	Pleistocene.				Terrace deposits.
Tertiary.	Eocene.		Mount Selman formation.	350-600	Sand, in part highly glauconitic and fossiliferous, clay, lignite, and thin beds of iron ore.
			Wilcox formation.	450-650	Sand lenses, sandstone, clay, sandy clay, and lignite.
			Midway formation.	250-500	Micaceous sandy clay, fine argillaceous sand, and limestone concretions.
Cretaceous.	Gulf (Upper Cretaceous).		Navarro formation.	1,800-2,000	Light to dark gray calcareous clay, sandy clay, and fine lenticular beds of sand.
			Taylor marl.[b]		Massive calcareous clay marl, little sand or glauconite.
			Austin chalk.	400-500	Gray to white chalky limestone containing some hard beds.
			Eagle Ford shale.	300-400	Light to dark colored shale or clay and thinly laminated impure limestone.
			Woodbine sand.	400-450	Sand, sandy lignitic clay, sandstone, ferruginous sand, and clay.
	Comanche (Lower Cretaceous).	Washita.	Denison formation.	150-200	Clay and limestone.
			Fort Worth limestone.	25-75	Alternating beds of limestone and marl.
			Preston formation.	50-100	Calcareous laminated clay and impure limestone.
		Fredericksburg.	Edwards limestone.	300-400	White chalky limestone, variously indurated, and in places fine arenaceous beds.
			Comanche Peak limestone.		
			Walnut clay.	100-200	Calcareous clay and impure marly and chalky limestone.
		Trinity.	Paluxy sand.	125-200	Fine-grained sand and lenticular beds of clay.
			Glen Rose limestone.	300-500	Impure limestone, marl, and calcareous shale.
			Travis Peak sand.	±250	Conglomerate, sand, sandstone, shale, and impure limestone.

[a] Matson, G. C., and Hopkins, O. B., U. S. Geol. Bull. 661, pp. 215, 257, 1918.

[b] In northeastern Texas and southern Oklahoma the upper part of the Taylor marl has been divided by L. W. Stephenson (U. S. Geol. Survey Prof. Paper 120, pp. 155-157, 1918) into the Pecan Gap chalk member at the top, 25 to 50 feet thick, and the Wolfe City sand member below it, 75 to 100 feet thick; the remainder of the formation consists of typical Taylor strata.

OIL AND GAS IN EASTERN TEXAS.

GENERAL OCCURRENCE.

The possibilities of obtaining oil and gas in eastern Texas are as yet little known. Practically all accumulations of petroleum in the Mid-Continent field are in areas of favorable geologic structure. In the sediments of the Coastal Plain the presence of closed anticlines may be inferred but not proved by local dips, and the proof of the existence of an anticline in the deeper strata, where petroleum is not found in commercial quantities, is seldom if ever obtained, because at least three wells near together are necessary to afford adequate proof, and these wells must pass through the Austin chalk, the only reliable horizon marker. Therefore valuable oil deposits may be found in eastern Texas at any time, and such dry holes as have been drilled condemn the region only so far as they show unfavorable sand conditions. Only in northern Louisiana and in a line from Richland past Currie, Mexia, Groesbeck, Kosse, and Luling, Tex., has oil in commercial quantities been obtained from beds below the Austin chalk. A suitable thickness of sand exists both in northern Louisiana and in the area from Corsicana southward. Although rotary wells are frequently drilled through sand without its presence being noted, and although many wildcat wells are drilled under contracts so expressed that the driller makes more money by completing the well as a dry hole with all possible speed than by carefully testing for oil, the fact remains that logs of wells drilled in eastern Texas in the area underlain by the Wilcox formation record few soft sands below the Wilcox.

In eastern Texas most of the wells that start in the Wilcox or the overlying Mount Selman formation fail to pass through those formations, and few reach the Austin chalk. Many of the logs of these wells record showings of oil in Wilcox sands or at the base of the Mount Selman formation, as in Nacogdoches County. It is possible that oil in commercial quantities may yet be obtained from sands in these Eocene formations. It is also possible that oil sands may be found in the Taylor marl, especially in the western part of eastern Texas. The most promising horizons are near the top and base of the Austin chalk, where gas showings are occasionally reported, and especially in the Woodbine sand. This sand will be found to be productive in eastern Texas wherever the subsurface structural conditions are favorable. Several sands are usually found in the Woodbine formation. The Lower Cretaceous also contains favorable formations—the Kiamitia clay, the Georgetown and Edwards limestones, and the Trinity sand—but these formations are very deeply buried.

OCCURRENCE IN SALT DOMES.

Each salt dome presents a problem in itself because of the difference in the amount of uplift and of penetration by the salt. Each dome is so small in extent that it has a small "gathering ground" from which to drain the oil, and therefore the presence of the large quantities of oil in the coastal domes is difficult to explain. It is possible that the oil in the interior domes escaped as the salt core rose and tilted and penetrated the overlying beds. It is also possible, however, that in the interior as in the coastal domes the oil may be concentrated on certain sides of certain domes and that these particular spots have not yet been found. The average producing area of the twelve largest coastal domes is 450 acres, and the Humble dome is the only one that has a producing area of more than 1,000 acres.

Only one authenticated showing of oil has yet been found on an interior dome—a very heavy, asphaltic oil obtained in the first test on the Keechi dome in Anderson County, at the horizon of the Woodbine sand. The oil had to be heated to flow readily. No trace of oil was found in the other test holes drilled near by. As oil is produced from beds at the Woodbine horizon on both sides of the eastern Texas synclinal area, this showing of oil in the middle of the area points to the logical conclusion that commercial production from beds at this horizon is possible on any of the salt domes or on any anticline in the area.

The possibility of finding oil in each of the domes here described is discussed separately.

BROOKS SALT DOME.

LOCATION AND HISTORY.

The Brooks salt dome (Pl. XXI, fig. 11) is in the extreme southwest corner of Smith County, Tex., 6 miles west of Bullard, 17 miles southwest of Tyler, and 1½ miles east of Neches River. The saline prairie in the center of the dome covers about 200 acres and is on the west half of the Pedro Elias Bean league. The outcrops to the west are on the José María Acosta league.

During the Civil War the Brooks saline was one of the places where salt was evaporated in small furnaces and kettles. S. B. Buckley states that "seven furnaces were run at this saline during the war, making 100 sacks (20,000 pounds) of salt daily. It takes 300 gallons of water to make 1 bushel of the salt."[7] Traces of the

[7] Texas Geol. and Agr. Survey First Ann. Rept., p. 126, Houston, 1874.

furnaces are found on the islands in the prairie. The dome is also mentioned or described by others.[8]

Limestone was quarried for many years north of the prairie to be made into lime. The quarry was formerly owned by the State of Texas and was worked with slaves before the Civil War.

Shallow wells around the dome yield potable water on the east side of the prairie and salty water on the northwest side. These wells average 30 to 40 feet in depth. It is probable that the wells yielding nonpotable water are affected by the artesian conditions which furnish the continuous supply to the prairie. Sulphur water, characteristic of domes, was not reported around the prairie, but alum ("sour") water undoubtedly was the cause of the abandonment of some of the shallow wells. Recent developments on this dome are due to the interest of Dr. Albert Woldert, of Tyler, who showed the outcrops to the writers and furnished all available

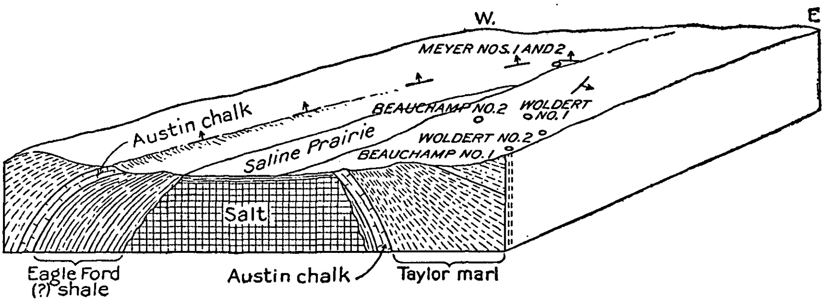


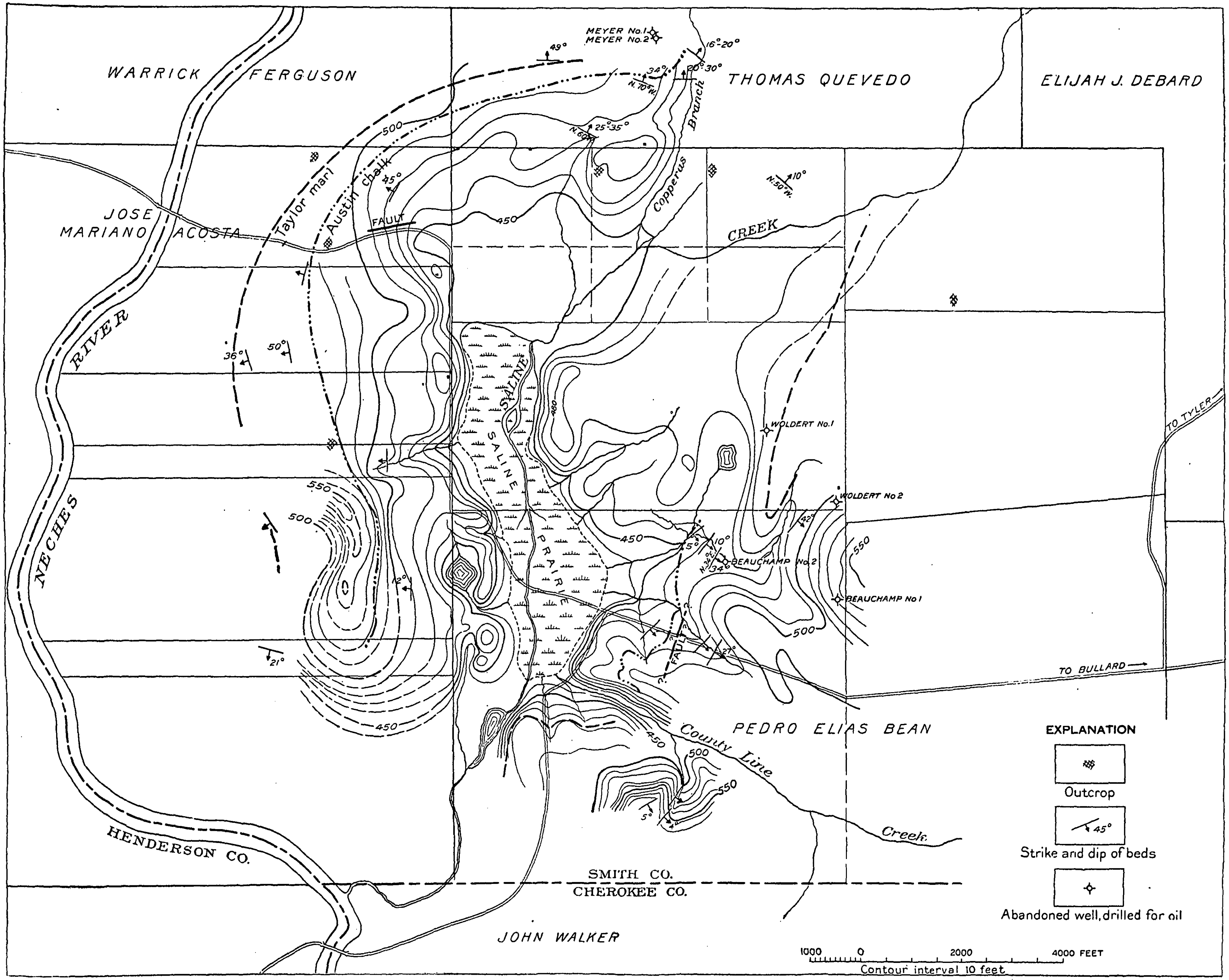
FIGURE 11.—Block diagram of Brooks salt dome, Smith County, Tex.

data. Mr. Will A. Woldert made the map of the saline showing land lines which is here used. Mr. J. H. Herndon, of Tyler, also furnished information supplemental to his published description of the dome.

TOPOGRAPHY.

The altitude of Bullard, the nearest town on the St. Louis Southwestern Railway, is 575 feet, and that of the highest hills in the region is about 50 feet more. The altitude of the Brooks saline is about 430 feet. The top of the derrick on the Beauchamp No. 1 test, 112 feet high, is visible from a hill not far west of Bullard.

[8] Johnson, L. C., Report on the iron ores of northern Louisiana and eastern Texas: 50th Cong., 1st sess., House Ex. Doc. 195, p. 20, 1888; Herndon, J. H., Texas Geol. Survey Second Ann. Rept., pp. 221–224, 1901; Adams, G. I., Oil and gas fields of the Upper Cretaceous and Tertiary of the western Gulf coast: U. S. Geol. Survey Bull. 184, p. 39, 1901; Harris, G. D., Oil and gas in Louisiana: U. S. Geol. Survey Bull. 429, p. 14, 1910; Louisiana Geol. Survey Bull. 4, pp. 19, 66, 1905; Bull. 7, p. 58, 1907; Hager, Lee, The mounds of the southern oil fields: Eng. and Min. Jour., July 28, 1904, p. 137; Deussen, Alexander, Geology and underground waters of the southeastern part of the Texas Coastal Plain: U. S. Geol. Survey Water-Supply Paper 335, p. 84, 1914; Dumble, E. T., The geology of east Texas: Texas Univ. Bull. 1869, pp. 25, 26, 1920; Phalen, W. C., Salt resources of the United States: U. S. Geol. Survey Bull. 669, p. 121, 1919.



TOPOGRAPHIC MAP OF THE BROOKS SALT DOME, SMITH COUNTY, TEX.

The salt dome has a central saline 1¼ miles in length and about a quarter of a mile in width, surrounded by gently sloping hills. Back of these low hills is a rim of higher hills on the east and west sides, giving a relief of 120 feet. There is a pond on each side of the dome behind the first row of hills. These ponds and the pools of standing water on the saline receive water from springs that flow throughout the year. Saline Creek rises northeast of the dome and flows into the saline at the northeast end. The cultivated flat north of the saline has possibly been slightly aggraded by this stream. The creek loses its identity in the saline in many winding channels and marshes but leaves the saline in a well-defined channel and flows through the Neches River flood plain into the river. There is a topographic gradation from the saline into this flood plain, but a dense forest of hardwood trees in the river bottom forms as conspicuous a boundary to the saline as the pine trees on the adjoining hills.

The saline represents the center of the dome and covers the central part of the area underlain by the salt core. The depressed area originally was higher than the surrounding region, and the present form is due to erosion, which was possibly aided by solution by ground water of the underlying salt at a depth of less than 300 feet and a corresponding subsidence of the surface.

A conspicuous feature of the saline is the presence of wooded "islands" or mounds, some of which are more than 600 feet in length and 150 feet in width. Their height above the flat salt marsh ranges from 2 to 5 feet. These mounds are believed to be of erosional origin, as described in another paper.[9]

Radial streams empty into the saline from all sides. Some of them are supplied only by surface run-off, but most of them are fed by ground water in boggy areas or by springs. The abundance of water is in large part due to artesian conditions arising from the local uplift. Surface water could not supply the persistent springs and seepages. The slight salinity of the artesian water is possibly influenced by the presence of the salt core, but principally by dilution of connate salt water and chemical changes in it.

GEOLOGY.

SURFACE GEOLOGY.

GENERAL FEATURES.

The Brooks salt dome lies in the area of the typical Mount Selman formation,[10] but on account of the magnitude of the local uplift the

[9] Powers, Sidney, The Butler salt dome, Freestone County, Tex.: Am. Jour. Sci., 4th ser., vol. 49, p. 132, 1920.

[10] The town of Mount Selman, from which this formation takes its name, is the next station south of Bullard on the St. Louis Southwestern Railway, and is about 10 miles from the dome.

underlying Eocene and Cretaceous formations, including the Austin chalk, are exposed at the surface over a small area, whereas they would normally be buried several thousand feet. The formations identified at the surface are the Mount Selman, the Wilcox, the Taylor marl or Navarro formation, and the Austin chalk. With the exception of abundant fossils in the weathered glauconite beds of the Mount Selman formation on the east side of the conspicuous "mountain" south of the dome, no recognizable fossils of Eocene age have been found. The rough topography is one of the means of distinguishing the Wilcox from the Mount Selman formation.

