THE PALESTINE SALT DOME, ANDERSON COUNTY, TEXAS.

By Oliver B. Hopkins.

INTRODUCTION.

The Palestine salt dome has been known for many years, having been described briefly by Penrose[1] in 1890 and by Dumble[2] in 1891. The dome was recognized through the occurrence of salt, which was obtained here in small quantities prior to 1890. The production of salt lapsed for many years, but recently the industry has been revived and a modern plant producing a large quantity of salt of various grades has been established. There are no conspicuous indications of oil or gas here, and so far no deep test wells for oil have been put down. The discovery of tarry oil in a deep well on the Keechi dome, 6 miles north of the Palestine dome, has stimulated interest in the oil possibilities of the domes of this area and has led to the leasing of the lands on and around them.

The writer spent one week in October, 1916, in studying the geology of this dome and the surrounding area. He wishes to offer grateful acknowledgment to Judge O. C. Funderburk, of Palestine, for assistance in the field, and to Mr. A. L. Bowers, president of the Palestine Salt & Coal Co., for information relating to the drilling of salt wells. L. W. Stephenson, of the Geological Survey, studied the Cretaceous fossils from the area, and to him the writer is indebted for much of the information concerning the age of the formations present.

LOCATION.

The Palestine salt dome is in Anderson County, eastern Texas, 6 miles south of west of Palestine. It lies immediately north of Town Creek about 6 miles from its confluence with Trinity River. This dome is roughly in line with the Keechi, Brooks, and Steen domes, to the northeast, and the Butler dome, to the southwest. (See index map, Pl. XXII.) It is about 6 miles from the Keechi dome and the same distance from the Butler dome. None of the domes along this

[1] Penrose, R. A. F., jr., A preliminary report on the geology of the Gulf Tertiaries of Texas [etc.]: Texas Geol. Survey First Ann. Rept., pp. 33–34, 1890.

[2] Dumble, E. T., Anderson County: Texas Geol. Survey Second Ann. Rept., pp. 304–305, 315–317, 1891.

line are at present productive of oil; the productive domes, such as the Humble, Dayton, and Saratoga, are limited to a relatively narrow belt along the coast. The nearest productive oil and gas fields are the Corsicana, which is 48 miles northwest, and the Mexia-Groesbeck, which is about the same distance west of this dome.

TOPOGRAPHY.

The Palestine dome is near the northwestern margin of a cuesta which was described by Deussen[1] as the "Nacogdoches wold" and which consists of a dissected, gently sloping dip plain, terminated landward by a line of hills with steep slopes. The superior elevation of this plain is due to the hardness of the surface rock, which is in part iron ore. The western part of this plain, in which the Palestine dome is situated, is much dissected and is rolling to hilly. It ranges in altitude above sea level from about 230 feet along Trinity River to 650 feet on the tops of the highest hills. The altitude in the immediate vicinity of the dome ranges from 280 to 350 feet.

The dominant topographic features of the area of the dome consist of a centrally located lake, Dugeys Lake, a sunken area, surrounded by a ring of hills, which in turn are bordered on the north, west, south, and southeast by the valleys of Wolfe and Town creeks. The hills forming the rim of the depression have an altitude of 330 to 350 feet above sea level, or 60 to 70 feet above the centrally located lake. The hills rise steeply on the west side and gently on the east and northeast sides of the lake, which occupies a natural basin but which is formed by the damming of its outlet. Of this basin Dumble[2] wrote in 1891:

> During the winter months it contains some water, but in summer it is dry, and there are small patches scattered here and there on which an incrustation of salt appears. The soil of the saline has the same appearance as that of the "black waxy" or *Ponderosa* clays soil. The timber appears to be encroaching on it gradually. The drainage from the surrounding hills builds delta-like formations farther and farther outward, and the trees push out on the edges of these.

The 280-foot contour on the accompanying sketch map indicates the areas normally covered by water, which has a maximum depth of about 4 feet. The lake is half a mile long and three-eighths of a mile broad and has an irregular shape. The salinity of the water in the lake is increasing, owing to the inflow of salt water from salt wells and the salt works. The broad flat that borders the lake on the south and east is barren of vegetation, owing to the precipitation of salt, which forms a white incrustation on the surface in dry seasons.

The unusual features of the topography are the central depression, the circular ring of hills, the courses of Town and Wolfe creeks,

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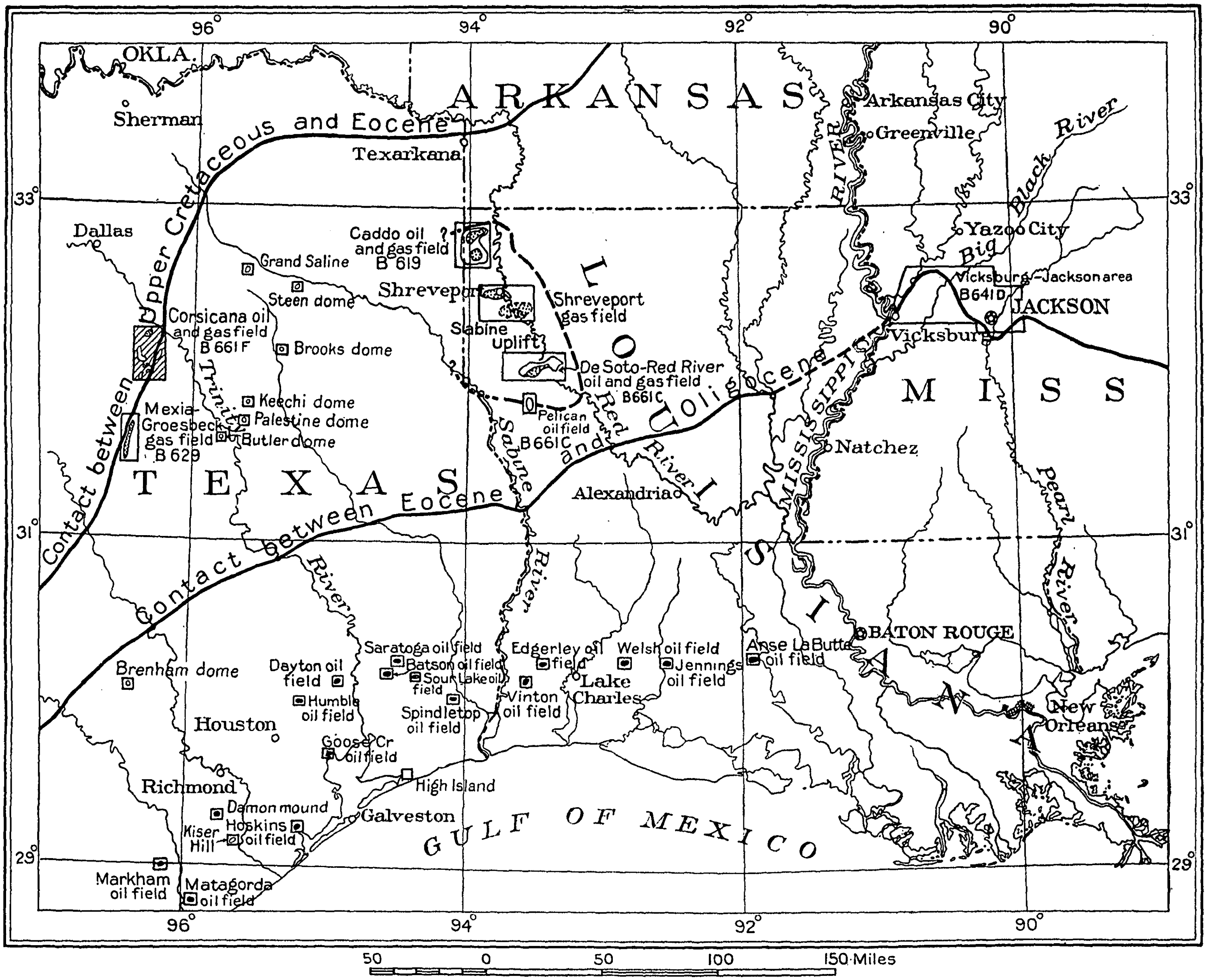
[1] Deussen, Alexander, Geology and underground waters of the southeastern part of the Texas Coastal Plain: U. S. Geol. Survey Water-Supply Paper 335, pp. 15–18, 1914.

[2] Dumble, E. T., Anderson County: Texas Geol. Survey Second Ann. Rept., p. 305, 1891.



INDEX MAP SHOWING THE LOCATION OF THE PALESTINE SALT DOME, TEX., WITH REFERENCE TO THE OTHER DOMES AND TO THE OIL FIELDS OF THE REGION.

which border the area on three sides, and the details of the drainage in the rim of hills. South of Dugeys Lake there is a gap in the hills, 30 or 40 feet below the hilltops, which has the appearance of a "wind gap" or a former stream channel. For a distance of one-third of a mile this channel is almost flat, and at some places water stands in it; within a quarter of a mile of the lake it dips steeply into the lake basin. It is evident that this is not a normally developed stream bed, as the gradient instead of being greatest near its head is greatest near its mouth, a feature which is due to the sinking of the lake area in relatively recent time. This channel is pushed back abnormally far toward Town Creek, and its valley is too large in proportion to the amount of water it carries. It is likely either that one branch of Town Creek originally flowed through this gap and into that creek by way of Dugeys Lake or that this channel has been partly formed through the process that gave rise to the lake. Before the sinking of the area of Dugeys Lake by reason of the solution and removal of the underlying salt, a small stream with its head near the center of the lake may have flowed southeastward into Town Creek, but the subsidence of the lake area diverted most of the water to the west and caused the lowering of the upper part of the water-course sufficiently to make the water flow in the opposite direction. If this is the correct interpretation the diversion of the stream must have taken place when the bed of Town Creek was only slightly below the level of this abandoned channel.

