BULLETIN

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UNIVERSITY OF TEXAS

1916: No. 66

NOVEMBER 25 1916

Bureau of Economic Geology and Technology

J. A. Udden, Director

The Thrall Oil Field

BY

J. A. UDDEN and H. P. BYBEE

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E. P. SCHOCH

THE CHEMICAL COMPOSITION OF THE PETROLEUMS OBTAINED AT THRALL, TEXAS

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Published by the University six times a month and entered as second-class matter at the postoffice at AUSTIN, TEXAS

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

Sam Houston.

Cultivated mind is the guardian genius of democracy. . . . It is the only dictator that freemen acknowledge and the only security that freemen desire.

'President Mirabeau B. Lamar.

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THE THRALL OIL FIELD

Location

The Thrall oil field is located about one mile southeast of Thrall, which is in Williamson County, on the International & Great Northern Railroad. It lies in the Black Prairie region, which has a gently undulating surface with a heavy black soil. The surrounding territory has a relief of less than three hundred and twenty-five feet, while in the oil field proper there is less than sixty-five feet of relief. A small branch of Brushy Creek flows in a south-easterly direction across the field. It is this small valley that gives relief to the field and facilitates the storage of water to be used in drilling.

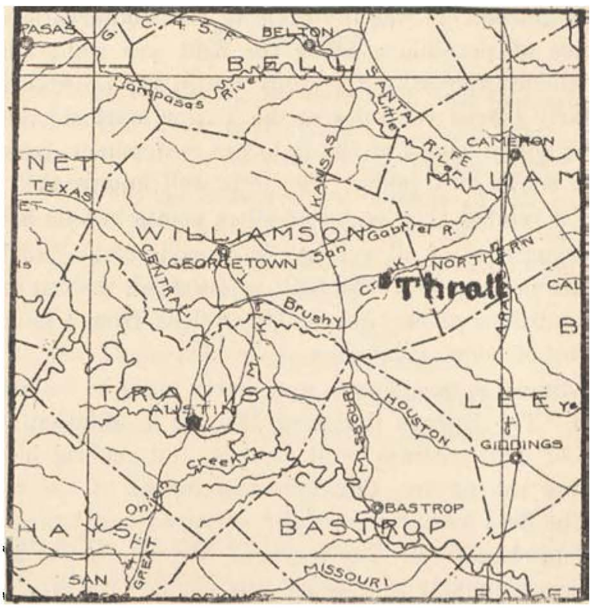

Figure 1....Location of the Thrall oil field.

History

In 1914, Mr. Fritz Fuchs attempted to drill for water in the southwest corner of his one hundred acre farm on the Daniel

Kimbro Survey. Little or no water was found, but there was a considerable amount of oil in the well at a depth of about three hundred feet. In February of 1915, arrangements were made to drill deeper for oil; and on February 22, 1915, the "discovery well" was brought in. During the next four months the development of the field proceeded rapidly.

Quite early in the development of the field the senior author of this paper discovered that the oil in one of the wells came from a green igneous rock. In a thin slide made of some of the cuttings of the green rock that had been submitted by one of the early operators as the "pay rock," he saw outlines of crystals of augite, and noted that magnetite and pseudomorphs of olivine occurred in association with what appeared to be spherulitic structures.*

The importance of making a detailed study of this field was early recognized. It was desirable to make observations on the occurrence of petroleum, while the field was being developed. The economic interest of the study lay in the possible existence of similarly placed volcanics in the Taylor Marl at other points along the entire length of the Balcones escarpment, from east of Waco to south of Uvalde. For it is well known that volcanic rocks of a related type occur at other points in this belt.

The occurrence of oil and gas in igneous rock is such an unusual phenomenon, and is so little understood, that an exposition of the conditions present in the Thrall field, from a purely scientific point of view also, seem desirable.

Accordingly arrangements were early made to collect data in the field. The Bureau first sent Mr. W. F. Bowman to collect samples of drill cuttings, well records, and general information concerning the nature, thickness and extent of the oil-bearing rock. The field was also carefully surveyed and topographically mapped by Mr. W. D. Dockery and Mr. H. E. Gatlin. Later, the junior author of this paper was engaged to take charge of the field work, after Mr. Bowman had left the Bureau to engage in private work.

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*Thrall Oil in Serpentine, by J. A. Udden, The Oil and Gas Journal, Tulsa. Oklahoma; April 22, 1915.

Oil in an Igneous Rock, by J. A. Udden, Economic Geology, Vol. X, pp. 582-585.

Acknowledgments

The Bureau of Economic Geology has received the cordial co-operation of all parties concerned in the development of the Thrall oil field in the securing of well logs, samples of borings. and data on production. Special acknowledgments are due to Mr. J. T. Bailey, manager of the Corsicana Petroleum Company; Mr. Thomas Burns, manager and part owner of the Taylor Oil and Gas Company; Mr. Murphy, of the Murphy Oil and Gas Company; Mr. C. L. Witherspoon, of the Bowers & Witherspoon Oil Company; and Mr. Fritz Fuchs, discoverer of the Thrall oil. Obligation to other parties who have helped in the work is acknowledged elsewhere in the text.

GEOLOGY

Stratigraphy

The rocks that outcrop in the Thrall oil field generally have been referred to the upper part of the Cretaceous system, representing apparently the upper part of the Taylor marl.*

All of the formations explored by borings in the course of development of the field belong to the Upper Cretaceous System of Texas, and to the uppermost part of the Comanchean Cretaceous, as shown in the following table:

Upper Cretaceous	Taylor Marl
	Austin Chalk
	Eagle Ford Shale
Comanchean Cretaceous: Buda Limestone	

Comanchean Cretaceous

The oldest rocks penetrated by the drill in the course of the development of the field are, as already has been stated, of the upper part of the Comanchean. Mr. Fritz Fuchs reports that in

*Report on the Cretaceous Area north of the Colorado River, by J. A. Taff, Third Annual Report of the Geological Survey of Texas, pages 354-363; and Geography and Geology of the Black and Grand Prairies, by R. T. Hill, 21st Annual Report of the United States Geological Survey, Part VII, page 336.

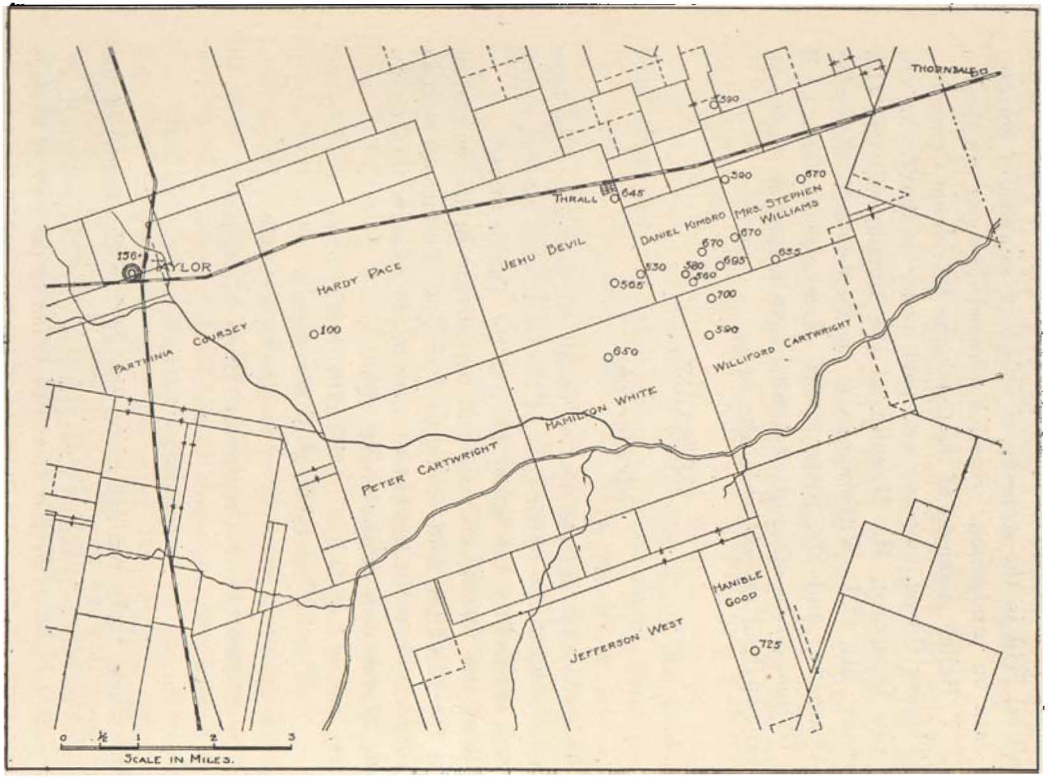

Figure 2....Map showing locations of wells known to have been drilled into the Austin Chalk in and near the Thrall oil field. Figures indicate depth of the upper surface of the Austin Chalk below sea level.

drilling well No. 175-a,* the drill passed the base of the Austin Chalk at a depth of 1630 feet, into a series of clays, shales, and thin-bedded rock, which was about 150 feet in thickness. This boring finally stopped in a very hard lime rock at a depth of 1790 feet. While none of the cuttings from this hard limestone was obtained, it is believed that the clays and shales were the Eagle Ford shale, and that the hard limestone was the Buda.

Upper Cretaceous

Eagle Ford Shales

In the above paragraph it was noted that the drill passed through a series of clays, shales and thin-bedded rock in First Thrall 26, our number 175-a. This appears to have been the Eagle Ford shale.

No further data are at hand from the field on the formations below the Austin Chalk.

Austin Chalk

Several wells penetrated the Austin Chalk, giving some information as to its position, thickness, depth below the surface, and the direction and amount of dip of the formation. The small map on this page has been prepared to show the approximate locations of these wells. The figures give the elevation of the top of the Austin Chalk with respect to sea level, in each case. The following table gives the name of each of the wells from which data on these points have been taken, their serial numbers in our list of wells, and the elevation of the top of the Austin Chalk with respect to sea level, in each case:

*In the following discussion references will be made to borings in this field by serial numbers which have been given to all those explorations on which any data have been secured. The locations of these wells will be found on a general map of the field, Plate 1, and the data secured on each well will be found in the List of Borings, in the appendix; the serial numbers on the map and in the appendix being the same.

TABLE SHOWING THE WELLS THAT HAVE BEEN DRILLED INTO THE AUSTIN CHALK.

Serial well number	Name of Lease	Elevation of well curb, in feet	Elevation of the top of Austin chalk, with respect to sea level, in feet
25	Corsicana Petroleum Company No. 25	485	-695
39	Corsicana Petroleum Company No. 39	490	-670
62	Corsicana Petroleum Company No. 62	490	-670
101	Taylor Oil and Gas Company No. 31	526	-580
115	Taylor Oil and Gas Company No. 45	520	-560
146	Murphy Oil Company No. 11	500	-700
224	Jacksonville-Thrall Oil Company No. 1	554	-645
208	Giddings Taylor Oil Company No. 1	500	-585
209	Guffey Petroleum Company No. ?	497	-590
216	Bowers & Witherspoon Oil Company No. 1	501	-530
229	Fritz Fuchs Oil Company No. ?	500	-570
175 a	Fritz Fuchs Oil Company (?)	450	-840
230	Fritz Fuchs Oil Company	540	-695
	Bowers & Witherspoon Oil Company (M. R. Kennedy Farm)	475	-670
	Robert Evans Oil Company (E. Phillips farm, H. Goode Survey)	500?	-725
	J. Zeischang farm (H White Survey)	500	-650
	Dr. C D. Johnson farm (F. Bradley Survey)	550	-590
	Deep well at Taylor, Texas	550	-150

A study of the foregoing table in connection with Figure 2 on page 10 indicates that the descent of the top of the Austin Chalk is about 83 feet to the mile in an easterly direction and possibly fifteen feet to the mile to the south. The average depth to the Austin Chalk, in the Thrall field, is at least 645 feet below sea-level.

The only available record of the thickness of this formation shows that it is four hundred and fifty feet. The upper surface is more or less uneven, unless it has happened that the drillers have differed in judging of the change. As there are some chalky layers in the lower beds of the Taylor Marls, differences in determining the position of the contact of the two formations are quite probable.

The Taylor Marl

In his report on the Upper Cretaceous etc.* J. A. Taff has commented on the uniformity of these beds which were then known as the Blue Marl. He says: "The Blue Marl is the final division of the Cretaceous system in Texas. It presents a

*See Third Annual Report of the Geological Survey of Texas, p. 279.

series of beds remarkable for their persistency and homogeneity of deposits. The Austin limestone ends in a chalky lime marl, which grades gradually into the Blue Marl. This marl continues upward for nearly one thousand feet with but little lithologic or faunal change. The body of this deposit, from the base almost to the top, occurs as a continuous deposit from the Colorado to the Red River. The upper layers, however, show slight changes northward from the Colorado. In Navarro County the upper arenaceous or glauconitic bed is nearly five hundred feet thick."

Later these marls were, however, subdivided by R. T. Hill into the Taylor Marls and the Navarro beds. This author remarks that owing to lack of outcropping sections for measurements, it is difficult to ascertain the exact thickness of the lower formation or to separate it from the overlying Navarro, the Navarro being the upward continuation of the Taylor Marls, and the one passing into the other by gradual transition. He also states that the chief lithologic differences are that the clays, chalks and sands composing the Navarro formation contain more or less sand and glauconite, while the Taylor Marls are apparently more free from these substances.*

On the general map accompanying Hill's report the boundary between these two formations is drawn close to, and apparently slightly north of, the site of the Thrall oil field.

With our present indefinite knowledge of the limits between the two formations it is neither advisable nor desirable to attempt any precise location of this surficial boundary near the field. It will suffice to say that at a point on the Brushy, due south from the field, some sandy and glauconitiferous marl is exposed which no doubt should be referred to Hill's upper division of these sediments; and also that these sandy beds have not been noted either in surface exposures or in cuttings from the upper part of any of the borings in the oil field.

The Taylor Marl Below the Igneous Rock

Most of the drilling done in the field naturally extended only into the igneous rock, which contains the oil, and which lies in

*Geography and Geology of the Black and Grand Prairies, etc., XXI An. Rept. Vol. 7, U. S. Geol. Surv., p. 335, et seq.

the lower part of the Taylor Marl. This igneous rock is nearly always called the "oil sand" in the drillers' logs. Very few of the operators or prospectors drilled through and below this rock and records of no more than six such explorations are at hand. These give some idea of the nature of the beds While the data are not as full as is desirable, they nevertheless appear worth summarizing. The facts known are as shown in the following table:

DATA SHOWING THE EXTENT AND NATURE OF THE BEDS BETWEEN THE BASE OF THE IGNEOUS ROCK AND THE TOP OF THE AUSTIN CHALK

Well No.	Depth to top of Austin chalk	Depth to base of igneous rock	Distance between top of Austin chalk and base of igneous rock	Nature of formation as reported
25	1185 feet	877 feet	303 feet	Light gray shale
39	1160	920	240	Hard gumbo
101	1105	In nearby well, 860	245	Gumbo and shale
115	1080	In nearby well, 880	200	Not described
146	1200	In nearby well, 1000	200	Gray shale
175-a	1290	1280	10	Bluish gray shale

Though there possibly are inaccuracies and subjective differences in reporting the logs, it is nevertheless evident that the base of the igneous rock follows the upper surface of the Austin Chalk at a distance averaging about two hundred and forty feet. Well No. 175-a is clearly at a point where there is a downward extension of the igneous rock filling the channel through which the magma was forced up to its present position. The differences in thickness shown in the other five borings can very well be accounted for by differences of reporting, as the hundred feet between the typical Austin Chalk and Taylor Marl are known to consist of alternations of chalk and marl.

A sample of cuttings was obtained from Well No. 25. It was a very fine-grained, fossiliferous, calcareous, light gray shale that was somewhat indurated. It is the only sample examined from this part of the section.

Taylor Marl above the Igneous Rock.

The many explorations made by the drill in the Thrall Oil Field presented an opportunity for securing material for a description of the nine hundred feet, more or less, of marls which immediately overlie the igneous rock in this locality. The observations made show that these beds are quite uniform in character. The logs of borings made by a score of different drillers use no more than nine different designations, most of which are applicable to marly clays, and thin layers of limestone.

Our own inquiries extend along two lines. We have made a comparative study of some of the best well records in the field, and we have made a somewhat close examination of a series of cuttings taken from one single boring, well No. 69.

Study of Twenty Well Records.

Twenty well records that appeared to have been carefully taken were made the basis for the construction of an average section extending up from the top of the igneous rock. It will be understood that this does not make a complete section of the sediments of the Taylor marl, as there are some 240 feet of these marls under the igneous rock.

It was found that the only distinctive designation made for the different materials in this section were: "Cap." "Cap Rock," "Shale," "Gumbo," "Clay," "Surface clay," "Surface," "Rock," and "Hard rock." "Cap" and "cap rock" were used to designate the material immediately on top of the oil-bearing rock. "Surface," "surface clay," and sometimes "clay" designated the surface drift and the surficially altered Taylor marl. "Rock" and "hard rock" were applied to thin limestones. Really "cap rock," "shale," "gumbo," "surface clay," and "rock," seem to represent all types of formations reported.

The score of logs used were numbers 3, 5, 12, 10, 19. 38, 92, 94, 97, 98, 99, 102, 105, 106, 110, 111, 146, 205, 206, and 103, in our serial list. In attempting to make an average section from these twenty records, each log was divided into several parts. The lowest division measured only fifty feet, and included the fifty feet immediately overlying the igneous rock The upwardly succeeding divisions each measured one hundred feet. We then found the number of feet of each kind of sediment reported for each division, taken in the order from below upward, in each of the twenty logs, and ascertained the percentages of these for each division in all the wells taken together. In the table below these percentages are given for each division, from below upward. The divisions are designated in the same order; *a, b, c,* etc.

TABLE SHOWING PERCENTAGES OF DIFFERENT SEDIMENTS IN THE TAYLOR MARLS ABOVE THE IGNEOUS BODY AS DETERMINED BY THE DRILLERS

Per cent shale	Per cent gumbo	Per cent cap-rock	Per cent "rock"	Per cent surface clay	Divisions	Position of division above igneous rock, in feet
70.40	8.70		.77	20.13	h	650–950
85.50	14.40		.10		g	550–650
92 60	6.60		.80		f	450–550
57.10	42.90		.00		e	350–450
50.00	50.00		.00		d	250–350
54 40	45.60		.00		c	150–250
43.00	55.70	1.30	.00		b	50–150
42.10	44.30	10.00	3.40		a	0–50
*49.30	47.70	2.30	.70		a to e	0–450
**74.80	11.80	?	.80	12.60	f to h	450–950
***64.40	27.10	1.70	1.80	6.00	a to h	0–950

*Averages for the 450 feet next the igneous body.
**Averages for the divisions between 450–950 feet above the igneous body.
***General averages for the entire section.

It will be seen that "gumbo" was used as a descriptive term for much more of the material in the lower four hundred and fifty feet than in the upper part of the section, and that "rock" was more frequently reported from the upper half of the section than from the lower half. Shale was more frequently noted in the upper half of the section. "Cap rock" was reported mostly from the lower fifty feet, but singularly enough also, in a few cases, for the interval lying from fifty to one hundred and fifty feet above the igneous body. This is clearly due to the differences in determinations by the drillers, some of whom reported more than fifty feet of cap rock.

About the only other feature of stratigraphic consequence appearing in the study of the logs is the occurrence in some of the borings of a rock that comes up to the surface in the western part of the field, in the wagon-road near well No. 218. Here it is a hard layer of arenaceous limestone, yellow when weathered and of fine texture, measuring from a few inches to a foot or a little more in thickness. In thin section it is seen to contain considerable fine sand, consisting of angular grains measuring mostly about one-eighth mm. in diameter. On fractured surfaces, the rock shows filled tubular structures some two or three mm. in diameter, and these resemble worm burrows. This, or a similar thin rock, was noted in a large number of the logs. It dips to the east. Figure 3, page 17 has been prepared to show the position of this rock with respect to sea-level, by contour lines having an interval of fifty feet. The thin rock lies at an elevation of about five hundred feet above sea-level on the west side of the field, while on the east side it is found at a depth of only three hundred and fifty feet above sea-level. The distance across the field is about one mile and a half, hence

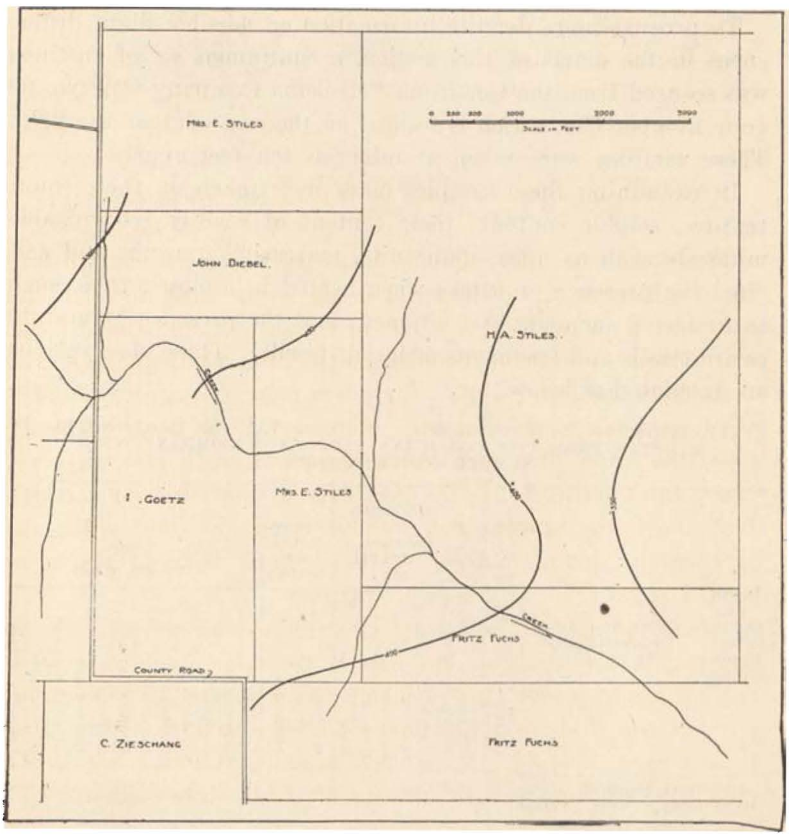

Figure 3....Map showing contours on the upper surface of an apparently continuous thin rock in the Taylor Marl, noted in many wells. Figures represent feet above sea level.

the thin rock slopes eastward at a rate of approximately one hundred feet to the mile. The amount of slope of this rock seems to be greater than that of the Austin Chalk, but this difference may very well be due to inaccuracies of observations recorded in the logs.