Many collections of Cretaceous fossils have been made on the sides of the dome. R. T. Hill[11] identified *Plicatula* sp., *Ostrea* sp., *Gryphaea vesicularis*, and *Inoceramus* sp. and referred them to the Marlbrook marl. Harris[12] collected *Exogyra costata*, *Gryphaea vesicularis*, and *Ostrea larva* from some part of the dome. At an outcrop three-quarters of a mile from the northwest corner of the saline prairie *Exogyra ponderosa* Roemer and *Anomia argentaria* Morton were collected. They are of the age of the Austin chalk. L. W. Stephenson has examined fossils submitted by Dr. Woldert and confirms the age determination as Austin, and not the younger "Saratoga" chalk, a member of the Marlbrook marl.

The fossils in the Woldert collection from the chalk exposed in the Brooks saline are typical examples of *Exogyra ponderosa* Roemer, and this is good evidence that this chalk is not of "Saratoga" age. The "Saratoga" chalk forms the top of the *Exogyra cancellata* subzone of the *E. costata* zone and is therefore stratigraphically higher than the chalk in the Brooks saline.

Each formation crops out in an elliptical belt around the saline prairie. The outcrops are so scattered and so difficult to find that besides the locations on Plate XXI, notes on location are given with the descriptions.

UPPER CRETACEOUS FORMATIONS.

Eagle Ford shale.—Within the exposures of Austin chalk the Eagle Ford shale probably crops out, but only one outcrop is referred to this formation, and this reference is tentative. It consists of yellow clay, which is probably blue when fresh, exposed west of the saline, near the head of a gully south of a large cultivated field.

Austin chalk.—The Austin chalk is exposed on all sides of the dome except the southwest. The chalk appears as beds not more than 15 feet thick, separated by greenish calcareous shale. At the northwest corner of the dome 200 to 300 feet of chalk and shale can be measured. Elsewhere the exposures are probably confined to a single bed of relatively great hardness, which is only about 15 feet in thickness.

[11] Texas Geol. Survey Second Ann. Rept., p. 223, footnote, 1901.
[12] Louisiana Geol. Survey Bull. 4, p. 19, 1905.

In the road from Bullard at the edge of the prairie lowland about 20 feet of chalk is exposed with a strike N. 55° E. and an easterly dip of unknown steepness. North of the saline, at the lime quarry, 12 feet of chalk overlain and underlain by greenish calcareous clay strikes N. 70° W. and dips 34° N. A pit was dug for lime half a mile southeast of the quarry, south of the north line of the Bean league. Another exposure of the same thin chalk a quarter of a mile to the southwest gives a strike of N. 60° W. and a dip of 25°–35° N. Northwest of the saline, both south and east of the northwest corner of the large cultivated field on the A. J. McMinn land, the greatest thickness of chalk is exposed, with a strike of N. 30° E. and a dip of 45°–55° NW. Dr. A. Woldert collected *Exogyra ponderosa* in the marl beds exposed in a gully at this locality. A fault was observed in the series of outcrops as described elsewhere.

Analyses of the limestone at the quarry follow (1 and 2), together with an analysis of the Austin chalk at Austin, Tex. (3):

Analyses of limestone from Brooks salt dome and of Austin chalk at Austin, Tex.

	1	2	3
Lime (CaO)	46.66	46.0	46.64
Carbon dioxide (CO_2)	36.66	35.7	36.65
Water (H_2O) and organic matter	2.40	8.05	3.35
Silica (SiO_2)	7.15	6.2	7.80
Alumina (Al_2O_3)	7.10	3.75	3.45
Iron oxides (FeO, Fe_2O_3)		.25	1.35
Magnesia (MgO)	....	None.	None.
Sulphur (S)	....	.05	....
Pyrite (P)	....	Tr.	....
	99.97	100.00	99.24

1. S. H. Worrell, analyst.
2. J. H. Herndon, analyst.
3. Texas Univ. Bull. 365, p. 65.

Taylor marl (?).—Above the beds of Austin chalk there is a series of green and yellow marls and clays, originally blue, which may belong to the Taylor marl or be part of the chalk formation or may even include beds of Navarro age. Some of the outcrops described under this heading contain claystone concretions with or without cone-in-cone structure, in which are obscure fossils that look very similar to the small corals of Eocene age in the Butler salt dome. At other exposures *Exogyra ponderosa* was found, proving the Cretaceous age of the material. At the Palestine and Keechi domes fossils of Navarro age were identified, but no evidence of the presence of the Taylor marl was found. At the Butler dome clays containing Cretaceous fossils were found, but the horizon within the Cretaceous is uncertain.

On the east side of the saline dome plastic greenish-gray gypsiferous clay crops out between the Austin chalk and Wilcox formation in a drain a quarter of a mile northeast of the Bullard road, striking

N. 40° E. and dipping 48° E. The next observed exposure is three-quarters of a mile north of the dome, a short distance north of the lime quarry near Copperas Branch. At this locality fragments of *Inoceramus* were found in the shale, which strikes east and dips 20°–30° N. It is difficult to distinguish between the outcrops of Taylor (?) marl and of marl belonging to the Austin chalk, and some of the other exposures in this vicinity may belong to the Taylor. West of the north end of the saline and west of the cultivated field outcrops of concretionary shale are exposed in westward-draining gullies a short distance west of the Austin chalk. These clays strike N. 17° W. and dip 32°–36° W. An outcrop of similar clay containing an *Exogyra* was found a quarter of a mile west of the saline, a short distance south of the road that crosses it. The yellow and gray banded clays contain tiny lime nodules and larger balls of hard clay. They strike north and dip 12° (?) W.

EOCENE FORMATIONS.

Midway formation.—Sandy clay exposed on the divide southwest of the dome and in a westward-draining gully may be of Midway age. If the Midway formation is present in the normal stratigraphic section it is carried out of sight by faulting on the east side of the dome.

Wilcox formation.—On the east side of the dome about 1,000 feet east of the exposure of Austin chalk in the Bullard road 35 feet of typical sand and clay of reddish-brown color is exposed in a gully. The beds strike N. 30°–35° E. and dip 27°–29° E. Between these two outcrops there is probably Taylor marl. The great hiatus must be explained by an unconformity or a fault. South and east of this outcrop the Wilcox formation is concealed by beds of ferruginous sand of the Mount Selman formation, which weathers to a brilliant red color. A quarter of a mile northeast of this exposure the Wilcox is exposed with a strike of N. 34° E. and a dip of 34° SE. A quarter of a mile farther northeast, near the center of the Bean league, there is an exposure of dark-colored carbonaceous laminated clay which strikes N. 42° E. and dips 42° SE. Half a mile northeast of the saline, between Copperas and Saline creeks, sandy clay is exposed in a drain running through a cultivated field, having a strike of N. 50° W. and a dip of 10° N. On Copperas Creek a quarter of a mile north of the lime quarry reddish clays are exposed with a strike of N. 55° W. and a dip of 16°–20° N. The hills farther north are covered with red ferruginous sandstone of Claiborne age dipping north at a low angle and unconformable with the Wilcox. A quarter of a mile northwest of the lime quarry Wilcox gray sandy clays strike east and dip 49° N. West of the south half of the dome three exposures of sandy clay were observed. One on top of a ridge west of Saline Creek shows ironstone concretions with no distinguishable dip. One in a westward-draining gully strikes N. 10° E. and dips 21° W.; a third, half a mile west of the prairie, on a hill, shows concretionary iron beds with a strike of N. 35° W.

Mount Selman formation.—Numerous exposures of the Mount Selman formation are found on the hills east and south of the dome. A conspicuous "mountain" on the south, a quarter of a mile north of the Smith-Cherokee county line, is capped by beds of limonitic sandstone and limonite, which are underlain by beds of fossiliferous glauconite. At the crest of the hill the strike is N. 35°–50° E. and the dip 5° S.; a quarter of a mile east of the crest, in a gully, the strike is N. 20° E. and the dip 4° S. An exposure of red and white sand 1½ miles east of the dome, on the Bullard road, is referred to this formation. Northeast of the saline, in the northeast quarter of the Bean league, there is an outcrop of hard sandstone which appears to be nearly horizontal. Other exposures near Copperas Branch show a dip of about 3° N. An exposure of ferruginous sandstone of unknown age is found on top of a hill a quarter of a mile due west of the northwest corner of the Bean league, where blocks of rock 2 to 3 feet thick stand as pillars 3 to 4 feet high. The exposures northeast of the saline show the unconformable relation of the Wilcox and Mount Selman formations. Blocks of conglomerate cemented with hematite and limonite are found on some of the hills, and they are believed to be of comparatively recent age.

UNDERGROUND GEOLOGY.

Seven wells have been drilled on the sides of the Brooks dome—two on the Woldert land, two on the Beauchamp land, two on the Meyer land, and one on the Kimball land. Four of these wells penetrated salt, and therefore the subsurface geology aside from the outline of the salt core on the east side of the dome is difficult to interpret. The central salt core must be 1½ miles in diameter. In the center of the dome it comes within 220 feet of the surface. The area underlain by salt at a depth of less than 300 feet must be about a mile in diameter, but the upper surface of a salt core is undulating.

STRUCTURE.

The Brooks salt dome is a local uplift in the geosynclinal part of eastern Texas. In general saline domes consist of a more or less circular core of salt which has bent the strata upward into a dome (fig. 11). In the Brooks dome the uplift appears to be elliptical, with the longer axis trending north and south. The presence of at least one fault is known. This one was observed west of the north end of the saline, displacing Austin chalk against white clay. The direction of the fault is N. 80° E., the hade 75° NW. There is possibly a fault on the east side of the dome, as stated elsewhere.

Localization of the uplift is indicated by the small size of the area within which steep dips are found. Dips of 70° are the rule near the salt core, but within 1½ miles of the center the strata are undisturbed by the uplift. The amount of uplift may be estimated as 3,500 feet.

DEVELOPMENT.

Seepages of petroleum led to drilling on many of the coastal salt domes, but no seepages are known around any of the interior domes. In the cap rock at the Winnfield marble quarry, near Winnfield, La., a few samples of solid bitumen have been found. In the cap rock of the Pine Prairie salt dome, near Easton, La., spots of oil appear on freshly fractured surfaces. However, the association of oil with the coastal domes led to the prospecting of the interior domes for oil, and the real development of them has only begun.

In 1903–4 five shallow wells were drilled for salt near the center of the saline prairie on the Brooks dome, and the deepest encountered rock salt at 220 to 280 feet, which was overlain by 20 feet of gypsum. In June, 1919, the Brooks Saline Oil & Development Co. drilled Woldert well No. 1 east of the saline (Pl. XXI) and encountered salt from 260 feet to the bottom of the hole at 429 feet. Then Beauchamp well No. 1 was drilled farther from the dome and 3,500 feet from the nearest exposure of Austin chalk. The base of the Wilcox was found in this well at 1,300 feet, and the Austin chalk was probably passed through from 2,864 to 3,090 feet, giving a dip of 40°. The well was abandoned at 3,193 feet. Showings of oil and gas are reported in this well.

A second test on the Beauchamp land to a depth of 2,161 feet found streaks of salt below 875 feet and entered solid salt at 1,343 feet.

The fourth well drilled was Woldert No. 2, north of Beauchamp No. 1, and in this well salt was encountered at 840 feet under chalk at 584 to 840 feet that is probably limestone cap rock. The discovery of salt in this well was contrary to expectations, and outcrops of the Wilcox formation appeared to indicate the edge of the salt half a mile to the west. Evidently the outline of the salt core is elliptical, with an irregular curve between Beauchamp No. 2, Woldert No. 1, and Woldert No. 2.

Because of the poor success on the east side of the dome the next well, Meyer No. 1, was drilled on the north side, but it was abandoned at 528 feet. Meyer No. 2 was then started and struck the Austin chalk at 1,701 feet. The Woodbine sand was found at 2,386 feet, or 685 feet below the top of the Austin chalk. At Mexia the Woodbine lies 725 feet below the top of the Austin chalk, and at Palestine about 700 feet. Therefore this interval seems to be fairly uniform over that portion of eastern Texas. The total depth of Meyer well No. 2 was 2,769 feet, the well ending in salt found at 2,744 feet. The formations penetrated in this well are not of normal thickness because of the shear involved in the upthrust of the salt.

The most recent attempt to find oil on this dome was through a well drilled by the Brooks Saline Oil & Development Co. on the B. B. Kimball tract, on the southwest side of the dome. This well reached a depth of at least 1,864 feet without encountering either oil or gas.

Logs of these wells were obtained through the courtesy of Dr. Albert Woldert.

Log of well No. 1 on Woldert 65¼-acre tract in Pedro E. Bean survey.

[Drilled by Brooks Saline Oil & Development Co., Tyler, Tex. Well begun August 23, 1919.]

	Feet.
Surface	0–16
Red gumbo	16–30
Red sand	30–50
Water, sand, salt	50–70
Hard chalky shale (driller reported a light showing of oil and gas at about 117–125 feet)	70–195
Gypsum	195–205
Hard sand and salt	205–270
Hard rock	270–276
Rock	276–280
Hard sand and salt	280–309
Salt rock; had a little showing of oil in top of salt	309–345
Rock salt	345–429

Log of well No. 1 on Beauchamp 225-acre tract in Pedro E. Bean survey.

[Drilled by Brooks-Saline Oil & Development Co., Tyler, Tex. Well begun September 27, 1919.]

	Feet.
Surface clay, red	0–25
Red sand	25–50
Hard sand; showing of lignite	50–110
Hard sand, dark	110–120
Rock	120–123
Hard sand, dark	123–180
Hard sand and streaks of dark gumbo	180–246
Hard sand and boulders	246–375
Hard sand	375–405
Gyp	405–420
Hard sand and shale, dark	420–430
Hard sand and shale; struck pocket of gas between 490 and 500 feet	430–513
Sand and boulders	513–585
Gumbo	585–600

Log of well No. 1 on Beauchamp 225-acre tract in Pedro E. Bean survey—Contd.

	Feet.
Sand and boulders	600–720
Sand and shale, dark	720–740
Sand and boulders	740–1, 190
Hard sand and boulders	1, 190–1, 240
Tough black shale	1, 240–1, 250
Sand and boulders	1, 250–1, 270
Gumbo and gypsum	1, 270–1, 274
Sand and boulders	1, 274–1, 300
Black shale	1, 300–1, 320
Gumbo	1, 320–1, 367
Shale and gumbo	1, 367–1, 388
Shale	1, 388–1, 430
Blue sandy shale	1, 430–1, 530
Tough blue shale	1, 530–1, 735
Sandy blue shale	1, 735–1, 810
Tough blue shale	1, 810–1, 860
Sandy blue shale	1, 860–1, 920
Sandrock	1, 920–1, 923
Sandy shale	1, 923–2, 010
Sandy blue shale	2, 010–2, 070
Hard sandy shale	2, 070–2, 215
Hard sandy shale and boulders	2, 215–2, 243
Soft sandy shale	2, 243–2, 443
Tough sandy shale	2, 443–2, 470
Soft sandy shale	2, 470–2, 540
Sandy shale	2, 540–2, 575
Tough sandy shale	2, 575–2, 740
Blue sandy shale	2, 740–2, 790
Tough sticky shale	2, 790–2, 850
Tough shale	2, 850–2, 864
Hard sandy shale	2, 864–2, 874
Tough shale	2, 874–2, 904
Hard sandy shale	2, 904–2, 915
Tough shale	2, 915–2, 945
Hard sandy shale	2, 945–3, 015
Hard sandy shale and lime	3, 015–3, 022
Hard sandy shale and showing of oil	3, 022–3, 027
Hard sandy shale	3, 027–3, 030
Hard black slate rock; struck small cavity at 3,033–3,037 feet, between rocks showing some gas, which continued about 40 minutes. Driller stated that after he had pulled out for the night, then resumed drilling on the next day, large gas bubbles showed up in the runway and continued for about 2 hours	3, 030–3, 037
Hard sand with streaks of pure lime	3, 037–3, 040
Hard sand with streaks of lime	3, 040–3, 050
Hard brown sandy shale	3, 050–3, 075
Hard brown sand and shale	3, 075–3, 080
Hard sandy shale; traces of brown shale	3, 080–3, 091
Hard sandy shale	3, 091–3, 099
Hard sandy shale; bothered by iron	3, 099–3, 103

Log of well No. 1 on Beauchamp 225-acre tract in Pedro E. Bean survey—Contd.