A similar anomalous stream channel is found near the southeast end of the lake. Here the conditions are more nearly normal, but the broad, flat "wind gap" is conspicuous and points to recent stream adjustments.

The valley of Wolfe Creek is more mature than that of Town Creek, and as the creeks are of about equal size, it is suggested that Wolfe Creek has maintained its present course longer than Town Creek.

The Palestine road crosses a small branch of Wolfe Creek 1¼ miles north of east of the salt works at Little Saline, an open valley over which are scattered a few salt licks, or areas where the soil is salty and barren of vegetation. No drilling has been done there, but it seems likely that salt water finds its way to the surface along faults from the central salt core. It is possible, however, that rock salt may underlie this area at a relatively shallow depth.

Half a mile down Wolfe Creek from this locality there are a number of small circular areas where the ground is unstable and where the surface heaves up and down when walked upon. These areas are generally covered with a thick sod, which is underlain by soft blue mud, into which a stick can be pushed with ease 4 to 6 feet or more. These so-called quagmires, which are common on salt domes, are probably near faults or other openings along which water finds its way to the surface. The water about these quagmires is not briny and there is no evidence of gas or oil in their vicinity.

Other interesting features of the dome are the glades which surround it on all sides. These are low areas along stream valleys where no bushes or trees grow, and the principal vegetation is a peculiar swamp grass. The absence of a normal growth of vegetation on these areas suggests that the soil may be slightly saline, owing to the escape of salt-bearing water.

GEOLOGY.

STRATIGRAPHY.

SURFACE GEOLOGY.

GENERAL FEATURES.

Under normal structural conditions this area would lie near the contact of the Eocene Wilcox and Mount Selman formations and would be underlain by the Wilcox formation. Extensive local uplift, however, has brought to the surface and exposed over small areas Cretaceous formations that would normally be buried by several thousand feet of strata. The exposure of Cretaceous rock here thus represents an inlier which is 42 miles from its nearest outcrop. The normal succession of rocks for this area is shown in the accompanying table. Of the formations listed the Eagle Ford, Austin, Navarro, Wilcox, and Mount Selman and probably the Woodbine sand are exposed at the surface. If the Taylor and Midway formations are exposed, they have not been recognized. The area covered by the formations normally lying below the Wilcox is small, and only parts of the formations are exposed.

The Cretaceous rocks, although probably near the surface on all sides of the dome, are exposed best on its northwest and west sides; small exposures are found on its southeast side. Of these formations the Navarro covers much the larger area. The normal succession of the Cretaceous formations is obscured by faults that cause a duplication of outcrops. The succession of rocks is best shown on a small ridge a few hundred yards northeast of the salt works; here sandstones of Woodbine (?) age crop out on the crest of the ridge and are paralleled on its west side by narrow outcrops of the Eagle Ford, Austin, possibly Taylor, and Navarro, beyond which is the Wilcox, which completely encircles the dome.

Partial section of geologic formations involved in the Palestine salt dome.

System.	Series.	Formation.	Thickness.	Lithology.
Tertiary.	Eocene.	Mount Selman formation.	*Feet.* 350-600	Sands, in part highly glauconitic and fossiliferous, clays, lignite, and thin beds of iron ore.
		Wilcox formation.	450-650	Sand lenses, sandstones, clays, sandy clays, and lignites.
		Midway formation.	250	Clays and limestones of marine origin.
Cretaceous.	Gulf (Upper Cretaceous).	Navarro formatio.	600-900	Marls, bluish black, and glauconitic clays; blue clays with siderite and limonite concretions; yellow and brown sands with hard sandy concretions.
		Taylor marl.	800-1,000	Clay marls, blue, calcareous.
		Austin chalk.	400-500	Chalk, interstratified with thin beds of soft marl.
		Eagle Ford shale.	350-400	Shale and thin arenaceous beds of laminated limestone.
		Woodbine sand.	350-500	Sand, arenaceous clay, and clay.

WOODBINE SAND.

A narrow belt of gray to yellow friable sandstone and hard ferruginous sandstone containing scattered shells of probable Woodbine age crops out on a narrow ridge that projects into the lake a few hundred yards east of the salt works. This sandstone, which strikes N. 30° E. and dips 46° NW., parallels a narrow belt of limestone of Eagle Ford age on the west and a more conspicuous belt of Austin chalk still farther west but on the same ridge.

Samples of this sandstone with poorly preserved fossils were submitted for examination to L. W. Stephenson, who expressed the opinion that they are certainly of Cretaceous age and probably belong to the Woodbine sand. A definite determination was not possible, because the fossils could not be identified.

EAGLE FORD SHALE.

The only recognized exposures of the Eagle Ford shale occur on the ridge a few hundred yards east of the salt works, between narrow belts of Woodbine (?) sand and Austin chalk. They consist of a hard, somewhat flaggy fossiliferous limestone that appears to underlie the Austin chalk. Mr. Stephenson has identified *Ostrea lugubris* Conrad, *Plicatula* (?), and *Corbula* sp. in this limestone and considers it of Eagle Ford age. Only a few isolated exposures of this limestone are present, and these occur along the east side of the belt of Austin chalk, which dips steeply to the northwest.

AUSTIN CHALK.

The Austin chalk is exposed in the railroad cut just south of the salt works, on the hill one-third of a mile east of north of it, on the Palestine road, on the ridge immediately east of the road, and on the east slope of this ridge one-third of a mile northeast of the salt works. There are three parallel belts of chalk here, the duplication being caused by northeasterly faults. The chalk is massive, white to cream-colored and in part bluish gray, and argillaceous. It strikes in general northeast and dips 40°–50° NW. Mr. Stephenson has identified this chalk as Austin and has recognized in it two or more species of *Inoceramus*.

Fragments of chalk are present on the surface on the southeast side of the lake, but no ledges of it were found in place. The best exposures are in the railroad cut at the salt works, where about 25 feet of pure white to cream-colored and bluish-gray argillaceous chalk is exposed. It strikes N. 15° E., dips 48° NW., and is overlain by either Taylor or Navarro clay.

TAYLOR MARL.

The Taylor marl has not been recognized in outcrops in this area, although it is quite possible that part of the dark plastic clay here belongs to this formation. No fossils of Taylor age have been found.

NAVARRO FORMATION.

The Navarro formation is exposed over a semicircular area with a radius of about one-third of a mile extending from the salt works north and northeast almost to Wolfe Creek and in a smaller area three-fourths of a mile southeast of the salt works and about one-third of a mile southeast of the east end of Dugeys Lake. Fossils collected from a small draw at the Dugeys Lake locality were identified by Mr. Stephenson as *Ostrea plumosa* Morton, *Exogyra cancellata* Stephenson, and *Pecten quinquecostatus* Sowerby. He states that these fossils represent the *Exogyra cancellata* subzone of the *Exogyra costata* zone, or, in other words, the lower part of the Navarro formation of Texas.

The Navarro consists of soft bluish-gray clay shale and thin ledges of hard limestone. The shale weathers to dark-gray or black plastic clay, which is conspicuous along the road from the salt works to Palestine.

MIDWAY FORMATION.

The Midway formation has not been recognized in this area and is believed to be absent here as well as in the Keechi dome, 6 miles east of north. The absence of this formation at the surface may be due to faulting or to local unconformity between the Navarro and Wilcox. The absence of beds of Midway age at both the Palestine and Keechi domes, the great differences in the faunas of the Cretaceous and overlying Tertiary, and the great extent of the unconformity separating them, which doubtless records not only erosion but great diastrophic movement, make it seem highly probable that these domes began to be uplifted at the end of the Cretaceous period and that they were islands in the Midway sea on which no sediments were deposited.

WILCOX FORMATION.

The Wilcox formation entirely surrounds the Palestine dome and dips steeply in all directions away from its center. Near the inner margin of its outcrop the dips are steepest, ranging from 38° to 57°; they diminish away from the center of the dome, at a distance of a mile ranging from 20° to 30°, and within 2 or 2½ miles become almost horizontal. To the northeast and southeast the Wilcox formation disappears beneath the Mount Selman formation.

The Wilcox formation consists of lenticular beds of lignitic sand and clay and thin beds of sandstone and lignite; these materials are very irregularly bedded, and the individual beds vary widely from place to place. On Waterworks Branch of Town Creek, 1½ miles south of east of the salt works, the following section is exposed:

Partial section of Wilcox formation on Waterworks Branch.

[Strike N. 60° E., dip 24° SE.]

	Feet.
Sand, white to brown, hard, with leaf impressions	10
Lignite, in fairly uniform bed	5½
Sand, light gray to brown, carbonaceous, with leaf impressions	6
Clay, brown, carbonaceous, to bed of branch	2
	23½

Partial section of Wilcox formation in bluff of Trinity River at mouth of Town Creek, 12 miles southwest of Palestine.