The presence of hard rock was noted in many logs. also at other levels, but in many cases no conformity as to depth can be made out for these layers and they are not traceable from one well to another. This indicates that most such rock layers are lenticular and discontinuous.

Section of Corsicana Petroleum Company Well Number 69

To procure more definite information on possible slight differences in the marls of this section, a continuous set of cuttings was secured from the Corsicana Petroleum Company well No. 69 (our number 69), which is located on the east edge of the field. These samples were taken at intervals ten feet apart.

In examining these samples notes were taken on their color, texture, soluble content; their content of readily recognizable minerals such as mica, glauconite, marcasite, gypsum and calcite; the presence of fumes when heated in a closed tube, such as fumes of ammonia and bitumen; and the presence of minute entire fossils and fragments of larger fossils. These observations are tabulated as below.

TABLE SHOWING CHARACTERISTICS OF THE TAYLOR MARL NOTED IN SAMPLES FROM THE CORSICANA PETROLEUM COMPANY WELL NUMBER 69 (OUR NUMBER 69).

Depth of sample in feet below surface	Color and other characteristics of the marl	Texture shown by per cent of sand of total of sample	Per cent of material soluble in hydrochloric acid	Minerals noted, presence indicated by x					Fumes* noted on heating		Fossils noted											
				Marcasite	Glauconite	Gypsum	Calcite	Mica	Bitumen	Ammonia	Textularia	Anomalina	Nodosaria	Globigerina	Cristellaria	Lagena (?)	Frondicularia	Bolivina	Inoceramus	Other pelecypods	Bathocypris	Echinoid spines
0-10	Dark brownish, sticky	6.	16.2	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
10-20	Gray, with yellow spots	.6	--	--	--	--	--	--	--	m	--	--	--	--	--	--	--	--	--	--	--	--
20-30	Dirty gray	.9	--	--	--	x	--	--	--	m	--	--	--	--	--	--	--	--	--	--	--	--
30-40	Dark gray	.1	--	--	--	--	--	--	m	m	--	--	--	--	--	--	--	--	--	x	--	--
40-50	Light, dirty gray	.1	16.2	x	--	--	--	--	l	m	--	--	--	--	x	--	--	--	--	x	--	--
50-60	Light gray	.1	--	x	--	--	--	--	l	l	x	--	--	--	x	--	--	--	--	x	--	x

*Light, l; medium, n; strong, m.

TABLE SHOWING CHARACTERISTICS OF THE TAYLOR MARL NOTED IN SAMPLES FROM THE FIRST THRALL OIL COMPANY WELL NUMBER 26 (SERIAL NUMBER 175-a).—Continued.

Depth of sample in feet below surface	Color and other characteristics of the marl	Texture shown by per cent of sand of total of sample	Per cent of material soluble in hydrochloric acid	Minerals noted—presence indicated by x: Marcasite	Glauconite	Gypsum	Calcite	Mica	Fumes* noted on heating: Bitumen	Ammonia	Fossils noted: Textularia	Anomalina	Nodosaria	Globigerina	Cristellaria	Lagena (?)	Frondicularia	Bolivina	Inoceramus	Other pelecypods	Bathocypris	Echinoid spines
60-70	Gray, with some limestone	.1	---	x	--	--	--	--	n	n	x	--	x	x	x	--	--	--	--	x	--	x
70-80	Bluish gray	.1	----	x	--	x	--	--	n	n	x	--	x	x	x	--	--	--	-	--	--	--
80-90	Light gray	.1	----	x	--	--	--	--	n	n	--	--	--	--	--	--	--	--	--	--	--	--
90-100	Light gray	.1	15.0	x	--	--	--	--	n	m	x	--	x	--	x	x	--	-	--	--	x	x
100-110	Light gray	.1	----	x	--	--	--	--	n	n	x	x	x	--	x	x	--	--	--	--	--	x
110-120	Light gray, with limestone	.1	----	x	--	--	--	--	l	m	x	--	x	--	x	--	x	--	--	--	--	x
120-130	Light gray	.6	----	x	--	--	--	--	l	l	x	x	x	x	x	--	--	--	--	--	--	--
130-140	Light gray	.5	----	x	--	--	--	--	n	n	x	x	x	x	x	--	--	--	--	--	--	x
140-150	Light gray	.1	16.9	x	--	--	--	--	n	n	x	x	x	x	x	--	--	--	--	--	--	--
150-160	Light gray	.1	----	--	--	--	--	--	n	n	x	x	--	--	x	--	--	--	--	--	--	--
160-170	Light gray	.1	----	x	--	x	--	--	n	n	x	x	x	x	x	--	--	--	--	--	--	--
170-180	Light gray	.1	----	x	--	--	--	--	n	m	x	x	x	x	x	--	--	--	--	--	--	x
180-190	Light gray	.1	----	x	--	--	--	--	n	n	x	x	x	--	x	--	--	--	--	--	--	x
190-200	Dirty gray	.7	20.2	x	--	--	--	--	n	n	x	x	x	x	x	x	--	--	x	--	--	--
200-210	Dirty gray	.7	----	x	x	x	--	--	n	n	x	x	--	--	x	--	--	--	x	--	--	--
210-220	Dirty gray	.6	----	x	x	x	--	--	n	n	x	x	x	x	x	--	--	--	x	--	--	--
220-230	Dirty gray	.7	----	x	--	--	--	--	l	m	x	x	--	--	x	--	--	--	x	--	--	--
230-240	Light gray	.8	----	--	x	--	--	--	n	n	x	x	x	--	x	--	--	--	x	--	x	--
240-250	Light gray	1.9	18.8	x	x	--	--	--	l	m	x	x	--	x	--	--	--	--	x	x	--	--
250-260	Light gray	1.5	----	x	x	--	--	--	n	n	x	x	x	x	x	--	--	--	x	x	--	--
260-270	Light gray	2.4	----	x	x	--	--	--	n	n	x	x	x	--	x	--	--	--	x	x	x	--
270-280	Light gray	.6	----	x	x	--	--	--	n	n	x	x	x	--	x	--	--	--	x	x	x	--
280-290	Light gray	1.3	----	x	x	--	--	--	n	n	x	x	x	x	x	--	--	--	x	x	x	--
290-300	**Gray, very fine-grained**	1.5	20.0	x	x	--	--	--	l	m	x	x	x	x	x	--	--	--	x	x	x	--
300-310	Dirty gray	1.4	----	x	--	--	--	--	n	n	x	x	x	x	x	--	--	--	x	x	x	x
310-320	Dirty gray	1.1	----	x	x	x	--	--	n	n	x	x	x	x	--	--	--	--	x	x	--	--
320-330	Dirty gray	.8	----	x	x	--	--	--	----	n	x	x	x	x	--	--	--	--	x	--	x	--
330-340	Dirty gray	.6	----	x	--	--	--	--	n	n	x	x	x	x	--	--	--	--	x	x	x	--
340-350	Dirty gray	1.0	24.4	x	x	--	--	--	----	n	x	x	x	x	--	--	--	--	x	x	x	x
350-360	Dirty gray	1.1	----	x	x	--	--	x	l	n	x	x	x	x	x	--	--	--	x	x	x	--
360-370	Dirty gray	1.9	----	x	x	--	--	--	----	l	x	x	x	x	x	--	--	--	x	--	x	--
370-380	Light gray	1.1	----	x	x	--	--	--	n	n	x	x	--	x	x	x	--	--	x	--	x	--
380-390	Dirty gray	1.1	----	x	x	--	--	--	l	m	x	x	--	x	x	x	--	--	x	--	x	--
390-400	Bluish gray	.8	25.0	x	x	--	--	--	n	n	x	x	x	x	--	--	--	--	x	--	x	--
400-410	Bluish gray	1.2	----	x	x	--	--	--	n	m	x	x	x	x	--	--	--	--	x	x	x	x
410-420	Bluish gray	.9	----	x	x	x	--	x	n	m	x	x	x	x	x	x	--	--	--	x	x	x
420-430	Light gray	.9	----	x	x	--	--	--	n	n	x	x	x	x	--	--	--	--	x	--	x	--
430-440	Light gray	.7	----	x	x	--	--	--	----	n	--	--	x	--	--	x	--	--	--	--	x	x
440-450	Bluish gray	.7	21.0	x	x	--	x	--	n	n	x	x	x	x	--	--	--	--	x	--	--	--
450-460	Dirty gray	.7	----	x	x	x	--	x	n	n	x	x	x	x	--	--	--	--	x	x	x	--
460-470	Light and bluish gray	.1	----	x	x	--	--	--	n	n	x	x	x	x	--	--	--	--	x	--	x	x
470-480	Light gray	.1	----	x	x	--	x	--	n	m	x	x	x	x	--	--	--	--	--	--	x	--
480-490	Light gray	.7	----	x	x	--	x	--	n	m	x	x	x	--	--	--	--	--	x	--	--	x
490-500	Dirty gray	.7	22.8	x	x	--	--	--	n	m	x	--	x	x	--	--	--	--	x	--	x	--
500-510	Light and dark gray	1.1	----	x	x	--	--	--	l	m	x	x	x	x	--	--	--	--	x	--	x	--
510-520	Dull bluish gray	1.1	----	x	x	--	--	--	----	n	x	x	x	-	--	--	--	--	x	--	x	x
520-530	Dull bluish gray	.6	----	x	x	--	--	--	l	m	x	x	x	x	--	--	--	--	x	x	x	x
530-540	Light gray	.8	----	x	--	--	--	--	l	m	x	x	x	x	--	--	--	--	x	x	x	--
540-550	Light bluish gray	.1	21.8	x	x	--	x	--	l	m	x	x	-	x	--	--	--	--	x	x	--	--
550-560	Dull bluish gray	1.1	----	x	x	--	x	--	l	m	x	x	x	x	--	--	--	--	x	x	x	x
560-570	Dirty gray	.6	----	x	x	--	--	--	l	m	x	x	x	x	x	--	--	--	--	--	--	--
570-580	Dirty bluish gray	.9	----	x	x	--	--	--	l	m	x	x	x	x	--	--	--	--	x	--	--	x
580-590	Dull bluish gray	1.5	----	x	x	--	--	--	l	m	x	x	x	x	--	--	--	x	x	--	--	x

*Light, l; medium, n; strong, m.

TABLE SHOWING CHARACTERISTICS OF THE TAYLOR MARL NOTED IN SAMPLES FROM THE FIRST THRALL OIL COMPANY WELL NUMBER 28 (SERIAL NUMBER 175-a).—Continued.

Depth of sample in feet below surface	Color and other characteristics of the marl	Texture shown by per cent of sand of total of sample	Per cent of material soluble in hydrochloric acid	Minerals noted—presence indicated by x					Fumes* noted on heating		Fossils noted											
				Marcasite	Glauconite	Gypsum	Calcite	Mica	Bitumen	Ammonia	Textularia	Anomalina	Nodosaria	Globigerina	Cristellaria	Lagena (?)	Frondicularia	Bolivina	Inoceramus	Other pelecypods	Bathocypris	Echinoid spines
590-600	Light bluish gray----	1.6	21.6	x	--	--	--	--	l	m	x	--	x	x	--	--	--	--	--	--	--	--
600-610	Bluish gray----------	.8	----	x	--	--	--	--	l	m	x	x	--	x	x	--	--	--	--	--	--	--
610-620	Dirty bluish gray----	.1	----	x	--	--	--	--	l	m	x	x	--	x	--	--	--	--	--	--	--	x
620-630	Dirty bluish gray----	.1	----	x	--	--	--	--	l	m	x	x	x	--	x	--	--	--	x	--	--	--
630-640	Light bluish gray----	.1	----	x	--	--	--	--	l	m	x	x	x	x	--	--	--	--	x	--	--	--
640-650	Dirty bluish gray----	.1	26.1	x	--	--	--	--	l	m	x	x	x	--	--	--	--	--	--	--	--	--
650-660	Bluish gray----------	.1	----	x	--	--	--	x	l	m	x	x	x	x	--	--	--	--	--	--	--	--
660-670	Bluish gray----------	.1	----	x	--	--	--	x	l	m	x	--	--	x	--	--	--	--	x	--	--	--
670-680	Dirty bluish gray----	.1	----	x	--	--	--	x	----	m	x	x	x	x	--	--	--	--	x	x	x	--
680-690	Dirty bluish gray----	.6	----	x	--	--	--	--	l	m	x	--	x	--	x	--	--	--	--	--	--	--
690-700	Light bluish gray----	2.7	27.0	x	--	--	--	--	l	m	x	x	--	x	--	--	--	--	x	--	--	--
700-710	Light gray, oil-bearing	1.2	----	x	x	--	--	--	m	m	x	x	--	--	--	--	--	--	x	--	x	--
710-720	Light gray, oil-bearing	1.8	----	--	x	--	--	--	m	l	x	x	--	x	--	--	--	--	x	--	x	--
720-730	Light gray, oily, calcareous ----------	1.8	----	x	--	--	--	x	m	l	x	x	x	x	x	x	x	--	x	x	--	x
730-740	Light gray, calcareous	2.0	----	x	--	--	x	--	m	l	x	x	--	x	x	--	x	--	--	--	x	--
740-750	Bluish gray, calcareous------------	2.2	48.6	x	--	--	--	--	m	n	x	x	--	x	--	--	--	--	x	x	x	--
750-760	Bluish gray----------	1.3	----	x	--	--	--	--	n	n	--	x	--	--	x	--	--	--	x	--	x	--
760-770	Light bluish gray----	1.7	----	x	--	--	--	--	n	n	x	x	--	--	--	--	--	--	--	--	x	--
770-780	Light gray, calcareous	6.9	----	x	--	--	--	--	m	n	x	x	--	x	--	--	--	--	--	--	--	--
780-790	Dark bluish gray, with limestone ----------	34.5	----	x	--	--	--	--	n	n	x	x	--	--	--	--	--	--	--	--	x	--
790-	Gray, with some limestone --------------	----	51.6	x	--	--	--	--	l	----	x	--	--	--	--	--	--	--	--	--	--	--

*Light, l; medium, n; strong, m.

Color

Though no great significance can be attached to color in marly clays like these, it seems worth the while to note that light and neutral gray predominate in the upper half of the section. A bluish tinge of the gray was more frequently noted in the lower half of the section, and most frequently in its lowest two hundred feet, where half of the samples admit of being characterized as bluish gray, or light bluish gray.

Texture

The sandy ingredient in the marl is perhaps of greatest lithological importance. On the basis of this characteristic four zones can clearly be made out. Disregarding the sand in the first ten feet, which represents surface material not belonging to the bed rock, the marl in the uppermost two hundred and forty feet contains on the average less than three tenths of a per cent. of sand grains measuring more than one-sixteenth mm. in diameter, and in none of twenty-three samples does this ingredient amount to one per cent. The marl penetrated from thirty to a hundred and twenty feet below the surface contains only one-tenth per cent. of such sand, and with the exception of the ground at from 120 to 140 feet below the surface, the same scarcity of coarse material extends down to 190 feet. From 240 feet down to 600 feet below the surface the sand ingredient is less than six-tenths per cent. in only three samples, from 460 to 480 and from 540 to 550 feet; and it averages one per cent., which is more than three times the amount found in the marls above. Again, from 600 to 690 feet the sand makes less than two-tenths per cent., while from here down to 780 feet it makes 2.4 per cent. of the sediments, but consists largely of calcareous organic material. The last two samples contain many fragments of limestone and much calcareous organic material, but very little quartz sand.

Soluble Contents

Tests were also made on the soluble contents of the samples. For this purpose equal quantities of the samples were taken and these were mixed for each fifty feet of the section, making twenty larger samples. These were weighed, digested in hydrochloric acid, washed and again weighed to ascertain the loss. This no doubt dissolved not only the carbonates present, but also some ferruginous siliceous material, such as glauconite. The soluble material varies in a way to indicate nearly the same divisions in the section as were shown by the arenaceous content of the beds. It is least in the upper 250 feet, where it averages 17.4 per cent.; slightly greater in the next 350 feet, where it averages 22.2 per cent. The next fifty feet has 21.1 per cent., and below this it increases from 27 to 51.6 per cent., owing no doubt to the increase mainly in the calcareous ingredient.

Glauconite and Other Minerals

Glauconite is present in its usual form of rounded green grains that evidently have formed internally in the tests of foraminifera. It is found chiefly in those divisions of the section that contain most sand, having been noted in the samples from 200 to 590 feet and from 700 to 720 feet below the surface. Marcasite or pyrite was noted in almost all the samples, except those from the uppermost forty feet, where it has evidently been oxidized or removed by leaching. Calcite and mica were each noted only in a few cases below the depth of 350 feet, while gypsum was noted in eight samples in the upper 460 feet. Thus it may be said that at least one of the minerals originally present shows a distribution which is correlated with changes in the sand content and the soluble content of these sediments.

Volatile Constituents

Tests for bituminous fumes and fumes of ammonia were made by heating small quantities of the samples in a closed tube. A slight bituminous odor was perceptible in nearly all the samples, and from 700 down to 750 feet, and below this at from 770 to 780 feet, there were strong bituminous fumes from which visible droplets of oil condensed on the glass. Fumes of ammonia were in each case noted by their action on litmus and also by their reaction with nitric acid fumes. In some cases they were strong enough to be recognized by their odor. They were produced sparingly in almost all samples and were quite strong and pronounced in the samples from 480 to 710 feet below the surface. Fumes of a peculiar odor were noted in a few samples, mostly in the parts of the section having the strong fumes of ammonia.

Fossils

Observations were made on the presence of fossils, mostly foraminifera, which were present in every sample except one, below the depth of thirty feet. From the upper thirty feet these delicate tests have probably been removed by leaching of the marls. The foraminifera appear to be so uniformly distributed through the section that it is evident they are of no use as horizon markers. The outstanding fact is that these fossils are almost universally present throughout the section of these sediments. Perhaps it can also be said that this fauna shows a slightly greater diversity in the lowest 100 feet of the beds. In this part of the section forms like Nodosaria are least common, and none of the group of foraminifera seemed to occur in any sample in abundance. It should be noted that no reliable determinations were attempted in the study of the foraminifera, as neither of the authors has specialized in the study of these fossils. The reference to genera, in the table, must be regarded merely as based upon general resemblance in form. The relative abundance of different forms noted in this manner is indicated in the following table.

TABLE SHOWING RELATIVE FREQUENCY AND ABUNDANCE OF FORAMINIFERA IN THE TAYLOR MARL IN THE THRALL FIELD, BASED ON OBSERVATIONS ON EIGHTY SAMPLES.

Forms resembling	Number of samples in which observed	Number of samples in which abundant
Textularia	72	12
Anomalina	63	0
Nodosaria	54	3
Globigerina	52	3
Cristellaria	37	2
Lagena	8	0
Frondicularia	5	0
Bolivina	1	0

Notes were also taken on the frequency of occurrence of fragments of pelecypod shells, mostly, of course, of the oyster family. Separate notes were taken on shells like Inoceramus, that can be readily recognized by a transverse columnar structure; on a small ostracod, which consists of two elliptic valves of porcelaneous lustre, and resembles a Bathocypris; and on minute spines of sea urchins, which are recognized by a fluted external sculpture and occasionally by their characteristic socket joint at their proximal end. It was found that Bathocypris as well as the pelecypod fragments are markedly more frequently present at the depths from 240 to 600 feet and from 700 to 790 feet below the surface, than in the other parts of the section; while spines of sea urchins are most frequent in the uppermost

200 feet and from 400 to 600 feet. The distribution of these larger fossils bears, therefore, a relation to the slight differences already noted in the sediments themselves. Excepting the sea urchin spines, they are most frequent in that part of the section found to contain glauconite.