	Feet.
Black slate rock	3,103–3,108
Hard fine gray sand	3,108–3,110
Hard fine greenish sand	3,110–3,113
Hard sandy shale	3,113–3,115
Hard greenish sand	3,115–3,116
Hard fine greenish sand	3,116–3,120
Hard fine sand	3,120–3,124
Hard fine greenish sand	3,124–3,128
Hard sandrock	3,128–3,132
Hard sandy shale	3,132–3,137
Hard sandrock	3,137–3,139
Brown shale	3,139–3,146
Hard black sand	3,146–3,150
Hard sandrock, very fine	3,150–3,153
Hard fine sandy shale	3,153–3,155
Hard black shale	3,155–3,157
Hard sandy shale	3,157–3,158
Tough sticky shale	3,158–3,163
Hard fine sandy shale	3,163–3,166
Tough sticky shale	3,166–3,171
Hard fine sandy shale	3,171–3,174
White gypsum	3,174–3,175
White gypsum, very tough	3,175–3,189
Dark tough sticky shale streaked with a white formation like lime or gypsum	3,189–3,191
Dark tough sticky shale with gypsum	3,191–3,193

Log of well No. 2 on Beauchamp 225-acre tract in Pedro E. Bean survey.

[Drilled by Brooks Saline Oil & Development Co., Tyler, Tex. Well begun March 23, 1920.]

	Feet.
Surface soil and quicksand	0–14
Red clay and gravel	14–45
Blue clay and cobblestone	45–50
Sandrock	50–52
Red sandrock	52–54
Sticky blue shale	54–178
Hard sandy shale with boulders	178–185
Hard sandy shale	185–192
Loose blackish-blue shale and boulders	192–235
Loose blue shale with streaks of hard shale	235–275
Loose blue shale with boulders	275–280
Hard sandy shale and boulders	280–315
Sticky blue shale	315–345
Sandy shale and boulders	345–460
Hard black sand	460–480
Hard black sandrock	480–492
Rock	492–495
Sandy shale	495–502
Sticky blue shale	502–525

Log of well No. 2 on Beauchamp 225-acre tract in Pedro E. Bean survey—Contd.

	Feet.
Loose black shale with some gravel and white crystallized sand	525–607
Black shale or slate	607–677
Hard black sand	677–702
Sticky blue shale	702–707
Blue shale	707–725
Black rock	725–730
Black sand and dark-colored rock	730–733
Gray gypsum	733–742
Gray limerock	742–749
Hard sandy shale	749–765
Conglomerate streaked with white lime	765–789
Conglomerate	789–800
Conglomerate, streaks of hard black sand	800–812
Hard black sand	812–820
Hard sandy shale and coarse gravel	820–840
Hard sandy shale with some gravel	840–870
Sandy shale and gravel	870–875
Sandy shale with streaks of salt	875–920
Salt rock	920–945
Sand and shale	945–960
Sand, shale, and gravel; salt lying in shale	960–1,025
Shale, sand, and gravel streaked with salt	1,025–1,070
Black sandy shale	1,070–1,080
Shale and salt	1,080–1,085
Black shale and streaks of salt	1,085–1,115
Gray sand and black shale	1,115–1,145
Hard shale and boulders	1,145–1,154
Gumbo and boulders	1,154–1,159
Shale, gray sand, and streaks of salt	1,159–1,175
Boulders, shale, streaks of salt	1,175–1,218
Salt and shale	1,218–1,278
Sandy shale with streaks of salt	1,278–1,343
Rock salt	1,343–2,161

Log of well No. 2 on Woldert 654-acre tract in Pedro E. Bean survey.

[Drilled by Brooks Saline Oil & Development Co., Tyler, Tex. Well begun May 31, 1920.]

	Feet.
Red clay	3–12
Red sand	12–40
White sand, very fine	40–45
White chalky shale	45–60
Hard chalky shale	60–70
Sand	70–74
Hard chalky shale and gypsum	74–110
Tough gumbo	110–116
Hard chalky shale with gypsum and gumbo	116–137
Loose shale with little sand	137–241
Soft chalky shale	241–308
Gumbo	308–318
Soft chalky shale	318–440

Log of well No. 2 on Woldert 654-acre tract in Pedro E. Bean survey—Contd.

	Feet.
Soft chalky shale and gumbo	440–525
Hard shale with little slate	525–572
Rock	572–584
Chalky shale and gypsum	584–589
Chalky hard shale and gypsum	589–644
Chalk rock	644–710
Limerock	710–840
Rock salt	840–850

Log of well No. 1 on Meyer 200-acre tract in Don Thomas Quevado survey.

[Drilled by Brooks Saline Oil & Development Co., Tyler, Tex. Well begun August 2, 1920.]

	Feet.
Sandy clay, red	0–8
Water sand	8–45
Sand and boulders	45–92
Gumbo and shale	92–98
Sand and boulders	98–143
Water sand (coarse white sand)	143–314
Water sand	314–324
Lignite	324–331
Black sand	331–345
Lignite	345–349
Hard gypsum	349–356
Gypsum and gumbo	356–374
Water sand	374–419
Sand	419–524
Hard sand	524–528

Log of well No. 2 on Meyer 200-acre tract in Don Thomas Quevado survey.

[Drilled by Brooks Saline Oil & Development Co., Tyler, Tex. Well begun September 2, 1920.]

	Feet.
Red sandy clay	0–8
Water sand	8–45
Sand and boulders	45–80
Gumbo	80–94
Gumbo and gyp	94–106
Sand and boulders	106–223
Hard packed sand and boulders	223–259
Packed sand	259–280
Pack sand boulders	280–333
Hard sand and boulders	333–374
Rock	374–375
Limerock	375–376
Rock	376–377
Hard packed sand	377–404
Packed sand and boulders	404–426
Hard packed sand	426–600
Soft shale	600–650
Hard packed sand	650–700
Tough gumbo and gyp	700–774

Log of well No. 2 on Meyer 200-acre tract in Don Thomas Quevado survey—Con.

	Feet.
Hard packed sand	774–782
Gumbo and gyp	782–840
Hard packed sand	840–848
Gumbo and boulders	848–854
Hard packed sand	854–900
Hard sand and rock	900–907
Gumbo and shale	907–916
Rock	916–917
Hard packed sand	917–952
Gumbo	952–968
Shale and boulders	968–1,000
Shale	1,000–1,042
Rock	1,042–1,044
Gumbo and hard shale	1,044–1,055
Rock	1,055–1,057
Hard shale and boulders	1,057–1,066
Shale and hard boulders	1,066–1,116
Shale and boulders	1,116–1,124
Boulders	1,124–1,128
Gumbo and shale	1,128–1,148
Gypsum	1,148–1,152
Shale and boulders	1,152–1,195
Hard boulders	1,195–1,217
Gumbo and shale	1,217–1,227
Shale and boulders	1,227–1,239
Hard boulders	1,239–1,251
Shale, gumbo, and boulders	1,251–1,282
Hard boulders	1,282–1,284
Shale and hard boulders	1,284–1,312
Hard blue shale and boulders	1,312–1,327
Blue shale with gray sand	1,327–1,352
Gumbo strata and boulders	1,352–1,367
Gumbo, shale, and boulders	1,367–1,370
Hard blue shale and boulders	1,370–1,407
Hard blue shale and boulders with gray sand	1,407–1,422
Hard broken rock boulders showing some lime with pyrites	1,422–1,428
Hard boulder with little lime	1,428–1,458
Hard gumbo gyp shale and pyrites	1,458–1,470
Hard gumbo with some blue shale	1,470–1,475
Hard gumbo and blue shale and pyrites	1,475–1,485
Hard blue shale and boulders	1,485–1,501
Hard packed sand, pyrites, gray	1,501–1,521
Hard sand, pyrites, gray and fine	1,521–1,525
Hard gumbo shale and boulders	1,525–1,539
Shale and boulders	1,539–1,552
Hard gumbo shale with little gray sand	1,552–1,559
Hard gumbo and shale	1,559–1,578
Soft shale and boulders	1,578–1,602
Hard gumbo and shale	1,602–1,618
Hard gumbo and hard shale	1,618–1,646

Log of well No. 2 on Meyer 200-acre tract in Don Thomas Quevado survey—Con.

	Feet.
Soft shale	1, 646–1, 673
Tough gumbo and hard shale	1, 673–1, 684
Chalky shale	1, 684–1, 701
Chalk rock	1, 701–1, 705
Chalk rock with small streaks of gyp and limerock	1, 705–1, 739
Chalk rock with some shale	1, 739–1, 749
Chalk rock and hard shale	1, 749–1, 767
Hard gumbo and hard shale	1, 767–1, 781
Hard gumbo and hard shale with little gray sand and pyrites	1, 781–1, 812
Hard gumbo and shale and pyrites with little gray sand (coarse)	1, 812–1, 818
Soft shale with pyrites	1, 818–1, 840
Soft shale	1, 840–1, 845
Hard gumbo and hard shale and pyrites	1, 845–1, 851
Soft shale	1, 851–1, 855
Hard shale with a little chalk	1, 855–1, 864
Hard shale and pyrites	1, 864–1, 876
Hard shale and little pyrites	1, 876–1, 885
Soft shale	1, 885–1, 900
Hard shale and little pyrites	1, 900–1, 910
Hard shale with little chalk	1, 910–1, 928
Chalk rock, hard, dove-colored, streaked white	1, 928–1, 932
Light-blue chalk rock	1, 932–1, 936
Chalky shale	1, 936–1, 944
Chalk rock	1, 944–1, 948
Hard light-blue chalk rock	1, 948–1,960
Hard white chalk rock; some pyrites mixed with chalk	1, 960–1, 969
Hard slate and chalk and pyrites	1, 969–1, 975
Hard slate, pyrites, chalk, little sheets of shell	1, 975–1, 977
Hard slate, white chalk, pyrites and streaks of fine black sand and sheets of shell and rock; some hard dark shale	1, 977–1, 986
Hard slate and hard shale and pyrites	1, 986–1, 989
Hard light-blue chalk rock	1, 989–1, 997
Hard black sand and pyrites	1, 997–2, 004
Hard dark shale and black sand, pyrites	2, 004–2, 012
Hard blue shale and dark-gray sand, pyrites	2, 012–2, 018
Hard gray fine sand showing little gas. Gas showing stronger on mud for three-fourths of an hour, then getting weaker but still present	2, 018–2, 024
Hard gray fine sand showing gas up to about 2,027 feet. No oil. Gas sand 9 feet thick. Gas bubbles showing from mouth of well in run way in ditch and on slush pit from about 2,018 feet to 2,027 feet	2, 024–2, 027
Hard gray sandy shale with some pyrites	2, 027–2, 029
Hard blue sandrock	2, 029–2, 032
Hard blue sandrock not showing oil or gas	2, 032–2, 041
Hard blue sandrock	2, 041–2, 043

Log of well No. 2 on Meyer 200-acre tract in Don Thomas Quevado survey—Con.

	Feet.
Hard gray fine sandy shale showing little chalk and pyrites	2,043–2,051
Hard chalky blue shale with streaks of hard lime. The formation is still carrying some fine gray sand and a little pyrites	2,051–2,059
Hard limerock. (The lime cuttings seem to all pulverize in mud before getting out in ditch. Can tell it is lime by way the drill cuts.)	2,059–2,071
Hard limerock	2,071–2,083
Hard chalky blue shale and some fine gray sand and pyrites; some lime shells	2,083–2,091
Hard chalky blue shale	2,091–2,099
Hard limy blue shale	2,099–2,109
Hard fine gray sandrock	2,109–2,110
Hard limy blue shale with little fine gray sand and some yellow clay	2,110–2,112
Hard white limerock	2,112–2,114
Hard limerock	2,114–2,121
White limerock	2,121–2,126
Hard gray sandrock, slightly limy	2,126–2,127
Gas showing in hard gray sand, pyrites, slightly limy. Gas bubbles showed at mouth of well in runway all the way around to and in slush pit. Gas bubbles showed up one-fourth size of dime. Gas showing lasted 1½ hours. Rotated pipe all night the night before gas showed and no chance for air getting into the well	2,127–2,136
Snow-white gyp; no lime	2,136–2,137
White gyp	2,137–2,146
White hard gyp	2,146–2,155
Hard rock salt	2,155–2,161
Hard rock salt, very small showing of gas for 9 hours. Bubbles one-twentieth to one-fourth of a dime. Gas bubbles showed at mouth of well in runway ditch and slush pit	2,161–2,212
Hard rock salt; no gas	2,212–2,237
Soft gumbo and some black shale, salty taste	2,237–2,246
Soft gumbo and black shale	2,246–2,250
Black and blue shale and hard boulders	2,250–2,258
Hard dark and blue shale and boulders; some pyrites; dark-blue shale containing thin streaks of yellow clay	2,258–2,271
Hard dark-blue shale and boulders	2,271–2,286
Hard dark-blue shale; pyrites, boulders. Some thin layers of salt	2,286–2,290
Hard rock salt	2,290–2,302
Dark-blue fine gray sandy shale, showing lignite and pyrites. A very small showing of gas while drilling out of salt into the sandy shale. Gas bubbles showed at mouth of well in the runway and clear around in slush pit. Gas bubbles one-twentieth to one-half size of dime	2,302–2,367

Log of well No. 2 on Meyer 200-acre tract in Don Thomas Quevado survey—Con.

	Feet.
Black and blue shale; some fine gray sand and pyrites	2,367–2,386
Fine gray sand; some pyrites	2,386–2,459
Dark-blue sandy shale	2,459–2,478
Rock salt	2,478–2,502
Dark-blue shale and boulders	2,502–2,532
Hard boulders and broken rock	2,532–2,536
Fine gray sand, showing some lignite between broken rock and in top of sand	2,536–2,541
Fine gray hard sand	2,541–2,551
Soft dark-blue shale	2,551–2,578
Dark-blue shale mixed with rock salt	2,578–2,605
Rock salt	2,605–2,630
Dark-blue shale mixed with rock salt	2,630–2,649
Rock salt	2,649–2,678
Hard dark-blue shale and boulders	2,678–2,716
Dark-blue sandy shale and boulders	2,716–2,744
Rock salt	2,744–2,769

Log of well No. 1 on B. B. Kimball 76-acre tract, in José María Acosta survey, Smith County, Tex., on southwest side of Brooks salt dome.

[Drilled by Brooks Saline Oil & Development Co., Tyler, Tex. Well begun May 20, 1921.]

	Feet.
Fine gray quicksand	0–21
Sandrock	21–23
Fine gray water sand	23–53
Sandrock	53–56
Black sandy gumbo	56–90
Black and blue sandy gumbo	90–102
Sand and boulders	102–140
Blue soft gumbo	140–153
Dark-brown sandy gumbo	153–168
Coarse gray water sand	168–188
Dark-brown sandy shale and gumbo	188–215
Blue sandy gumbo	215–250
Blue sandy gumbo and some white shale	250–308
Blue sandy gumbo and some white shale; showing of lignite	308–320
Loose fine gray water sand	320–360
Soft blue gumbo; showing of lignite	360–395
Sandy gumbo with lignite	395–410
Tough blue gumbo with fine white sand and lignite	410–430
Coarse gray water sand and boulders	430–500
Tough blue gumbo	500–515
Fine white sand and blue sandy gumbo and lignite	515–580
Fine white sand, blue shale, and gumbo	580–632
Gumbo and hard shale with white sand	632–690
Sand and hard boulders	690–700
Gray sand and hard boulders	700–715
Tough gumbo and some lignite	715–730
Gray sand and boulders	730–745

Log of well No. 1 on B. B. Kimball 76-acre tract, in José Maria Acosta survey, Smith County, Tex., on southwest side of Brooks salt dome—Continued.