Top of bluff.	Ft.	in.
Sand and gravel cemented by limonite	2–3	
Sand and sandy clay, gray, with thin beds of limonite	2	0
Sand, hard, green to brown	2	6
Iron ore, laminated		2
Clay, carbonaceous		6
Greensand		4
Clay, brown		2
Sandstone, soft, brown		10–12
Clay and sand, brown, laminated, carbonaceous, containing scattered concretions, more regularly bedded below than above		11
Iron ore, concretionary; iron carbonate on inside weathered to limonite on outside		1–4
Sand, brown, carbonaceous, highly cross-bedded, with vertical layers of ferruginous sandstone filling joints	3	0
Iron ore, concretionary, giving place along bedding to earthy lignite		6
Sand, carbonaceous, very irregularly bedded, containing irregular masses of brown clay	3	4
Clay, carbonaceous, sandy		10
Sandstone, soft, yellow		5
Clay, carbonaceous, sandy		10
Sand, yellow, with irregular concretionary layer at top	1	0
Clay, carbonaceous, hackly	1	0
Water level in Trinity River.		
	30	7

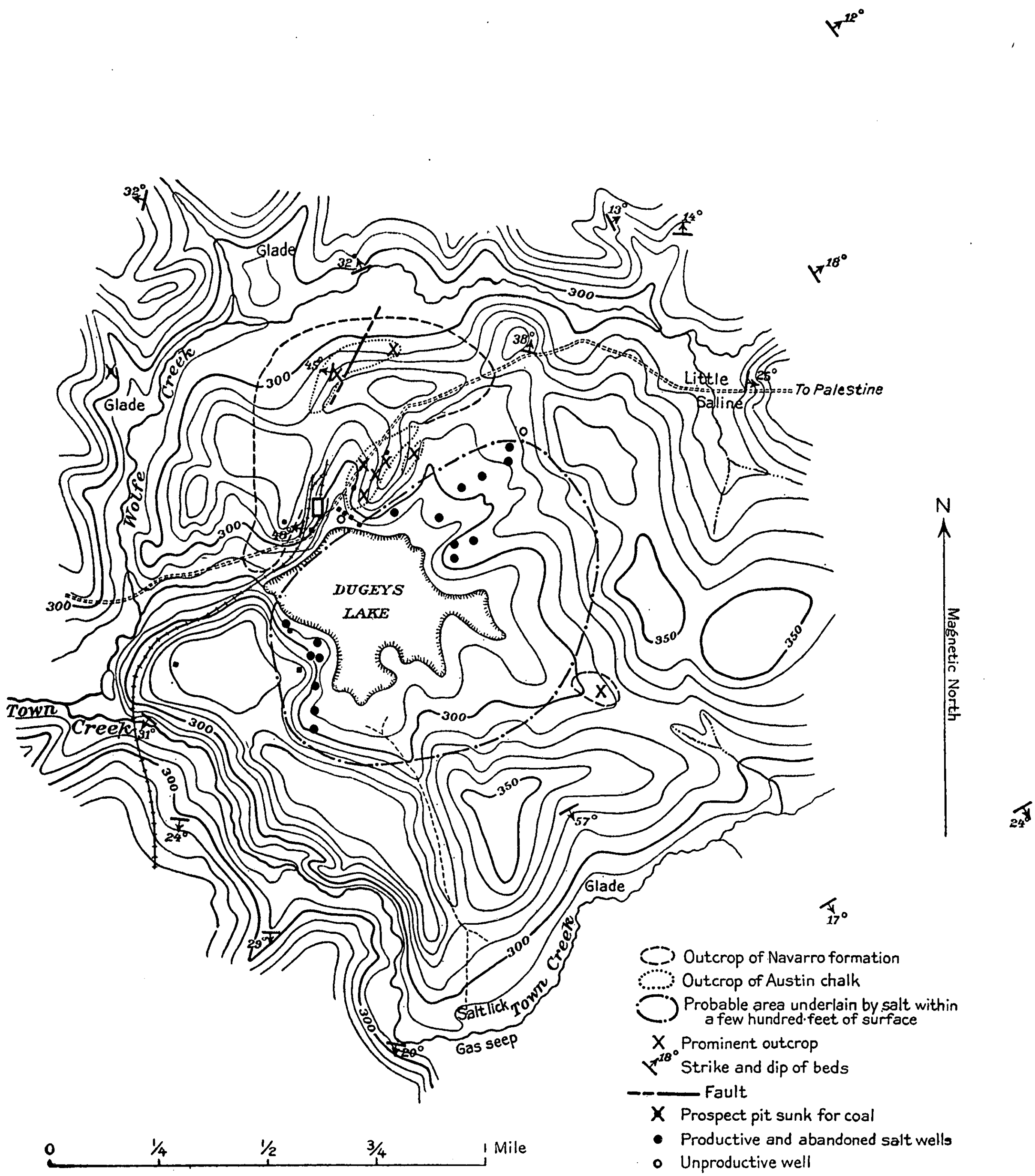
Numerous casts of elongated pelecypods are present in the sands and sandy clays near the top of this section.

The highly irregular character of the Wilcox beds in this area and the rather abrupt change in dip on the flanks of the dome led Deussen to believe that there was a slight upward movement of the dome in late Wilcox time, causing a local structural unconformity within that formation. This inference seems probable, but no definite proof of such an unconformity was found.

MOUNT SELMAN FORMATION.

The Mount Selman formation, the oldest formation of the Claiborne group in this area, skirts the north, east, and southeast sides of the dome at so great a distance from the center (3 to 5 miles) that it is only slightly disturbed by the uplift. The normal southwesterly trend of the formation is, however, deflected somewhat to the east. The dip of this formation is low and is measurable at few if any places near the dome.

The Mount Selman consists of massive sands, highly glauconitic sands, clays, and marls, with abundant shells. It is dominantly ferruginous and sandy. On weathering most of the beds turn red at first and become gray only after thorough leaching of the iron content. Beds of limonite are found at some places.



SKETCH MAP OF THE PALESTINE SALT DOME, TEX.

UNDERGROUND GEOLOGY.

The deepest wells on the dome do not exceed 500 feet in depth, and few go down more than 250 or 300 feet. The drilling has been done entirely in search of salt, and where that has not been found within a few hundred feet of the surface the locations were abandoned in favor of others. Most of the wells reach rock salt at a depth of about 140 feet, or about 160 to 170 feet above sea level, the small differences in the depth being due to the surface topography; the upper surface of the salt is thus fairly level in the area near the lake. In the second farthest well to the northeast from the lake, however, the top of the salt was found at 77 feet above sea level, thus showing that the salt mass has a pronounced dip to the north from the nearest well to the southwest. A well drilled near the western margin of the lake on the west side of the railroad penetrated a jumbled mass of rock and shale to a depth of 500 feet without reaching salt; another well near the northwest margin of the lake penetrated 360 feet of rock without reaching salt. It thus seems that the salt mass dips strongly to the west and reaches a considerable depth near the western margin of the lake. No wells have been drilled on the east or southeast side of the lake, but it is inferred from the topography that this area is underlain by salt at no great depth. The area supposed to be underlain by salt at a depth of a few hundred feet is indicated on the accompanying map (Pl. XXIII).

The shallow salt wells penetrate about 85 feet of gray to yellow water sand and 40 feet of dark-gray to black sandy clay, below which is in places a cap rock of hard limestone of varying thickness. The casing is set on this rock and the well deepened through sand until rock salt is reached at about 140 feet. The main factor controlling the location of salt wells is the presence of a good cap rock which serves as a seat for the casing and also holds up the overlying strata until a large cavity is dissolved out underneath it. When the supporting salt is sufficiently removed this rock, being undermined, caves in, with the overlying formations, forming a large sink hole.

STRUCTURE.

Penrose[1] recognized the presence of an uplift here in 1889, saying:

> In many places on the top and slopes [of the hills] are seen outcrops of white chalky fossiliferous limestone with dark specks (glauconite). The fossils have been identified by R. T. Hill as belonging to the "glauconitic" beds of the Upper Cretaceous epoch and possibly represent the Ripley group of Alabama. This locality is over 50 miles east of the main Cretaceous area of central Texas and doubtless represents the remains of an island in the old Tertiary sea.

[1] Penrose, R. A. F., jr., A preliminary report on the geology of the Gulf Tertiaries of Texas [etc.]: Texas Geol. Survey First Ann. Rept., pp. 33–34, 1890.

The existence of a dome here is proved by the presence of a Cretaceous inlier in an area of Tertiary rocks where the Cretaceous would normally be several thousand feet below the surface, by the presence of rock salt near the surface, and by the characteristic topography of a salt dome.

The occurrence of Cretaceous rocks at the surface, at a distance of 42 miles from their nearest normal outcrop, proves the presence of an uplift of great intensity. The best available information regarding the thickness of the formations involved in this uplift is given in Plate XXIII. As this dome is near the line of contact of the Wilcox and Mount Selman formations, the amount of uplift is equivalent to the thickness of the strata between the top of the Wilcox and the lowest formation exposed. The thickness of the strata between the top of the Wilcox and the top of the Eagle Ford, which has been definitely recognized, is 2,500 to 3,300 feet. If the Woodbine sand is present at the surface, as it probably is, the uplift is 350 to 400 feet greater. A moderate estimate of the maximum vertical movement of the Cretaceous formations is about 3,000 feet.

This local uplift is highly complicated by faults, many of which are indicated at the surface, although their exact location and extent have not been determined. How much of the vertical displacement found here is due to folding and how much to faulting is not known, but it is highly probable that faulting played as important a part as folding. The dip of the Cretaceous rocks is observable only on the north and west sides of the dome, where it is to the northwest, away from the center of the uplift.

The depressed area of the dome, which is considered to represent with fair accuracy the center of the uplift, is completely encircled by the Wilcox formation, which dips away from it in all directions, thus showing the quaquaversal nature of the dome. The Wilcox dips at angles of 30° to 57° at its outcrops nearest the dome, but the decrease in the rate of dip away from the center of the uplift is pronounced. The dip of the Cretaceous formations below the Wilcox outcrops is probably greater than that observed in the Wilcox, a feature which is characteristic of salt domes.