Divisions of the Section

As shown by these samples the body of marls overlying the igneous rock in this boring is notably uniform and clearly proves continuous deposition in the same sea. Nevertheless it is evident, upon close examination of the materials, that geographical conditions were not exactly the same during the period represented by the section in this boring. At least three times slight changes in the depositon occurred, so that four different zones can be discerned, not only on the basis of the physical characteristics of the sediments, but also of their organic contents. If we designate the four zones from below upward approximately by depths in feet below the surface, a summary of these slightly different characteristics is as follows:

Feet below surface	
0-240	Light gray color shades predominant; sandy ingredient and soluble content relatively small; glauconite mostly absent; gypsum occasionally present; calcite and mica very rare; nitrogen content in places relatively high; bituminous fumes moderate; ostreidae, Inoceramus and Bathocypris scarce, Cristellaria and echinoid spines relatively common.
240-600	Dull gray colors predominating; sandy ingredient and soluble content relatively high; glauconite common throughout; gypsum scarce; calcite and mica present in places, but scarce, bituminous fumes moderately strong; nitrogenous content relatively large in lower part; foraminifera, ostreidae, Inoceramus, Bathocypris and spines of echinoderms relatively more abundant than in the other divisions
600-690	Bluish gray colors predominant; sandy ingredient small, soluble content intermediate in quantity; glauconite, gypsum and calcite absent; bituminous content small; nitrogenous content high; fossils, excepting Textularia, relatively least common.
690-790	Color shades variable; sandy ingredient relatively high, especially below; soluble content very high, below; glauconite in a few samples; bituminous fumes generally strong; nitrogenous fumes moderate; fossils about as at from 240 to 600 feet.

Only two of the horizons distinguished by this study appear in the averaging of the driller's logs, where the lower part of the section up to 450 feet above the igneous body was found to be much more frequently reported as "gumbo" than the part above this horizon. The level of the change indicated by the drillers also lies lower down than the change between the two larger divisions based on the study of the samples.

The "Cap Rock"

In the well section just described the lowest three samples contain much more calcareous shell fragments and sand than is found in the samples above. Material of this kind is frequently found resting on the underlying igneous rock, and is generally reported by the drillers as "cap rock." This same term is, however, used also to denote marl, clay, and limestone, when found in the same position. In many records no "cap rock" has been reported. In other records the "cap rock" measures no less than fifty feet in thickness. It is evident this designation is in many cases used arbitrarily.

Samples of the material immediately overlying the igneous rock were collected from twenty-six wells. These samples were carefully examined and may be described as below:

SAMPLES FROM THE NORTHEAST PART OF THE FIELD.

Well No. 15 Depth of sample, 802-805 feet. Above the green volcanic rock occurs a light gray, very porous shell breccia about three feet in thickness. At the point of contact between the green rock and the shell breccia there are large cavities filled with calcareous materials and in some cases with iron pyrite.

Well No. 19: Cap rock, 730-735 feet: A mixture of gray marl and shell breccia with fragments of green igneous rock. In a fragment of the green rock a cavity one-half inch wide was noted. The cavity was lined with small crystals of calcite.

Well No. 20: Cap rock, 765-772 feet. The sample of cap rock is a mixture of gray shale, shell breccia, and green igneous rock.

Well No. 25: Cap rock, 863-867 feet. A dense argillaceous limestone, and green igneous rock, which contains numerous irregular pockets and small veins of white calcareous material. Small crystals of calcite and pyrite were noted.

Well No. 29: Cap rock, 865-866 feet. The cap rock consists of a dark gray, soft, fine-grained shale and a gray, fine-grained limestone, with a small amount of fragments of shells. Below the cap rock was seven feet of porous limestone, some fragments of which were very porous and other fragments were more or less dense, compact and hard. At a depth of 12 feet below the cap rock, the cuttings consist of a light gray shale of fine texture. No green rock was noted.

Well No. 38: Cap rock at about 875 feet. The cap rock appears to be a dark gray, very fine-grained shale, mixed with a shell breccia. The sample just below this consists of equal parts of porous, altered green rock and shell breccia.

Well No. 69: Cap rock, 795-800 feet. The sample is a mixture of porous, green, igneous rock and a shell breccia. There were fragments of crystalline calcite that must have come from pieces more than an inch in diameter. There are fragments of large pelecypod shells. Fragments of white crystalline limestone were also noted. It seems that the upper surface of the green rock contains irregular cavities filled with calcite and other calcareous materials.

Well No. 108: *Cap rock, 816-822 feet.* The cap rock seems to be of dark, hard breccia with crystalline calcite, possibly with included fragments of green igneous rock. Some pyrite noted.

Well No. 30: *Cap rock, 855 feet.* A drab-colored, medium hard marl mixed with green igneous rock. Below this is a very porous limestone which contains the oil.

Well No. 35: *Cap rock at 920 feet.* A light gray, very highly calcareous shale, with some green rock below.

SAMPLES FROM THE SOUTHWEST PART OF THE FIELD.

Well No. 96: The only sample from this well is composed of fine fragments of light gray limestone, some calcite and a small amount of gumbo. There were a few small rounded fragments of igneous rock noted, indicating that it was present in small quantities or that the drill had not penetrated it very deeply. Depth unknown.

Well No. 102: *Cap rock, 738-739 feet.* About one-half of this sample is a light gray, soft shale, while the other part is a hard, dense, light and dark gray limestone. Below this was green igneous rock

Well No. 103: *Cap rock, 704-762 feet.* A dark, fine-grained shale and a light gray, dense limestone with considerable amounts of calcite and pyrite.

Well No. 110: *Cap rock, 830-834 feet.* Very light gray, soft, calcareous shale, with possibly a greater amount of hard, dense limestone and a smaller amount of light gray, soft, crystalline limestone. The deeper samples showed very little green rock in this well

Well No. 121: *Cap rock, 805-810 feet.* A light gray, fine-grained, shell breccia, and gray marl and shale. The bottom of the cap rock seems to be much more coarse and is composed of shells of large pelecypods, crystalline calcite, porous limestone with fragments of green igneous rock filling the cavities.

Well No. 133: *Cap rock, 860-870 feet.* A dark gray, somewhat porous limestone mixed with a gray marl. Some of the fragments are extremely porous and from their color appear to have held oil.

Well No. 138: *Cap rock, 860-872 feet.* A light gray, calcareous, fine-grained, medium hard shale, and light gray, fine-grained limestone. A small percentage of green rock present. Fragments of pelecypods noted in the cap rock.

Well No. 139: *Cap rock, 860-882 feet.* A hard, very fine-grained, light gray marl. At the bottom of the well, depth 905 feet, a light gray, fine-grained, hard shale occurs.

Well No. 143: *Cap rock, 748-789 feet.* A hard, dense, light gray shale. At the base of the cap rock, fragments of calcite occur in which there are fine inclusions of green igneous rock.

Well No. 145: *Cap rock, 866-874 feet.* Gray, fine-grained, calcareous marl which is mixed with volcanic rock. The fragments of the green rock are cemented together with lime-carbonate.

SAMPLES FROM THE NORTHWEST PART OF THE FIELD.

Well No. 33: *Cap rock at 844 feet.* A dark gray, very fine-grained shale with what appears to be green rock Below this is a soft, gray limestone to a depth of 855 feet. The lower part of the well shows a dense, dark limestone and some shale.

Well No. 176: *Cap rock, 847-863 feet. Sample from top of cap rock.* A hard, porous, gray shell breccia, or limestone. The shell fragments are from one to two millimeters in diameter. Some of the pore space is filled with calcite, some is open, and as much as two mm. in diameter. Small fragments of pyrite noted. The rock yields drops of yellow oil when heated in closed tube. Fossils noted: Globigerina, Anomalina, and fluted spines of Echinoids.

Sample at middle of cap rock.

Mostly gray, porous shell breccia, containing much calcite in irregular streaks among the shell fragments and some pyrite. Some fragments are dark, almost black. One black fragment contains rounded, light green grains, which lie in a black matrix containing shell fragments and foraminifera. Heated in closed tube the material gives off strong fumes of sulphur and globules of oil collect on the sides of the tube. There are some fragments of chalcedonic flint and rounded grains of quartz sand present. Fossils noted: Textularia, Globigerina, fluted spines of an Echinoid and fragments of a serrated shark tooth.

Sample from bottom of cap rock.

About half of this sample is a green igneous rock. The other half of the sample consists of a porous, gray shell breccia. Some of the pore spaces are filled with very clear calcite, seen in fragments, and as drusy incrustations. Pyrite noted. Foraminifera and fluted spines of Echinoids also noted.

Well No. 191: *Cap rock, 878-908 feet.* Top of cap rock consists of a gray marl, with a porous, gray shell breccia. Calcite present but not abundant. Foraminifera noted.

Well No. 194: *Cap rock, 852-868 feet.* Mostly dark gray, porous shell breccia with a small amount of light gray, fine-textured shale or marl.

Well No. 204: At 855-865 feet the sample consists of gray marl with shell breccia. Heated in closed tube, faint fumes of sulphur and bitumen were noted. Fossils noted: Textularia, Globigerina and Anomalina, also fluted spines of a sea urchin. At a depth of 880 feet, the cap was composed of gray marl, with fragments of shell breccia. At the bottom of the cap rock, there was still gray marl and shell breccia, but it did not carry foraminifera. There were crystals of calcite. Drops of oil condensed on the sides of the tube, when heated. Below the cap was the igneous rock.

Well No. 220: *Cap rock, 867-894 feet.* A light gray shale with a few fragments of fine-grained limestone.

From these samples it appears that the material immediately resting on the igneous mass contains much crystalline calcite, which no doubt has been secondarily deposited, apparently in a zone more open in texture than either the igneous material below or the marl above. This "cap rock" zone is found to consist of three types of material: a shell breccia or shell sand, being a rock composed largely of small shell fragments; a clay or marl; and a compact, fine-grained, calcareous sandstone. The latter two are usually associated in the same samples.

If the Thrall field be divided into two halves by a line approximately running from northwest to southeast, a few hundred feet north of the highest points on the igneous rocks, we will find that these different kinds of cover on the igneous rock characterize the two halves of the field separated by this line, especially if we except the six wells located farthest northwest. In the borings on the northeast slope of the igneous body the "cap rock" consists, in most cases, of an organic breccia usually of an open porous texture, as shown in wells 15, 19, 20, 25, 29, 38, 69, and 108; wells 30 and 35 being the only exceptions. In the borings on the southwest slope we find that the "cap rock" consists of a fine clay or marl together with some compact limestone, well 121 being the only exception. These are wells numbers 96, 102, 103, 110, 121, 133, 138, 139, 143, and 145. This difference in the nature of the beds overlying the igneous body was known to the drillers in the field and the authors are satisfied that the difference in the nature of the cap rock for these two parts of the field is as general as indicated by the few samples examined. In the extreme northwest part of the field, where the igneous rock is quite thin or absent, and where the topography of the upper surface of this rock body is quite flat, no such distinction is apparent, and the two types of cap rock occur promiscuously, as in the wells Nos. 33, 176, 191, 194, 204, and 220. We shall have occasion to refer to this significant distribution in discussing the probable origin of the igneous body.

The Igneous Rock

Distribution

The igneous rock, which has yielded most of the oil in this field, lies in a flat dome-shaped mass having its highest known point in the vicinity of well No. 37, where it reaches an elevation of about 612 feet below the surface. From here this rock slopes downward very rapidly in all directions for a distance of 1500 feet to 2000 feet, while beyond this distance the slope becomes more gentle. The slope is most gradual towards the north, more abrupt towards the south, and it is intermediate to the east and west. The greatest thickness of the igneous rock noted was in well No. 175-a, where it was found from a depth of 733 feet to 1280 feet, with a total thickness of 547 feet.

The known area of igneous rock is approximately 5,000 feet in a north and south direction, by about 4,800 feet in an east and west direction. On the east side of the Goetz Tract, the igneous rock is at least seventy or eighty feet in thickness (see wells Nos. 188 and 189) and this thickness probably extends for some distance farther towards the west. There is little doubt that the rock extends to the south and west of well No. 90. Its boundaries in this direction have been determined only in a general way. However, it was apparently not found in the following wells: On the south, wells Nos. 209, 210, and 211; on the west, Nos. 212, 216, and 218; on the north, Nos. 208, 213, and 229; and on the east, 230. About one year after well No. 227 was drilled, a few fragments of very soft, porous igneous rock were found by digging into the old dump. Later, well No. 131 was drilled within a few feet of No. 227, and the igneous rock was not noted. It is possible that the rock extends this far eastward, but it cannot be regarded as certain that such is the case.

Reference to the cross-section sheets, Plates 2 and 3, will show the extent, thickness, and approximate position of the lower limits of the igneous rock so far as known. The position of the igneous rock with respect to sea level and with respect to the surface of the ground may also be found on these sheets. Sea-level is indicated by a heavy black line and the surface of the ground is shown by a similar line, so that the position of the igneous rock may be gained at a glance.

The igneous rock lies everywhere below sea level. On Plate No. 1 the line marked "175," signifies that all known points of the upper surface of the igneous body on this line are 175 feet below sea level; and the line marked "200" indicates that all like points on that line are 200 feet below sea level, and so on. It should be stated that the contour lines mark the upper surface of the "shell breccia" as well as the surface of the igneous rock. Where the contours are drawn on the "shell breccia," this is indicated by broken lines. These occur mostly in the northern part of the field, where the igneous rock is thinnest.

Upper Surface

The upper surface of the igneous rock has been fairly accurately determined. A large number of wells have here been drilled on a comparatively small area. The wells are generally located about five hundred feet apart, but in many places they are much closer. The upper surface of the igneous rock, as determined by drilling, is shown by contour lines having a twenty-five foot contour interval, in Plate 1.

The outstanding feature of these contours is, as already stated, that they show the upper surface of the igneous body forming an irregular dome with a diameter of about three-fourths of a mile. This dome has a low extension to the north-west and its western limit is yet unexplored. The highest point on the dome has an elevation of some three hundred feet above its south limb, and about two hundred feet above its north limb. As the highest point is about at the center of the dome the south slope is the steeper one of the two. There is also to be noted a series of depressions upon the surface of this rock. These depressions may be actually present, or they may represent errors in recording the depths of some wells. This line of depressions in a general way occurs where the first rows of wells were drilled, and before the difference between the igneous rock and the marl was well understood. In many of the wells the upper layer of the igneous rock was mixed with considerable calcareous materials, including calcite, porous limestone and fragments of shells.

Lower Surface.

The lower limits of the igneous rock have been less accurately determined, as few of the wells have been drilled through into the shale and gumbo below. This lack of data is more pronounced where the igneous rock is thickest, as in this area the oil was thought to occur in the upper 50 feet, so that the wells were seldom drilled through into the shale below.

Thin layers of gumbo were reported from between parts of the igneous body, in many of the wells where the igneous rock was thickest. In wells Nos. 121 to 125, there was a streak of "sandy gumbo" some 55 to 57 feet below the top of the "pay rock." Wells Nos. 73 and 75 show shale or gumbo alternating with the igneous rock ("pay"), while in wells Nos. 155 and 160, a shale 40 inches in thickness, called "slate" by the drillers, occurs 60 feet below the top of the pay rock. The same formation was reported in all of the early wells drilled on the First Thrall Lease. The records of the Corsicana Petroleum Company show that the igneous rock ("pay"), in several of the wells first drilled, was separated by beds of marl and shale, varying in thickness: while the "pay sand" between, varies in thickness from a few feet to more than 59 or 60 feet. The occurrence of these layers of marl, if they exist, makes the determination of the base of the igneous rock even more difficult, for one cannot be sure that there is not more igneous rock below, when the well stops in the shale or gumbo. It was impossible to get samples of cuttings from these streaks of shale or gumbo and the writers are of the opinion that interbedded shales may not occur. In our samples streaks of igneous rock were noted that did not have the characteristic green color and were somewhat softer than the ordinary green igneous rock. These could easily have been mistaken for shale by the drillers. The bottom is, at any rate, ill-defined.

Where the igneous rock is thinner and the wells have been more frequently drilled through into the lower marl, the lower limits are better defined. From the data at hand it is evident that the base is lower, where the igneous rock is thickest, than in the outer parts of the field where it is thinner and more often penetrated. This would be the logical position of the bottom whether the igneous rock is a volcanic flow or an intrusion. (Pls. 2 and 3.) The greatest thickness known is in well No. 175-a, where it measured 547 feet, and persisted from 733 to 1280 feet below the surface. This boring no doubt extends into some part of the vent through which the igneous material was forced up to its present position.

Nature of the Igneous Rock

The nature of the igneous rock is that of a very basic basalt that has suffered extreme metamorphism chiefly by hydration and by abstraction of some of its original ingredients such as magnesium and sodium. It is known principally from a great number of pieces of cuttings, mostly less than a half-inch in diameter, and from two larger pieces, one of which was about four inches long, three inches wide, and one and a half inches thick. This piece is said to have been shot out of well No. 164. (See Plate 4.) The rock is soft enough to be readily cut with a knife, and it is of dark green color, like chlorite or like some varieties of serpentine. Though soft, it takes a fairly good polish. The large piece shows a brecciated structure in which angular fragments and irregular lumps having a lighter green color and in part an ill-defined outer surface lie imbedded in a darker green matrix. The light green fragments, or ill-defined lumps, appear in section with their longest diameter from one-eighth to one-third inch and a width of from one to three-sixteenths inch. The orientation of the fragments evidently varies and many of the fragments are as broad in the section as long. The darker shade of the matrix is due to the greater frequency, in this part of the rock, of some very dark green particles, apparently pseudomorphs after some crystals. These are also present in the breccia fragments, though found there in lesser number. When immersed in water this piece of rock absorbed water with great avidity and slaked superficially, so that its outer part fell off in flakes, leaving a rounded rough surface that followed the exterior form of the specimen, somewhat in the manner of the flaky weathering of granite. By crushing and washing the rock thoroughly some small flat octagonal crystals of green color were separated and also minute particles of magnetite, some of which show imperfect and etched crystalline faces. Minute particles of crystalline calcite, and rarely pyrite, are present, in places.

In the cuttings from other wells at least three types of the rock can be made out. The type represented by the piece blasted out of well No. 164 is most abundant. No further description of this type is needed except to say that the crystalline texture is variable. In some fragments it is coarse enough to be readily made out with a hand lens; in others it is microscopic. As a rule this type does not slake in water.

Another type of the rock is very dark green. This is always of fine texture. Much of this rock slakes rapidly and disintegrates into a mud, when immersed in water. It is also slightly softer than the other types. A few fragments were found to show what appears to be a lamination very much like fine stratification, and at least in one instance such a fragment had a texture like that of a clastic rock, consisting of sharply angular particles of lighter green with their outlines marked by darker green lines. In most fragments with a laminated structure the

Plate 4....Photograph of a piece of chlorite rock said to have come from well no. 164, at somewhere from 727 to 917 feet below the surface. The photograph shows the polished surface of the rock. Natural size.

texture was, however, found to be micro-crystalline. Still another type of this green rock is shattered by calcite veins and a few fragments were seen that consisted partly of green rock and partly of sedimentary marly material containing foraminifera. Fragments of this kind were mostly from near the upper contact of the igneous body.

Micro-Petrographic Characters

The extreme metamorphism which the igneous rock has suffered, makes it difficult to arrive at any definite conclusion as to whether it originally was a submarine contemporaneous extrusive or a later laccolitic intrusion into the Taylor marl. For the purpose of learning as much as possible of the real nature of the rock, several samples were submitted to petrographers for microscopic examination, several specimens were analyzed by Mr. J. E. Stullken of the Chemistry Division of the Bureau, and some hundred and fifty sections were submitted to Prof. C. L. Baker of this Bureau for study.

Baker's Observations

Professor Baker's report is as follows:

"Every slide of the more than one hundred examined shows extreme and widespread alteration. The only primary minerals left are olivine and magnetite and in these olivine was seen in only a very few instances and then always partially altered to serpentine. The serpentine belongs to the varieties chrysolite and picrolite. Minute, rounded, colorless particles ("insect eggs") found in a few instances are probably titanite. More abundant are slender, often branching, needles of rutile in crystals that were originally olivine. There is also often a little bowlingite or iddingsite.

"The most abundant minerals are the secondary serpentine and chlorite. In crystals which were originally olivine, the most abundant primary mineral in the original rock, the process of alteraton to serpentine corresponds exactly to the description given by Rosenbuch (Physiography of the Rock-making Minerals, translated by Iddings, page 221): 'The most common one (alteration) is the alteration of olivine to serpentine; this always starts from the surface and from cracks and leads to a fibration, at the same time with the separation of the iron in the form of ferric oxide, hydrous oxide, and magnetite. The greenish to yellowish-green fibers stand perpendicular to the crystal boundaries and the cracks. This produces a net-like appearance, the strings of serpentine forming the web of the nět, the meshes consisting of olivine as yet unaltered. As the process advances, new cracks form with the increase in volume accompanying the serpentinization, resulting finally in the complete alteration of the olivine. Although the serpentinization of olivine in many cases may be a simple act of weathering, yet in others it is probably due to the action of warm waters.'

"The calcite occurs mainly in seams and cracks and is also often seen in the interior of crystals originally olivine, where it is now surrounded by serpentine. Calcite is very widespread.

"The serpentine, light leek-green in color, is very often found in ellipsoidal to spherical aggregates with radiating finely fibrous structure. These are often hollow. Hour-glass structure in skeletal lath-shaped crystals originally of olivine exhibit short needles of titanite oriented parallel to the longer crystal axis. Such structures are not abundant. Slender lath-shaped crystal forms are still apparent in some specimens and were probably originally augite. A very few hexagonal outlines of original nepheline were seen.