	Feet.
Tough blue gumbo	745–755
Tough gumbo mixed with some boulders	755–783
Hard sandy gumbo and boulders; some lignite	783–811
Hard gumbo and some rough boulders	811–837
Hard gumbo and rough boulders containing some lime	837–847
Hard packed sand	847–864
Hard gray packed sand	864–870
Hard boulders	870–874
Hard gray packed sand	874–892
Hard packed sand	892–900
Hard gumbo containing some lime boulders	900–916
Hard black limy boulders and some pyrites	916–932
Hard gumbo mixed with boulders	932–950
Hard gumbo mixed with rough lime boulders	950–961
Hard gumbo and some hard shale with rough boulders	961–978
Tough gumbo, some hard white fine sand, showing of lignite	978–1,000
Hard gumbo and hard shale	1,000–1,010
Packed sandy shale	1,010–1,016
Hard gumbo and hard shale	1,016–1,024
Hard tough gumbo	1,024–1,028
Hard white sandy shale	1,028–1,042
Hard gumbo and hard white sandy shale	1,042–1,062
Hard gumbo and hard shale with some lime in shale	1,062–1,070
Soft shale and boulders	1,070–1,082
Hard boulders	1,082–1,090
Hard gumbo and boulders	1,090–1,095
Loose fine gray sand	1,095–1,110
Shale and boulders	1,110–1,130
Loose sand, shale, and boulders	1,130–1,200
Hard gumbo	1,200–1,210
Sandy shale	1,210–1,240
Blue sandy shale and some boulders	1,240–1,300
Blue sandy shale and some pyrites	1,300–1,343
Blue shale and boulders	1,343–1,426
Blue sandy shale and boulders	1,426–1,506
Hard gumbo and shale	1,506–1,531
Sandy gray gumbo and shale	1,531–1,561
Hard limy shale and limy boulders	1,561–1,586
Loose shale	1,586–1,611
Hard sandy gumbo	1,611–1,618
Hard sandy gumbo and shale	1,618–1,630
Hard gumbo and shale	1,630–1,651
Hard sandy gumbo	1,651–1,671
Hard sandy gumbo and boulders	1,671–1,692
Hard sandy gumbo and hard shale	1,692–1,713
Hard sandy gumbo, shale, and boulders	1,713–1,736
Soft blue sandy shale and boulders	1,736–1,824
Soft blue sandy shale	1,824–1,864

Analyses of gas found in shallow wells in Brooks saline prairie.

[W. T. Read, Austin, Tex., analyst, April 4 and July 30, 1917.]

Carbon dioxide (CO_2)	4.0	7.5	Oxygen (O)	None.	0.7
Methane	4.0	58.4	Nitrogen (N)	92.0	31.1
Ethane	None.		Hydrogen (H)	None.	None.
Carbon monoxide (CO)	None.	.5			
Illuminants	None.	.8		100.0	100.0

Deep truncation of the dome has exposed the beds at the horizon of the shallow gas sand of the Mexia-Groesbeck fields and the oil sand of the Corsicana field, on the west, and beds at the horizons of all the producing sands of the Louisiana fields, on the east, above the so-called Woodbine sand. The facts that the salt core displaces this sand and that it comes so close to the surface suggest a ready escape for petroleum in past geologic time, leaving only a residuum, such as was found at the Keechi dome, near Palestine, or possibly none at all. Geographically the dome is 95 miles from the nearest locality at which oil is obtained from the Woodbine sand, in Louisiana; 70 miles from the Mexia field; and 65 miles from the nearest point where oil is produced from the higher Blossom sand, in Panola County, Tex. Smith County is in the center of the eastern Texas geosynclinal area, far from the Cretaceous and Wilcox (Eocene) shore lines. The Austin chalk is believed to lie normally at a depth of about 3,500 feet and the first Woodbine sand about 900 feet deeper in this part of Smith County. Several more deep wells on the south side of the dome will be necessary to make an adequate test of the possibility of oil in the Woodbine sands.

STEEN SALT DOME.

LOCATION AND HISTORY.

The Steen salt dome is in the northeast corner of the M. de los Ángeles Carmona league, 5½ miles east of Lindale, in northern Smith County, Tex., 14 miles north of Tyler and 2½ miles south of Sabine River. It is about 24 miles southeast of the Grand Saline salt dome and 27 miles north of the Brooks salt dome. It is the northernmost dome on the line that connects the Butler, Palestine, Keechi, and Brooks domes.

This dome (Pl. XXII) has been known for many years and has been briefly described in the publications cited in the description of the Brooks dome. In appearance it differs from the others because the former saline prairie is being rapidly filled with sediment on which large trees have grown, giving the appearance of a swamp.[1] Salt is reported to have been found at a depth of 300 feet, below gypsum cap rock, in two wells drilled about 1902 to depths of 400 and 412 feet. The salt has never been exploited commercially since the Civil War, both on account of the depth and on account of the distance from a railroad. A deep well was drilled here in the spring of 1920 in search of oil.

Richard Burleson reports that during the Civil War "twenty furnaces were run at this saline, making 12,000 sacks (1,200 tons) of salt daily. It takes 670 gallons of water to make a bushel of salt."[13] It is also reported that 3,000 Confederate soldiers were employed here during the war. The sites of the old furnaces can still be found.

Several days were spent at this dome by the writers in February, 1918. Mr. J. S. Fleming, of Lindale, kindly placed at their disposal reports by Alexander Deussen, consulting geologist, Houston, Tex., who has examined the dome in great detail. Mr. Fleming also assisted materially in the examination of the dome by exhibiting the exposures. The work of Mr. Deussen has been utilized in this report, with his permission. Mr. Fleming has furnished a copy of the log of the well which he and his associates, under the name Steens Saline Oil Co., drilled on the Winter farm. A portion of the map (Pl. XXII) is taken from the topographic map of the dome made by Mr. F. B. Plummer for the Roxana Petroleum Corporation and is reproduced by permission.

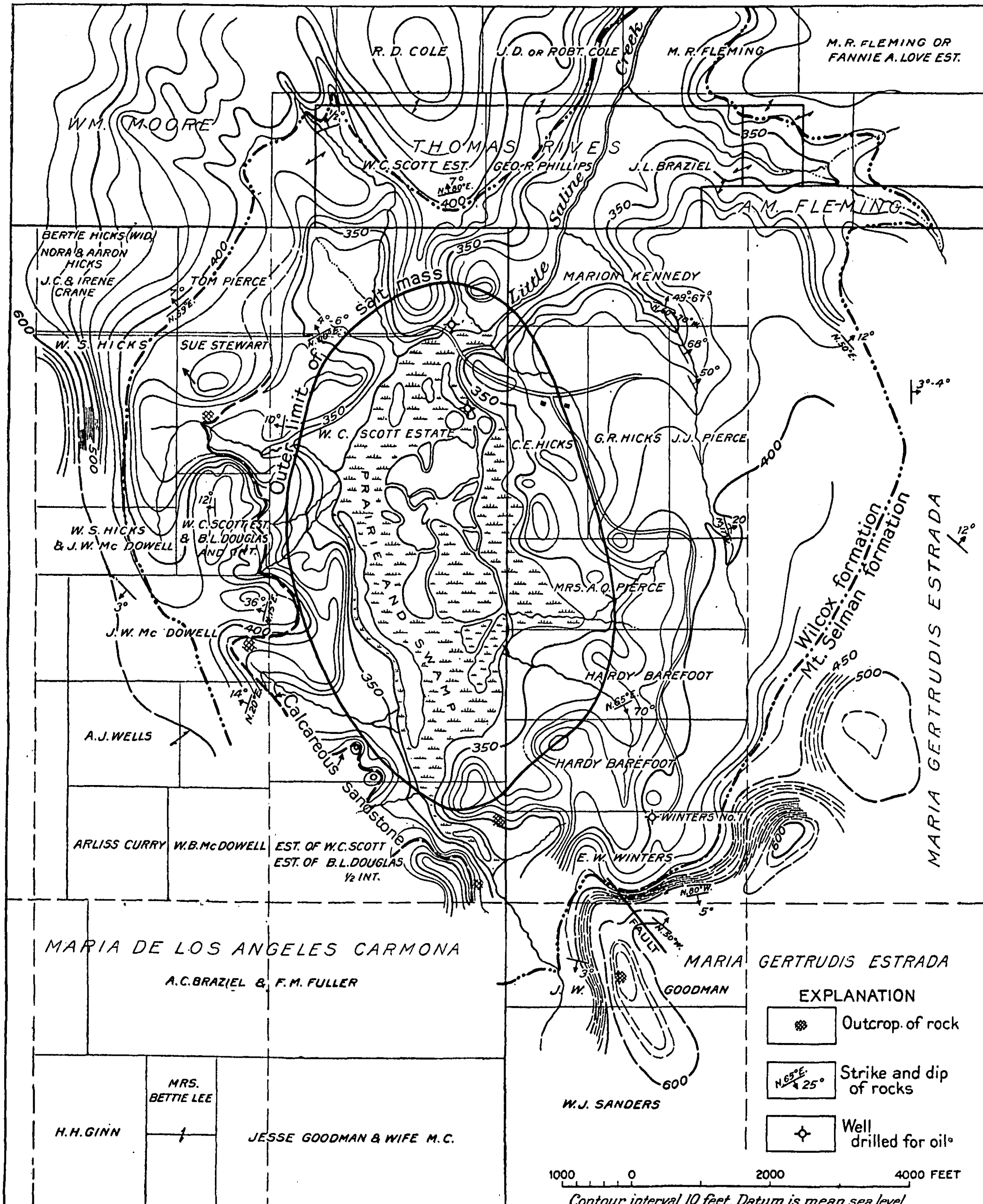
TOPOGRAPHY.

The Steen saline dome is very much like the Brooks dome. It consists of a long and relatively narrow salt marsh, which is a lake most of the year, surrounded by a rim of low hills with an outer partial rim of higher hills on the southeast side. The central saline is 6,000 feet long and 2,000 feet wide at the widest point. The relief of the lower hills is 60 to 90 feet; of the higher hills, 300 to 340 feet. The elevation of the lake above sea level is about 340 feet.

Reeds and rushes cover the surface of the lake. Large islands in its eastern portion are covered with hardwoods, which take root only a foot or two above the water level. Oaks cover the sandy hills that surround the saline, but on the east the trees have been killed to permit farming. Both pines and deciduous trees grow on the hills to the west.

The salt-dome region is drained by a northward-flowing creek called, like most streams associated with salines, Saline Creek. The development of a lake has evidently been brought about by a solution of the salt beneath and by a corresponding subsidence at the surface. Radial drainage lines from the surrounding hills converge at the saline, and peripheral springs and boggy areas also supply water of artesian origin to the lake. Only one stream on the east

[13] Texas Geol. and Agr. Survey First Ann. Rept., p. 223, Houston, 1874.



TOPOGRAPHIC MAP OF THE STEEN SALT DOME, SMITH COUNTY, TEX.

and one on the west tend to parallel the structural outlines of the dome and to develop a circular drainage system outside its center, as in the Butler dome.

GEOLOGY.

SURFACE GEOLOGY.

General features.—The Steen, Brooks, and Butler domes lie near the line of contact between the Wilcox and Mount Selman formations. The high hills around the Steen dome are composed of limonitic and hematitic beds of the Mount Selman formation. The low hills, with the exception of the nearest ridges on the west, are composed of beds of shale, sand, and lignite of Wilcox age. Calcareous sandstones and limestones that crop out on two hills west of the saline and also near the southeast corner are believed to be possibly of Midway age. Fossils are reported to have been found in black clay below the outcrops of calcareous sandstone about 40 years ago, before the valley became filled with alluvium. Strata of Midway age are unknown in the Brooks dome and are not certainly identified in the Butler dome. The nearest outcrop of the Midway formation in the regional homocline is 45 miles to the west.

The amount of uplift in this dome is not as great as in any of the interior domes to the south, and consequently no rocks of proved Cretaceous age are known at the surface. They probably underlie the edges of the salt body at a very shallow depth.

Midway formation (?).—About 1,000 feet west of the center of the dome, as indicated by the center of the saline tract, there is a double ridge of white calcareous sandstone which grades into limestone. The locality is known as the lime quarry, but no lime has been made there for many years. The thickness of the massive calcareous rock that has been quarried is 15 feet or more. The strike is N. 25°–35° E., the dip 40° W. The second ridge is 500 feet west of the first, but the rock is very similar except for a gray color.

Fossils have not been found in these beds but were found in the flat north of them, as stated above. The appearance of the rock is indicative of secondary changes, including the introduction of a large part of the lime after deposition. It is believed that the rock was originally sandstone. Possibly lime was introduced at the time of the growth of the salt core and the formation of a cap rock, which is ordinarily composed of gypsum, limestone, and sulphur. If this is the case, the limestone may give a very erroneous conception of age. The rock is very similar to the exposure of Claiborne age at Coochie Brake, near Atlanta, La.

Analysis of rock at "lime quarry," Steen dome.

[J. H. Herndon, analyst.]

Lime (CaO)	20.62
Carbon dioxide (CO_2)	16.20
Magnesia (MgO)	Tr.
Silica (SiO_2)	55.00
Iron oxide and alumina (FeO, Al_2O_3)	8.30
	100.12

Limestone is exposed also at the southeast side of the lake, and limestone concretions with poorly developed cone-in-cone structure in plastic clay are found southwest of the lake.

The Midway formation is commonly described as consisting of clay and limestone of marine origin. On the outcrop a few miles west of Mexia it is composed of clay weathering yellow and, where the lime is a primary constituent, of thin limestone beds. On the strength of the field evidence that lime is very rare in the Wilcox formation and abundant in the Midway, the limestone outcrop at the Steen saline has been referred to the Midway instead of the Wilcox. The bedding planes of the calcareous beds show obscure traces of markings such as are commonly ascribed to fucoids or to worms. They do not look like markings of marine origin, but they are very obscure at best. It is barely possible that these beds belong to the base of the Wilcox.

Wilcox formation.—On the east side of the dome, at a creek on the farm of Mrs. A. O. Pierce, there is an excellent exposure of sandy clays of yellow to red color filled with partings of limestone and of calcareous sandstone a quarter to half an inch in width. Beneath these sandy clays are beds of soft yellow sand containing calcareous concretions, some of which have cone-in-cone rims. The concretions increase in size and abundance until several beds of hard massive sandstone appear in the creek. These beds have very irregular surfaces, are slightly calcareous, and clearly show secondary hardening. The sand and sandy clay are typically Wilcox. The secondary lime is rare in this formation, but this exposure must be of Wilcox age, because several water wells between it and the saline, with one exception, encounter lignite. The exception is a cistern on the low hill immediately west of the creek exposure, which to a depth of 18 feet encountered only yellow clay with small clay-ironstone concretions below the surface wash. The other wells are nearer the saline, and even those very near the edge of it find lignite and nonpotable water. There is no outcrop east of the center of the saline, so far as known, which can be interpreted as belonging to a pre-Wilcox formation. The same holds true on the west side of the saline north of the road and south of the location of the Winter well drilled for oil. Shallow water wells throughout this region find lignite and bad water. Wells have not been dug west of the saline near the lime quarry.

A good exposure of Wilcox blue clay is found in the gully at the pump that furnished water for drilling the well. The clay beds strike N. 56° E. and dip 70° S. Other exposures of the Wilcox formation are found in gullies around the dome. Excellent exposures at the side of the road to Lindale and in the creek directly below the road, 1,200 feet west of the edge of the saline, show cross-bedded Wilcox thin-bedded yellow to purple sands and clays. The dip is probably 4°–6° NW. but can not be accurately determined on account of the cross-bedding. Other good exposures are found in the branch west of the saline and north of the main highway, also in the branches north of the saline.

Mount Selman formation.—Beds of ferruginous sandstone, as well as beds of hematite and limonite which have become concentrated by circulating waters after deposition, are exposed on the hills south and southeast of the saline. The exposure nearest the center of the dome is within 200 feet of the Winter well. Here a small knoll is capped by blocks of ferruginous sandstone, which dip apparently about 10° SE. South of this well the hills are held up by beds of similar composition. On the hill nearest the well the strike is N. 80° E. and the dip 6° SE.

At the south side of the dip-slope valley between the first and second hills south of the well there is a continuous exposure of a bed of hematitic sandstone standing almost vertical but dipping at a high angle to the northeast. The bed is about 5 feet thick and is exposed for more than 600 feet; it strikes N. 40° W. Locally it is known as the "stone fence." The bed is believed to be the same as the one which formerly capped Todd Mountain, to the southwest, and probably the same as the one to the northeast. The "stone fence" evidently represents the drag of a fault with a downthrow of about 80 feet on the northeast. The fault extends toward the saline, but it can be traced only across one hill, as there are no exposures nearer the saline. The possible continuation of the fault to the southeast has not been traced.

Glauconite beds are undoubtedly present between the ferruginous beds, but they were not observed in the outcrops. The other hills to the northeast are composed of the same ferruginous sandstone.

On the west side of the dome between the lime quarry and the highway there are two hills capped with ferruginous sandstone dipping about 10° W. This sandstone is unconformable with the limestone and is believed to be of Mount Selman age. The unconformity is also observed near the Winter well.