Viewed as a whole the Palestine dome is a quaquaversal fold on whose flanks are highly inclined beds that dip in all directions away from its center but become approximately horizontal within a few miles; the center of the uplift is extensively faulted, mainly in a northeasterly direction, producing an irregular distribution of the Cretaceous beds and a triplication of the outcrop of the Austin chalk. The structure in the Cretaceous formations is doubtless more complicated than in the Wilcox, as the dome, with the attendant folding and faulting, probably began to develop prior to the deposition of the Wilcox.

DEVELOPMENT OF THE DOME.

AGE OF FORMATION.

The great diastrophic movements that are known to have taken place in this region at the end of the deposition of the highest Cretaceous formation, the Navarro, and the absence of the earliest Tertiary formation, the Midway, in both the Palestine and Keechi domes suggest that the initial uplift of these domes occurred during the hiatus between the Navarro and the Midway and that the dome was an island in the Midway sea, around which sediments accumulated. It is likely that this island was degraded during this period, for in Wilcox time this area was at about the level of the surrounding country, and the deposits of that age probably extended over it. There may have been a slight upward movement during late Wilcox time, as Deussen[1] has suggested, causing the early Wilcox beds to be tilted at a greater angle than the later ones. However, the forces that produced the domes, if they became operative prior to the Wilcox deposition, must have been comparatively dormant during most of that time, and any previous upward movement must have been offset by erosion during Midway time. A considerable part of the uplift was in post-Wilcox time, as beds of Wilcox age are highly tilted around the flanks of the dome.

The Claiborne formations (Mount Selman, Cook Mountain, and Yegua) do not crop out near enough to the dome to record how much of the uplift occurred after their disposition; and no chronologic record of movement is left, although it doubtless took place, until recent time, when it was recorded by the physiographic development. If the Palestine and Keechi domes were developed at the same time as the Brenham dome, which has involved younger beds, their history may be expanded by inference from the history of that dome. The uplift in the Brenham dome since Cook Mountain time has been from 600 to 900 feet (see p. 276), and therefore it seems likely that the Palestine and Keechi domes also have been considerably uplifted since that time. This is likewise suggested by the deformation of the Claiborne beds in the area near the domes. The uplift in the Brenham dome was practically completed in Lagarto (Pliocene) time, as beds of that age are only slightly disturbed. It seems likely that the main uplift in these domes was completed during late Eocene, Oligocene, or Miocene time, and that only slight movements have taken place since then.

That there has been relatively recent movement, although of small amount, is proved by the stream adjustments that have taken place in the area. The dome was either degraded as fast as it was

[1] Deussen, Alexander, informal communication.

uplifted or it was base-leveled afterward, for in relatively recent time the dome appears to have had no topographic expression and the streams flowed in their normal courses over it; later a slight uplift occurred and the streams began to sink their channels and to shift their courses in adjustment to this movement. The abandoned "wind gaps" (see p. 255) were cut during this time. The uplift caused active solution and removal of salt from the top of the salt core, with the formation of large cavities, which finally caused the collapse of the crest of the dome and the gradual formation of the basin. Minor stream adjustments attended this change in the crest of the dome, with the consequent formation of the present topographic features shown on Plate XXIII and described on pages 254–256.

CAUSE OF UPLIFT.

Such an intensive and highly localized vertical uplift of quaquaversal form could be produced only by vertical thrust from below. The results observed are analogous to those produced by driving a punch into a sheet of cold steel; the effects are entirely local, and the metal arches over the end of the punch until the strain is too great and the steel shatters at the point where the force is applied. Such conditions are most commonly produced by igneous intrusion, of which no direct evidence has been found in any of the numerous salt domes of the Gulf coast. It is evident from the nature and amount of the secondary minerals found in these domes (mainly salt and gypsum, which are not known in any Cretaceous formations of this area) that the forces had deep-seated connections, and it is quite probable that they were connected with igneous activity. In the early study of salt domes it was suggested that such domes were caused by igneous intrusions. Later the great thickness of salt led to the belief that the crystallization of salt may have caused the doming. Recently the trend of opinion has been toward a combination of both hypotheses.

The writer believes that forces which initiated and aided in the development of salt domes also produced the folds and faults in the areas where no salt domes are known, and that there were lines of weakness, as suggested by Harris, along which salt domes were formed by the action of dynamic forces, whereas at other places normal anticlinal folds and faults were developed. The peculiar local nature of salt domes may be due to the effect of dynamic activity at certain points along lines of deformation, aiding in the solution and transportation of salt, gypsum, etc., from deep-lying formations, probably Permian, to the position in which they are found.

POSSIBILITIES OF OIL AND GAS.

The highly folded, faulted, and eroded condition of the Palestine dome and the general absence of oil and gas as surface seepages and in shallow wells in this area detract from its oil prospects. The tilting and faulting of the rocks probably provided outlets for the escape of oil, and as no evidence of oil exists the conclusion is suggested that no large amount remains here, even if it ever accumulated. It is possible, however, that the soft and dominantly impervious nature of the formations involved in this fold closed up any possible lines of escape for the oil, as its absence at the surface may be interpreted to indicate. The eroded condition of the dome, as shown by the presence of Cretaceous rocks at the surface, and the presence of the salt core within 140 feet of the surface over a large area are also unfavorable conditions, as they eliminate the possibility that oil may be found on the crest of the dome, which might otherwise be the most favorable area for its occurrence. Oil in commercial quantities has not yet been found in a salt dome so far removed from the coast as this one.

The most likely area for the occurrence of oil, if it is present in this dome, is within a belt about half a mile wide that surrounds the area in which salt approaches within a few hundred feet of the surface, as indicated on Plate XXIII. The most favorable part of this belt is probably near its inner margin, where the underlying formations may be tilted up against the salt mass and probably end against it.

So far as observed, there are no subsidiary folds on the flank of the dome that would serve to trap upward-migrating oil; if such a trap exists it is at a considerable distance from the dome or is produced by the pinching out of a porous bed or by a fault.

A sample of gas collected from a natural escapement in Town Creek south of this dome was analyzed with the following result:

Analysis of gas from Town Creek, 1¼ miles south of the Palestine Salt Works.

[Made by the Bureau of Mines; F. M. Seibert, analyst; laboratory No. 8486.]

Carbon dioxide (CO_2)	0.5
Oxygen (O_2)	.2
Methane (CH_4)	64.7
Nitrogen (N_2)	34.6
	100.0

Specific gravity, 0.70.

Heating value (British thermal units per cubic foot at 0° C. and 760 millimeters pressure), 697.

The small percentage of carbon dioxide present in the gas suggests a deep-seated origin, whereas the absence of ethane (C_2H_5), which characterizes many but not all deep-seated gases, suggests but does not prove its surface origin. The most significant features of the gas are its high content of nitrogen and low content of carbon dioxide. Most surface gases which have as high a content of nitrogen as this one have also a much higher content of carbon dioxide.

AREA SURROUNDING THE PALESTINE DOME.

KEECHI SALT DOME.

LOCATION.

The Keechi salt dome is 6 miles in an air line west of north of Palestine and the same distance east of north of the Palestine dome. (See index map, Pl. XXII.) It is near the head of Keechi Creek, from which it derives its name. The surrounding country is rolling to hilly, and there is nothing in the topography to indicate to the casual observer the presence of a salt dome; there are no extensive salt flats or quagmires, no ring of hills, and no central depression. Some small salt licks are reported, but they are not conspicuous. The crest of the uplift probably lies near the top of a low rounded hill; Keechi Creek crosses its northern flank and a small intermittent branch crosses its south-central part, affording the most conspicuous exposures in the area. This dome has been known for many years, but no attempt was made to exploit it until 1916, when the Producers Oil Co. drilled two deep test wells; that company is at present drilling a third. During a reconnaissance examination in this country in the fall of 1916 the writer spent parts of two days investigating this dome and the surrounding area.

GEOLOGY.

This dome, like the Palestine dome, is indicated on the surface by a Cretaceous inlier, of which Dumble[1] wrote in 1890:

> Here the soil has its characteristic black waxy appearance (of *Ponderosa* clays) and exposed clays their yellow color. They contained yellow calcareous nodules and many fine specimens of *Exogyra ponderosa* Roemer, accompanied by *Gryphaea vesicularis* Lamarck. The highest beds were found to contain a decided intermixture of limestone in small fragments, below which was an arenaceous bed, containing fragments of a small thin-shelled oyster of which no specimens could be secured sufficiently perfect for identication.