"Practically all specimens show traces of orignal crystal boundaries. For this reason the original rock was not a tuff, for no basic tuff would exhibit so many crystals of such large size and so well developed. The rock was originally undoubtedly porphyritic with large and abundant phenocrysts of olivine, less abundant and considerably smaller phenocrysts of augite, an occasional phenocryst of nepheline, and a fine-grained ground mass made up of a large percentage of finely granular magnetite and of other minerals the nature of which cannot now be determined. In composition the rock was a nepheline-basalt very likely limburgite. Its structure and texture was practically identical with that of the intrusive nepheline-basalt (limburgite) of Pilot Knob, Travis County, Texas. The evidence thus indicates that the oil-bearing rock in the Thrall field was originally intrusive, probably in the form of a sill."

Tomlinson's Observations

Mr. W. Harold Tomlinson made and examined sixteen thin sections of the rock, and also reported on them. It should be noted that three of these samples were fragments of limestone, believed to have come from near the contact between the Taylor marl and the igneous rock, submitted to ascertain if they showed any evidence of contact metamorphism. No such evidence is reported. Mr. Tomlinson's report is followed by a table giving his notes on the several sections examined. He states that:

"Three of the lot are finely crystalline limestone: *Caldwell Oil Company, cap rock, 847 feet; First Thrall Oil Company No. 3, dump; and First Thrall Oil Company No. 3, contact below the igneous body.* All these show fragments of fossil shells. In addition to shells the First Thrall Oil Company No. 3, below the igneous contact, shows opaque brownish material, probably markings from animal remains. Another sample from the First Thrall Oil Company No. 3, dump, shows small amorphous fragments or grains of limestone cemented together by a zeolite.

"The remaining sixteen sections show different phases of an igneous rock in last stages of decomposition. Only a few of the sections give any idea of the original nature of the rock; the rest being breccias. One sample marked *Taylor Oil and Gas Company No. 3, depth 754-758* feet, and one marked *Taylor Oil and Gas Company No. 3, depth 768-780 feet,* give the best idea of the rock. (See Plates 5 and 6.) Although all the original minerals are metamorphosed, their crystalline form and texture is sufficiently preserved to enable one to recast the original rock with a fair degree of certainty. The sections show outlines of phenocrysts of augite and olivine set in a base of brownish glass containing numerous smaller phenocrysts of plagioclase in the form of small rods and containing clouds of minute specks of magnetite. The rock is therefore a basic basalt approaching limburgite. The sections show many roundish patches of zeolites, which probably indicate that the rock was originally somewhat cellular. Either this or they represent volume changes during abstraction of the alkalies. The altered rock shows patches of fibrous zeolites, calcite and the serpentine variety deweylite, replacing the phenocrysts and an amorphous material replacing the glassy base.

"I have recast the original rock on an analysis sheet as nearly as I can approximate it. On the analysis sheets representing the different sections I have set down the minerals in a way to give an idea of their volumetric proportions without marking percentages. To do the latter for these rocks with any degree of accuracy would be nearly impossible. You will find, however, that the mineralogic composition will explain the chemical analysis.

"In regard to the breccias, most of them show large angular fragments of the meta-basalt with concave sides, as though broken from a cellular rock. The cementing material is mostly deweylite of a pale green color. In one section, *Bowers and Witherspoon No. 1, dump,* the cement is a carbonate. In others, and in parts of nearly all, zeolites are present in the cement, as well as through the fragments of basalt. One sample, *Taylor Oil and Gas Company No. 3, 795 feet,* is a somewhat different rock. In this one the fragments are much smaller and more even in size and more closely set.

"The metamorphism of this rock seems to have followed two courses. First, carbonation and hydration, which results in the removal of most of the alkalies and some of the combined silica, and is accompanied with some decrease in volume. Secondly, further hydration by which the serpentines and zeolites were formed. This stage of the alteration was accompanied by a large increase in volume. These processes may readily have caused the formation of the breccias."

TABLE GIVING W. HAROLD TOMLINSON'S DESCRIPTIONS OF SIXTEEN SAMPLES OF CUTTINGS OF THE ALTERED IGNEOUS ROCK IN THE THRALL FIELD

Where Taken	Primary parts	Secondary minerals	Texture	Structure	Origin	Metamorphosis	Rock Species
Bowers & Witherspoon, No. 1, from dump of well. Serial No. 121	Basaltic fragments	Deweylite Siderite(?) Calcite	Earthy	Brecciated	Igneous	Hydration extreme	Meta Basaltic Breccia
Bowers & Witherspoon, No. 1, from dump. Serial No. 121	Basaltic fragments	Deweylite Zeolites Calcite Siderite(?)	Earthy	Fragmental	Igneous	Hydration extreme	Meta Basaltic Breccia
Bowers & Witherspoon, No. 1, from dump. Serial No. 121	Magnetite	Serpentine Zeolites	Earthy, compact		Igneous	Hydration extreme	Meta Basalt
Bowers & Witherspoon, No. 1, from dump. Serial No. 121	Basaltic fragments Magnetite	Calcite Deweylite Zeolites	Earthy	Brecciated	Igneous	Hydration extreme	Meta Basaltic Breccia
Bowers & Witherspoon, No. 1, at 840 ft. Serial No. 121	Magnetite	Deweylite Zeolites Calcite	Earthy	Brecciated	Igneous	Hydration extreme	Meta Basalt
Bowers & Witherspoon, No. 2, at 950 ft. Serial No. 122	Basaltic fragments Magnetite	Deweylite Calcite Magnesite(?)	Earthy	Brecciated	Igneous	Hydration Carbonation	Meta Basaltic Breccia
Bowers & Witherspoon, No. 5, from dump. Serial No. 125	Basaltic fragments	Deweylite Zeolites Calcite	Earthy to crystalline	Fragmental	Igneous	Hydration extreme	Meta Basaltic Breccia
Taylor Oil & Gas Co., No. 3, at from 744 to 754 ft. Serial No. 73	Basaltic fragments Magnetite	Deweylite Pyrite	Earthy	Fragmental	Igneous	Hydration	Meta Basaltic Breccia
Taylor Oil & Gas Co., No. 3, at from 754 to 768 ft. Serial No. 73	Magnetite	Serpentine Zeolites Deweylite Calcite Pyrite	Porphyritic		Igneous	Hydration Carbonation	Meta Basalt

TABLE GIVING W. HAROLD TOMLINSON'S DESCRIPTIONS OF SIXTEEN SAMPLES OF CUTTINGS OF THE ALTERED IGNEOUS ROCK IN THE THRALL FIELD—Continued.

Where Taken	Primary parts	Secondary minerals	Texture	Structure	Origin	Metamorphosis	Rock Species
Taylor Oil & Gas Co., No. 3, at from 768 to 780 ft. Serial No. 73	Basaltic fragments Magnetite	Deweylite Zeolite Calcite	Earthy	Fragmental	Igneous	Hydration extreme	Meta Basaltic Breccia
Taylor Oil & Gas Co., No. 3, at from 768 to 780 ft. Serial No. 73	(Glass), (Augite) (Olivine) Plagioclase	Serpentine Deweylite Zeolites Calcite	Porphyritic	Cellular	Igneous	Hydration Carbonation	Meta Basalt (approaching Limburgite)
Taylor Oil & Gas Co., No. 3, at from 780 to 790 ft. Serial No. 73	Magnetite	Zeolites Deweylite Siderite ?	Porphyritic	Cellular	Igneous	Hydration extreme	Meta Basalt
Taylor Oil & Gas Co., No. 3, at 795 ft., on top of marl, basal part of igneous body. Serial No. 73	Basaltic fragments Magnetite	Zeolites Deweylite	Fine fragmental	Brecciated	Igneous	Hydration extreme	Meta Basaltic Breccia
First Thrall Oil Co., No. 1, from dump of well. Gumbo below. Serial No. 151	Basaltic fragments Magnetite	Magnesite? Zeolites Chlorite or Serpentine Deweylite	Porphyritic	Fragmental	Igneous	Hydration extreme	Meta Basalt
First Thrall Oil Co., No. 3, from dump. Serial No. 153	Basaltic fragments	Deweylite Zeolites Magnesite	Earthy	Fragmental	Igneous	Hydration extreme	Meta Basaltic Breccia
Thrall Independent Oil Co., No. 2, from dump. Serial No. 194		Serpentine Zeolites Calcite	Fine compact	Cut by veins	Igneous	Hydration extreme	Meta Basalt
Approximate recast of the original rock	Basaltic lava (glass) Augite Olivine Plagioclase Magnetite		Porphyritic	Cellular	Igneous		Basalt approaching Limburgite

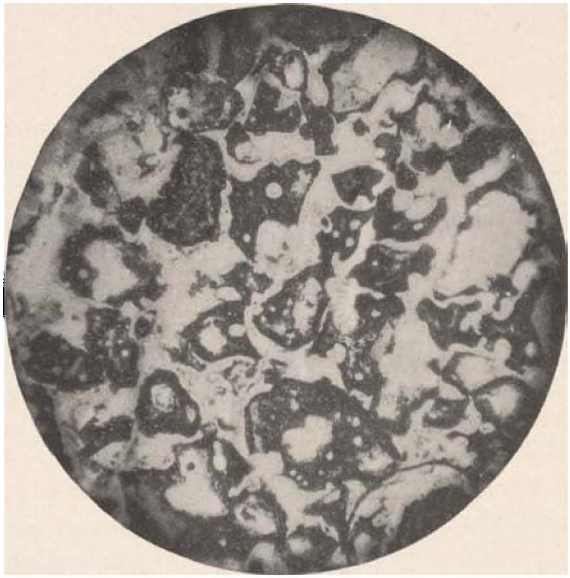

Plate 5....A...Micro-photograph of a thin section of the igneous rock taken from well No. 164. The dark portion shows the structure of the original basalt. The light parts are mostly Deweylite. Magnified about 40 diameters. Photograph by W. H. Tomlinson.

Plate 5....B...Micro-photograph of a thin section of altered igneous rock taken from well No. 73, showing the structure of the original basalt. Plane polarized light. Magnified about 40 diameters. Photograph by W. H. Tomlinson.

Larsen's Observations

Several samples of cuttings of the igneous rock were sent to Mr. E. S. Larsen, of the United States Geological Survey, for petrographical identification, and Mr. Larsen reports as follows:

"Thin sections of five of the samples have been examined. The original materials have been completely decomposed and the rocks are now chiefly chlorite with more or less carbonate. The greater part of the chlorite is so finely crystalline as to give aggregate polarization, but that occupying the position of the original phenocrysts, as well as spherulitic and less regular areas, is finely fibrous. The details of the original texture are obliterated, but the rock was unquestionably porphyritic and with little doubt had scattered, tabular crystals of plagioclase and probably crystals of augite, perhaps of olivine and other minerals, in a fine-textured or glassy ground mass. Parts of it appear to have been highly vesicular and some specimens strongly suggest a rather fine-textured tuff. The rock was without much doubt a basaltic rock, although it may not have been strictly a basalt.

"The chemical analyses which you have published confirm the determination of the material as now essentially a chlorite. Altered basaltic rock would probably be preferable to serpentine, as a name for the rock.

"In interpreting the analyses one must bear in mind that the rock has undergone large changes in its chemical makeup."

Chemical Composition

The chemical composition of the oil-bearing igneous rock at Thrall is now known from several analyses made by Prof. J. E. Stullken, chemist of the Bureau. These are the analyses 3, 4, 5, and 6 in the table below, and four somewhat more detailed analyses given in a second table, which follows, under 7, 8, 9, and 10.

TABLE OF ANALYSES OF UNALTERED IGNEOUS ROCKS FROM PILOT KNOB AND OF METAMORPHIC OIL-BEARING IGNEOUS ROCK IN THE THRALL OIL FIELD

Constituents	1	2	3	4	5	6	Averages of 1 and 2	Averages of 3, 4, 5, and 6
Silica	38.35	38.00	33.52	31.55	27.30	32.30	38.17	31.14
Alumina	20.32	26.76	21.44	19.69	23.90	22.44	23.54	21.87
Oxide of iron	9.18	14.36	14.36	12.44	9.70	12.76	11.77	12.31
Lime	11.76	14.89	6.07	5.96	11.90	7.14	13.32	7.77
Magnesia	13.78	--------	9.06	11.08	7.48	8.06	6.89	8.92
Carbonic acid	--------	.82	1.92	--------	9.35	5.61	--------	3.74
Sulphuric acid	--------	.82	1.92	2.77	.86	.69	.41	1.56
Potassium oxide	2.02	.64	.05	.08	--------	--------	1.33	0.03
Sodium oxide	2.77	2.32	.17	.04	--------	--------	2.54	0.05
Loss on ignition	1.20	1.76	13.20	15.64	9.21	10.53	1.48	12.14
Total	99.38	99.55	99.79	99.25	99.70	99.43	99.47	99.53

1. Basalt from Pilot Knob, Travis County. Analysis reported by Prof. J. F. Kemp, American Geologist, Vol. VII, p. 293.
2. Basalt from Pilot Knob, Travis County. Analysis by J. E. Stullken, chemist, Bureau of Economic Geology and Technology.
3. Cuttings from the oil-bearing igneous rock in Murphy Oil and Gas Company Well No. 1, Thrall field, depth 831-912 ft. Analysis by J. E. Stullken.
4. Cuttings from the oil-bearing igneous rock in Bower and Witherspoon Well No. 1, in the Thrall oil field. Analysis by J. E. Stullken.
5. Cuttings from the oil-bearing igneous rock in Bower and Witherspoon Well No. 5, in the Thrall oil field. Analysis by J. E. Stullken.
6. Cuttings from the oil bearing igneous rock from the Temple-Taylor Oil and Gas Company Well No. 2, depth 917 feet, Thrall oil field. Analysis by J. E. Stullken.

TABLE OF ANALYSES OF FOUR SAMPLES OF IGNEOUS ROCK FROM THE THRALL OIL FIELD. J. E. STULLKEN, ANALYST

	7			8			9			10			Averages		
	Soluble in hydrochloric acid	Insoluble in hydrochloric acid	Total	Soluble in hydrochloric acid	Insoluble in hydrochloric acid	Total	Soluble in hydrochloric acid	Insoluble in hydrochloric acid	Total	Soluble in hydrochloric acid	Insoluble in hydrochloric acid	Total	Soluble in hydro chloric acid	Insoluble in hydro chloric acid	Total
Silica	0.30	31.70	32.00	0.20	32.50	32.70	0.40	26.80	27.20	0.50	30.50	31.00	.35	30.37	30.72
Alumina	6.59	2.00	8.59	12.22	1.20	13.42	7.16	1.35	8.51	7.07	1.34	8.41	8.26	1.47	9.73
Ferric oxide	7.74	1.30	9.04	5.45	1.00	6.45	10.79	1.35	12.14	4.36	1.00	5.36	7.08	1.16	8.24
Ferrous oxide	5.35	None	5.35	8.21	None	8.21	5.00	None	5.00	10.00	None	10.00	7.14	.00	7.14
Phos. pentoxide	1.12	None	1.12	1.61	None	1.61	0.87	None	0.87	1.40	None	1.40	1.25	.00	1.25
Titanic oxide	0.80	None	0.80	0.80	None	0.80	0.21	None	0.21	.80	None	0.80	.65	.00	.65
Lime	10.09	0.52	10.61	3.91	2.00	6.51	11.96	1.14	13.10	11.96	0.73	12.69	9.48	1.25	10.73
Magnesia	12.38	None	12.38	11.23	None	11.23	9.27	None	9.27	15.19	None	15.19	12.02	.00	12.02
Sodium oxide	0.77	None	0.77	1.81	None	1.81	0.84	None	0.84	0.05	None	0.05	.87	.00	.87
Potassium oxide	0.16	None	0.16	0.21	None	0.21	0.19	None	0.19	0.14	None	0.14	.17	.00	.17
Carbon dioxide	None	None	None	None	None	None	3.30	None	3.30	None	None	None	.82	.00	.82
Sulphur trioxide	None	None	None	0.45	0.48	0.93	None	0.04	0.04	None	0.48	0.48	.11	.25	.36
Water, hygroscopic	11.40	None	11.40	8.32	None	8.32	7.16	None	7.16	5.10	None	5.10	7.99	.00	7.99
Water, combined	7.40	None	7.40	8.18	None	8.18	12.50	None	12.50	9.90	None	9.90	9.49	.00	9.49
Total	64.10	35.52	99.62	62.60	37.78	100.38	69.65	30.68	100.33	66.47	34.05	100.52	65.68	34.50	100.18

7. Cuttings from Taylor Oil and Gas Company Well No. 51. Serial number 120-a.
8. Cuttings from Corsicana Petroleum Company Well No. 65. Serial number 65.
9. Murphy Oil Company Well No. 10. Serial number 145.
10. Taylor Oil and Gas Company Well No. 50. Serial number 80.

TABLE OF ANALYSES OF THREE SAMPLES OF METAMORPHIC IGNEOUS ROCK FROM ONION CREEK, NORTH OF PILOT KNOB, TRAVIS COUNTY

	11			12			13			Averages		
	Soluble in hydrochloric acid	Insoluble in hydrochloric acid	Total	Soluble in hydrochloric acid	Insoluble in hydrochloric acid	Total	Soluble in hydrochloric acid	Insoluble in hydrochloric acid	Total	Soluble in hydrochloric acid	Insoluble in hydrochloric acid	Total
Silica	0.20	31.30	31.50	0.50	26.56	27.00	0.90	19.84	20.74	.53	25.87	26.41
Alumina	9.05	1.10	10.15	9.97	1.50	11.47	7.21	3.00	10.21	8.74	1.87	10.61
Ferric oxide	8.48	1.10	9.58	7.43	1.46	8 89	11.10	2.94	14.04	9.00	1.83	10.84
Ferrous oxide	4.14	None	4.14	4.28	None	4.28	2.86	None	2.86	3.76	.00	3.76
Phosphorus pentoxide	0.51	None	0.51	0 64	None	0.64	Trace	None	Trace	.38	.00	.38
Titanic oxide	0.56	None	0.56	0.75	None	0.75	0.52	None	0.52	.61	.00	.61
Lime	6.24	0.52	6.76	13.73	0.52	14.25	18.51	1.97	20.48	12.83	1.00	13.83
Magnesia	14.24	None	14.24	5.53	None	5.53	3.11	None	3.11	7.63	.00	7.63
Sodium oxide	0.29	None	0.29	0.40	None	0.40	0.30	None	0.30	.33	.00	.33
Potassium oxide	0.10	None	0.10	0.21	None	0.21	0.41	None	0.41	.24	.00	.24
Carbon dioxide	None	None	None	4.40	None	4.40	10.00	None	10.00	4.80	.00	4.80
Sulphur trioxide	None	0.55	0.55	None	0.48	0.48	None	0.62	0.62	.00	.55	.55
Water+	12.52	None	12.52	10 86	None	10 86	8.90	None	8.90	10.76	.00	10.76
Water−	9.44	None	9.44	11.30	None	11.30	8.10	None	8.10	9.49	.00	9.49
Total	65.77	34.57	100.34	70.00	30.46	100.46	71.92	28.37	100.29	69.10	31.12	100.22

These analyses show that the siliceous content of the altered igneous rock on Onion Creek as well as in the Thrall oil field is quite uniform. It will be noticed that the basic elements are present in large percentages and are relatively more variable in quantity than the silica.

The very considerable variation in iron and alumina suggests the possibility of differentiation in the original igneous body. As the rock occurs in a formation of marl and clay which evidently is not in the slightest degree affected by metamorphism due to pressure or heat, it is believed that the change in the igneous rock has been effected by what is known as chemical metamorphism. From the analyses made, it appears that the rock corresponds more nearly to chlorite than to serpentine, which name was provisionally applied to it before its chemical composition was fully known. In serpentine the silica and magnesia content is relatively higher than in this rock, and there is less iron and alumina than is the case in the Thrall chlorite. It differs from an average of the analyses of chlorite quoted by Dana mainly in having more lime and less magnesia than these chlorites. This may be due to the fact that the formation in which it occurs, and from which the secondarily introduced ingredients have been derived, is itself quite calcareous but contains very little magnesia. Most chlorites which have been analyzed have no doubt come from older formations in which lime is more frequently replaced by magnesia. The very considerable variations in carbonic acid are in some cases due to the presence of calcite which it was found impracticable to separate from the samples.

In its original condition there is little doubt that the Thrall chlorite was a basic rock closely similar to some other igneous bodies which occur in the Cretaceous along the Balcones escarpment in Texas. The nearest known rock of this kind forms the landmark known as Pilot Knob, twelve miles southeast of Austin. The rock forming the hill which bears this name has been described by Prof. J. F. Kemp as a nepheline-basalt, related to limburgite. How closely related this nepheline-basalt, which has suffered very little change from its original condition, is to Thrall chlorite can be seen in the tables of analyses already given where numbers 1 and 2 are of rocks from Pilot Knob. By the substitution of magnesia for some of the lime, by the taking up of some carbonic and some sulphuric acid, by the extraction of potash and soda, and by hydration, the chlorite at Thrall could readily be derived from the basalt of Pilot Knob. We have, in fact, almost proof that a like chlorite has been produced from the unaltered Pilot Knob rock. This hill is surrounded on all sides by a sheet or other body of chlorite rock, like the Thrall chlorite. This appears to be continuous with the unaltered rock in Pilot Knob, and it has recently been penetrated for several hundred feet in a boring located about a half mile west of the hill. Farther out a similar rock is to be seen as a sheet of variable thickness and character in the Austin Chalk, surrounding the hill. Three analyses of this rock, taken from the bank of Onion Creek closely resemble those of the Thrall rock. (Analyses 11, 12 and 13.) In its physical properties, much of the rock on Onion Creek is not to be distinguished from the oil-bearing rock at Thrall. The resemblance of these two rocks will be evident from the foregoing analyses, which have been made with special care. The principal difference to be noted in the two averages is that in the Onion Creek material the iron is more highly oxidized, there is more hygroscopic water, more lime and more carbonic acid than is the case in the chlorite of the Thrall oil field. All these differences can be ascribed to the fact that the Onion Creek material is now exposed at the surface, while the Thrall rock lies buried under several hundred feet of marl, where it is not subject to oxidation or carbonization by the atmosphere, and where hygroscopic water is partly replaced by oil.