UNDERGROUND GEOLOGY.

Two wells near the road leading across the north end of the saline were drilled by the Scott heirs about 1902. They are reported to be 400 and 600 feet deep and to have encountered salt at 300 feet. If this report is true the top of the salt core must lie about 300 feet below the surface over the entire central part of the dome.

The log of the deep Winter well is given below.

Log of E. W. Winter well No. 1, 5 miles east of Lindale, Tex.

[900 feet south and 3,008 feet west from the northeast corner of the E. W. Winter tract, in the M. G. Estrada survey.]

	Feet.
Clay and sand	135
Hard sand; set 12-inch casing	194
Packed sand	233
Hard shale	390
Gumbo	412
Sand	488
Gumbo	500
Hard shale	669
Rock	672
Gumbo	722
Rock	723
Soft shale	733
Hard shale and boulders	754
Shale	829
Hard rock	831
Shale	870
Rock	872
Shale	878
Gumbo	900
Hard shale and boulders	960
Soft gray shale	965
Rock	966
Hard shale	1,027
Gumbo, shale, and boulders	1,500
Soft shale	1,600
Shale and gumbo	1,700
Packed sand	1,708
Gumbo	1,720
Packed sand	1,726
Gumbo; set and cemented 8-inch casing	1,740
Hard gumbo	1,850
Shale	1,875
Hard gumbo	1,900
Hard gumbo	1,935
Shale	1,960
Gumbo	1,974
Soft shale	2,400
Shale	2,495
Sand	2,500
Shale; set 6-inch casing with cement	2,506
Shale	2,509
Sand	2,511
Shale	2,512
Sand	2,515
Shale	2,518
Sandy shale	2,525
Gumbo	2,527
Sandy shale and limestone	2,532
Lime rock	2,533
Gumbo gip	2,541
Sandy limestone	2,546
Gumbo	2,548
Sandy limestone	2,551
Hard black shale	2,554
Packed sand	2,556
Shale and sand	2,567
Gumbo	2,569
Shale and sand	2,573
Sand	2,575
Sandrock	2,577
Sand and rock	2,583
Sandrock	2,585
Sand, shale, and soft marl	2,595
Gray gumbo	2,597
Sand and shale	2,603
Tough blue shale and gumbo	2,605
Sand and shale	2,616
Gumbo	2,618
Hard sand and limestone	2,622
Sand; setting 4½-inch liner to test, June 11, 1920	2,630

Dry and abandoned at 2,630 or 2,635 feet.

STRUCTURE.

Steep quaquaversal dips prove a considerable uplift at the Steen dome, irrespective of the question of the age of the oldest rocks exposed at the surface near the center of the dome. The amount of vertical movement was probably 1,000 feet. The Winter well seems to have reached the base of the Wilcox at 488 feet, and if so, the sandy beds below 2,569 feet must be near the Austin chalk, because this interval is normally 1,700 to 2,000 feet. The well should have been drilled about 1,300 feet deeper to test the Woodbine sands.

Only one fault has been noticed in the field, but others undoubtedly exist. This fault has been described above.

Evidence of a pronounced unconformity between the Wilcox and Mount Selman formations is found near the Winter well. The low hill at this well is capped by beds of Mount Selman age dipping 10°, but the creek at the pump 1,600 feet to the north shows Wilcox clays dipping 70°. It is scarcely possible that the dip diminishes 60° in so short a distance. On the west side of the dome, north of the hills composed of calcareous sandstone and limestone, a hill of the same height appears to be capped by a bed of ferruginous sandstone dipping only 10° away from the dome. If this sandstone is correctly interpreted as being of Mount Selman age, it unconformably overlies the calcareous beds of the Midway formation and the shales of the Wilcox formation, which are exposed farther west of the dome. On account of the unsatisfactory character of the exposure, the evidence of the unconformity is not as good as the evidence on the east side of the dome.

DATE OF UPLIFT.

Uplift of the dome commenced after the deposition of a large part if not all of the Wilcox section, if the interpretation of the stratigraphy here given is correct. The period of principal uplift was prior to the deposition of the lowest Claiborne formation—the Mount Selman. Uplift at a later date produced a dome with quaquaversal dips of 10° or more in the Mount Selman formation. The date of this later uplift is believed to have been pre-Pliocene.

POSSIBILITY OF OBTAINING OIL AND GAS.

Although the presence of a dome is favorable to the accumulation of petroleum, the deep erosion of the interior domes and the comparatively shallow depth of the rock-salt core beneath the surface offer a means of escape of any petroleum that may ever have been present. Stratigraphically the section at these domes is very similar to that at Mexia, Currie, and Richland. A number of tests will probably be necessary to prove or disprove the presence of oil or gas, and the absence of exposures of older strata in this dome makes it an attractive area for deep tests. Two beds of chalk are now known to underlie this area, and the deeper is the Austin, which may not be found above 3,300 feet. The first Woodbine oil sand lies about 1,200 feet below the top of the Austin chalk in this area.

GRAND SALINE SALT DOME.

The Grand Saline salt dome (fig. 12) is at the town of Grand Saline, on the Texas & Pacific Railroad, 63 miles east of Dallas and 107 miles west of Shreveport. Salt has been mined for many years near the railroad, both east and west of the station. The industry is very profitable because of the shallow depth, the purity, and the great amount of salt, combined with the presence of a hard rock above the salt, which serves as seat for the casing.

In 1874 Buckley [14] reported that in Grand Saline during the Civil War many wells were sunk and "about 1,000 sacks of salt daily made. Each sack has about 200 pounds. Now but one well is used, the supply from this being able to make about 50 sacks a day. One gallon of water makes 1⅓ pounds of salt. An analysis of the water gives 14 per cent NaCl. The price per sack is $3."

Many references to the Grand Saline have been made.[15] Veatch[16] described the salt as being a sedimentary deposit and not a salt dome, but more recent borings have proved that the salt occurs as a salt dome with a flat top and very steep sides—a thimble-shaped plug of salt which has domed the strata on all sides symmetrically.

One deep test hole has been drilled on the southwest side of the dome for oil, as described below. No good indications of the presence of oil around the dome were found in this well or in any of the shallower wells drilled into the salt. Seepages of oil in the Wilcox formation, which forms the surface rock, are practically unknown in Texas and Louisiana, and prospecting for oil has resulted from developments on coastal salt domes.

The operating salt companies at Grand Saline, B. W. Carrington & Co. and the Grand Saline Salt Co., kindly placed their available information at the disposal of the writers. Mr. J. T. Catchings was in charge of the test of the Hallville Oil & Gas Co.'s well at the

[14] Texas Geol. and Agr. Survey First Ann. Rept., 1874.

[15] Penrose, R. A. F., Texas Geol. Survey First Ann. Rept., p. 35, 1889; Herndon, J. H., idem, pp. 221–224; Kennedy, William, Texas Geol. Survey Third Ann. Rept., pp. 76–77, 1892; Harris, G. D., Oil and gas in Louisiana: U. S. Geol. Survey Bull. 429, p. 18, 1910; Louisiana Geol. Survey Bull. 4, p. 19, 1905; Bull. 7, p. 57, 1907; Hager, Lee, Eng. and Min. Jour., July 28, 1904, p. 137; Deussen, Alexander, U. S. Geol. Survey Water-Supply Paper 335, pp. 352–353, 1914; Dumble, E. T., The geology of east Texas: Texas Univ. Bull. 1869, p. 20, 1920; Phalen, W. C., U. S. Geol. Survey Bull. 669, pp. 118–119, 1919.

[16] Veatch, A. C., U. S. Geol. Survey Prof. Paper 46, p. 29, footnote on pp. 67–68, 1906.

time of visit and kindly submitted cuttings from the well, which have been examined by L. W. Stephenson. (See p. 232.)

The Roxana Petroleum Corporation furnished the accompanying topographic map (fig. 12), made by Fred B. Plummer, but the geology was added by Sidney Powers.

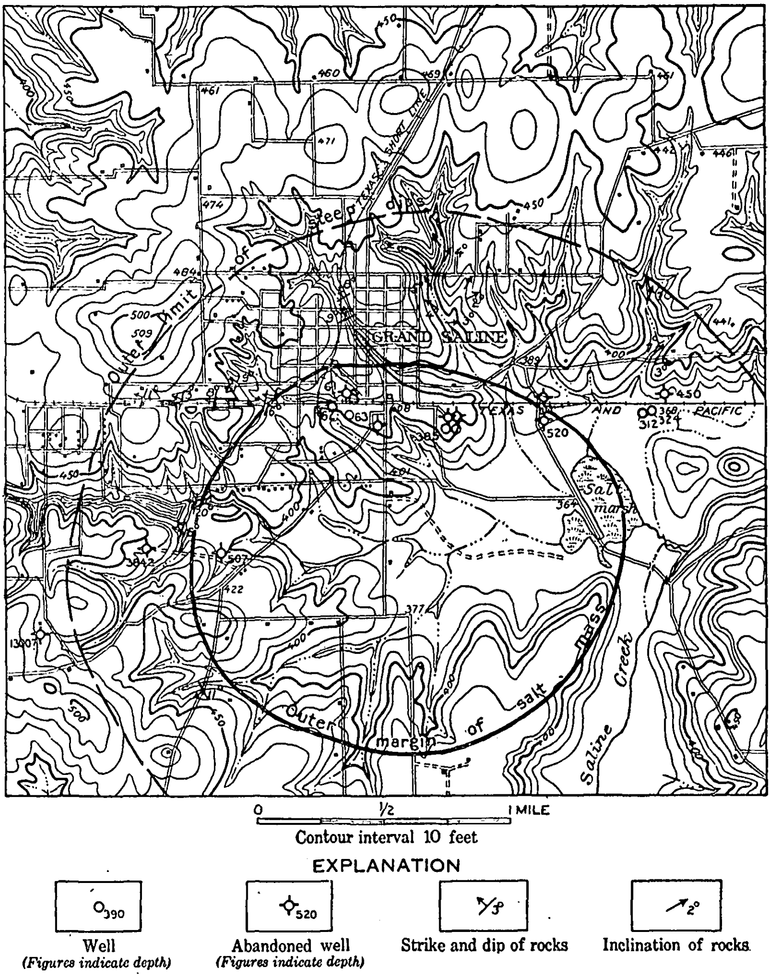


FIGURE 12.—Topographic map of the Grand Saline salt dome, Van Zandt County, Tex.

TOPOGRAPHY.

One of two types of topography is characteristic of salt domes—either a central depression or flat prairie surrounded by hills or a hill surrounded by a circular drainage system. The Grand Saline dome is of the former type. A salt marsh, drained by Saline Creek, occupies a part of the central depression which is east of the center of the dome, as judged by dips in the tilted rocks surrounding it. Barren prairies surround the marsh. These prairies are due to more rapid erosion of the strata in the center than on the sides and also to settling caused by solution of the salt. The prairies are barren because of the many springs of slightly brackish artesian water, such as occur in all interior salt domes. Brine from the salt works increases the salinity of the marsh.

Hills surround the central depression, and the hills on the north and west have greater relief than those on the south and southeast. The elevation of the marsh is 361 feet; the general elevation of the hills is 470 feet, and the highest point shown on the map (fig. 12) reaches 509 feet, giving a relief of 148 feet. The hills south and southeast of the dome are covered with a mantle of sand, which indicates the weathering of sandy strata no longer exposed, and the difference in the character of the topography is dependent on this geologic condition. Good outcrops of shale and sandy shale are found in the valleys and cuts in the hills surrounding the remainder of the dome, this fact showing that tilted shale beds give rise to greater relief than tilted sand beds. The town of Grand Saline is on the northwest side of the dome and is within the crest of the ring of hills that surrounds the prairie.

The dome is drained by Saline Creek, which enters the saline in a flat valley and leaves it in a narrow valley south of the railroad. The outlet from the central prairie may have been diverted from the flat area near the railroad by slight settling of the prairie over the salt core.

GEOLOGY.

SURFACE GEOLOGY.

The Grand Saline dome is nearer to the outcrop of the Cretaceous formations that underlie the Coastal Plain than any other known salt dome in Louisiana or Texas. All the exposures around the dome are of Wilcox age, and the appearance of the rocks exposed indicates that less uplift has taken place at this dome than at any other. It is 12 miles from Grand Saline to the nearest outcrop of the Midway formation at Wills Point and 30 miles to the nearest Cretaceous outcrop.

The outcrops surrounding the dome are shown on figure 12. They consist of shale, sandy shale, and sand, with a few ferruginous concretions and beds of lignite. The prevailing colors are pale red to brown. Sections of the strata are given by Kennedy.[17] The log of the Hallville Oil & Gas Co.'s well (pp. 226–232) shows that there is at least 500 feet of Wilcox beds in the normal stratigraphic section at this locality. If the strata dipped uniformly from the basal Wilcox outcrop, this figure would call for a dip of 40 feet to the mile, compared to the average dip in eastern Texas of 50 to 80 feet to the mile.

[17] Texas Geol. Survey Third Ann. Rept., pp. 76–80, 1892.

It is probable that the normal thickness of the Wilcox would be 700 to 800 feet, because the outcrop nearest to the well shows a dip of 16° at the surface.

UNDERGROUND GEOLOGY.

COVER OF SALT DOME.

The logs of shallow wells record shale and sand above the salt, which is found at depths of 300 to 500 feet. The age of the sand and clay above the salt in the interior salt domes is unknown, because there are no surface exposures. With an upward movement of the salt mass, the rocks immediately over it would become displaced and fractured, and secondary deposition of salt or gypsum might occur. Certainly at no time was there any great depression over the salt core, yet there may have been considerable solution of the salt by the artesian water. If the salt rose or was thrust up slowly in a mass and if erosion contemporaneously maintained the surface topography existing in the region over the rising dome, the salt may have attained a position relatively nearer the surface of the ground than at present (200 to 1,000 (?) feet). Ground water as well as artesian water would then dissolve the salt, and the present cover of sand and shale above the thin limestone or gypsum cap would represent material washed into the basin. This theory would account for the unconsolidated nature of the material in each dome that seems to have no relation to the amount of uplift or to the strata passed through but to resemble the reworked Wilcox material that fills drowned valleys of comparatively recent date.

SALT WELLS.

Four groups of shallow wells have been drilled near the Texas & Pacific Railroad in search of salt or water, and two companies were operating some of the salt wells at the time of the writers' visit.

B. W. Carrington & Co. have been operating at Grand Saline since about 1906. Their plant previously belonged to the Lone Star Salt Co. (Star & Crescent Salt Co.), and a part of the property to the Fielder and Southern salt companies. The first plant for steam operation was built by S. Q. Richardson on the site of the present plant in 1888–89, and the first deep salt well was drilled at that time. The production in 1918 was 1,000 barrels a day; that at the Palestine salt works, near Palestine, Tex., was 300 barrels.

The plant of the Grand Saline Salt Co., in charge of T. S. McGrain, was built and later destroyed by fire in 1918 and has not been rebuilt. It was east of the station and south of the Texas & Pacific Railroad.

At the Carrington plant the wells north of the track and near the plant are, from west to east, Carrington No. 1, abandoned in 1915, and Richardson No. 1, drilled in 1888–89 and abandoned in 1908. South of the track from west to east are the Carrington No. 2, formerly Fielder Salt Co., and Carrington No. 3, both on the Mrs. Sally Fielder fee; and the Southern Salt Co. fee No. 1 (now Carrington fee), drilled about 1907 and now abandoned. The last-mentioned well passed through an oil sand from which several gallons of asphaltic oil was recovered. These wells are on the west side of the dome, and they penetrate the flat top of the salt body, overlain by a hard cap of sand 5 feet thick. Water containing 15 per cent of salt is found in sand and gravel under the hard cap rock and above the salt, and this water is allowed to go down 100 to 200 feet into the salt body, where it becomes saturated and is pumped out. In all other salt wells at Grand Saline and at Palestine water has to be pumped into the wells. The wells produced salt for many years (the Richardson well for 20 years) without appreciable caving at the surface, because of the presence of the hard cap rock. The original well was abandoned because of a slight cave at the side of the plant. The Lone Star Salt Co. drilled a hole 200 feet deep half a mile north of the Carrington plant but found no salt, and the Fielder Salt Co. drilled near by and found fresh water. Neither of these wells is shown on the map. In 1922 the original Richardson well was reopened for drainage, and the cavity from which salt was obtained for 20 years was found to be completely filled with newly crystallized rock salt.