The area of Cretaceous clays is an open prairie, whereas that of the sandy Wilcox beds is thickly covered with post oaks, blackjacks, and pines. The exposed strata consist of the Navarro formation and the Austin chalk, which occupy the center of the dome, surrounded by the Wilcox formation; the Taylor marl may crop out but it was not recognized. The Austin chalk is represented by surface frag-

[1] Dumble, E. T., Anderson County: Texas Geol. Survey Second Ann. Rept., p. 305, 1891.

ments scattered thickly over a few acres near the center of the W. A. Cook property, one-third of a mile north of Producers Oil Co. Barrett & Greenwood well No. 1. The Navarro formation is exposed over most of the crest of the dome. It consists of grayish-yellow lumpy clay with small white calcareous concretions and weathers to greenish yellow and finally to a sticky black soil. L. W. Stephenson has identified *Exogyra cancellata* Stephenson from a deep gully 100 yards north of Barrett & Greenwood well No. 1 and says that it represents the *Exogyra cancellata* subzone of the *Exogyra costata* zone (the lower part of the zone), which constitutes the lower part of the Navarro formation. He has also identified the following fossils, which were collected loose on the surface near the locality mentioned: *Nucula* cf. *N. eufaulensis* Gabb, *Trigonia* sp., *Plicatula* n. sp., *Crassatellites* sp., *Ringicula* sp., and *Baculites* sp. These forms, he says, probably came from the middle or upper part of the Navarro formation. The Wilcox encircles the inlier of Cretaceous and dips away from it at angles ranging from 20° to 30°. It consists of sand, sandy clay, and beds of clay, lignite, and hard sandstone. It directly overlies the Navarro formation, and the contact may be determined within narrow limits in the deep gulch below Barrett & Greenwood well No. 1, which is near the contact. The Mount Selman formation crops out 3 to 4 miles northeast, east, and southeast of this dome.

The crest of the dome is on or near the W. A. Cook and R. R. Powers properties and is outlined by the dark plastic clays of the Navarro. On the southern slope of the dome the Navarro dips 26°–28° SE. near its contact with the Wilcox, which dips at approximately the same angle. The vertical displacement is less than in the Palestine dome, and faulting is less evident. The presence of the Austin chalk at the surface indicates that the uplift has a vertical displacement of 2,000 to 2,500 feet. The dips of the Wilcox around the dome show that it is a quaquaversal fold of probably more regularity than the Palestine dome.

DEVELOPMENT.

The Producers Oil Co. Barrett & Greenwood well No. 1 is on the southern slope of the dome, near the contact of the Wilcox and Navarro formations. It is reported to have reached the Austin chalk at 586 feet and the top of the Woodbine (?) sand at 1,686 feet; it penetrated rock salt from 2,200 to 2,900 feet, water-bearing sand from 2,900 to 2,930 feet, and rock salt from 2,930 to 3,130 feet, at which depth it was abandoned. The Woodbine (?) sand yielded 1 or 2 barrels of heavy tarry oil at 1,686 feet. A second well was drilled on the same lease, 1,000 feet east of south of the first. The Austin chalk is reported in this well at about 1,400 feet, and the Woodbine (?) sand, which yielded salt water that could not be bailed below 500 feet, at 2,297 feet. The dip from the first to the second well, as indicated by the Woodbine sand, is about 35°. The possibility of finding oil in this dome is considered better than in the Palestine dome because it appears to be less faulted, the salt core does not come so close to the surface, and the Woodbine (?) sand is within reach of the drill and also deeply enough buried to have retained its oil.

ELKHART.

Two miles southeast of Elkhart, along the International & Great Northern Railroad, the normal southeasterly dip is interrupted by reverse dips of a fraction of a degree to 1° NW. Four miles southeast of Elkhart a fault with a northeast trend and an indeterminable throw is exposed in a railroad cut. It is not known whether the reverse dips observed are due to this fault or whether the fault is incidental to a fold trending northeast which produces the reverse dips. The evidence gathered from a day's visit to this area suggests the presence of considerable deformation there.

One mile northwest of Elkhart, in the bottom of a branch on the southwest side of the railroad, a fault that is probably of considerable throw strikes N. 38° E. and dips 58° NW. This fault is near the south line of the William Frost survey. The beds are essentially the same on the two sides of the fault; on the east, the upthrown side, they dip gently to the northwest, and on the northwest side they dip locally in the same direction but at a much higher angle, showing the effect of the downward drag on that side. About 100 yards southeast of the fault the beds become practically horizontal for a few hundred yards, and beyond that they dip gently to the southeast.

Southwest of this locality, along the supposed continuation of this fault, 1¼ miles southwest of Elkhart, a dip to the northwest is observed in the banks of a small branch for a distance of several hundred yards. Here a hard bed of ferruginous shell marl is overlain successively by green lumpy clay with veins of gypsum and brown carbonaceous clay, and all dip progressively beneath the creek bed upstream. Farther upstream there are irregularities in the dip of the beds and clear evidence of faulting. This disturbance in the normal southeastern dip of the beds is probably connected with the fault described above and may have caused the asphalt seeps west of Jarvis that are described on the following pages. The deformation observed here may be sufficient to produce favorable structural conditions for the accumulation of oil and gas. Although the area was not studied in sufficient detail to ascertain the most favorable places to test it with the drill, a well near the east side of a line connecting the two localities described would be more favorably situated than the average wildcat wells, located with less regard for structure.

JARVIS.

Near Fields Chapel, half a mile northwest of Jarvis and about 12 miles east of Palestine, asphaltic sand crops out 100 yards north of the road, where a shallow well was dug, and in the road at three localities west of the chapel. The asphaltic sand is medium grained and irregularly bedded. Its pore space is filled with black asphaltic oil, which oozes out on the surface in warm weather. The shallow well showed the following section:

Log of well on M. A. Davey farm, near Jarvis, Anderson County, Tex.

	Feet.
Soil impregnated with asphalt; runs slightly in warm weather	½
Clay, hard, laminated	1½
Sand, asphaltic	1
Clay, hard, laminated	3
Sand, hard, asphaltic	2½
Clay, as above, but containing streaks of asphalt along bedding planes and joints	4
Sandstone, asphaltic	3
Clay, laminated, streaked with oil	5
Sandstone, hard and dry, but shows asphalt when treated with gasoline; about 2 tons used to patch street in Palestine	4
Sand, coarse, white, becoming damp	3
	27½

The brief inspection of this area did not show conclusively whether the asphalt indicates the outcrop of an oil-bearing sand or the presence of a fault that has allowed the upward migration of the oil from below. The evidence is in favor of the latter.

Mr. Davey drilled a well 1 mile northwest of Jarvis on the north side of the Palestine road to a depth of 1,300 feet. It shows considerable heavy black oil and is said to have flowed a stream of water when it was drilled. There is a seep of oil in the branch near by, and on the opposite side, to the west, Mr. Nemer, of Palestine, drilled a well to a depth of 700 feet without any significant results.

WELLS CREEK DISTRICT.

Twelve wells have been drilled by local companies in search of oil near Wells Creek, 4 miles south of Neches and about 12 miles northeast of Palestine. Most of these wells were drilled in the valley of Wells Creek near the crossing of the Alderbranch-Neches road. The deepest well was drilled by Mr. Granberry about six years ago on the north side of the creek to a depth of 2,500 feet; most of the other wells reached depths of 800 to 1,500 feet. Oil of 17° to 18° Baumé was found at about 864 and 1,010 feet, according to M. A. Davey, in the wells near the road crossing; a flow of sulphur water was found there at about 700 feet, and below the oil fresh water was found. The best showing of oil was found in the wells west of the Alderbranch-Neches road and on the south side of Wells Creek. Some of the wells only a short distance up the creek are said to have shown no oil. The rock exposures in this area are very poor, and it is considered difficult, if not impossible, to determine the local structure from surface outcrops.

POSEY SALINE.

The Posey saline is on the west side of Neches River, about 1 mile north of Stills Creek and 15 miles east of Palestine. It is marked by a flat, open prairie covering an area along the river of about 250 acres, which is dotted here and there by scalds, areas barren of vegetation, quagmires, soft wet boggy areas, and ponds. The evaporation of water leaves an incrustation of salts on the surface in certain areas. A large sulphur spring (Big Sulphur Spring) issues near Stills Creek, 1 mile southwest of the saline. It is in a low swampy area and flows a bold stream of water highly charged with hydrogen sulphide gas, which decomposes at the surface, causing the precipitation of quantities of white amorphous sulphur. A similar but smaller sulphur spring (Little Sulphur Spring) issues near the northeastern edge of the saline, on the bank of Neches River. Half a mile northwest of Little Sulphur Spring is the so-called soda spring, where, it is reported, soda was made by evaporating the water during the Civil War. North of the saline is an "island" or mound in the low land along Neches River. It is a comparatively small, flat-topped area about 6 to 8 feet above the bottom land. It is cut off from the high land by a slough that represents an old channel of Neches River. The "island" is a remnant of a terrace slightly elevated above the present river bottom. The salt incrustations formed at this saline consist of a mixture of alkaline carbonate and alkaline chloride.

This is a typical saline, but so far as surface evidence shows it is not a salt dome, as the strata in the surrounding area are not highly disturbed and there is nothing in the topography to suggest an uplift. The peculiar features of the saline are due to the presence of mineralized water. It is likely that this saline is situated near a fault which permits mineralized waters to reach the surface. If there has been any doming of the strata there, it was completed prior to the deposition of the surface formation, which belongs to the Claiborne group.

THE BRENHAM SALT DOME, WASHINGTON AND AUSTIN COUNTIES, TEXAS.

By Oliver B. Hopkins.

INTRODUCTION.

The discovery of heavy, tarlike oil in a shallow water well near the Washington-Austin county line, 9 miles southwest of Brenham (see Pl. XXII) led to drilling for oil there. A local company, the Brenham Oil Co., was formed and in the spring of 1915 drilled a well that showed such favorable indications of oil and gas that a second well was drilled, and this has yielded 4 to 6 barrels a day for almost two years. The completion of this small well led to the leasing of large areas in the vicinity and started the drilling of 12 additional wells, making altogether 14 that have been drilled to the present time (April, 1917). With the exception of the small oil well and the discovery of gas in another well, which "blew out" and finally became choked, the results of the drilling have been discouraging, except that they have demonstrated the presence of a salt dome.