Origin of the Igneous Body

Whether the igneous body at Thrall is an intrusive or an extrusive, contemporaneous with the deposition of the lower part of the Taylor marl, is a question on which it would be desirable to have more evidence. The authors of this paper are both of the opinion that this igneous body is an extrusive and most probably represents an irregular cone left by some small submarine eruption, on the bottom of the Cretaceous sea.

It may well be admitted that the evidence supporting this view is not conclusive, but it seems to us quite strong. The direct evidence is the fact that one specimen of chloritic rock showed a texture like that of volcanic tuff. It was a fragment of green rock in which the chlorite showed markings like the boundaries of angular fragments of sizes ranging mostly between one-sixteenth and one-half mm. in diameter.

Further, Mr. Tomlinson reconstructs the metamorphic rock as having been originally a basaltic lava, in part glass, and he speaks of a sample taken from the depth of 754 to 758 feet and another from 768 to 780 feet below the surface in the Taylor Oil and Gas Company well No. 3, as giving the best idea of the original rock. He says of this that the original texture is sufficiently preserved to enable one to recast the original rock with a fair degree of certainty. These sections show outlines of phenocrysts of augite set in a base of brownish glass, and the sections show many roundish patches of zeolites which probably indicate that the rock was originally somewhat cellular. He also says of the breccias that most of them show large angular fragments of the meta-basalt with concave sides, as though broken from a cellular rock. Mr. Larsen likewise says that "the rock was unquestionably porphyritic . . . and with little doubt had scattered . . . crystals . . . in a fine-textured or glassy groundmass. Parts of it appear to have been highly vesicular and some specimens strongly suggest a rather fine-textured tuff." Other direct but indecisive evidence is the presence in quite many of the samples of microscopic bodies resembling spheruliths, as if the rock were originally in part glassy. Glassy intrusives are, however, known to exist. Prof. C. L. Baker suggests that such structures may be the result of metamorphism, as if due to a kind of concretionary growth. The absence of all evidence of contact metamorphism from all the materials examined is negative evidence, also of some significance, for careful search has been made in a large number of samples without discovering the smallest fragment of any rock that can be regarded as having been subject to metamorphism by heat. The presence of much calcite in the zones of contact both below and above the igneous rock is, on the other hand, evidence of the existence of permeable material in the places where an intrusive would naturally have baked and hardened the inclosing beds.

The present authors regard two other features as strongly favoring the hypothesis of contemporaneous volcanic activity. These are the form of the igneous body and the nature of the cap rock. A glance at the map showing the contours of the upper surface of the igneous body is sufficient to suggest resemblance to a flat cone, such as might be produced by some small submarine volcanic eruption and by subsequent leveling by marine currents, which would naturally disintegrate and scatter the extruded materials. The central part of the cone is some 250 feet higher than its outer border, if referred to a horizontal base. An intrusive might very well have a form like this, but it is hardly probable that an intrusive would be found to thin out peripherally as gradually in nearly all directions as this body seems to do. Laccolites intruded into clay formations have the habit of terminating abruptly on nearly all sides, evidently for the reason that clay formations do not as readily open along cleavage lines as do more indurated stratified rocks, such as limestones and sandstones. A number of intrusives in the Upper Cretaceous marls in the western part of this State, show heaped up forms terminating in nearly vertical lateral slopes. The igneous body of the Thrall field has, edgewise, a cuspidate form. Its highest part is truncated. Beyond the border of this high area there is first a rapid slope of the upper surface and then a more and more gradual slope to what appears to be an indeterminate thin outer margin.

The material immediately overlying the igneous rock is known as the "cap rock" and differs markedly from the typical phase of the Taylor Marl in which the igneous body is contained. This is particularly true on the northeast half of the dome. In this part of the field the cap rock consists of a porous shell breccia more or less filled with clear calcite. In many wells this rock has furnished the greater part of the oil production. But in nearly all of the wells on the southwest half of the dome, from which samples of the cap rock have been examined, it is found to consist of much finer material, either like the typical Taylor Marl or finer than this, and calcareous so as to resemble limestone. This differentiation in the nature of the sediments immediately overlying the igneous body can readily be accounted for as a result of sorting by deep currents in the sea, in the presence of a local obstruction on the bottom of the basin. Not only might such an obstruction intensify the current on the fronting side against which it impinged and produce slack conditions on the lee side; but it would also naturally greatly favor the development of a flourishing fauna on the fronting side, to the detriment of the inhabitants on the lee side. At any rate, if the igneous body is supposed to have been an intrusive it is difficult to account for the presence of an unusual phase of brecciated organic sediment in an otherwise very uniformly developed marl formation, and to explain why this unusual rock occurs only on one slope of the intruded body.

Analogous Rock in Pilot Knob

The extrusive origin of the Thrall rock is strongly suggested by an analogous occurrence of a similar rock in the Upper Cretaceous in Travis County, only some 35 miles to the southwest of Thrall. Igneous rocks in this region were described quite fully by Prof. R. T. Hill more than a quarter of a century ago, and he regarded them as clearly being extrusive.*

Prof. Hill's Notes on Pilot Knob

As Professor Hill's paper is not now readily accessible to our readers, we will quote from his lucid description quite fully. He says:

" . . . These hills are found to consist of several cusps of igneous rock rising from a circular depressed area of about 1,000 acres, and projecting through and above the chalky strata of the Black Prairie which surround it on every side. The hills have an altitude of 750 feet above sea level and 50 above the surrounding prairie.

"They are composed of a hard black rock, the exact lithologic constitution of which, as shown by Prof. Kemp, is that of limburgite or nepheline basalt. The basalt has an imperfect columnar structure

*Pilot Knob: A Marine Cretaceous Volcano. R. T. Hill, American Geologist, Vol. VI, pp. 286-294.

nearly vertical at the south extremity of the hill and nearly horizontal at the north side. The flat region between the basaltic hills and the chalky perimeter of the igneous area is filled with a soft yellow amygdaloidal exfoliating material, some of which is undoubtedly the product of basaltic decomposition, while in other places it resembles volcanic ash. The exfoliations are perfect and resemble the illustration of that structure given by Geikie.

"Proceeding in any direction from the basaltic hills which form the center of the whole outcrop, the average distance to its edge is about one-half mile, where excellent contacts with the chalk are found. The chalky stratum forming the margin of this area throughout its whole extent is crenulated into gently waving undulations and presents different aspects of hardness. In places of direct contact with basaltic material the chalk is converted into hard marble; where the ash-like material intervenes between the basalt and chalk the latter retains its soft unaltered pulverulent nature.

"The induration of the chalky sheet away from the central hills and its metamorphism are clearly indicative of activity after the deposition of the chalk, and would be a sufficient reason for making its period later than the age of the Austin chalk, were it not for other evidences found within a radius of ten miles. Proceeding in any direction, instructive outcrops are found. One mile north (from Pilot Knob) Onion creek has cut its way through a great archway of this hardened chalk to a bed of ancient debris which must have been deposited by an eruption previous to the event that marmarosed the chalk.

"This canyon of Onion creek is from fifty to one hundred feet deep and is formed by undermining erosion. Its walls consist of (a) an upper layer of massive chalk or a metamorphosed chalk-bed, and (b) a lower softer portion of thin alternations of red, green and white layers. The alternations are the most remarkable features of all the phenomena, for upon closer examination they are found to consist of volcanic debris mixed with shells of oysters (O. laeviuscula Roemer, which is but the young of O. ponderosa Roemer), whose original shell matter is preserved without change from heat or other cause, and the casts of the Inocerami (I. umbonatus?), the characteristic Inoceramus of the Austin chalk; showing that this preservation of fossil remains was by falling debris in their habitat.

"The ashy layers are from one to six inches thick and alternate with layers of similar thickness of chalky but laminated material, showing there were alternations of deposition of volcanic ejecta in a molluscan inhabited ocean. . . .

"The knobs were probably the center of disturbance, and the basaltic hills of today represent the neck of an ancient volcano whose crater has long since been denuded. Proof of this hypothesis is the

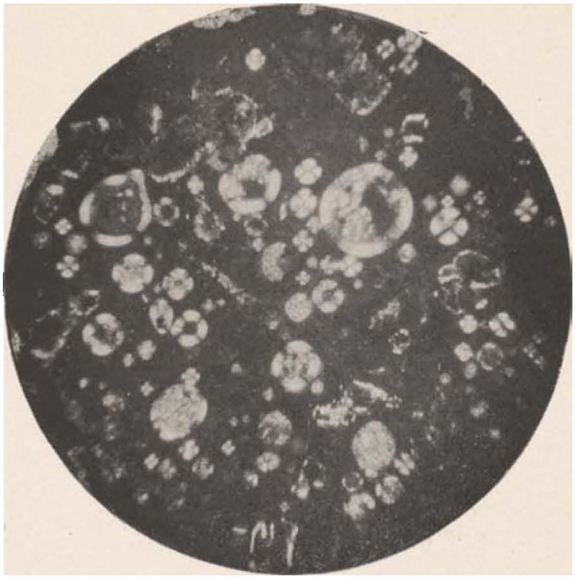

Plate 6...A...Micro-photograph of a thin section of altered igneous rock taken from well No. 73, showing Deweylite spherules. Crossed nicols. Magnified about 40 diameters. Photograph by W. H. Tomlinson.

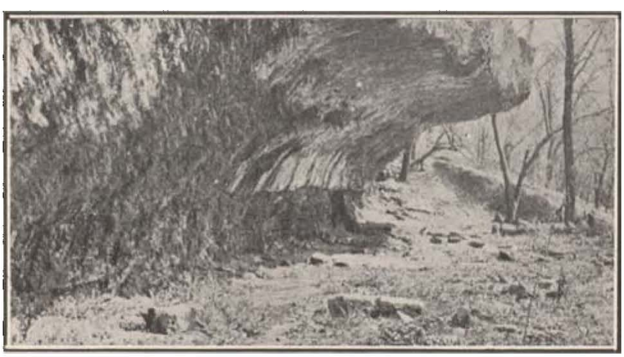

Plate 6...B...Photograph of a part of an exposure in the north bluff of Onion Creek north from Pilot Knob, showing the contact between a bed of tuff, below, and overlying limestone, which is a part of the Austin Chalk formation. Photograph by F. L. Whitney.

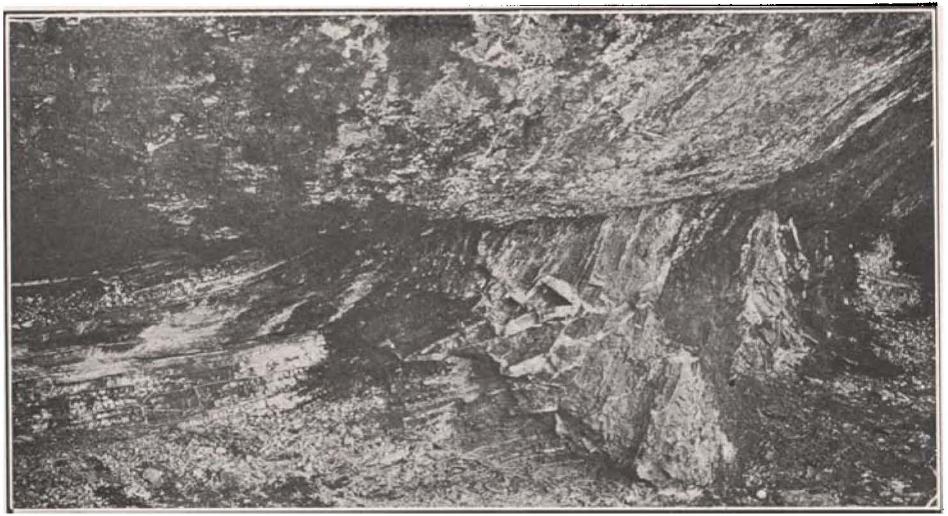

Plate 7....An enlarged view of a detail in the face of the bluff shown on Plate 6, B. The bedded tuff is seen to have been tilted and afterward cut down to a horizontal surface. Photograph by F. L. Whitney.

increasing occurrence of debris as we recede from the knobs for four or five miles around. . . .

"Accompanying the exposures of debris are occasional strata of yellow or black-yellow crystalline limestones full of the fossils of the chalk. Thin slices of this limestone made by Mr. R. L. Ziller show olivine specks in the calcareous mixture, hence I incline to think it a mixture of chalky material and debris.

"Structural Features Throwing Light Upon the Age of Pilot Knob Activity.—The historic geology revealed in the sedimentary strata of the adjacent region is complete and by its aid the period of the activity of Pilot Knob can be determined. The intermingling of the earliest debris with the O. loeviuscula beds and Inoceramus horizon of the Austin chalk shows that Pilot Knob was active during the latter half of the Austin-chalk sub-epoch of the upper Cretaceous period (about the Niobrara sub-epoch of the Northwest). The alternations of chalk and debris show long continuance of activity, while the great bed of chalk above shows a succeeding period of quiescence and subsidence. . . .

"Relation to Other Areas.—Pilot Knob is but one of a score of igneous outcrops between Austin and the Rio Grande west of Eagle Pass, to which I have previously given the name of Shumard Knobs, but its exact relation to them has not yet been studied. It is in line with the igneous features of North Texas and southeast Arkansas. The general structural features indicate an affinity between them and suggests that together they constitute a line of igneous activity which once extended from the Ouachitas to the Rockies. It is interesting to note the proximity of this Cretaceous igneous outcrop to the Burnet granite. It is probable that this has been a region of intermittent activity since early Paleozoic time.

"Conclusions.—From its structure it is shown that Pilot Knob is the neck of an ancient volcano which rose out of and deposited its debris in the deep water of the Upper Cretaceous sea (probably Niobrara sub-epoch). From its isolated position remote from any contemporaneous shore line, it must have been an island eruption. Pilot Knob probably belongs to a great chain of igneous localities, eruptive and basaltic, extending from the mountains of northern Mexico to the Ouachita system of Arkansas, both of which regions abound in related features."

Additional Notes on the Igneous Rocks Southeast of Austin

Professor Hill refers to several other occurrences of igneous rocks in the region. One of these is in South Austin and in this a piece of rock was recently found which was clearly amygdaloidal. The upper part of this rock also contains, in some places, fossils in what appears to be a tuff.

On a recent visit made to see the localities described by Hill on Onion Creek, his observations were verified. In one place in the north bluff of this stream are exposed several feet of bedded and even conglomeratic tuff under a part of the Austin Chalk, and at a half mile farther west this overlies the highly tilted edges of layers of the tuff. There is here evidently a folding of the tuff, involving probably only a small part of the latter, such as might result from creeping under pressure of soft freshly deposited tuff beds. These folds were later truncated and planed down by erosion, which, as it appears to us, may very well have resulted from the action of deep currents in the sea. (See plate 6A and plate 7.)

At any rate, this eroded surface is immediately overlain by white limestone which is about as different from the common phase of the Austin Chalk as a limestone can well be, but which nevertheless contains fossils that identify it as belonging to the middle part of this formation. Thin sections of this rock show that it has been crystallized. But it is open and porous and not at all like marble. The crystals are small, often less than one-tenth of a millimeter in diameter. Much of the rock shows a coarse texture, resembling that of a fine shell breccia or coarse calcareous sand. In thin sections fragments of shells a millimeter or more in diameter are outlined by lines containing smaller and more compactly placed crystals than those inside the original shell fragments and in their intersticial places. Frequently the intersticial places are cavities lined by larger crystals. This feature makes most of the rock quite porous. Some few layers only are compact. These are also minutely crystalline, and scattered nests of larger crystals indicate the original presence in this fine-grained limestone of larger organic fragments. Foraminifera seem to have been obliterated and the only recognizable fossils are parts of large shells, such as Inocerami. Evidently this is a limestone which has been entirely changed by hydrous metamorphism. We have here a rock which is quite analogous, in position and nature, to the shell breccia "cap rock" of the Thrall oil field.

The significance of the analogous occurrence of a contemporaneous extrusive in the Austin Chalk at this point is self-evident. It proves the commencement of extrusive volcanic activity in the Cretaceous sea before the deposition of the Taylor marl; and this furnishes strong grounds for presumption that such activity may have occurred also at the somewhat later date of the early Taylor epoch.

Porosity of the Igneous Rock

The igneous oil-bearing rock has seemingly a compact texture. and takes a fine polish, considering its softness. It appeared desirable to secure some information on its pore-space, which holds the oil. For this purpose seven samples were selected consisting of large fragments about half an inch in diameter. These were polished on a hone and dried in an oven for three hours at a temperature of 212 degrees Fahrenheit. They were then weighed in the atmosphere and afterward immersed in hot water for two hours. After these were carefully wiped dry with blotting paper, they were again weighed and the difference in weight was taken to represent the absorbed water. From this the porous space was estimated as follows:

	Per cent of porous space.
Rock from well No. 15; depth, 820 feet...........	32.2
Rock from well No. 15; depth, 832 feet...........	35.6
Rock from well No. 133; depth, 870 feet...........	32.8
Rock from well No. 133; depth, 875 feet...........	34.8
Rock from well No. 133; depth, 880 feet...........	34.9
Rock from well No. 133; depth, 890 feet...........	33.4
Rock from well No. 144; depth, 815 feet...........	21.9

Another determination of porous space was made on a large piece of the rock weighing nine ounces. This specimen was reported to have come from well 164, which was practically nonproductive. This rock slacked in water, evidently from the great avidity with which it absorbed the liquid. The sample was submitted to Mr. James P. Nash, the Bureau's testing engineer, who reported as follows:

"This rock slaked so much when placed in water that it was necessary to make the absorption tests in gasoline which had a specific gravity of 0.727 at room temperature. The absorption was obtained for this stone in the gasoline and corrected for water, at four days, seven days, and fourteen days, the maximum absorption being obtained at the later period. The apparent specific gravity was gotten by weighing the specimen in the air and immersing it in gasoline, getting the weight after immersion before it had time to absorb any gasoline. The actual specific gravity, however, was obtained by subtracting the absorption from the weight of displaced water which had been corrected from the weight of the gasoline. The voids were then obtained by multiplying the actual specific gravity of the stone by its absorption of water.

"In order to check these tests and to ascertain if this absorption would hold true if the test were actually carried out in water, some stone from Onion Creek was used. This material, which was a chlorite, had less tendency to slake in water than had the one from Thrall. Absorption tests were made on this former material, both in water and in gasoline, which checked each other within 6 per cent. Apparent specific gravities were made both on the sample weighed in water and also on that weighed in gasoline which was corrected for water, and these checked within about 3 per cent. So it may be inferred that the absorption of voids on the Thrall chlorite is reasonably correct.

"The sample of Thrall chlorite gave the following results:

Average of three samples:

Absorption of water (corrected from gasoline)......	8.55	per cent
Apparent specific gravity........................	2.22	
Actual specific gravity..........................	2.71	
Voids filled with gasoline.......................	22.6	per cent

To check this a more compact chlorite from Onion Creek was used (No. 2859), which gave:

Absorption of water (actual), average of two samples..	11.3	per cent
Absorption of water (corrected from gasoline), average of three samples..............................	12.0	per cent
Apparent specific gravity (made in water), average of two samples	2.15	
Apparent specific gravity (corrected from gasoline), average of three samples......................	2.11	

"It can therefore be said that the above results on the voids of the Thrall chlorite are correct to less than 6 per cent, provided the same relation exists between the two samples."

The porous space evidently varies in different parts of the igneous body and this may account for the small production in some of the wells that have been drilled through considerable thickness of the rock.

Distribution of Oil and Water in the Igneous Rock

Some observations were made on the relative abundance of oil and water at different levels in the chlorite. For these tests, large-sized cuttings were secured, taken at successively greater depths in each of five wells. The tests were made by distilling off the oil and water from a uniform quantity of the rock over a flame and then measuring both the distillates in a graduated tube. These analyses show that there is a general though evidently irregular distribution of water throughout the rock, and also that the oil in almost every case diminishes in quantity from the upper part of the rock downward. In the following table, which gives the result of these observations, the designated depths from which the samples were taken are to some extent approximations. As the distillations were made some days after the samples were collected, it is evident that these distillations do not represent the original quantities of either water or oil in the rock.