The logs of wells of the Southern Salt Co. (Lone Star Salt Co.) and Fielder Salt Co. (now Carrington No. 2) follow. The top of the salt in both was reached at 235 feet.

Log of Southern Salt Co.'s well 1 mile southwest of Grand Saline, Tex.

	Feet.
Red clay	0–26
Sandy clay	26–34
Sand and gravel, water-bearing	34–37
Wilcox formation:	
Black shale	37–57
Lignite	57–60
Sandy clay	60–80
Sand and water	80–85
Sandy shale	85–150
Sand and water; oil, yellow	150–164
Formation doubtful:	
Hard white sand; salt water (5 per cent salt)	164–178
Hard sandrock	178–184
Shale containing pyrites	184–188
Blue limestone mixed with streaks of sand and gray limestone	188–230
Gypsum	230–235
Rock salt, not penetrated	235–315

In January, 1908, according to Mr. Wilderspin, of Mineola, oil appeared in this well, flooding the brine tanks supplied by the salt water. The oil is stated to have been accompanied by considerable gas.

Log of Fielder salt well, Grand Saline, Tex.

[Now used by B. W. Carrington & Co. and called No. 2. Log furnished by Fred Fielder to T. I. Whitley. The well did not go through the salt rock.]

	Feet.
Soil and clay	0–5
Brown rock sand	5–31
Gray water	31–38
Chocolate-colored clay and boulders	38–50
Soapstone or clay	50–80
Shell lime	80–84
White water sand	84–92
Shale	92–112
White water sand	112–122
Slate rock (?)	122–182
Gray granite (?)	182–212
Marl	212–223
White water sand	223–235
Salt rock	235–255

A quarter of a mile east of these wells are the Grand Saline Salt Co.'s wells, four in number. The two on the northwest and the northeast are now abandoned. On the southwest, 50 feet south of the abandoned wells, is the first well drilled by the company, and 300 feet farther west is the second. These two wells are 385 and 390 feet deep. The first passed through 140 feet of salt, and the second through 145 feet, ending in 10 feet of lime.

Log of Grand Saline Salt Co.'s well 2,000 feet west of the plant.

[Drilled by R. H. Dearing & Son; begun in April, 1916.]

	Feet.
Surface	0–3
Sand	3–13
Yellow clay	13–15
Yellow granite sand	15–25
Lignite	25–28
Rotten shale	28–38
Tough gumbo	38–40
Water sand	40–50
Yellow gumbo	50–55
Quicksand in layers	55–80
Sand	80–81
Hard sand and streaks of red gumbo	81–105
Soft marl	105–125
Gumbo, sand, and gravel	125–140
Hard sand	140–155
Hard, tough gumbo	155–158
Hard sandy shale and streaks of gumbo	158–185
Flint and lime	185–226

Log of Grand Saline Salt Co.'s well 2,000 feet west of the plant—Continued.

	Feet.
Cavity	226–239
Shell rock	239–245
Salt	245–385

Log of Grand Saline Salt Co.'s well 2,300 feet west of the plant.

[Drilled by R. H. Dearing; completed April 25, 1916; 10⅝-inch casing set at 63 feet; 8-inch casing set at 192 feet.]

	Feet.
Surface	0–3
Yellow quicksand	3–18
Yellow clay	18–30
Blue gumbo	30–38
Pyrite	38–39
Rotten shale	39–50
Lignite	50–55
Blue gumbo	55–80
Hard shale	80–90
Gumbo and sand	90–110
Hard shale and gravel	110–116
Black flint	116–117
Gumbo	117–138
Hard sand and layers of flint and lime	138–160
Blue gumbo	160–178
Black flint	178–179
Gumbo	179–181
Black flint	181–182
Gumbo	182–187
Lime and magnesia	187–218
Cavity and soft rock	218–229
Soft rock	229–235
Salt rock	235–380
Limerock	380–390

At the Grand Saline Salt Co.'s plant the well south of the track, now abandoned, was drilled by Tom Marsden for S. Q. Richardson. Two different logs of this well are in existence, and the one given below is the more complete. The well north of the track was drilled by the Grand Saline Salt Co. for a water well, but neither water nor salt was found.

Log of S. Q. Richardson well at Grand Saline Salt Co.'s plant.

[Drilled by Tom Marsden.]

	Feet.
Soil, brownish-black sand	0–3
Sandy clay	3–15
Gravel and clay	15–20
Yellow sand and water	20–26
Fine blue clay and gravel	26–28
Quicksand with water	28–30
Coarse white sand	30–35

Log of S. Q. Richardson well at Grand Saline Salt Co.'s plant—Continued.

	Feet.
Blue-gray merging into bluish-black dirt with iron pyrites and broken limestone	35–83
Hard gray limestone	83–86
Sandy shaly clay (slate?)	86–103
Blue clay with iron pyrites	103–123
Shale	123–132
Shale with iron pyrites	132–137
Sandy shale with pyrites	137–149
Sandstone with pyrites	149–163
Hard blue limestone	163–188
Hard gray limestone	188–191.5
Quicksand (salt water, 10 per cent salt)	191.5–194
Alternate strata of salt and limestone	194–212
Rock salt (first 40 feet of salt mixed with gypsum and shale; last 10–12 feet of salt mixed with shale, gravel, and sand)	212–512
Bluish-gray sand	512–514
Black sand with water, in bottom of well; not bored through	514–520

Half a mile east of the plant there are three artesian water wells, one north of the track 450 feet deep and two south of the track 312 and 324 feet deep. W. P. Gibson in 1902 drilled the northern well into salt water but found no salt. The Grand Saline Salt Co. drilled the other two, which yielded artesian fresh water for the plant. The log of the shallower one, which was completed November 1, 1909, is given below. The second one, 324 feet deep, was drilled in September, 1916, and yielded 50,000 to 100,000 gallons a day.

Log of water well 1,800 feet east of Grand Saline Salt Co.'s plant.

	Feet.
Clay	0–18
White sand	18–28
Yellow clay	28–54
Fine white sand	54–64
Clay	64–139
Fine white sand	139–151
Soapstone	151–164
Gumbo clay	164–233
Lignite coal	233–239
Hard sandrock	239–245
Sand, part black	245–248
Rock 7 inches thick.	
Fine white water sand	248–312

The first test hole for oil by the Hallville Oil & Gas Co., southwest of the town of Grand Saline, drilled in 1915, entered salt at 306 feet and was abandoned in salt at 507 feet because of caving. This well completes the list of recorded salt wells. The log, furnished by Thomas S. McGrain, is as follows:

Log of Hallville Oil & Gas Co.'s Lindsey well No. 1, Grand Saline, Tex.

[Elevation 403 feet.]

	Feet.
Clay, sand, iron ore, and rock	3–40
Streaks of sand and clay	106
Lignite	108
Clay, light-blue gumbo, and streaks of limerock	132
Black sand; very slight showing of oil	134
Blue gumbo and streaks of limerock	142
Light-blue sand and pyrites	174
Lignite	174½
Dark-brown rock, very hard	175
Lignite	186
Hard sand	192
Lignite	194
Pack sand	206
Dark shale, slightly sticky	215
Shale and lignite	220
Lignite	224
Fish-egg lime and pyrites	228
Streaks of sand and sandy shale	245
Shale	249
Rock with much pyrites	253
Slaty shale	255
Lignite	257
Sandy fish-egg lime and pyrites of iron, hard	260
Hard sand	265
Softer shale	272
Sandy shale with hard streaks of pyrites	275
Green sand and shelves of rock and clay	289
Rock	291
Soft	293
Hard rock with streaks of soft formation	297
Gumbo	304
Soft or cavity. Lost all water and mud here	306
Salt rock	350
Supposed to be sand	355
Mixture of sand and lignite	357
Sand and porous rock	360
Impure salt	386
Rock and "golded" gravel [coated with iron pyrite]	389
Salt and gravel and sand boulders	423
Salt with hard streaks	507

306 to 507 not certain of formation, as this part of the hole was drilled without return of water. Only cuttings we could get was what would stick to the bit in pulling out. Lost hole in cave.

Fresh water for the town of Grand Saline comes from four wells 25 to 30 feet deep north of the Texas & Pacific Railroad 1 mile west of the station. The railroad has wells near by, 50 feet in depth, in which water rises within 18 or 20 feet of the surface. A well between these shallow wells and the town is reported to have found 5 feet of salt at an unrecorded depth.

It has been found by drilling on the top of the dome that there is less gypsum and lime under the western part of the saline than elsewhere and in that part the shale cover caves too badly to permit salt wells to be drilled. The salt recovery from any solution process is dependent on a firm cap rock, in which casing can be set to make a tight joint and under which caving will not take place. In the domes without cap rock salt must be mined, and the success of mining depends on a tight joint where the shaft enters the salt.

SALT.

Salt-dome mines show that the salt has the form of an enormous body of coarsely crystalline rock salt, practically free from foreign material. Water is never encountered in the salt mass. Enormous chambers may be excavated without any danger of collapse of the roof because of the homogeneity and crystallinity of the rock salt. Black color bands and definite black coloration of the salt are known and are due to the presence of gypsum and insoluble matter.[18] Bands of sandstone 1 foot or less in thickness and some of them 10 feet or more in length are known at Avery Island and are probably sands originally interbedded with the salt.

Analyses of brines from adjoining wells at Grand Saline show slight differences in composition even in brines from wells less than 100 feet apart. The brines in the wells show different degrees of pressure. These facts show that solution proceeds in a vertical rather than in a horizontal direction and that the wells do not become connected underground.

Analyses of brine and salt from B. W. Carrington & Co.'s wells, Grand Saline, Tex.

[Illinois Chemical Co., Chicago, analyst, January, 1914.]

Brine.	Grains per U. S. gallon.	Finished salt.	Per cent.	Per cent.
Calcium carbonate	9.152	Moisture	0.18	0.12
Calcium sulphate	253.614	Calcium carbonate	.09	.14
Magnesium sulphate	26.851	Calcium sulphate	1.26	1.13
Sodium sulphate	66.521	Calcium chloride	.21	.18
Iron and aluminum oxides	2.147	Magnesium chloride	None.	Trace.
Salt ... per cent.	25.91	Insoluble matter	.006	.007
		Iron and aluminum oxides	Trace.	Trace.
		Sodium chloride	98.21	98.38
			99.956	99.957

[18] Veatch, A. C., The five islands: Louisiana Geol. Survey Rept. for 1899, p. 226.

Gypsum is evidently present in minute quantities. Analyses of salt from coastal domes are given below for comparison.

Analyses of salt from coastal domes in Louisiana.[a]

	1	2	3	4
Sodium chloride (NaCl)	92.750	96.405	99.252	98.88
Calcium sulphate ($CaSO_4$)		3.053	.694	.782
Magnesium chloride (MgCl)		.074	.012	.003
Magnesium carbonate ($MgCO_3$)	.201			
Sodium carbonate (Na_2CO_3)	.067			
Sodium sulphate (Na_2SO_4)	.837			
Calcium carbonate ($CaCO_3$)	1.804			
Calcium chloride ($CaCl_2$)		.226	.042	.402
Iron and aluminum oxides (Fe_2O_3, Al_2O_3)	.500	.025		
Insoluble matter	3.325	.059		.33
	99.484	99.840	100.000	100.00

[a] Veatch, A. C., The five islands: Louisiana Geol. Survey Rept. for 1899, pp. 227, 248.

1. Black salt, Belle Isle; depth 120 feet.
2. White salt, Belle Isle; depth 175 feet.
3. Avery Island; G. Bode, analyst.
4. Avery Island; C. A. Goessman, analyst.

DEEP WELLS.

Two deep test holes have been drilled on the southwest side of the dome. An oil well was also drilled about a mile west of Grand Saline, but it is not shown on the map. The first deep test hole was the A. Wilderspin fee No. 1, drilled about 1,300 feet deep in 1902 in the southwest corner of the area shown on figure 12. The second was the Hallville Oil & Gas Co.'s Lindsey No. 2, drilled in 1917–18 by local capital. A total depth of 3,842 feet was reached, but if the dip is 15°, as indicated by surface exposures, only about 3,710 feet of strata were passed through. Cuttings from the well were examined by L. W. Stephenson, of the United States Geological Survey, and by J. A. Udden, director of the Bureau of Economic Geology, Austin, Tex. Their analyses, together with the log, are given below. The log below 2,264 feet is given both as recorded by the driller and as analyzed by Mr. Stephenson. Following this is the analysis of the same cuttings from 2,664 to 2,900 feet by Dr. Udden.

Driller's log of Lindsey well No. 2 of Hallville Oil & Gas Co., 1 mile southwest of Grand Saline, Tex.

[Furnished by J. T. Catchings. Elevation, 445 feet.]

	Feet.
Soil, red clay, gray clay, and sand	0–50
Shaly clay and lignite and rock	50–64
Light-blue gumbo	64–72
Lignite and shale	72–82
Lignite and clay	82–94
Streaks of lignite and clay	94–103
Rock	103–105
Sandy clay	105–110
Hard flinty limerock	110–111

Driller's log of Lindsey well No. 2 of Hallville Oil & Gas Co., 1 mile southwest of Grand Saline, Tex.—Continued.

	Feet.
Streaks of white and gray lime, and gumbo with pyrites nuggets, showing very slightly with asphaltum	111–125
Light-colored clay	125–134
Lignite	134–137
Clay	137–140
Hard gumbo and boulders	140–153
Limerock and pyrites and hard shale	153–156
Sandy clay	156–158
Hard sand and sandy shale	158–170
Hard sandy shale and pyrites of iron	170–178
Light-gray lignitic sandy clay with hard streaks	178–185
Sandy pyrites, very hard	550–552½
Sandy shale or clay with hard streaks	185½–192
Gumbo or very stiff clay	192–214
Hard lignitic clay and pyrites	214–227
Lignite and lignitic clay and pyrites	227–233
Lignitic clay and pyrites, harder; small showing of gas	233–236
Lignitic clay and pyrites	236–250
Hard dark clay and pyrites	250–262
Limerock	262–263
Gray lignitic sand and nuggets of pyrites	263–289
Calcareous sandrock with very hard streaks; small amount of pyrites; set 10-inch casing at 294 feet	289–296
Gray or brownish-gray very hard rock with small specks of black	296–333
Lignite and asphaltum; small show of oil and gas; cuttings have very strong odor of petroleum	333–336
Light-blue clay and sand	336–363
Lignite and asphaltum; odor of oil	363–372
Calcareous sand with hard streaks; odor of oil	372–376
Lignite and asphaltum; very small showing of oil	376–379
Very fine grained white sand	379–383
Lignite, with odor of oil	383–384
Hard chalky sand	384–392
Blue sand, hard streaks	392–397
Soft blue sand	397–443
Hard chalky sand	443–445
Clay and pyrites; very hard streaks and shelves of lignite, with odor of oil	445–454
Pack sand	454–484
Hard rock	484–486
Sand and fish-egg lime	486–510
Hard rock	510–514
Sand and sandy shale	514–529
Rock	529–530
Hard sandy shale [base of Wilcox formation; Powers and Hopkins]	530–534
Rock	557–557½
Soft	534½–536

Driller's log of Lindsey well No. 2 of Hallville Oil & Gas Co., 1 mile southwest of Grand Saline, Tex.—Continued.

	Feet.
Very hard rock	536–541
Hard digging	541–545
Hard limerock	545–550
Clay	550–552½
Hard chalky limerock	552½–554
Clay	554–555
Rock	555–557
Clay	557–557½
Rock	557½–563
Soft clay	563–563½
Rock	563½–567
Hard sand	567–570
Hard rock	570–573
Hard sandy shale	573–606
Chalky sand	606–611
Hard chalky limerock	611–614
Hard sandy shale with strong odor of oil	614–645
Hard rocky shale with pyrites and chalky lime streaks. Occasional strata of blue clay	645–770
Very hard rock	770–785
Rocky shale or clay	785–819
Hard sandy shale with streaks of clay	819–850
Clay	850–860
Hard shale and boulder gravel	860–870
Clay	870–880
Thin strata of hard chalky shale and limerock, thickness from 1 inch to 1 foot, separated by strata of clay or gumbo, thickness from 2 inches to 4 feet. Gumbo is filled with boulder gravel	880–939
Hard chalky shale, slightly sandy, showing a little green sand and pyrites	939–950
Soft sandy shale	950–959
Sandrock	959–960
Chalky clay	960–978
Hard sandy shale; very small showing of gas from 959 to 980 feet	978–980
Soft sandy shale	980–982
Hard chalky shale; much better showing of gas from 980 to 986 feet	982–986
Hard and soft strata of shale and hard shaly sandrock and boulders; sandrock strata every few feet to few inches from 1 to 10 inches thick	986–1,072
Hard sandrock	1,072–1,073
Hard sandy shale	1,073–1,081
Thin strata of shale and hard sandrock	1,081–1,100
Stiff dark clay	1,100–1,130
Sandrock	1,130–1,132
Shale	1,132–1,141
Shale and strata of very hard sandrock. Rock beds vary from 2 to 8 inches thick and are separated by shale from 4 inches to 1 foot thick	1,141–1,155

Driller's log of Lindsey well No. 2 of Hallville Oil & Gas Co., 1 mile southwest of Grand Saline, Tex.—Continued.