At the request of residents of the vicinity of Brenham, who were interested in the development of the area and who volunteered to furnish all the available well logs and samples for study, an investigation was undertaken by the United States Geological Survey to determine whether the structure of the area could be determined from surface study and from the well records and whether any geologic assistance could be given in the development of the area. The results of the studies have been largely disappointing, as they fail to throw much light on the probable presence and location of oil there. It is hoped, however, that the information set forth here may be of value to those who may continue drilling in this area.

LOCATION AND TOPOGRAPHY.

The Brenham salt dome lies along the Washington and Austin county line, 9 miles southwest of Brenham and about 70 miles northwest of Houston, Tex. It is most easily reached from Brenham, which is on the Atchison, Topeka & Santa Fe and Houston & Texas Central railways.

The country is a rolling prairie with a general altitude of 300 to 450 feet above sea level. The hills are mostly grass covered and treeless and have gentle rounded slopes. The structural dome is situated between the valleys of Williams and East Mill creeks, and although its crest is believed to occupy high ground, it does not occupy the highest ground in the area, probably because of its proximity to the two creeks mentioned. Topographically it is not a conspicuous feature, like the "mounds" on the low, flat prairie near the coast, although the details of the drainage may suggest to the trained observer the presence of a salt dome.

GEOLOGY.

SURFACE GEOLOGY.

The Brenham salt dome (Pl. XXIV) is near the middle of a belt of the Lagarto clay, which extends southwestward from Brazos River past Brenham and Cuero to and a short distance beyond San Antonio River.[1] A partial list of the geologic formations that lie below the Lagarto clay is given in the accompanying table.

The Lagarto clay consists dominantly of clay and sandy clay, which are gray or green when fresh and which weather into a black plastic clay, and lenticular beds of cross-bedded sand and soft sandstone. The cross-bedding and lenticularity of the beds make the structure of the area in which they crop out difficult or impossible of determination. There are chalky beds and beds with numerous chalky concretions which may be traced short distances where the rock exposures are exceptionally good. Outcrops of this formation surround the Brenham dome and cover its entire area, with the possible exception of a few small exposures of coarse-grained pebbly sand with waterworn Cretaceous fossils in the bed of Williams Creek, one-third of a mile south of the center of drilling operations. This sand may represent the base of the Lagarto clay or the top of the underlying Oakville sandstone. Deussen[2] reports that near Halstead, 6 miles east of LaGrange, at the base of the Lagarto clay, which rests unconformably on the Oakville standstone, there is a bed of gravel with worn Cretaceous shells. It is possible that these exposures represent the same beds, which are elevated in the area of this dome sufficiently to bring them to the surface where normally they would be several hundred feet below it.

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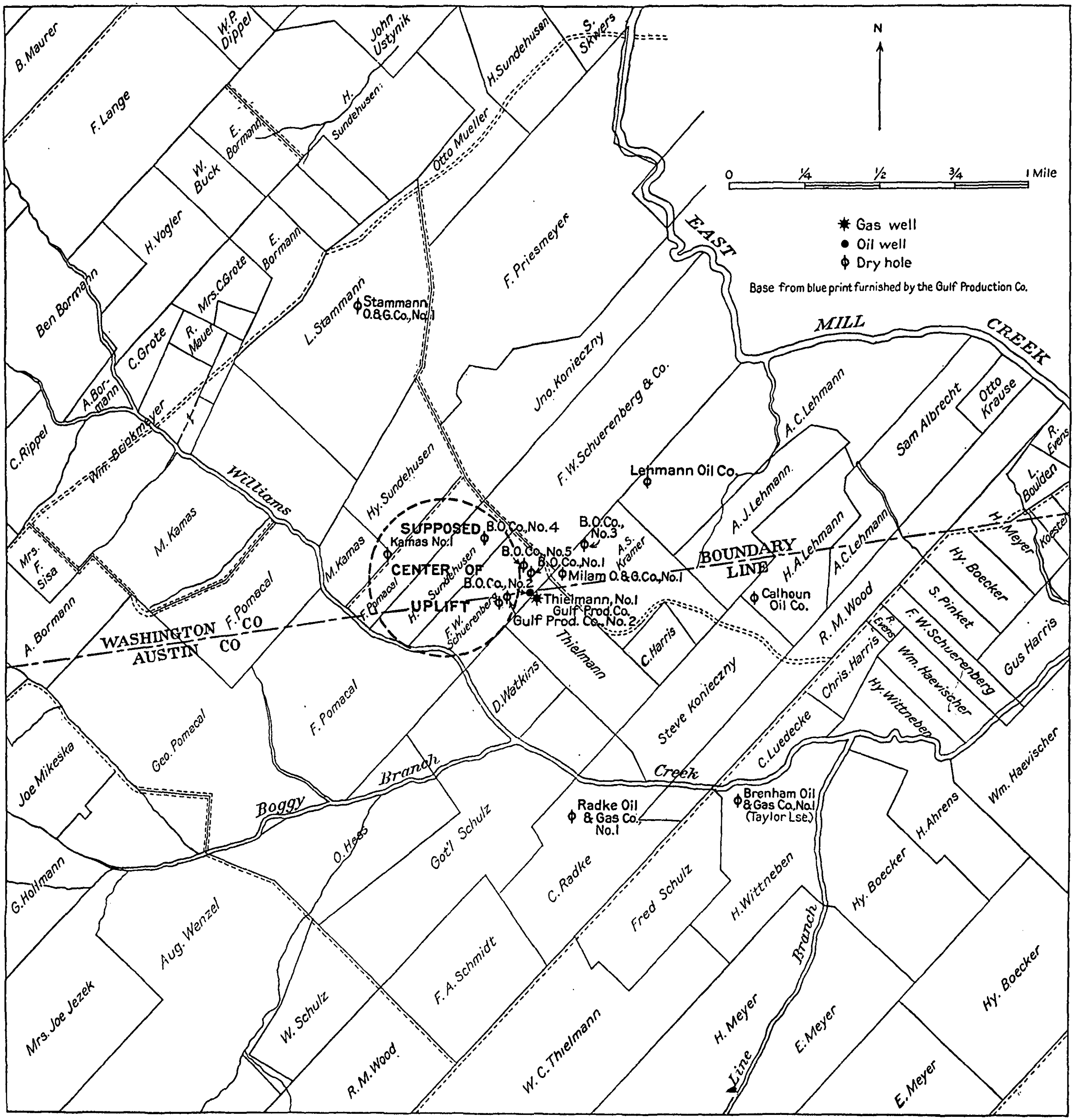
[1] The distribution of this formation is stated as shown on an unpublished map of the Coastal Plain of Texas west of Brazos River, by Alexander Deussen.

[2] Deussen, Alexander, op. cit.



MAP OF THE BRENHAM SALT DOME, TEX.

Partial geologic section exposed in the Coastal Plain of Texas west of Brazos River.[a]

System.	Series.	Formation.	Thickness.	Lithology.
Tertiary.	Pliocene.	Lagarto clay.	*Feet.* 200-400	Clay with lime concretions and calcareous cross-bedded sand. Clay light-colored or green when fresh, black on weathering.
		Lapara sand.[b]	50-100	Sand and clay, interbedded; clay red, green, and pink.
	Miocene.	Oakville sandstone.	200-300	Sandstone, gray, soft, calcareous in places; some clay lenses.
	Oligocene.	Catahoula sandstone.	200	Sandstone, hard, blue, quartzitic; green, blue, brown, and white clay; and gray cross-bedded sandstone.
	Eocene.	Frio clay.	500	Clay, green and pink, with small lime nodules; beds of volcanic ash; beds of brown marl in lower part.
		Fayette sandstone.	800	Sandstone and sand, gray; brown and lignitic clay; volcanic ash and white kaolin-like clay.
		Claiborne group. Yegua formation.	600-720	Clay, dark green and brown, lignitic; sand, yellow and dark colored; lignite.
		Claiborne group. Cook Mountain formation.	700-800	Greensand, greensand marl, iron ore, lignite, lignitic clay, clay, sandstone, and sand. Glauconitic sand and clay predominate.
		Claiborne group. Mount Selman formation.	600-700	Sand, dark green and brown; thin seams of iron ore; lenses of lignite and clay; beds generally iron bearing.
		Claiborne group. Carrizo sandstone.	200-450	Sandstone, coarse grained, cross-bedded, calcareous in part; coarse quartzitic sand and fine-grained micaceous sandstone.
		Wilcox formation.	350-650	Sand lenses, sandstone, clay, sandy clay, and lignite.
		Midway formation.	260	Clay and limestone of marine origin.
Cretaceous.	Gulf (Upper Cretaceous).	Navarro formation.	500-600	Marl, bluish black, and glauconitic clay; blue clay with siderite and limonite concretions; yellow and brown sand with hard sandy concretions.
		Taylor marl.	600-700	Clay marl, blue, calcareous. West of Bexar County the Taylor marl is replaced by the Anacacho limestone.
		Austin chalk.	304-500	Chalk, interstratified with thin beds of soft marl.
		Eagle Ford shale.	21-200	Shale and thin arenaceous beds of laminated limestone.

[a] From manuscript report by Alexander Deussen on geology of Coastal Plain of Texas west of Brazos River.
[b] This formation is absent in the area near the Brenham dome.

UNDERGROUND GEOLOGY.

The knowledge of the underground geology in the area of the Brenham dome is obtained from the 14 wells that have been drilled there. The character and thickness of the beds penetrated in these wells are shown in Plate XXV, which shows five representative well records, arranged roughly in an east-west line across the dome. It is not possible to divide the beds as shown in the well records into the formations that have been recognized at their surface outcrops, as the materials lack distinctive features.