TABLE SHOWING THE RELATIVE AMOUNT OF WATER AND OIL AT DIFFERENT HORIZONS IN THE ALTERED IGNEOUS ROCK AT THRALL

Number of well	Depth below surface, in feet	Per cent of water	Per cent of oil
15	802	2.0	0.5
	807	1.0	0.5
	812	4.0	Trace
	820	8.0	Trace
	832	12.0	Trace
	841	13.0	Trace
29	855	5.1	1.4
	858	5.1	1.4
	860	1.7	1.1
	862	1.7	0.7
	864	Trace	Trace
	865	1.7	1.4
	866	2.4	Trace
	867	6.4	Trace
133	860	5.1	3.2
	870	12.8	2.6
	875	18.0	1.4
	880	23.1	2.2
	890	15.4	1.4
	900	14.0	Trace
	910	10.9	Trace
	920	9.6	Trace
	938	11.5	Trace
30	835	8.5	0.2
	865	1.3	0.4
	870	1.7	0.2
144	784	7.7	Trace
	800	10.0	1.3
	815	15.4	1.3
	824	18.0	2.6

Geologic Structure of the Field

In the discussion of some layers of limestone in the Taylor Marl as well as in the presentation of some data on the position of the Austin Chalk reference has already been made to the general geological structure of the region. Several borings away from the field show that there is a general dip of the formations eastward or southeastward. of some 60 to 100 feet per mile. This is also known from earlier studies in this part of the State. Some deep borings at Rockdale show a considerable thickness of the post-Austin marls at that point, and this suggests the existence at Thrall of the crest of a fold running transversely to the general monocline dipping to the southeast. The structure immediately responsible for the retention of the oil in the igneous rock is no doubt the dome-like form of the body of this rock, as it lies imbedded in the marl. Whether this form is to any extent the result of deformation by tectonic forces or whether it is to be ascribed mainly to the original form of the igneous rock, must at present remain a matter of opinion. If the igneous body was a volcanic extrusion its form may very well have been from the first what it is today, except that it has been titled southeastward with the formation in which it is contained.

Origin of the Oil

Very little needs to be said on this subject. There can hardly be any doubt that the oil in the Thrall field has been derived from the organic material contained in the Upper Cretaceous marls. These marls will almost invariably yield oil by distillation. The hydrous metamorphism of the igneous rock very likely proceeded rapidly. It may have been favored by the presence of water under a considerable pressure. This change was of course effected first. The oil filtered in later. It may have migrated into the igneous body through and along some more or less pervious layer upward along the dip from the southeast, after the Cretaceous beds were tilted into their present positions. Or it may have filtered into the porous rock directly from the marls above and below. The theory has been advanced that the oil may have migrated from some more deep-seated source along the vent, through which the igneous material was forced. It is really quite natural that such a theory should suggest itself. It cannot be disproved. To the present authors it seems far-fetched. The Comanchean Cretaceous which underlies the region has a considerably smaller bituminous content than the Upper Cretaceous, and concerning the nature of the beds underlying the Comanchean, we know very little. The nearest exploration into these rocks was recently made in a deep well at Georgetown, and at that place the Comanchean is found to rest on incipiently metamorphosed slates that have, long before the Comanchean time, given up what bituminous material they may have once contained.

Composition of the Thrall Oil

The following three analyses of the Thrall oil were made during the early history of the field, and are given here for general information. The oil is red, of low specific gravity, and has a paraffine base. It resembles the Corsicana oil, which comes from a sand in the Taylor Marl. For full information on the chemical nature of this oil the reader is referred to the thorough report on this subject given in an accompanying separate paper by Dr. E. P. Schoch and Dr. W. T. Read.

ANALYSES OF THREE SAMPLES OF OIL FROM THE THRALL FIELD

	1		2		3	
Specific gravity at 60 deg. F.	0.829 = 39.1 B.		0.830 = 38.8 B.		0.825 = 39.9 B.	
Flash point	70 deg. F.		74 deg. F.		70 deg. F.	
Burning point	70 deg. F.		74 deg. F.		70 deg. F.	
Water	None		----------		None	
Distillation (Engler method)						
	Per cent	Color	Per cent	Color	Per cent	Color
Up to 212 deg. F.	6.00	None	3.0	None	8.0	None
212 to 302 deg. F.	14.00	None	15.4	None	12.0	None
302 to 392 deg. F.	11.00	None	14.4	None	13.2	None
392 to 482 deg. F.	12.00	Prime white	11.4	Prime white	12.0	Prime white
482 to 572 deg. F.	12.20	Prime white	13.2	Prime white	12.4	Prime white
572 to 662 deg. F.	14.80	Cream white	19.60	Cream white	14.60	Cream white
	4.80	Extra pale	11.80	Extra pale	6.40	Extra pale
			9.00	Lemon pale		
Above 662 deg. F.	8.80	Lemon pale			6.00	Lemon pale
	10.80	Orange pale			4.40	Orange pale
	3.20	Red			7.60	Red
Residue	2.4		1.2		3.40	

1. Oil from the Murphy well No. 1, Thrall field, Williamson County, Texas. From igneous rock at 831 to 913 feet. An. by J. E. Stullken.
2. Oil from Corsicana Petroleum Company (H. A. Stiles) well No. 2, Thrall field, Williamson County, depth 707 to 965 feet. An. by J. E. Stullken.
3. Oil from Taylor Oil and Gas Company well No. 1, Thrall field, Williamson County, Texas. From igneous rock at 827 to 928 feet. An. by J. E. Stullken.

Oil Production

The initial production of the wells in this field varied greatly. Data on this feature of the production were secured from 105 wells, out of which number thirty-five were dry. Seven of the remaining wells had an initial production of less than eight barrels a day, while seven other wells began with a production of more than 1000 barrels a day. The largest initial production was estimated at 5000 barrels. This was from the Murphy Oil Company No. 1. Nineteen wells came in with twenty-five barrels, while fifteen began with an average of about 600 barrels. Twenty-two wells averaged some 120 barrels at the start.

TABLE SHOWING INITIAL PRODUCTION IN BARRELS PER DAY OF SEVENTY-TWO WELLS IN THE THRALL OIL FIELD

	Number of Wells
From 5000 to 1001 barrels	7
From 1000 to 201 barrels	15
From 200 to 41 barrels	22
From 40 to 9 barrels	19
From 8 to 1 barrel	7

The first few wells that were drilled were larger producers than any other equal number of wells drilled later. Four wells were reported to have an initial production ranging between 2000 and 5000 barrels. All of these were drilled early. Of sixty productive wells on one lease, whose initial production is known, the first twenty drilled had an initial average production of 393 barrels; the second twenty drilled an average initial production of 165 barrels; and the third twenty wells drilled had an average production of only 27.5 barrels. As the development of the field progressed and as the wells were drilled farther and farther from where the igneous rock was thickest, and where drilling happened to begin, the initial production rapidly decreased.

Reliable records of the production of seventy-nine wells were obtained and have been made the basis of some calculations to determine more precisely the average rate of decrease in production in individual wells in this field. Measurements on the production of each of these wells had been made when they were first brought in and observations were again taken later, on two dates separated by an interval of ten months. By arranging these observations in their proper sequence, from the beginning of the production in each well, it was found that the average decrease in the production of this group of wells was about as in the following table:

TABLE SHOWING THE AVERAGE DECREASE OF PRODUCTION IN SEVENTY-NINE INDIVIDUAL WELLS IN THE THRALL FIELD, FOR THE FIRST FIFTEEN MONTHS

	Per cent of initial production
Initial production	100
Production at end of first month	51
Production at end of the fourth month	17
Production at end of the ninth month	7
Production at end of the fourteenth month	1

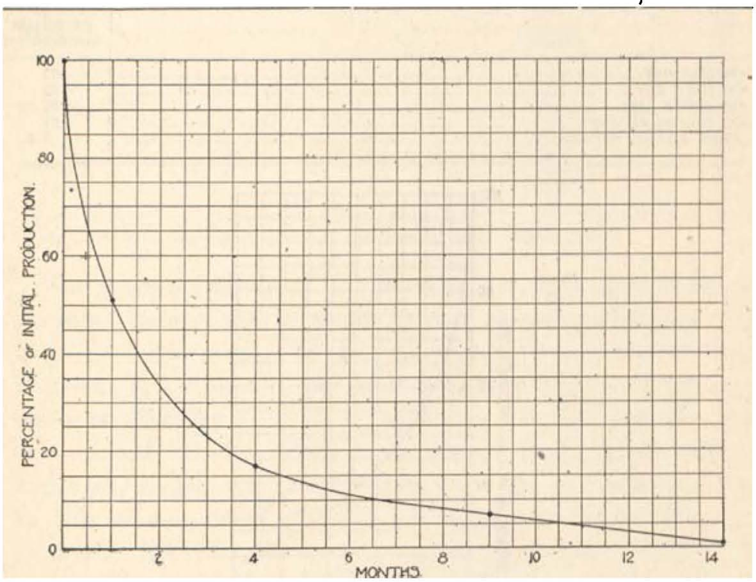

Figure 4....Curve showing the average decrease of production from the Thrall oil field in 79 wells of moderately low initial production, shown in percentages of the initial production during the first 16 months of the life of the wells.

None of the largest wells were included in the lot averaged in this table. It included only six wells with an initial production of more than 500 barrels per day. For nine of the larger wells, not included in this table, and having, with one exception.

an initial production of more than 500 barrels and mostly producing more than 1500 and up to 5000 barrels, data were secured which gave the production at irregular intervals for the first fourteen days of each well. These wells had a combined initial production of 15,150 barrels a day. By properly grouping the data at hand, it was found that the average rate of decrease in the production of these wells was at first much more rapid than in the case of the smaller wells, already discussed, being about as follows:

TABLE SHOWING THE AVERAGE DECREASE OF PRODUCTION IN NINE LARGE WELLS IN THE THRALL FIELD, DURING THE FIRST FOURTEEN DAYS

	Per cent of initial production
On first day	100
On third day	56
On eighth day	37
On fourteenth day	24
After sixteen months	1.3

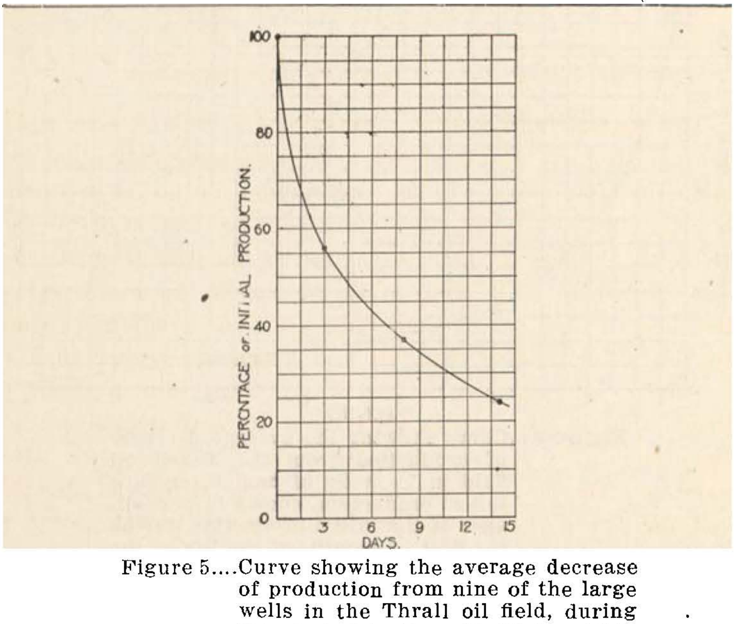

Figure 5....Curve showing the average decrease of production from nine of the large wells in the Thrall oil field, during the first 14 days of their yield; shown in percentage of initial production.

The daily production of a few wells is given below to show a few individual cases of the rapidity with which production decreased during the first few days after the wells were brought in:

		Production in barrels per day
Well No. 136*	March 28, 1915	5,000
	April 6	3,000
	April 7	2,000
	April 8	1,500
	April 11	1,400
	April 16	1,200
Well No. 121	April 1	3,000
	April 2	1,000
	April 6	700
	April 7	500
Well No. 122	April 7	500
	April 8	350
	April 9	250
	April 15	200
	April 19	200
Well No. 124	April 7	2,000
	April 8	1,500
	April 9	1,000
	April 15	250
Well No. 71	March 31	400
	April 2	350
	April 6	300
	April 8	250
	April 11	175
Well No. 1	March 30	400
	April 3	150
	April 6	100
Well was drilled deeper and gave, on	April 14	175
	April 16	150
	April 24	112

*After fifteen months this well is still making about fifteen barrels.

The general falling off in production for wells of more nearly average size may also be shown by data on some individual wells as in the table below. In the first column the initial production is given; in the second, the approximate production of the same wells on October 2, 1915, or about six months after the field was opened up. The wells at the bottom of the middle column had been drilled only a short time when the productions shown in this column were obtained and hence are higher than the average. Likewise the bottom of the third column shows the production at nine months after the wells were drilled, while in the upper part of the column is shown the production fifteen months after the wells were drilled. The middle of the third column shows the production about twelve months after the wells were drilled.

TABLE SHOWING THE DECREASE IN PRODUCTION IN BARRELS PER DAY, DURING A PERIOD OF FIFTEEN MONTHS, OF THIRTY-TWO WELLS DRILLED ON ONE LEASE

	Initial production	Production six months after the field was opened up	Production fifteen months after the field was opened up
	400	35	2
	470	40	2
	600	45	1
	900	35	8
	878	35	2
	10	1	1
	536	35	3
	50	20	2
	400	40	10
	150	25	3
	50	20	2
	150	20	1
	150	60	10
	60	35	2
	100	10	1
	20	35	10
	25	35	2
	400	100	1
	1500	50	0
	900	60	20
	100	25	1
	150	25	1
	100	20	1
	10	6	1
	0	0	0
	60	20	1
	0	0	0
	50	50	1
	35	30	12
	40	30	25
	40	?	1
	400	100	20
Average	398	30	5

In July of 1916, about sixteen months after the field was first opened for development, the writers secured an approximate estimate of the daily production of one hundred and thirty-eight wells. The following is a summary of the data thus obtained:

AVERAGE PRODUCTION OF 138 WELLS SIXTEEN MONTHS AFTER FIELD WAS OPENED, IN BARRELS PER DAY.

Size of Daily Production	Number of Wells
Below six barrels	96
Between six and ten barrels	12
Between eleven and twenty-five barrels	22
About twenty-six barrels	8

Thus almost 70 per cent. of the productive wells were at that time making less than six barrels of oil per day, while only 6 per cent. of them were making more than 25 barrels per day.

Some other features of the production in this field seem worthy of notice. The wells with the largest production are located on the north and the south slopes of the dome-like igneous mass. There is also another tract of relatively large production on the northwest edge of the igneous mass, where most, if not all of the oil came from the shell breccia on top of the north fringe of the igneous body, and where this oil-bearing sedimentary layer itself soon disappears farther to the north. It is also to be noted that the largest well was drilled in on the steeper slope on the south side of the igneous body. See Figure 6.

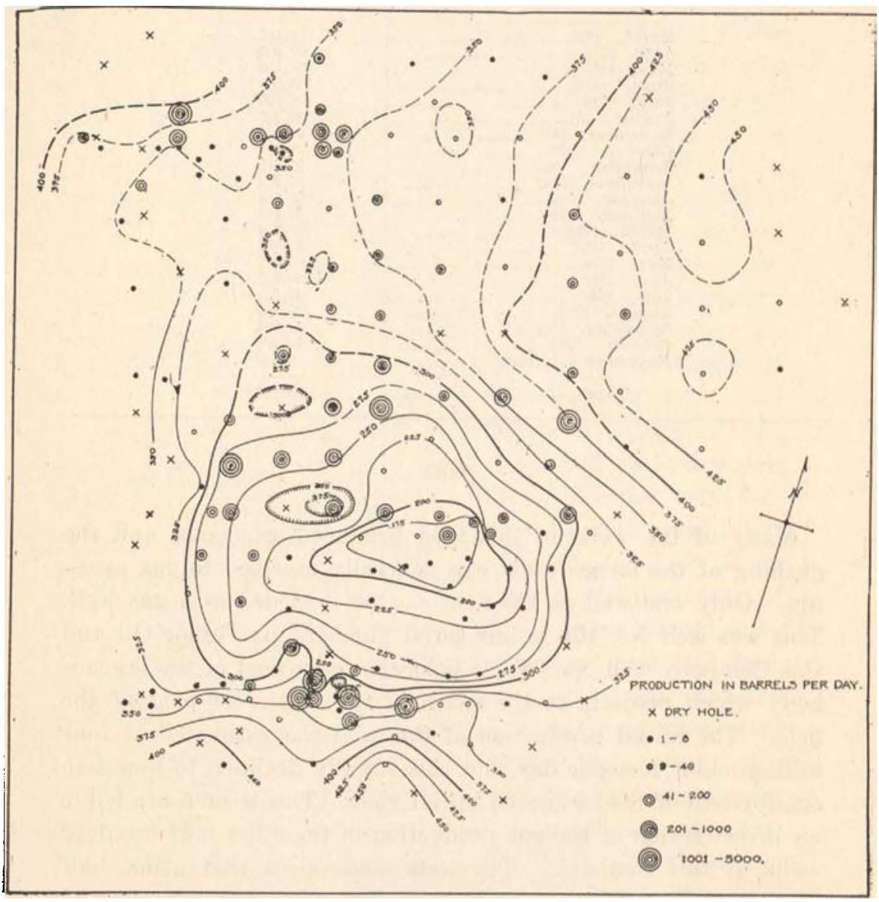

Figure 6....Sketch map showing the distribution of wells giving different amounts of production in the Thrall oil field. Contour lines show elevation of upper surface of oil-bearing rock in feet below sea level.

Total Production of the Field

The total production of the Thrall field to the present time (Nov. 4, 1916) is, in round numbers, 1,500,000 barrels. The present monthly production is about 24,000 barrels. The statistics are mainly from shipments made, and shipments by months have been about as in the table following:

PRODUCTION OF THRALL OIL FIELD, FROM MARCH, 1915, TO NOVEMBER 4, 1916

	Barrels of 42 Gals.
March, 1915	12,143
April, 1915	93,809
May, 1915	205,190
June, 1915	160,086
July, 1915	98,020
August, 1915	76,650
September, 1915	90,443
October, 1915	79,675
November, 1915	91,515
December, 1915	87,434
January, 1916	93,564
February, 1916	51,815
March, 1916	53,354
April, 1916	57,381
May, 1916	63,007
June, 1916	39,827
July, 1916	44,521
August, 1916	39,400
September, 1916	23,837
October, 1916	24,401
November 1-4, 1916	2,540
Total	1,488,612

Gas

Many of the wells in this field produced some gas, and the gushing of the larger wells was generally ascribed to gas pressure. Only one well in the field can be regarded as a gas well. This was well No. 104 in our serial numbers, or Taylor Oil and Gas Company well No. 34. It is located on a part of the igneous body which projects to the south in the southwest part of the field. The initial production of this well was estimated at four million cubic feet per day, but this rapidly declined to less than one-fortieth of the estimated initial yield. This occurrence led to an investigation of the gas production in the other half hundred wells of this company. The tests made show that about half of their wells produced some gas. The measured gas yield in twenty-four wells ranged from less than a thousand to nearly two hundred thousand cubic feet per day. Five wells produced more than 25,000 feet per day, four produced more than 5000 and less than 25,000; while thirteen produced less than 5000 cubic feet.

Prospecting for Oil in Similar Igneous Bodies

The chances of finding other oil pools like that at Thrall must be considered very small. The accumulation of the oil in this field has been contingent on several rarely recurrent geological conditions. The volcanic activity responsible for the extrusion of the igneous material would limit the chances to the Upper Cretaceous sediments, unless this activity was indeed continued in the Tertiary age. For such continued activity there is as yet no proof as far as the central and east parts of the State are concerned. On the theory, which we believe is correct, that the oil has its source in the bituminous materials of the Taylor Marl, similar pools cannot be looked for in volcanics in the Austin Chalk, or in the Woodbine sand. Another requisite condition is evidently to be found in the unusual metamorphism by aqueous agency which the original igneous rock has undergone at Thrall, leaving it sufficiently porous to absorb the oil. Other igneous bodies that were in all probability made during the Upper Cretaceous age, are known to be still in their orignal unchanged condition, as Pilot Knob and various bodies in Uvalde and McKinney counties. These volcanics are, furthermore, probably to be looked for only on the outer and lower side of the Balcones escarpment. (See Figure 7.) This marks a line of compound fractures and faults, the adjustments of which no doubt caused the igneous activity. Some altered igneous bodies along this line have been uncovered and laid bare by erosion. If any of these ever held any oil, it has vanished long ago for want of a retaining cover. This circumstance still more narrows the belt of prospective possibilities on its northwest and north side. A further unfortunate circumstance, unfavorable to the discovery of possibly similarly placed metamorphic igneous bodies, is the fact that the marls which overlie, are almost devoid of beds that resist erosion more effectively than the main body of the marl itself. This renders it very difficult for the geologist to detect any structures that might otherwise indicate favorable conditions underground.

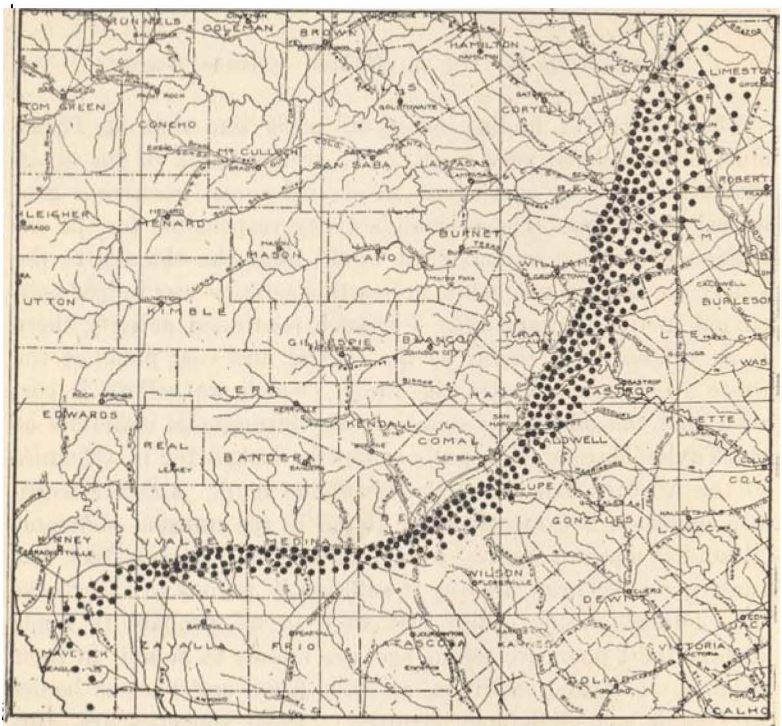

Figure 7....Map approximately locating a belt following the downthrow of the Balcones escarpment, where the Taylor Marl and the overlying Cretaceous and Tertiary deposits are from 0 to 2500 feet in depth and where igneous bodies like that at Thrall are believed to be most likely to occur in situations analogous to those at Thrall.