	Feet.
Very hard sandrock	1,155–1,156
Thin strata of hard sand and blue and white clay or shale	1,156–1,181
Very hard sandrock	1,181–1,182
Strata of shale and clay	1,182–1,202
Hard sand	1,202–1,204
Hard sandy shale and clay	1,204–1,212
Rock	1,212–1,213
Shale	1,213–1,225
Rock	1,225–1,226
Shale	1,226–1,227½
Rock	1,227½–1,228
Hard sandy shale and clay	1,228–1,236
Hard and very sandy shale	1,236–1,241
Very hard sandrock	1,241–1,243
Hard sandy shale	1,243–1,249
Hard sandrock	1,249–1,251
Very tough clay or gumbo	1,251–1,253
Hard sand or sandy shale	1,253–1,261
Very hard rock, sandy lime with pyrites, and crystals	1,261–1,266
Very tough clay or gumbo	1,266–1,270
Sandy clay	1,270–1,275
Very tough clay	1,275–1,293½
Rock	1,293½–1,294
Dark hard clay	1,294–1,317
Rock	1,317–1,318
Clay	1,318–1,359½
Rock	1,359½–1,360
Clay	1,360–1,393
Rock	1,393–1,393½
Clay	1,393½–1,423
Clay and thin hard strata of sand	1,423–1,432
Hard sandy shale	1,432–1,448
Hard, stiff clay	1,448–1,453
Hard sandy shale	1,453–1,462
Soft shale and sandy shale	1,462–1,473
Hard sandy shale	1,473–1,495
Rotten shale or marl	1,495–1,628
Asphaltic clay	1,628–1,630
Chalk and chalky shale	1,630–1,650
Shale	1,650–1,660
Chalk and chalky shale	1,660–1,670
Chalky shale	1,670–1,692
Brown clay	1,692–1,703
Shale	1,703–1,707
Hard sandrock	1,707–1,726
Lime, gravel, sand, and pyrites	1,726–1,730
Hard sandy shale	1,730–1,743½
Limerock and pyrites	1,743½–1,745½
Rotten shale, very hard	1,745½–1,753½
Very chalky shale or clay	1,753½–1,763½

Driller's log of Lindsey well No. 2 of Hallville Oil & Gas Co., 1 mile southwest of Grand Saline, Tex.—Continued.

	Feet.
Hard gray sandrock	1,763½–1,767
Gravel	1,767–1,768
Chalky shale and clay	1,768–1,781
Hard sandy shale and pyrites	1,781–1,786
Hard sand rock	1,786–1,790
Shale and sandy shale	1,790–1,810
Clay or gumbo with strata of chalk or very chalky shale	1,810–1,826
Sandy shale and chalk	1,826–1,842
Sand, clear glassy grains.	1,842–1,851
Strata of shale and sandy shale	1,851–1,859½
Rock, chalky sand, or lime	1,859½–1,861
Clay and shale	1,861–1,873
Soft sand and very sandy chalky marl	1,873–1,887
Hard sandrock; cut bit badly; some pyrites	1,887–1,906
Sandy marl	1,906–1,935
Chalky and sandy rotten shale or marl	1,935–1,970
Clay or gumbo	1,970–1,976
Strata of clay or shale and sand. Sand has many black grains [glauconite?] or particles. Cuttings show some chalk	1,976–1,990
Strata of calcareous clay; balls up slightly	1,990–2,008
Lost some water all along from 1,906 to 1,992 feet. No other indications for oil or gas to speak of. One joint 4-inch drill stem with drill collar and fishtail bit altogether lost in hole; side-tracked. Top end of joint 1,072 feet from surface; lower end of joint 1,094 feet. 7⅝-inch hole to 1,072 feet, 5⅝ inches from 1,072 to 2,008 feet.	
Sandy shale	2,008–2,016
Hard sandrock with chalky streaks	2,016–2,026
Gumbo shale	2,026–2,030
Hard limerock with soft streaks	2,030–2,037
Hard shale	2,037–2,043
Hard sand and yellow limerock, very hard	2,043–2,049
Gumbo	2,049–2,051
Hard sand and gravel	2,051–2,057
Rotten shale	2,057–2,067
Gumbo	2,067–2,082
Hard shale	2,082–2,106
Rock	2,106–2,107
Rotten shale	2,107–2,173
Very hard shale	2,173–2,178
Rotten shale	2,178–2,190
Chalk; made slush very white	2,190–2,195
Rotten shale	2,195–2,252
Chalk rock	2,252–2,256
Shale	2,256–2,288
Gumbo	2,288–2,297
Very chalky shale	2,297–2,318
Gumbo	2,318–2,350

Driller's log of Lindsey well No. 2 of Hallville Oil & Gas Co., 1 mile southwest of Grand Saline, Tex.—Continued.

	Feet.
Hard shale	2, 350–2, 358
Chalk rock	2, 358–2, 359
Tough gumbo	2, 359–2, 404
Chalk rock	2, 404–2, 407
Hard shale	2, 407–2, 431
Tough gumbo	2, 431–2, 449
Hard shale	2, 449–2, 530
Tough gumbo	2, 530–2, 542
Shale	2,542–2, 560
Chalk or very chalky shale	2, 560–2, 568
Hard shale	2, 568–2, 578
Chalk	2, 578–2, 620
Hard fine white sandy lime, porous, containing shells and pyrites or iron; good gas showing. From 2,000 to 2,400 feet we find a shell that is very thin and delicate, and also a very small perfect shell. From 2,400 to 2,620 feet a much larger and thicker shell, and more numerous near the chalk rock	2, 620–2, 664
Hard chalk, struck at 2,620 feet	2, 664–2, 680
Hard chalk, soft in places	2, 680–2, 690
Hard chalk (bottom of Austin chalk; driller)	2, 690–2, 828
Hard fine sandrock	2, 828–2, 843
Rock stratified with hard dry marl	2, 843–2, 850
Fine hard sandrock, stratified, dry	2, 850–2, 860
Hard marl	2, 860–2, 870
[Marl?], softer here	2, 870–2, 880
[Marl?], seems to be dry, fine	2, 880–2, 890
Sediment, sandy marl or lime	2, 890–2, 900
Hard sandrock	2, 900–2, 910
Softer limerock	2, 910–2, 920
Medium whitish lime	2, 920–2, 930
Very dark and hard marl	2, 930–2, 940
Very dark and hard marl, fine sand	2, 940–2, 950
Very dark and hard marl, slush	2, 950–2, 960
Very dark and hard marl, looks chalky	2, 960–3, 030
Soft gumbo	3, 030–3, 050
Dark hard marl, mud still white	3, 050–3, 090
Fine sediment, sand	3, 090–3, 103
Fine sediment, sand, hard rock	3, 103–3, 116
Fine sediment, sand, dry, hard shale	3, 116–3, 170
Dark hard marl	3, 170–3, 180
Dark hard marl; mud continues to show white	3, 180–3, 300
Dark hard marl	3, 300–3, 410
Hard white lime	3, 410–3, 420
Hard dark marl, hard as rock	3, 420–3, 450
Hard dark marl; 4 feet of soft gumbo	3, 450–3, 460
Very hard rock, fine sediment, sandy	3, 460–3, 470
Marl rock; carries some pyrites	3, 470–3, 500
Hard chalky marl	3, 500–3, 620
Very hard chalky marl (lost rotary mud at 3,630 feet)	3, 620–3, 630

Driller's log of Lindsey well No. 2 of Hallville Oil & Gas Co., 1 mile southwest of Grand Saline, Tex.—Continued.

	Feet.
Marl and very fine sand	3,630–3,650
Hard slate	3,650–3,660
Sand; chloroform test showed oil	3,660–3,700
Shale	3,700–3,750
Fine gray sandy marl and chalk	3,750–3,842

The following section is compiled from samples examined by Mr. Stephenson:

	Feet.
Apparently more or less sandy chalk	2,664–2,740
Very fine gray calcareous marine sand, with layers of clay, some of which appears to be chalky	2,740–2,960
Gray calcareous marine clay. In washed samples this clay is moderately hard and shaly. Occasional fibers of *Inoceramus* shells noted in the washed samples. A thin chalky layer appears to have been struck at a depth of about 3,420 feet	2,960–3,842

Mr. Stephenson makes the following comments:

Apparently the only part of this section (below 2,664 feet) that is a pronounced chalk is that between 2,664 and 2,740 feet. The driller described this as chalk, as well as the next 88 feet of sandy strata below to a depth of 2,828 feet, where he believed he had reached the base of the Austin chalk.

The part of the section between 2,740 and 2,960 feet appears to be predominantly fine sand, and the remainder of the section to the bottom of the well at 3,842 feet predominantly gray marine clay. The sand and clay make up 1,100 feet of strata that do not have a pronounced chalky aspect.

If the chalky beds between 2,664 and 2,740 feet belong to the Austin chalk, then this 1,100 feet of strata below should represent the Eagle Ford clay and Woodbine formation. They could scarcely be regarded as representing only the Eagle Ford, which is nowhere known to be more than 550 feet thick. But the samples show absolutely no indication that the Woodbine formation [a sandy formation] has been reached. There is but little sand in the lower half of the section, and no lignite, both of which are characteristic of the Woodbine. None of the materials appear to me to be typical of the Eagle Ford.

I am therefore disposed to regard the 76 feet of chalky strata between 2,664 and 2,740 feet as representing the stratigraphically higher Pecan Gap chalk member of the Taylor marl that crops out in the vicinity of Pecan Gap in Delta County, south of Wolfe City in Hunt County, and at Farmerville in Collin County. If this interpretation is correct, the 220 feet of fine sand between 2,740 and 2,960 feet would represent the Wolfe City sand member that underlies this higher chalk, and the 882 feet of clay between 2,960 and 3,842 feet would be typical Taylor marl. In other words, if my conclusions are correct, the well has not yet reached the Austin chalk but should reach it soon.

It is very much to be regretted that the samples contained almost no trace of fossil shells, which are generally of great service in identifying formations. The lack of opportunity to see samples from the remainder of the section above 2,664 feet has also been a handicap.[10]

[10] Fossil foraminifers from these samples (depths 2,664 to 3,842 feet) were recently identified and correlated with those of the Taylor marl by Miss Alva C. Ellisor, paleontologist in the geological department of the Humble Oil & Refining Co., Houston, Tex.

The following analysis was made by Dr. J. A. Udden:

	Feet.
Gray stony marl, with a very small amount of fine sand. Fragments of *Inoceramus* noted	2,670
Grayish-white and brown marl with some sand, size varying from $\frac{1}{8}$ to 1 millimeter in diameter, large grains polished; minute fragments of lignite present, a few grains of mica noted. *Textularia* and *Anomalina* present. Drillers' note: "We struck the Austin chalk at 2,620 feet; we thought we passed through it at 2,664 feet, but we find not."	2,670
Brownish-gray marl with a quantity of fine sand and some large slightly red polished grains; a grain of pyrite noted. *Inoceramus* fragments, *Globigerina*, and *Cristellaria* and grains of lignite present	2,670
Gray silty and sandy marl; some red grains noted. Very few *Foraminifera* noted	2,680
Yellowish-brown marl, silty sand, grains from $\frac{1}{8}$ to $\frac{1}{2}$ millimeter in diameter; a few large polished grains and a small amount of lignite. *Foraminifera* scarce, a few *Globigerina*, *Textularia*, and one *Anomalina* noted. Small amount of calcite in fine columnar sections	2,690
Grayish-brown sandy marl; sand grains $\frac{1}{8}$ to $\frac{1}{2}$ millimeter in diameter, a few large polished grains. Lignite present. Fragments of shells; *Inoceramus* fragments noted; *Foraminifera* infrequent; *Textularia*, *Anomalina*, and *Cristellaria* noted	2,700
Gray marl with a very small quantity of fine sand; a few pieces of pyrite noted; small amount of calcite fragments noted; *Foraminifera* infrequent; *Textularia*, *Anomalina*, and *Cristellaria* noted	2,700
Gray marl with a very small quantity of fine sand; a few pieces of pyrite noted; small amount of calcite. Fragments of *Inoceramus* present. *Textularia*, *Globigerina*, *Anomalina*, and *Cristellaria* noted	2,710
Reddish-gray marl with considerable sand, from $\frac{1}{8}$ to 1 millimeter in diameter; larger grains polished; lignite present. *Globigerina*, *Anomalina*, *Cristellaria*	2,710
Gray silty marl; fragments of fine-grained hard sandstone present. *Textularia*, *Globigerina*, *Anomalina*, *Cristellaria*, and *Lagena* noted	2,720
Grayish-brown marl, with considerable fine sand; a few large polished grains; mica scales noted; lignite present. Fragments of shells (?), *Textularia*, *Globigerina*, *Cristellaria*, and *Anomalina* noted	2,730
Brownish silty, marly sand; grains of sand $\frac{1}{8}$ to $\frac{1}{2}$ millimeter in diameter; mica noted; lignite present. *Textularia* and fragments of *Inoceramus* noted	2,740
Gray silty sand with some marly material; minute mica scales and fragments of hard sandstone noted; red sandstone present. *Textularia* scarce	2,750

	Feet.
Sandy, silty, larger sand grains, in part etched. Foraminifera scarce	2,760
Gray silty sand; few red sand grains. Foraminifera scarce	2,770
Gray sandy silt and marl; some large red sand grains noted; mica scales present. No Foraminifera noted	2,780
Gray silty sand and marl; some red sand grains noted. No Foraminifera noted	2,790
Gray marly silt; minute mica scales noted. *Cristellaria* (?) and *Textularia* noted	2,800
(Off of end of bit.) Gray silty marl; some red sand grains present. No Foraminifera noted	2,800
Grayish-brown marly silty sand, grains principally from ⅛ to ½ millimeter in diameter; a few polished grains; one grain of pyrite noted; lignite present	2,810
Yellowish-brown marl with considerable sand; few fragments of sandstone; grains of sand mostly very fine; lignite present	2,820
Grayish-brown silty marl with considerable sand from ⅛ to ½ millimeter in diameter; small amount of lignite noted. Foraminifera infrequent. *Globigerina* noted	2,830
Gray marl; considerable very fine sand, about ⅛ millimeter in diameter; lignite present. *Textularia* and possibly *Cristellaria* noted	2,840
Gray silty marl with considerable very fine sand; lignite present	2,850
Brownish-gray marly and silty sand from ⅛ to ½ millimeter in diameter; lignite present. *Textularia* and possibly *Cristellaria* noted	2,860
Gray sand silt with some marl and a little lignite	2,870
Gray silty marl with considerable fine sand from ⅛ to ½ millimeter in diameter; lignite present	2,880
Dark-gray marl with considerable sand from ⅛ to ½ millimeter in diameter; lignite present; few fragments of shells (?)	2,890
Gray marly, silty sand; sand grains mostly from ⅛ to ½ millimeter in diameter; mica scales noted; lignite present. Foraminifera infrequent; *Globigerina* noted; sponge spicule present	2,900

The log of a well near Grand Saline is given below for comparison with that of the Lindsey well.

Log of Jewell & North Texas Oil Co.'s Davis No. 1 well, 4½ miles southeast of Grand Saline, Tex.

[In east half J. J. Moore survey; spudded Apr. 7, 1921; abandoned June 16, 1921.]

	Feet.		Feet.
Clay and sand	28	Gumbo or tough clay	170
Wood	30	Hard shale; some rock	175
Gray sand and shale	130	Gumbo or clay	193
Hard shale; some lignite	148	Gumbo	205
Soft rock and lignite	155	Hard shale	219

Log of Jewell & North Texas Oil Co.'s Davis No. 1 well, 4½ miles southeast of Grand Saline, Tex.—Continued.