Shells submitted by Alexander Deussen from the Brenham Oil Co.'s well No. 1 (Schuerenberg lease), from a depth of 1,275 to 1,360 feet, were examined by C. W. Cooke and identified as probably of Cook Mountain age. A larger collection from this well at a depth of 1,294 to 1,319 feet was determined by C. L. Baker as of Cook Mountain age, thus proving that that formation had been reached. Mr. Baker also recognized the greensand marl found at 1,600 feet in the Gulf Production Co.'s No. 1 Thielmann well as Cook Mountain. Other fossils of Claiborne (Eocene) age were identified by Mr. Baker from the Brenham Oil Co.'s well No. 2, and from the Milam Oil & Gas Co.'s well No. 1.

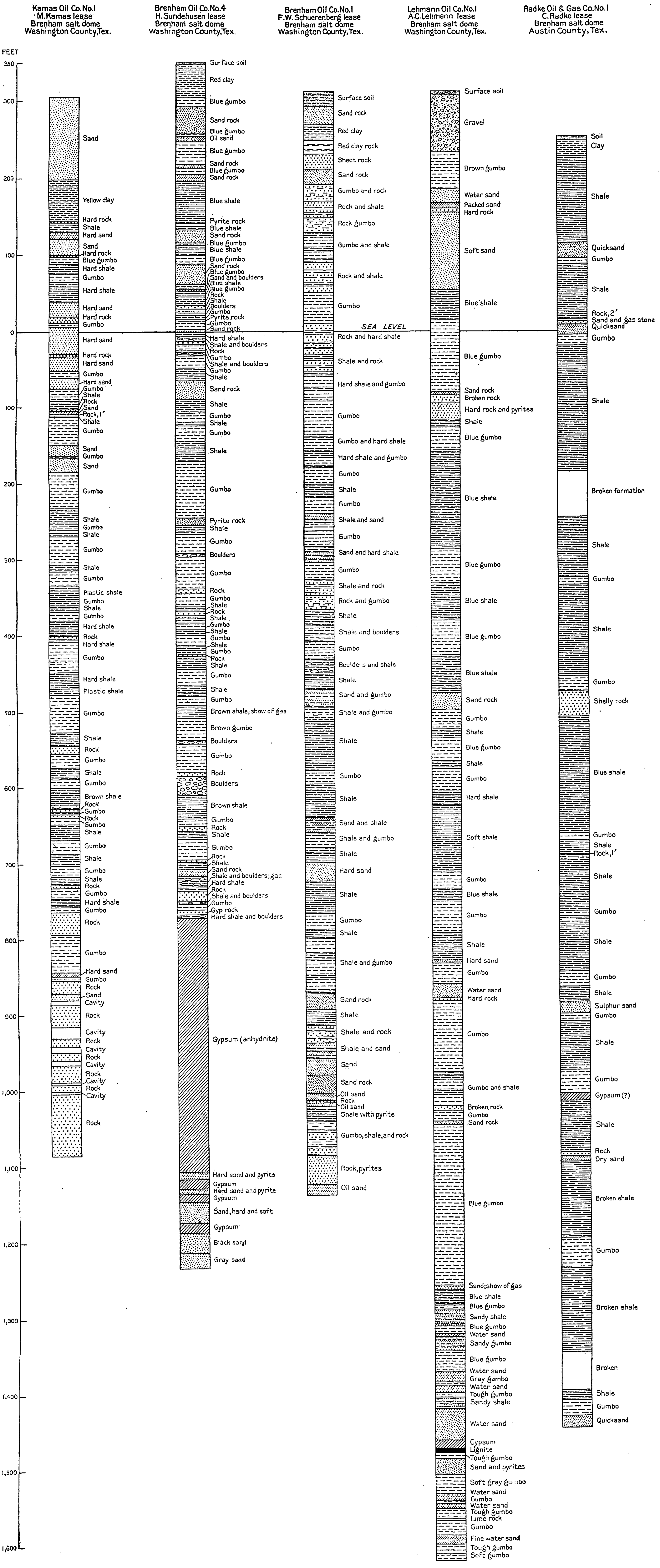
The minimum thickness of the formations between the base of the Lagarto clay and the Cook Mountain formation is, according to Deussen, 2,300 feet, and as the wells here start in the Lagarto and reach the Cook Mountain at 1,300 to 1,600 feet, either the intervening formations must be locally much thinner than the normal or some of them must be absent, a condition which suggests the uplift and erosion of this area between the periods of deposition of the Cook Mountain and Lagarto formations.

Brown gumbo and streaks of lignite, which may belong to the Yegua formation, were found in well No. 1 of the Brenham Oil Co. at a depth of 861 to 996 feet, in No. 2 at 1,027 to 1,067 feet, in No. 3 at 1,262 to 1,282 feet, and in well No. 1 of the Kamas Oil Co. at 905 to 932 feet. The Brenham Oil Co.'s well No. 4 penetrated gypsum (largely anhydrite) from 1,113 to 1,500 feet, and sand and some gypsum from 1,500 to 1,587 feet.

Gray sandy clay, secondary (?) limestone, and gypsum are reported from the Brenham Oil Co.'s well No. 5 at a depth of 1,360 to 1,395 feet, also a salt-water flow, which was not reported from any of the neighboring wells.

The second test of the Gulf Production Co. (not numbered) was abandoned at 1,296 feet in a porous rock which absorbed the return fluid and made deepening impossible.

Gypsum was reported from the Gulf Production Co.'s well No. 2 (Schuerenberg tract) at depths of 1,303 to 1,312 and 1,354 to 1,392 feet, and rock salt at 1,392 to 1,442 feet. Numerous fragments of cuttings from the slush pit of this well were tested and found to be chalk. However, the absorption of the return fluid by the beds at depths near 1,442 feet, the depth at which the well was abandoned, indicates clearly that the core of secondary minerals of the salt dome had been reached. Returns were also lost in the Kamas Oil Co.'s well No. 1 at different levels from 1,185 to 1,390 feet, where the well was abandoned. It is likely that the rock reported from these intervals is secondary limestone or gypsum.



WELL LOGS ARRANGED ALONG AN EAST-WEST LINE ACROSS THE BRENHAM SALT DOME, TEX.

The secondary limestone, gypsum, and salt are typical of salt domes, and their presence in this area indicates the presence of a dome of that type. Drilling indicates that the core of secondary minerals comes nearest to the surface on the Kamas, Sundehusen, and Schuerenberg tracts, which may represent approximately the center of the uplift.

Fresh, potable water was abtained in a well a short distance west of the Milam Oil & Gas Co.'s well No. 1 at a depth of 525 feet.

EVIDENCE OF SALT DOME.

The evidence of a salt dome in this area includes (1) the presence of Cook Mountain fossils 600 to 900 feet nearer the surface than is normal for this area, (2) the marked differences in the strata found in neighboring wells, (3) the apparent discordance in the dip of the surface and underlying beds, (4) the presence of shallow oil, (5) the presence of porous beds that absorb the return fluid and make drilling difficult or impossible, and (6) the occurrence of secondary limestone, gypsum, and salt (?). As examples of the marked differences in the character of the strata encountered in neighboring wells may be mentioned the salt water found in the Brenham Oil Co.'s well No. 5 and not in any of the surrounding wells; "quicksand," which caused the abandonment of the well, found in the second test boring of the Gulf Production Co. and not found in that company's well No. 2 near by; and gypsum found in Brenham No. 4 and not in neighboring wells at the same depth. The occurrence of porous material, such as limestone or gypsum, in which the returns are lost, is good evidence of the presence of a salt dome.

STRUCTURE.

A study of the surface outcrops around the Brenham dome shows that the beds have not been highly deformed but dip gently away from the center of the uplift. This is particularly noticeable on its north side, where the exposures are best. Because of the obscurity and scarcity of exposures and because the principal folding had taken place prior to the deposition of the surface formation, the shape and extent of the uplift can not be determined from surface study. Fossils from wells drilled here show that the Cook Mountain formation is reached at about 1,300 feet, near what is considered the center of the uplift, whereas this formation should normally be about 2,000 to 2,200 feet below the surface and has therefore been uplifted 600 to 900 feet. It is evident that this formation dips away steeply from the crest of the uplift and that there is a wide discordance in dip between the Cook Mountain and the surface formation. It is impossible to correlate with certainty the beds represented in the well logs and thus to determine the amount of dip. If the shallow oil sand found at about 100 feet in nearly all the wells near the center of development is the same in the different wells, the results are entirely consistent; the dip is 160 feet to the mile to the east from the Brenham Oil Co.'s well No. 4 to the Milam Oil & Gas Co.'s well No. 1; 207 feet to the mile from the Brenham Oil Co.'s well No. 4 to No. 3; and 244 feet to the mile from the Brenham Oil Co.'s well No. 4 to the Gulf Production Co.'s well No. 2. These figures suggest that the dip is to the northeast, east, and southeast from Brenham well No. 4, which may be near the center of the uplift. If the oil sand in Brenham well No. 1 is the same as in No. 2 the dip is to the south at about 900 feet to the mile. This may or may not be the correct dip.

A tentative correlation of the lignite and brown shale was made, but the results did not harmonize with the supposed facts, and they are therefore believed to be unreliable for the determination of the structure.