Paraffin (Ozokerite)

Early in the development of the Thrall oil field the operators were confronted with a serious proposition, in that the flowing wells and the surface pipes which carried the oil to the storage tanks soon became stopped up with a yellow wax that appeared to be ordinary paraffin. Many of the operators stated that they never had seen oil wells so badly affected by paraffin.

The flowing wells closed up at a depth of 250 to 300 feet, while the tubing in the wells that were being pumped frequently would be more or less filled from the top to the bottom. It was not uncommon to see surface pipes entirely filled with this wax. In the case of the surface tubing, it was necessary to replace this with clean pipe, to remove the pipe filled with the wax to the boiler and run hot steam through it, thereby melting and blowing out the wax. The Murphy Oil Company patented a steam collar which was fastened around the tubing at a depth of 250 to 300 feet, and when the wax began to choke the oil a strong current of steam was passed through the collar and the paraffin would be melted and brought to the surface by the oil. Possibly the most effective device used in this field for cleaning out the flowing wells was an iron bar some twelve or fifteen feet in length, upon whose sides were small slugs, so hinged that upon being lowered into the paraffin they rested flat against the iron bar, but as the bar was raised they spread out almost at right angles, bringing the wax to the surface.

Some of the wells that were being pumped had to have the tubing pulled and steamed out at least every fifteen or twenty days, while those wells less badly affected had their tubing pulled at longer intervals. The surface pipes were affected to a greater extent in the winter season than during the summer.

A review of the wells affected most reveals the fact that they are located mostly within the area of the igneous rock. Some of the wells drawing oil from the shell breccia were slightly affected, none very badly. Wells located where the igneous rock was thickest seem to be affected more than where the igneous rock was thinner. Also wells having a strong gas pressure were affected by the paraffine more than those with light pressure, or with none. Wells that made a little salt water were always free from the paraffin, but one evil was as serious as the other.

There was no attempt made to sell the paraffin. Each well, when cleaned, yielded from a few pounds up to two or three hundred pounds and sometimes more. The substance was to some extent used as fuel, and some was even used as road material to protect the surface pipes where they crossed the road. Many tons of the wax were brought to the surface during the most active time of oil production.

The first thirty-one producing wells on one lease may be used to gain an idea as to the number of wells that were affected by the paraffin. These wells are representative of the entire field, for some of these wells are in the shell breccia, some are located where the igneous rock is thin, and the others where it is thickest.

TABLE SHOWING THE RELATIVE AMOUNT OF PARAFFIN IN THIRTY-TWO WELLS

Amount of Paraffin	Approximate average production in barrels per day	Number of wells
None	20	7
Very slight	50	6
Slight	100	12
Considerable	500	6

The amount of paraffin evidently varies with production. In some places there are local variations no doubt due to other causes. Well No. 7 was very badly affected, but the wells that completely surround it were either entirely free or were only very slightly paraffined. Four of the wells that surround it are not over two hundred and fifty feet away. The same conditions are repeated with respect to Well No. 19.

Several samples of the paraffin-like substance were collected from various parts of the field and were submitted to Dr. E. P. Schoch for chemical analysis. The results of his investigation will be found as a separate paper in this bulletin. He has found that what was generally known in the field as paraffin has physical and chemical properties known to be characteristic of ozokerite.

APPENDIX

Well Data

LIST OF WELLS*

Serial map No.	Lease No.	Elevation of well curb, in ft. above sea level	Log of Well	General Remarks.
			CORSICANA PETROLEUM COMPANY.	
1	1	460	Surface, shale and gumbo, 0-150; sand, 150-160; shale and gumbo, 160-500; sand, 500-510; shale and gumbo, 510-665; lime shells, 665-670; oil sand, 670-759; blue shale, 759-810; sand, 810-820; blue shale, 820-875.	Great deal of paraffine.
2	2	477	Cap, 704-707; pay, 707-956; below 956 there was gumbo.	
3	3	500	Soil, 0-5; yellow clay, 5-60; gray rock, 60-63; blue shale, 63-400; gumbo, 400-707; sand (slight show of oil), 707-710; gumbo, 710-845; oil sand, 845-890; gumbo, 890-892.	Great deal of paraffine. Little paraffine.
4	4	469.5	Surface clay, 0-5; shale and gumbo, 5-150; sand with slight show of oil, 150-160; shale and gumbo, 160-505; sand with slight show of oil, 505-512; shale and gumbo, 512-605; hard rock, 605-615; shale and gumbo, 615-645; gumbo and hard formation, 646-716; hard rock, 716-722; pay, 722-797.	Great deal of paraffine.
5	5	498	Soil, 0-5; yellow clay, 5-60; rock, 60-63; blue shale, 63-410; gumbo, 410-715; sand with show of oil, 715-722; gumbo, 722-845; oil sand, 845-886; gumbo, 886-888.	Little paraffine.
	6	462	Surface, 0-5; shale and gumbo, 5-676; rock, 676-686; gumbo, 686-782; oil sand, 782-970; lime rock, 970-977; gumbo, 977-981.	No paraffine. Makes some salt water.
7	7	498	Soil, 0-5; yellow clay, 5-63; rock, 63-67; shale, 67-406; gumbo, 406-707; sand with show of oil, 707-710; shale and gumbo, 710-842; oil sand, 842-884; shale, 884-886.	Great deal of paraffine.
8	8	461	Surface, 0-6; shale, 6-150; sand with show of oil, 150-160; shale and gumbo, 160-505; sand with show of oil, 505-510; shale and gumbo, 510-626; rock, 626-628; shale, 628-655; oil sand, 655-998.	No paraffine. Makes a little salt water.
9	9	465	Soil, 0-6; shale and gumbo, 6-750; rock, 750-755; gumbo, 755-770; sand, 770-815; gumbo, 815-821.	Some paraffine.
10	10	491	Soil, 0-3; yellow clay, 3-58; rock, 58-62; shale, 62-400; gumbo, 400-840; oil sand 840-875; shale, 875-880.	A little paraffine.
11	11	463	Surface, 0-6; shale and gumbo, 6-155; sand with show of oil, 155-160; shale and gumbo, 160-508; sand with show of oil, 508-513; shale and gumbo, 513-600; sand with show of oil, 600-605; shale and gumbo, 605-638; pay sand, 638-672.	Very little paraffine.
12	12	501	Surface, 0-5; yellow clay, 5-64; gray rock, 65-68; blue shale, 68-420; gumbo, 420-840; oil sand, 840-869; shale, 869-875.	A little paraffine.
13	13	476.3	Surface, 0-6; shale and gumbo, 6-770; oil sand, 770-815.	No paraffine.
14	14	472	Surface, 0-6; shale, 6-150; oil sand, 150-155; shale and gumbo, 155-721; oil sand, 721-787; gumbo, 787-790.	A little paraffine.

*In the drill records the green chlorite is almost invariably called "oil sand" or merely "sand".

LIST OF WELLS—Continued

Serial map No.	Lease No.	Elevation of well curb, in ft. above sea level	Log of Well	General Remarks.
15	15	176	Shale and gumbo, 0-802; oil sand, 802-841.	No paraffine.
16	16	178	Surface, 0-6; shale and gumbo, 6-804; sand and shale, 804-825; shale and gumbo, 825-904.	A little paraffine.
17	17	179	Shale and gumbo, 0-818; oil sand, 818-838; gumbo, 838-853.	A little paraffine.
18	18	181	Earth and clay, 0-40; shale, 40-60; rock, 60-61; gumbo and shale, 61-773; caprock, 773-782; oil sand, 782-792; shale, 792-821.	A little paraffine.
19	19	162	Earth and clay, 0-40; lime rock at 35; shale, 40-160; shale and gumbo, 160-230; shale, 230-450; show of oil, 450; shale and gumbo, 450-667; shale, 667-730; caprock, 730-735; oil sand, 735-800; shale, 800-805.	Working some gas, July 18, 1916. Great deal of paraffine.
20	20	179	Earth and clay, 0-50; rock (limestone), 50-51; shale and gumbo, 51-270; shale and hard gumbo, 270-468; gumbo and shale, 468-765; caprock, 765-772; oil sand, 772-832.	A little paraffine.
21	21	181	Shale and gumbo, 0-812; oil sand, 812-940.	A little paraffine.
22	22	186	Shale and gumbo, 0-55; hard rock, 55-57; shale and gumbo, 57-839; oil sand, 839-898.	A little paraffine.
23	23	491	Shale and gumbo, 0-50; rock, 50-51; shale and gumbo, 51-855; oil sand, 855-870; shale, 870-890.	A little paraffine.
24	24	163	Shale and gumbo, 0-400; oil sand, 400-405; shale and gumbo, 405-690; oil sand, 690-1032.	No paraffine. Makes some salt water.
25	25	485	Earth and clay, 0-40; shale, 40-90; hard limestone, 90-91; gumbo and shale, 91-867; rock, broken formation, possibly oil sand, 867-877; shale, 1170-1180; limestone, 1180-1582.	A dry hole. Green igneous rock present.
26	26	178	Shale and gumbo, 0-765; oil sand, 765-847.	Samples of green igneous rock taken from dump.
27	27	487	Shale and gumbo, 0-60; rock, 60-62; shale and gumbo, 62-520; oil sand, 520-525; shale and gumbo, 525-846; sand, 846-861; shale, 861-948.	A dry hole.
28	28	194	Shale and gumbo, 0-75; rock, 75-77; shale and gumbo, 77-845; oil sand, 845-877.	Very little paraffine.
29	29	501	Shale and gumbo, 0-865; pay, 865-880.	Very little paraffine.
30	30	492	Clay, 0-35, rock, 35-36; shale and gumbo, 36-855; oil sand, 855-870; shale, 870-883.	No paraffine. Oil sand is a shell breccia. Green igneous rock present.
31	31	176	Shale and gumbo, 0-770; oil sand, 770-870.	Oil is in shell breccia, above green igneous rock.
32	32	472	Shale and gumbo, 0-820; oil sand, 820-885; shale, 885-890.	Green igneous rock noted on dump.
33	33	503	Shale and gumbo, 0-60; rock, 60-61; shale and gumbo, 61-700; hard gumbo, 700-844; oil sand, 844-864; gumbo, 864-880.	
34	34	180	Shale and gumbo, 0-350; sandy shale, 350-360; shale and gumbo, 360-820; oil sand, 820-894.	
35	35	485	Pay, some green igneous rock, 920-935; rock, 60-61; total depth, 969 ft.	Green igneous rock found on dump.
36	36	470	Shale and gumbo, 0-145; sandy shale, 145-150; shale and gumbo, 150-415; sandy shale, 415-420, shale and gumbo, 420-636; oil sand, 643-713.	Green igneous rock is found on dump.
37	37	460	Shale and gumbo, 0-50; rock, 50-51; shale and gumbo, 51-612; sand, 612-686.	Green igneous rock is found on dump.

LIST OF WELLS—Continued

Serial map No.	Lease No.	Elevation of well curb, in ft. above sea level	Log of Well	General Remarks.
38	38	476	Shale, 0-50; rock, 50-51; shale, 51-745; gumbo, 745-875; oil sand, 875-923.	Green igneous rock is found on dump.
39	39	4[illegible]0	Hard rock, 100-108; lime and shells, 902-904; hard gumbo, 904-1160; chalk, 1160-1170.	A dry hole. Green igneous rock found on dump.
40	40	478	Shale, 0-50; rock, 50-51; shale and gumbo, 51-420; oil sand and light show for oil, 420-425; shale and gumbo, 425-628; oil sand, 628-683.	Green igneous rock seen in dump.
41	41	462	Shale and gumbo, 0-420; oil sand and shale, 420-426; shale, 426-725; pay, 725-775.	
42	42	470	Shale and gumbo, 0-726; oil sand, 726-807.	
43	43	494	Very hard rock, 100-108; gas showing sand, 845-849; oil sand, 890-908; shale, 908-918.	
44	44	497	Hard rock, 100-104; oil sand, 867-902; blue shale, 902-818?	
45	45	503	Hard rock, 75-76; shells and shale, 865-884; oil sand, 884-902; shale and gumbo, 902-907	
46	46	470	Hard rock, 95-100; oil sand, 905-927; shale, 927-935	
47	47	483	Hard rock, 90-95; oil sand, 912-941; blue shale, 941-946.	
48	48	490	Water gravel, 60-100; oil sand, 924-949.	
49	49	493	Hard rock, 140-142; oil sand, 935-960; blue shale, 960-965.	
50	50	482	Hard rock, 110-115; shell rock and gumbo, 840-920; oil sand, 920-942; shale, 942-957.	
51	51	489.6	Shale and gumbo, 0-120; hard rock, 120-122; shale and gumbo, 122-912; oil sand, 912-933; shale, 933-943.	
52	52	498	Shale, 0-100; hard rock, 100-102; shale and gumbo, 102-877; oil sand, 877-896; shale, 896-905.	
53	53	?	Shale, 0-100; hard rock, 100-102; shale and gumbo, 102-836; oil sand, 836-852; gumbo, 852-857.	
54	54	488	Shale, 0-110; rock, 110-111; shale, 111-120; shale and gumbo, 120-935; oil sand, 935-953; shale, 953-971.	
55	55	498	Shale and gumbo, 0-105; rock, 105-106; shale and gumbo, 106-853; oil sand, 853-874; shale, 874-879.	
56	56	500	Shale, 0-80; hard rock, 80-81; shale and gumbo, 81-715; oil sand, show of oil and gas, 715-735; sandy shale, 735-780; shale and gumbo, 780-897; oil sand, 897-918; shale, 918-921.	
57	57	490	Shale, 0-145; rock, 145-146; shale and gumbo, 146-930; oil sand, 930-948; shale, 948-950.	
58	58	493	Shale, 0-150; rock, 150-151; shale and gumbo, 151-520; rock, 520-521; shale and gumbo, 521-900; oil sand, 908-917; shale, 917-948.	Green igneous rock found on dump.
59	59	497	Shale, 0-140; rock, 140-141; shale and gumbo, 141-938; oil sand, 938-954; shale, 954-956.	Green igneous rock found on dump.
60	60	495	Shale, 0-90; rock, 90-91; shale, 91-140; rock, 140-141; shale and gumbo, 141-863; oil sand, 963-979; shale, 979-981.	Green igneous rock found on dump.
61	61	487	Shale, 0-90; rock, 90-91; shale and gumbo, 91-943; oil sand, 943-960; salt water and sand, 960-962; shale, 962-965.	Green igneous rock found on dump.
62	62	490	Shale, 0-100; shells, 100-104; shale and gumbo, 104-800; hard gumbo, 800-975; shells, 975-990; shale and gumbo, 990-1160; chalk rock, 1160-1165.	A dry hole.

LIST OF WELLS—Continued

Serial map No.	Lease No.	Elevation of well curb, in ft. above sea level	Log of Well	General Remarks.
63	63	490	Shale, 0-160; rock, 160-161; shale, 161-943; oil sand, 943-949; shale, 949-957.	
64	64	508	Shale, 0-80; shale and gumbo, 80-938; oil sand, 938-951; shale, 951-958.	Green rock found on dump.
65	65	496	Shale, 0-90; shale and gumbo, 90-933; oil sand, 933-941; shale and gumbo, 941-1005.	
66	66	498	Shale, 0-100; rock, 100-101; shale and gumbo, 101-860; pay and broken formation, 860-876; shale, 876-910.	
67	67	499	Shale and gumbo, 0-930; thin shells, 930-940; shale and gumbo, 940-1053.	A dry hole.
68	68	500?	Shale and gumbo, 0-938; broken formation, 938-953; chalky shale, 953-1070.	A dry hole.
69	69	480	Surface clay, 0-5; yellow clay, 5-20; shale, 20-390; rock, 390-391; shale, 391-400; rock, 400-491; shale, 491-500; rock, 500-591; shale, 591-560; rock, 560-561; shale and gumbo, 561-626; rock, 626-638; shale, 538-790; lime shells and shale, 790-795; green rock, 795-827; shale and green rock, 827-836.	Collected samples from this well every ten feet. See p. 18.
70	70	500	Shale, 0-57; rock, 57-58; shale and gumbo, 58-423; rock, 423-425; shale and gumbo, 425-850; shells, 850-859; oil sand and broken formation, 859-869; shale and gumbo, 869-905.	
			TAYLOR OIL & GAS COMPANY. Mrs. E. Stiles Farm.	
71	1	496	Cap, 812-824; pay, 824-922. Still in pay.	Gas, 1200 ft.*
72	2	484	Caprock, 785-792; pay, 792-906.	Gas, 1200 ft.* Green igneous rock on dump.
73	?	491	Caprock, 732-742; oil sand, 742-809; gumbo, 809-827; oil sand, 827-862; gumbo, 862-905; sand and shale, 905-1019.	Green igneous rock present. Makes salt water. A little oil and no gas.
74	4	449	Pay, 833-870.	
75	5	492	Cap, 719-724; oil sand, 724-759; gumbo, 759-782; oil sand, 782-862; gumbo, 862-887.	Some salt water.
76	6	495	Pay, 844-864; gumbo, 864-895.	
77	7	495	Pay, 855-870; gumbo, 870-872.	
78	8	488	Cap, 785-789; oil sand, 789-933.	
79	9	498	Cap, 702-707; oil sand, 707-802; gumbo, 802-811.	
80	10	499	Cap, 854-873; pay, 873-885.	19,920 cu. ft. of gas.
81	11	484	Cap, 832-849; pay, 849-877.	
82	12	501	Gumbo, 640-720; caprock, 720-726; oil sand, 726-801.	Initial production, 400 bbls.
83	13	522	Cap, 833-837; oil sand, 833-882; gumbo and shale, 882-924.	
84	14	465	Like well No. 26.	
85	15	498	Cap, 823-855; oil sand, 855-875; broken formation of sand and shale, 875-893.	1656 cu. ft. of gas.
86	16	498	Pay rock, 851-866.	49,680 cu. ft. of gas.
87	17	501	Pay, 854-874; shale, 874-884.	2392 cu. ft. of gas.

*The estimate of production of gas on the Taylor Oil and Gas Company lease was made about July 1, 1916.

*This and like numbers below give the quantity of gas yielded in cubic feet per day.

LIST OF WELLS—Continued

Serial map No.	Lease No.	Elevation of well curb, in ft. above sea level	Log of Well	General Remarks.
88	18	503	No information about depth of pay.	Initial production, 50 bbls.
89	19	465	Cap, 710-730; oil sand, 730-766.	Initial production, 150 bbls. 456 cu. ft. of gas.
90	20	485	Cap, 816-830; pay, 830-841.	Dead. No gas.
91	21	491	Cap, 836-850; oil sand, 850-863.	4056 cu. ft. of gas.
92	22	511	Well begun June 9, 1915. Soil, 0-3; clay, 3-36; gravel, coarse, 36-41; gumbo, 41-200; white shale, 200-300, caved; shale, 300-540; shale, 540-620, caved; shale, 620-709; shale, much harder, 709-820; caprock, 820-821; oil sand, 821-848.	
93	23	496	Oil sand, 851-872.	Gas, 32,280 cu. ft.
94	24	487	This well begun June 18, 1915. Soil, clay and gravel, 0-40; white, hard shelly rock, 40-41; shale, 41-230; gumbo, 230-235; shale, 235-350; white, hard, shelly rock, 350-352; gumbo, 352-360; shale, 360-390; gumbo, 390-430; shale, 430-579; gumbo, 579-600; shale, 600-630; gumbo, 630-640; shale, 640-680; oil-bearing shale, 680-690; gumbo, 690-700; shale, 700-730; gumbo, 730-753; gumbo, 753-764; shale, 764-827; caprock, 827 (log incomplete).	Makes salt water. No gas pressure.
95	25	486	Pay rock, 822-836; bottom of hole, 841.5.	Makes some salt water. 1656 cu. ft. of gas.
96	26	465	Pay rock, 787-798.	This well is close to No. 14.
97	27	484	Surface clay, 0-40; shale, 40-245; gumbo, 245-265; rock, 265-266; gumbo, 266-305; shale, 305-360; gumbo, 360-460; shale, 460-500; gumbo, 500-560; shale, 560-604; gumbo, 604-620; shale, 620-660; gumbo, 660-792; shale, 792-839; pay, 839-855.	Dry hole.
98	28	482	Surface clay, 0-40; shale and gumbo, 40-313; rock, 313-314; shale and gumbo, 314-720; caprock, 720-734; pay, 734-760.	Gas, 11,472 cu. ft.
99	29	490	Clay and gumbo, 0-100; rock, 100-101; shale and gumbo, 101-700; rock, 700-703; shale and gumbo, 703-727; rock, 727-731; pay, 731-765; shale, 765-770.	Gas, 1200 cu. ft.
100	30	527	Clay and shale, 0-126; rock, 126-128; gumbo and shale, 128-608; rock, 608-609; gumbo and shale, 609-789; rock, 789-792; shale and gumbo, 792-839; cap, 839-855; pay, 855-870; gumbo, 870-875.	No gas.
101	31	526	Clay and gumbo, 0-150; rock, 150-152; shale and gumbo, 152-720; rock, 720-721; shale and gumbo, 721-864; rock, 864-865; shale and gumbo, 865-873; show of oil at 873; rock, 873-875; gumbo and shale, 875-1037; shale (show of oil), 1037-1100; gumbo, 1100-1105; chalk, 1105-1110.	A dry hole.
102	32	480	Surface clay, 0-38; rock, 38-39; shale, 39-450; gumbo, 450-532; shale, 532-738; shells, 738-739; oil sand, 739-768; gumbo, 768-771.	Gas, 191,688 cu. ft. Finished Sept. 11, 1915.
103	33	517	Surface clay, 0-19; soft rock, 19-22; clay, 22-41; gumbo and clay, 41-80; hard rock, 80-83; gumbo and shale, 83-704; caprock, 704-762; oil sand, 762-778.	No gas.