	Feet.
Packed sand	224
Rock	225
Gumbo and boulders	245
Hard shale	254
Hard shale and gumbo	267
Shale, soft gumbo, lignite	278
Shale and soft gumbo	284
Tough gumbo	290
Gumbo	318
Rock	319
Packed sand and boulders	390
Shale, gumbo, boulders	438
Rock	440
Shale	450, 479
Soft rock	480
Soft gumbo; 10-inch casing set at 484 feet	486
Gumbo	490
Rock and shale	492
Rock	494
Hard shale	532
Rock	534
Hard shale	557
Gumbo and boulders	598
Gumbo	605
Gumbo and shale	616
Hard, tough gumbo	626
Hard sandy shale	709, 714
Gumbo	761
Gumbo, very tough	792
Gumbo and boulders	800
Tough gumbo	841
Gumbo and lime shale	874
Hard rock	875
Gumbo	908, 936, 970
Gumbo and boulders	975
Tough gumbo	981, 986
Boulders	987
Tough gumbo	994
Hard shale; little pack sand	1,031
Tough gumbo	1,049
Tough gumbo, boulders	1,057
Tough gumbo	1,071, 1,077, 1,193
Shale	1,205
Tough gumbo	1,231, 1,323
Hard shale and boulders	1,338
Gumbo and boulders	1,351
Hard shale	1,369, 1,374
Tough gumbo	1,390, 1,455
Gumbo and shale	1,460
Tough gumbo	1,462, 1,471
Hard sandy shale	1,479
Tough gumbo	1,511, 1,600
Boulders and gumbo	1,602
Tough gumbo	1,621
Gumbo and boulders	1,630
Hard shale	1,638
Tough gumbo	1,649
Shale	1,655
Tough gumbo	1,664
Hard, tough gumbo	1,680
Gumbo and shale	1,700, 1,715
Gummy shale	1,723
Gumbo and boulders	1,732
Tough gumbo	1,760
Gumbo and boulders	1,770
Tough gumbo	1,785
Gumbo and boulders	1,790
Tough gumbo	1,795
Tough gumbo or gyp; boulders	1,800
Tough gumbo	1,809
Hard shale	1,830
Gummy shale or gumbo	1,832
Hard sandy shale	1,848
Tough gumbo	1,856, 1,914
Hard shale	1,928
Sandrock	1,930
Rock	1,932
Sandy shale	1,942
Boulders	1,943
Sandy shale	1,951
Rock and boulders	1,952
Hard, tough gumbo	1,988
Boulders	1,990
Tough gumbo, very hard	2,008
Hard, tough gumbo	2,160
Boulders in gumbo	2,161
Tough gumbo	2,184
Gumbo and boulders	2,195
Gumbo	2,251
Shale, with shells	2,279
Sandy shale	2,287
Soft gumbo	2,312
Shale; some shells	2,330
Soft gumbo and boulders	2,340
Shale; some shells	2,345
Soft sticky marl or clay	2,366
Shale	2,383
Gumbo and boulders	2,390
Gummy shale	2,397

Log of Jewell & North Texas Oil Co.'s Davis No. 1 well, 4½ miles southeast of Grand Saline, Tex.—Continued.

	Feet.
Tough gumbo	2,405
Soft gumbo and shale	2,450
Shale	2,465
Soft gumbo	2,474
Shale	2,490
Soft gumbo	2,495
Tough gumbo	2,591
Soft gray rock	2,624
Chalk rock	2,666, 2,693
Rock	2,700
Hard chalk rock	2,707
Soft chalk rock	2,725
Hard rock	2,733
Soft rock and boulders	2,754
Hard rock	2,758
Soft rock	2,770
Soft clay and boulders	2,789
Rock	2,790
Rock; 6-inch casing set at 2,790–2,796 feet	2,796
Hard slate or shale, with thin rock every 2 feet; some sand formation in the shale	2,804
Hard sandy shale	2,834
Shale or sand	2,836
Hard slaty shale	2,840
Hard slate and shale	2,850
Sandy shale, gumbo, and thin rock	2,876
Sandy shale and gumbo	2,918
Hard gumbo and some shale	2,934
Rock	2,936
Shale and soft gumbo	2,940
Gumbo; some boulders	2,983
Hard sandy shale	2,995
Sand and gumbo	3,009
Tough gumbo	3,018
Hard sandy gumbo	3,045
Hard sandy shale	3,062
Hard, tough gumbo	3,090
Hard shale	3,108
Gummy shale or soft gumbo	3,116
Shale	3,133
Tough gumbo	3,150
Shale	3,155
Hard, tough gumbo	3,168
Tough gumbo	3,185
Shale	3,190
Tough gumbo	3,201
Hard shale	3,238
Tough gumbo or gyp	3,278
Gumbo	3,305
Shale	3,325
Tough gumbo	3,360
Hard shale	3,366
Tough gumbo	3,383
Hard, tough gumbo	3,403
Hard shale	3,454
Tough gumbo	3,458
Hard shale	3,463
Tough gumbo	3,478
Hard shale	3,490
Gumbo	3,500
Hard shale	3,518
Tough gumbo	3,529
Hard shale	3,555
Gumbo	3,562
Shale	3,605, 3,615
Gumbo	3,621
Shale	3,630
Gumbo	3,644
Tough gumbo	3,655
Hard shale	3,664
Tough gumbo	3,678
Hard shale	3,690
Shale	3,770, 3,773
Tough gumbo	3,789
Shale	3,791
Gummy shale	3,792
Hard, tough gumbo or gyp	3,795
Gummy shale	3,835
Gumbo and shale	3,838
Soft rock	3,839
Boulders, shale, and some gumbo	3,852
Hard shale; some lime	3,894
Hard shale and soft lime	3,919
Soft lime and some gyp	3,938
Soft rock and gyp	3,983, 3,998
Soft rock	4,028
Hard and soft thin strata	4,036
Rock	4,038
Rock and gyp	4,058
Rock	4,063
Rock, gyp, or tough shale	4,075
Hard shale or gyp	4,081
Rock	4,084
Rock or gyp	4,093

Difficulty has arisen over the interpretation of formations in these logs because the Pecan Gap chalk member has been found on the surface above the Austin chalk and has been confused with it in wells. In Hunt, Fannin, and Delta counties the interval between these chalks is 500 feet. Wells in Wood and Van Zandt counties and the southeastern part of Kaufman County find both chalks, but they are separated by a greater interval. The depth of the chalks below the mouth of the wells and the interval between them, in feet, is shown in the following table:

Well.	Top of Pecan Gap chalk.	Top of Austin chalk.	Interval.	Total depth.
Trapshooter Development Co., Porter, 1 mile north of Mabank, Kaufman County (G. Isaacs survey)	1,915	2,695	780	2,960
Walker Consolidated Oil Co., Dawson, 5½ miles west of Canton, Van Zandt County (D. Chessher survey)	2,290	3,137	847	3,584
Gurley & Lee, Andrews, 5 miles southwest of Canton, Van Zandt County (I. Smith survey)	2,445	3,260	715	3,495
Hallville Oil & Gas Co., Lindsey No. 2, 1½ miles southwest of Grand Saline, Van Zandt County	2,664	(?)	....	3,842
Jewell & North Texas, Davis, 4½ miles southeast of Grand Saline, Van Zandt County	2,624	(?)	....	4,093
Golden Oil Co., near Golden, Wood County	Two chalks reported.		....	....
L. B. Carter, Vance, 1 mile east of Mineola, Wood County (Wm. Page survey)	2,235	(?) 3,238	1,003	3,261
Hoard Oil & Gas Co., Hoard, 6 miles east of Mineola, Wood County (Jas. Brewer survey)[a]	2,302	(?) 3,278	976	3,419
Sinclair Oil & Gas Co., Brooks, 7½ miles northeast of Tyler (B. S. Watts survey)	2,440	3,195	755	3,310

[a] Mr. Stephenson has identified fossils from the Hoard well at a depth of 3,146–3,160 feet as Upper Cretaceous, probably Navarro formation (*Exogyra costata* zone), but it is believed that the material fell into the hole from a higher horizon. The fossils are *Cristellaria* sp., *Micrabacia mineolensis* Stephenson, fragments of an unidentified coral, *Striarca?*, *Crassatellites?*, *Cadulus obnutus* Conrad, *Eulima*, *Ringicula?*, fragments of an ammonite.

On the outcrop both chalks are massive and do not show shale partings. At Brooks saline the Pecan Gap chalk is not exposed and has not been recognized in well logs and the Austin chalk consists of layers not more than 15 feet thick. At the Keechi and Palestine salt domes the Pecan Gap chalk is not known. The Austin chalk is represented at Keechi by only a few fragments and at the Palestine dome by an exposure 25 feet thick. Therefore it is doubtful if the Pecan Gap chalk extends south as far as Anderson County and if the Austin chalk is a single massive bed more than a few miles south of the outcrop. The identification of Austin chalk in the Beauchamp No. 1 well at Brooks saline is based on a few fragments similar to those found in the Lindsey No. 2 well at 3,420 feet and probably similar to the "gyp" in the Davis No. 1 well at 3,238 feet. The next chalk in the Davis well is below 3,852 feet and is not solid chalk. The interval of 1,228 feet between the top of the Pecan Gap chalk and the deepest chalk in this well is far greater than the corresponding interval in any of the wells listed above. It is therefore believed that the Austin chalk was passed through by both the Lindsey and Davis wells between 3,200 and 3,600 feet and that chalk is present only as thin beds.

If this correlation is accepted the Woodbine sand should not have been reached by the Davis well, because the interval between the top of the Austin chalk and the first Woodbine sand in the Cousins & Hall Mitchell No. 1 well, 5 miles east of Sulphur Springs, and in the Noco Petroleum Co. Smiddy No. 1 well, at Posey, Hopkins County, is 1,250 feet. Other Woodbine sands are found about 500 feet below the first. The interval between the top of the Austin chalk and the Woodbine sand decreases southward to about 700 feet at Keechi.

The drillers and owners of the Lindsey and Davis wells believed that the highest chalk, at about 2,600 feet, was the Austin and that the wells were sufficiently deep to reach the Woodbine sand.

STRUCTURE.

Quaquaversal structure around the Grand Saline dome is indicated in the dips in the exposures in gullies and in the railroad cuts west of the station. The degree of dip diminishes rapidly away from the center of the dome. Between the two wells of the Hallville Oil & Gas Co. (Pl. XXIII), on the precipitous edge of the salt core, dips of 20° and 16° were measured. In the first railroad cut west of the salt wells of B. W. Carrington & Co. the dip is 16°, but on the east side of the dome almost the same distance from the wells east of the Grand Saline Salt Co.'s plant the dip is only 3° to 7°. Within half a mile of the 16° dip on the railroad the dip becomes 1°, and beyond this outcrop the structure seems to be unaffected by the salt dome—in other words, the uplift affects the structure at the surface over an area only 3 miles in diameter.

The amount of the uplift as indicated by the exposures is at least 500 feet. The salt has arisen by a thrust or shear through an unknown thickness of strata, and the upturning of the surface rocks attains an abrupt maximum at the edge of the core of salt, 2 miles in diameter. As stated above, the salt may have originally risen to a higher level with a consequent greater uplift of the Wilcox strata than is judged from present surface exposures.

OIL AND GAS.

The Lindsey well was drilled on the edge of the dome within a quarter of a mile of the salt core and a shorter distance from a 16° dip, and yet it found the formations at the same depth as in the Davis well, 4½ miles from the dome. In other words, the uplift on this side of this dome does not appreciably affect an area a quarter of a

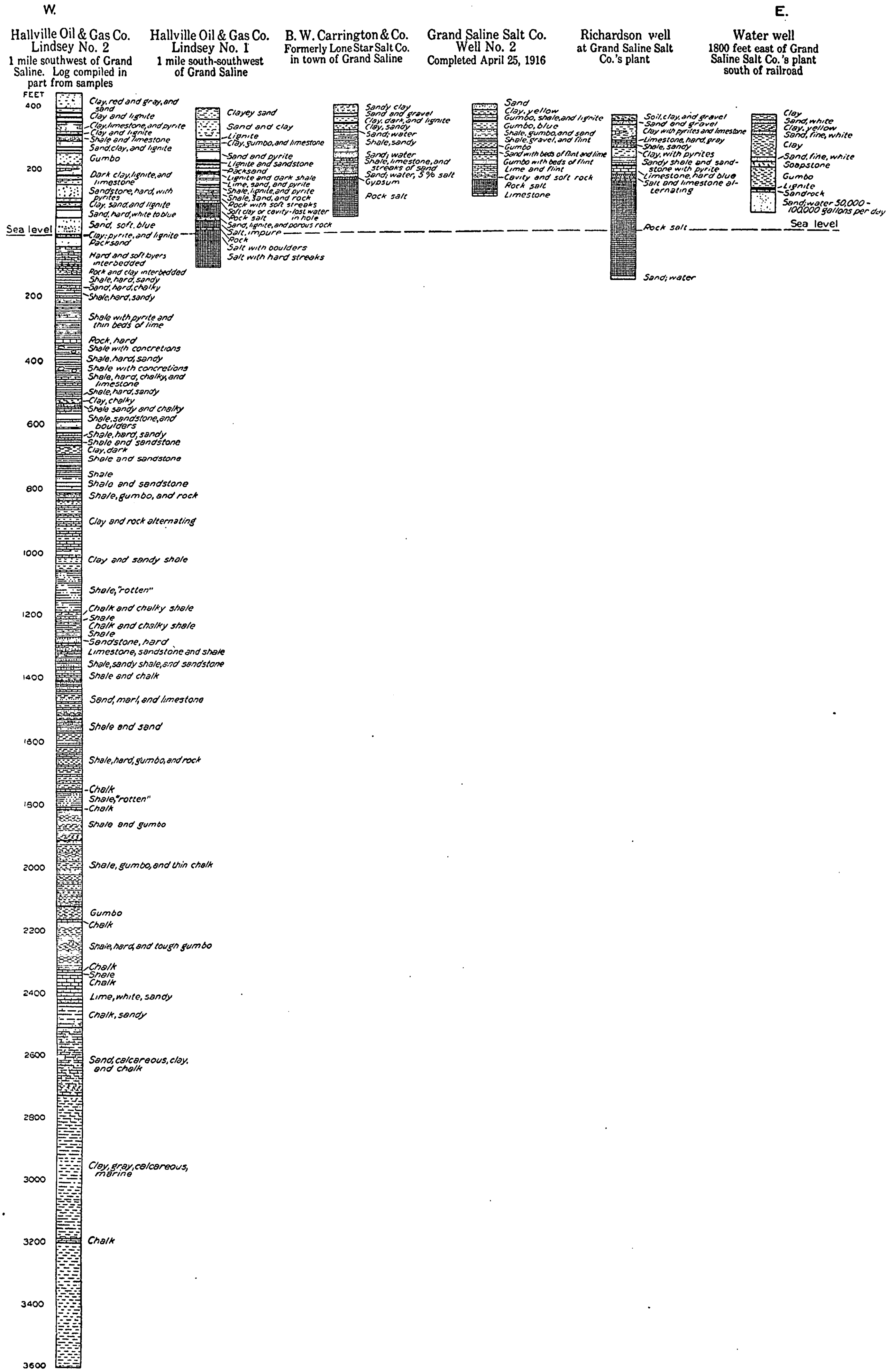


DIAGRAM OF LOGS OF WELLS DRILLED AT THE GRAND SALINE SALT DOME, VAN ZANDT COUNTY, TEX.

mile from the salt core. On Gulf coast domes of this type there are a few scattered oil wells at the very edge of the salt, but production does not extend down the dip. From this analogy it is inferred that commercial production on the interior domes will be limited to those where the uplift affects an area of greater diameter away from the salt core.

It is advisable to test this dome to a depth of 4,700 feet, and the southeast side is recommended for such a deep test. The south side of the dome should be near the southern edge of the area mapped (fig. 12). It is possible that the first test will be drilled into salt, and it is desirable to locate the deep test as near the edge of the salt as possible without penetrating it. It might even be well to locate the edge of the salt dome by shallow wells before drilling a deep well. Samples from the deep test should be carefully examined with a microscope, because it is usually possible to distinguish the formations by means of microscopic fossils that can be washed from the cuttings.