The folding associated with salt domes is so intense that regular quaquaversal structure is in most places much complicated by faults. It is therefore difficult and usually impossible to outline even the major structural features of a salt dome without numerous records of well-distributed borings. Such records are not yet available for this dome. It seems likely, however, that the crest of the dome is near well No. 4 of the Brenham Oil Co., which penetrated several hundred feet of gypsum, although possibly, as this well penetrated sand below the gypsum, it is not on the crest, and the gypsum found here is a tongue projecting from the main mass. The supposed center of the dome is indicated on the accompanying map. The wells within the area shown encountered either gypsum or some porous stratum that absorbed the fluid in the hole and prevented any returns reaching the surface.

Deussen[1] pointed out that this dome is in a general line connecting the Steen dome east of Lindale, the Brooks dome west of Bullard, the Keechi and Palestine domes in Anderson County, and the Butler dome southeast of Butler. This line roughly parallels the Balcones fault.

WELLS DRILLED.

BRENHAM OIL CO.

Well No. 1 (on Schuerenberg lease), drilled in 1915 to depth of 1,451 feet. Shallow oil reported at 108–112 feet; deep oil sand at 1,319–1,328 and 1,438–1,451 feet. Six-inch casing set at 1,320 feet. Well dry but made showing of oil and gas.

Well No. 2 (on Schuerenberg lease), depth 1,372 feet. Oil sand reported at 1,358–1,361 and 1,363–1,372 feet. Well pumped for about two years; yields

[1] Deussen, Alexander, op. cit.

4–6 barrels of oil of 40°–41° Baumé. This was the only productive well in the field in 1916. No secondary minerals were recognized in the cuttings.

Well No. 3 (on Kramer lease), drilled in 1915, and abandoned at depth of 1,686 feet in shale. Shallow oil found at 122–123 feet. No promising indications were found in the lower beds.

Well No. 4 (on Sundehusen lease), depth 1,587 feet. Encountered shallow oil at 98–104 feet and penetrated gypsum (largely anhydrite) from 1,113 to 1,500 feet. Yielded a flow of mineralized water at 1,587 feet.

Well No. 5 (on Schuerenberg lease), depth 1,395 feet. Encountered shallow oil at 104–140 feet, salt water at 1,376 feet, and probably secondary limestone and gypsum at 1,360–1,395 feet.

CALHOUN OIL CO.

Well No. 1 (on H. A. Lehman lease); no information available concerning this well.

GULF PRODUCTION CO.

Well No. 1 (on Thielmann lease), drilled in 1915 to depth of 1,694 feet. Shallow oil found at 108–120 feet, Cook Mountain fossils at 1,600 feet. Well blew out at about 1,573 feet and raised the 4-inch drill stem out of the well but became choked within a few days. Showing of oil and gas reported at 1,576–1,578 feet. This well yielded more gas than any other in the area.

Lost hole (on Schuerenberg lease, well not numbered), depth 1,296 feet. Cook Mountain fossils identified by J. A. Udden from depth of 1,140–1,150 feet. "Quicksand" near bottom which absorbed returns and caused the hole to be abandoned.

Well No. 2 (on Schuerenberg tract), depth 1,442 feet. Gypsum reported at 1,303–1,312 and 1,354–1,392 feet, and rock salt at 1,392–1,442 feet. Lower beds absorbed returns. No gypsum found in the slush pit.

MILAM OIL & GAS CO.

Well No. 1 (on Kramer lease), depth 1,756 feet. Showing of heavy oil at 104–107 feet, salt water at 1,686–1,693 feet. No indications of importance found.

KAMAS OIL CO.

Well No. 1 (on Kamas lease), drilled in 1915, abandoned January, 1916; depth, 1,390 feet. Returns lost between 1,190 and 1,390 feet, probably in porous gypsum or cavernous limestone.

LEHMANN OIL CO.

Well No. 1 (on Lehmann lease), depth 1,933 feet. Lignite reported at 1,786–1,790 feet. No secondary limestone or gypsum found; no indications of importance.

RADKE OIL & GAS CO.

Well No. 1 (on Radke lease), drilled by Badgett & Mulloy; depth 1,700 feet. Cuttings mostly loose gray sand and pink and green clay. Well flows small stream of fresh water; no showing of oil or gas reported.

STAMMANN OIL & GAS CO.

Well No. 1 (on L. Stammann lease), drilled and abandoned in 1915; no casing set; depth 1,500 feet. Showing of gas reported at 1,030 and 1,226 feet.

OCCURRENCE OF OIL.

In the Brenham dome tarlike oil has been found in small quantities at a depth of about 100 feet in most of the wells on and near the F. W. Schuerenberg lease, and in the same area oil has been found at depths of 1,319–1,451 feet in the Brenham Oil Co.'s well No. 1, and at 1,358–1,372 feet in well No. 2 of the same company.

Well No. 2 has yielded 4 to 6 barrels of oil a day for about two years. The oil is dark green, has a gravity of 40°–41° Baumé, and when freshly pumped is fairly liquid. On standing in an open tank a few days it loses a considerable part of its volatile constituents, and when cooled to 35° to 40° F. it solidifies, and a layer of semisolid oil, like axle grease, forms on the surface. On standing in a sealed bottle the heavy constituents settle to the bottom.

The heavy oil found at about 100 feet is probably in the Lagarto clay or possibly in the Oakville sandstone. As these formations are not known to contain oil at any locality and are not known to be bituminous, it seems likely that this oil has seeped upward from some underlying formation, although it is difficult to explain why some of the underlying sands do not show oil, and particularly why the sand at 525 feet, which yields fresh, potable water, has not been polluted by such an upward migration.

The evidence from fossil shells shows that the oil in the deep sand comes from the Cook Mountain formation, which has yielded a small quantity of oil at Oil City, Nacogdoches County, and at Crowther, McMullen County. It seems probable, therefore, that the oil in the Cook Mountain is indigenous. If this inference is true, it has an important bearing on the problem of the possible discovery of commercial pools of oil here.

The table on page 273 shows the position, lithology, and approximate thickness of the formations above and below the Cook Mountain. The oil from the salt domes of the coastal region of Texas—Humble, Sour Lake, Batson, and others—is believed by many geologists to come from sands above the Cook Mountain. If this is true, the sands which are oil bearing in those domes will probably not be so in this area, as these sands have been penetrated by a number of wells here without promising results. The Navarro formation is the next known oil-bearing formation below the Cook Mountain. The intervening beds, however, contain much sand and carbonaceous matter at their outcrops, and it is quite possible that some one of them may be found to contain oil under favorable structural conditions, such as probably exist here. The Nacatoch sand member of the Navarro formation yields gas in the Mexia-Groesbeck field and oil in the Corsicana field. If the thicknesses given on Plate XXV are applicable to this area, the Navarro may be reached here at about 3,500 feet.

However, faults and unconformities within the intervening formations, such as are indicated in the Palestine and Keechi domes, in Anderson County, may make any estimate unreliable. It is not known whether the Navarro is petroliferous in this area, or even whether it contains sand here.

According to some geologists, the oil in the salt domes of the coast is adventitious and is derived through faults from underlying formations, probably of Cretaceous age. If this is true, it is probable that oil may be found here under similar conditions. Oil is commonly found in porous limestone, or in sands overlying or tilted up against the salt core. The overlying sands in the Brenham dome have been drilled through at several places and yield a small quantity of oil in well No. 2 of the Brenham Oil Co. It seems doubtful whether these sands, which appear to be thin, contain oil in commercial quantities on or about this dome. The porous limestone also has been reached in several wells, notably in Kamas Oil Co. No. 1; but as it has not yielded oil in any of the wells, its possibilities are not encouraging. Below the porous secondary limestone, the "cap rock," gypsum is commonly found, and salt below that. This being true, it is probably useless to drill deeper when the limestone is reached and the general succession of materials is established. The remaining possibility is to find oil in sands or other porous beds tilted up around the flanks of the salt core. Oil is found at Humble both in the "cap rock" and in steeply inclined sands on the flank of the dome. The absence of oil in the "cap rock" in the Brenham dome does not necessarily mean that oil will also be absent in the surrounding sands, although it suggests that possibility.

SUGGESTIONS REGARDING FURTHER DRILLING.

If the inferences set forth in the preceding paragraphs are well founded, the sides and not the crest appear to be the most favorable parts of the Brenham dome for oil. A number of wells have already penetrated the sediments overlying the central mass of limestone and gypsum, and some have penetrated parts of the limestone with unfavorable results. If more wells are drilled they should be located on the flank of the dome, where the drill will miss the central core of secondary limestone and gypsum and will penetrate older beds below the Cook Mountain formation, as shown in Plate XXIV. It is possible that tongues of limestone and gypsum, which may be easily penetrated, may extend into the sedimentary beds from the central core. Such tongues may have been reached by Brenham Oil Co.'s well No. 4, which encountered sands below several hundred feet of gypsum. There is no good geologic reason why this well should not have been deepened so long as it did not encounter the central core of gypsum.

It seems unlikely that a deep test boring within the area marked "supposed center of uplift" on the accompanying map would be successful, as it would probably encounter the central core of limestone and gypsum at 1,000 to 1,200 feet. Although the shape and size of this core have not been determined, it is believed that wells located on the south or southeast side of the uplift and within 1,000 to 2,000 feet from the outline of the supposed center of uplift would have the best prospects for success. Wells here would probably reach the Cook Mountain formation at a somewhat greater depth than on the crest of the uplift, and deeper drilling than has been done will be necessary to test this area.

In the Brenham dome, as in most other salt domes, drilling is attended with many uncertainties and should not be undertaken without full knowledge of them. Failure to find oil in commercial quantities in the porous limestone, the "cap rock," and the sands overlying the crest of the dome makes deeper drilling necessary, with its increased costs and risks.