LIST OF WELLS—Continued

Serial map No.	Lease No.	Elevation of well curb, in ft. above sea level	Log of Well	General Remarks.
104	34	511	Surface clay, 0-40; shale and gumbo, 40-460; rock, 460-462; gumbo, 462-637. shale, 637-759, soft rock, 759-762; green rock, 762-769.	Came in making 4,000,000 cu. ft. gas; on July 18, 1916, was making 73,272 cu. ft.
105	35	472	Surface clay, 0-20; rock, 20-21; shale and gumbo, 21-769; rock, 769-773; oil sand, 773-789.	Gas, 2856 cu. ft.
106	36	497	Surface clay, 0-25; shale, 25-730; rock, 730-731; gumbo, 731-851; oil rock, 851-864; shale and gumbo, 864-896.	No gas.
107	37	491	Caprock, 817-837; oil sand, 837-852; shale, 852-861	Gas, 11,473 cu. ft.
108	38	485	Pay, 812-835; gumbo, 835-839.	No gas.
109	39	495	Cap, 852-867; pay sand, 867-883.	Gas, 2856 cu. ft.
110	40	495	Surface clay, 0-40; rock, 40-41; shale and gumbo, 41-826; cap, 826-830; oil sand, 830-845; gumbo, 845-851.	Gas, 25,000 cu. ft.
111	41	504	Surface clay, 0-45; gumbo, 45-55. rock, 55-56; gumbo and shale, 56-818; cap, 818-825; oil sand, 825-843; gumbo, 843-850.	Gas, 1652 cu. ft.
112	42	504	Cap, 723-763; oil sand, 763-830.	Gas, 72,697 cu. ft.
113	43	505	Cap, 763-767, oil sand, 767-826.	Gas, 23,904 cu. ft.
114	44	523	Cap, 761-821; oil sand, 821-870.	Gas, 1636 cu. ft.
115	45	520	Top of chalk, 1080, total depth, 1119 ft.	Dry hole.
116	46	484	Cap, 788-798; pay, 798-873; and still in green igneous rock.	Gas, 13,272 cu. ft.
117	47	472	Good pay, 802-808; green shale, 808-868; shale, 868-930	Gas, 1200 cu. ft.
118	48	468	Total depth, 852 feet.	Dry.
119	49	477	No information.	Dry.
120	50	487	Cap, 818-821; oil sand, 821-898; shale, 898-904.	Green igneous rock found on dump.
120a	51	476	*Gray limestone*, calcite, fragments of shells and shale, 805-815; gray rock which seems to be like the green rock in all respects except color, 815-820.	Very slight show of oil.
			BOWERS & WITHERSPOON OIL COMPANY. Fritz Fuchs Farm.	
121	1	510	Cap, 828-837; pay, 837-943; still in pay. About 55 to 57 feet below the top of the pay there was a layer of sandy gumbo about two feet in thickness. Mr. C. L. Witherspoon thinks that this layer occurred in every well on the lease. The writers have not seen any of this material. In June, 1916, this well was redrilled a few feet to one side and a very small well was the result, making 2 or 3 bbls. per day.	The top and bottom of pay seemed to be harder than the middle. This well made a small amount of salt water.
122	2	510	Cap, 821-832; pay, 832-963: still in pay.	Badly paraffined. Sandy gumbo 55 ft. below top of pay.
123	3	512	In rock at 465; cap, 814-826; pay, 826-930; gumbo, 930-940; sandy streak, 55-57 feet below the top of the pay.	Badly paraffined.
124	4	507	Cap, 843-853; pay, 853-957. The cap was much softer than in any other of the wells. This well was also redrilled a few feet away and came in April 17, 1916, making 100 bbls. per day; and is now, June 16, 1916, pumping 60 bbls. per day.	Sandy gumbo present. A little paraffin.

LIST OF WELLS—Continued

Serial map No.	Lease No.	Elevation of well curb, in ft. above sea level	Log of Well	General Remarks.
125	5	510	Cap, 860-869; pay, 869-961; and still in pay.	A little paraffine.
126	6	503	Cap, 861-874; pay, 874-970.	Slightly paraffined.
127	7	519	Cap, 862-880; pay, 880-978.	Slightly paraffined.
128	8	507	Cap, 857-868; pay, 868-965.	Slightly paraffined.
129	9	497	Cap, 836-847; pay, 847-958.	Some paraffin.
130	10	511	Cap, 861-885; pay, 885-970.	No paraffin. A little salt water.
131	11	510	Pay, 860-970.	
132	12	528	Cap, 858-860; pay, 860-938.	Slightly paraffined.
133	13	526	Cap, 858-860; pay, 860-938	
134	14	505	Cap, 907-912; pay, 912-939.	Very much paraffined.
135	15	500	Pay, 922-965.	
135a	16	511	Pay, 960-970.	Never productive.
135b	17	499	Cap, 867-872; pay, 872-892.	Not finished.
			MURPHY OIL COMPANY. *Fritz Fuchs Farm.*	
136	1	508	Cap, 755-821; pay, 821-914; in a blue sand at the bottom of the hole.	Some paraffin.
137	2	488	Cap, 808-816; pay, 816-856. At 820, there was a flow of 700 bbls. of oil which stopped the drilling. Later the well was drilled deeper, getting a flow of 2600 bbls.	Drilled to pay with a rotary drill and "drilled in" with cable tools.
138	3	510	Cap, 860-872; pay, 872-957.	Made some salt water all the time. No paraffin.
139	4	490	Earth and clay, 0-40; shale and gumbo, 40-800; hard limestone, shale, and grit, 800-860; caprock, 860-882; oil sand, 882-905.	Green igneous rock present.
140	5	479	Cap, 790-820; sand, 820-875.	
141	6	506	Cap, 917-935; oil sand, 935-980; shale, 980-1005.	
142	7	471	Cap, 800-830; oil sand, 830-885.	
143	8	468	Cap, 784-789; pay, 789-850; gumbo, 850-860.	Some paraffin.
144	9	474	Pay, 784-824.	
145	10	475	Cap, 866-874; pay, 874-917. This well made a little oil at first, but soon was dead. In about six months it was shot, cleaned out and baled, but still there was no oil.	
146	11	500	Clay, 0-20; blue shale, 20-800; gumbo, 800-900; blue shale, 900-937; gumbo, 937-952; rock, 952-960; blue shale, 960-970; rock, 974-978; gray shale, 978-1200; Austin limestone, 1200-1500; show of oil at 1450.	Dry hole.
147	12	480	Cap, 844-862; pay, 862-987.	
148	13	493	Cap, 835-848; pay, 848-901.	
149	14	468	Pay, 825-860.	Dry hole. Green igneous rock present.
150	15	504	Bottom of hole, 997.	Dry hole. Green igneous rock present on dump.

LIST OF WELLS—Continued

Serial map No.	Lease No.	Elevation of well curb, in ft. above sea level	Log of Well	General Remarks.
			FIRST THRALL OIL COMPANY. Fritz Fuchs Farm.	
151	1	510	Cap, 786-808; pay, 808-899, into gumbo; drilling in chalk (?) at 910.	"Discovery well". Life of well, 8 months.
152	2	499	Cap, 764-772; pay, 772-916.	
153	3	510	Cap, 847-855; pay, 855-940; bottom of well, 940 feet.	No. 22 has been drilled to replace it.
154	4	507	Pay, 784-876; gumbo, 876-1016.	
155	5	490	Cap, 777-778; pay, 778-869.	
156	6	470	Cap, 642-662; pay, 662-733; still in pay.	In green igneous rock.
157	7	480	Pay, 669-752.	In green igneous rock.
158	8	481	Cap, 708-709; pay, 709-864.	In green igneous rock.
159	9	480	Cap, 699-700; pay, 700-791.	In green igneous rock.
160	10	464	Cap, 615-635; pay, 635-677; into shale below. This is the shallowest well on the lease, and has been the best.	In green igneous rock.
161	11	450	Cap, 630-631; pay, 631-725.	In green igneous rock.
162	12	457	Cap, 653-654; pay, 654-775.	In green igneous rock.
163	13	509	Cap, 777-778; pay, 778-838; shale, 838-993; chalk (?) at 993.	Green igneous rock reported to be 208′ thick.
164	14	493	Cap, 727-735; green igneous rock, 735-809; gumbo, 809-813; green rock, 813-826; gumbo, 826-829; green rock, 829-917; still in the green rock.	Large fragment of rock said to have been blasted from this well. See Plate 4.
165	15	486	Cap, 725-731; pay, 731-825; into gumbo below.	Green igneous rock present.
166	16	464	Cap, 642-649; pay, 649-685.	Green igneous rock present.
167	17	470	Cap, 665-670; pay, 670-725.	Green igneous rock present.
168	18	455	Cap, 675-680; pay, 680-765.	Green igneous rock present.
169	19	465	Cap, 755-758; pay, 758-798.	Green igneous rock present.
170	20	468	Cap, 628-635; pay, 635-723.	
171	21	468	This is a shallow well beside No. 20. It is about 600 feet in depth and had a good show of oil, but a poor job of setting the casing seemed to spoil the well.	Not deep enough to strike the green rock.
172	22	510	Drilled fifty feet west of No. 3 and is the same depth.	
173	23	507	Depth, 400 feet. At 350 feet there was an oil-bearing strata that produced 4 bbls. per day for about three weeks.	Dead, after one month.
174	24	508	Show of oil, 400 ft., 600 ft., and at 730 ft. Green igneous rock, 740-836; still in green rock.	No gas pressure.
175	25	453	Gumbo and shale, 0-622; caprock, 622-648; pay (green igneous rock), 648-708.	
175a	26	453	Gumbo and shale, 0-728; caprock, 728-733; pay (igneous rock), 733-1280; gray shale, 1280-1290; chalk, 1290-1299.	
175b	27	455	Not finished.	

LIST OF WELLS—Continued

Serial map No.	Lease No.	Elevation of well curb, in ft. above sea level	Log of Well	General Remarks.
			CALDWELL OIL COMPANY. J. Dieble Farm.	
176	1	495	Gumbo and soft shale, 0-847; gray caprock, 847-862; hard green rock, 862-883; into gumbo below.	
177	2	495	Rock, showing of oil, 755-760; dark shale and gumbo, showing of gas, 760-881; gumbo and shale, 881-890; rock, 890-894; pay, 894-901.	
178	3	492	Gumbo and shale, 804-860; rock, 860-863; gumbo and shale, 863-872; rock, 872-876; gumbo and shale, 876-884; cap, 884-899; green rock, 899-912.	Well finished May 12, 1915.
179	4	496	Shale and gumbo, 765-847; rock, 847-848; gumbo and shale, 848-855; cap, 855-872; pay, 872-877; shale and gumbo, 877-937.	
180	5	486	Shale and gumbo, 759-855; with light showing of oil; cap, 855-856; pay, 856-873; gumbo, 873-875.	
181	6	482	Shale and gumbo, 820-843; cap, 843-861; pay, 861-866.	
			FIRST THRALL OIL COMPANY. Goetz Tract.	
182	1	489	Cap, 863-883; total depth, 900 feet.	Drilled May 20, 1915.
183	2	488	Cap, 814-836; total depth, 867 feet.	
184	3	474	Cap at 808; total depth, 835 feet.	
185	4	526	--	A dry hole.
186	5	470	Cap, 893-895; a gray sand, 895-899; gumbo, 899-913.	
187	6	480	Hard gray shale, 840-860; green igneous rock, 860-885.	Well finished in June, 1916.
188	7	490	Hard gray shale bearing some oil, 865-889; green rock, 889-967.	A dry hole.
189	8	528	Pay (green igneous rock), 920-975; still in igneous rock.	Slight show of oil at top of igneous rock. Dry.
			FIRST THRALL OIL COMPANY. Stauffer Farm.	
190	1	527	Cap, 850-852; pay, 852-893; shale and gumbo, 893-978.	
			LEE OIL & GAS COMPANY. J. Dieble Farm.	
191	1	492	Some sand at 866; cap, 878-908; pay, 908-926; into gumbo below.	A dry hole.
192	2	484	No information.	
			THRALL INDEPENDENT OIL COMPANY. J. Dieble Farm.	
193	1	501	Cap, 847-860; pay, 860-863.	
194	2	497	Cap, 852-868; pay, 868-874; still in pay.	
195	3	497	No information.	
196	4	493	No information.	
197	5	499	No information.	
198	6	498	No information.	

LIST OF WELLS—Continued

Serial map No.	Lease No.	Elevation of well curb, in ft. above sea level	Log of Well	General Remarks.
			HOME INDEPENDENT OIL COMPANY. J. Dieble Farm.	
199	1	504	Pay, 836-877.	
200	2	506	No information.	
201	3	506	No information.	
			THRALL-CALDWELL OIL COMPANY. J. Dieble Farm.	
202	1	504	Earth and clay, 0-40; hard limestone, 40-41; shale, 41-820; rocky shale, 820-835, shale, 835-895.	A dry hole.
			MORAN OIL COMPANY. J. Dieble Farm.	
203	1	494	Soft, black and yellow shale, 0-44; shale and gumbo, 44-505, lime rock, 505-506; gumbo and shale, 506-564; hard limestone, 564-574; (?) shale, 578-583; with show of oil and gas; gumbo and shale, 583-836; soft limestone, 836-838, which would not support the casing; gumbo, 838-852; caprock, 852-879; soft shells bearing some oil, 879-899; soft gray shale, 899-914, no oil, drills easily; gumbo, 914-916.	
204	2	495	No information.	
205	3	494	Soil and mixed shale, 0-40; rock, 40-41; shale, 40-166; rock, 166-166.5; shale, 166.5-760; show of oil in shale at 760-764; lime rock, 764-765; gumbo, 665-690; oil-bearing shale, 690-808; test showed 2 bbls. per day; tough gumbo, 808-825; shale, 825-840; shaly limestone, 840-842; shale, 842-860; shaly rock, 860-862; shaly rock and oil-bearing shale, 862-925; gumbo, 925-930; bottom of well.	
			PREMIER OIL COMPANY.	
206	1	502	Earth, 0-5; rock, 5-6; gumbo, 6-170; shale, 170-185; good showing of gas; limestone, 185-189; shale and gumbo, 189-244; tough gumbo, 244-573; shale with showing of gas, 573-592; shale, 592-595; hard shale, 595-613; gumbo, 613-649; shale, 649-670; gumbo, 670-675; shale, 675-680; gumbo, 680-720; shale, 720-735; rock, 735-736; shale, with show of oil and gas, 736-782; gumbo, 782-789; shale, 789-840; rock, 840-841; shale, 841-850; shaly rock, 850-851; fine blue shale, 851-860; brown shale, 860-872; rock, 872-873; shale, 873-900; gumbo, 900-905.	Finished June 18, 1915. A dry hole.
			NEAL OIL COMPANY.	
207	1	544	Soil, 0-3; white limestone, 3-9; black shale, 9-384; blue shale, 384-404; blue shale, 404-444; white gumbo, 444-479; blue shale, 479-619; gumbo, 619-641; sandy shale with showing of oil, 641-661; white gumbo, 661-676; white shale with showing of oil, 676-696; blue shale, 696-736; blue gumbo, 736-856; shale, 856-876.	A dry hole.
			GIDDINGS-TAYLOR OIL COMPANY.	
208	1	500	Gumbo, 1010-1050; were drilling in chalk at 1085; was abandoned in chalk at 1170 feet.	A dry hole.

LIST OF WELLS—Continued

Serial map No.	Lease No.	Elevation of well curb, in ft. above sea level	Log of Well	General Remarks.
			GUFFEY PETROLEUM COMPANY.	
209		497	Chalk, 1090-1200.	
210		499	Depth, 1250; abandoned in chalk.	
211		498		All dry.
212		551		All dry.
213		523	-------------------------------	All dry.
214		497		All dry.
215		523		All dry.
			BOWERS & WITHERSPOON OIL COMPANY. J. Bevil Survey. A. Marger Farm.	
216	1	501	Chalk, 1030. Abandoned at 1500 feet.	Dry.
			PEACH ORCHARD OIL COMPANY.	
217		563	-------------------------------	Dry.
			EMODA OIL & GAS COMPANY	
218	1	488	-------------------------------	Dry. Igneous rock present.
219	2	498	Pay at 925 feet.	
			TEMPLE-TAYLOR OIL & GAS COMPANY.	
220	1	494	No data.	Dry.
221	2	495	Pay at 917 feet.	Gray igneous rock present.
222		504	No data.	
223		507	No data.	
			JACKSONVILLE-THRALL OIL COMPANY.	
224		554	Depth to Austin chalk, 1220 feet.	Dry.
225		548	No data.	
226		519	No data.	
			SAN ANTONIO-THRALL OIL COMPANY.	
227		480	-------------------------------	A dry hole.
			WILTEX OIL COMPANY	
228		485	-------------------------------	A dry hole.
			FRITZ FUCHS OIL COMPANY.	
229		480	Depth to chalk, 1070 feet	All dry.
230-		540	Depth to chalk, 1195 feet	All dry.
231		475	No information	All dry.

LIST OF WELLS—Continued

Serial map No.	Lease No.	Elevation of well curb, in ft. above sea level	Log of Well	General Remarks.
			ADDENDA.	
			BOWERS & WITHERSPOON OIL COMPANY. S. Williams Survey. M. R. Kennedy Farm.	
			Shale, 985-1145; chalk, 1145-1395.	2639 ft. from north line, 675 ft. from west line of lease.
			ROBERT EVANS OIL COMPANY. Eugene Phillips Farm. H. Goode Survey.	
			Shale, 1100-1225; chalk, 1225-1250.	2155 ft. from south line, 870 ft. from west line of lease.
			J. M. GUFFEY PETROLEUM COMPANY. J. Zeischang 120-a Farm. H. White Survey.	
			Chalk, 1150-1200 feet.	100 ft. from north line, 730 ft. from west line of lease.
			J. M. GUFFEY PETROLEUM COMPANY. Chas. Stauffer Farm. H. White Survey.	
			Chalk, 1090-1200 feet.	100 ft. from north line; 575 varas from west line of lease.
			MANTOR & STAUFFER OIL COMPANY. Chas. Stauffer 50-a Farm.	
			Abandoned in chalk, at 1200 feet.	

OZOKERITE FROM THE THRALL OIL FIELD

By E. P. Schoch

Some dark brown waxy material which is obtained together with crude petroleum at Thrall, Texas, has recently been analyzed in the Chemical Division of the Bureau of Economic Geology, and it has been recognized as being *ozokerite* of an exceptionally good quality, as the following shows.

The crude material is soft, sticky, and of a dark brown color. Its specific gravity is 0.875. It has a strong odor of crude petroleum. Heated to remove the latter, the crude material loses 14.72 per cent. in weight up to 100 degrees C., and 8.42 per cent. more—or a total of 23.14 per cent.—up to 180 degrees C.

To refine it, this heated material was treated with 18 per cent. of its weight of concentrated sulphuric acid, and the mixture heated to 180-200 degrees C. until sulphur dioxide ceased to be evolved. Then the mass was mixed with animal charcoal and "extracted" sawdust, the mixture heated for twenty minutes. then cooled, and extracted with gasoline. On evaporating the gasoline, a material of the consistency of beeswax varying in color from orange yellow to white was obtained. The white samples are practically free from the odor of petroleum, and hence the color in the yellow samples is probably due to the presence of a trace of the original impurities. The amount of refined material thus obtained varies from 54 to 77 per cent. of the weight of the crude material employed. Such refined ozokerite is technically known as *ceresine*.

Since the material might be either paraffin or ozokerite, a comparison with paraffin of the same consistency or hardness was made. The Thrall ozokerite is perfectly "doughy" and can be "kneaded" while paraffin is "flaky" and brittle.

According to Lewkowitsch "Analysis of Oils, Fats and Waxes," ceresine is distinguished from paraffin by means of its lesser solubility in carbon tetrachloride, carbon bisulphide, and chloroform. Corresponding to this, we found 100 cc. of carbon tetrachloride dissolved respectively 3.08 grams of Thrall ceresine, and 24.14 grames of "Texaco" paraffin.

According to Holde-Mueller "Examination of Hydrocarbon Oils," the melting point of ozokerite varies "from below 60 degrees C. in the poorer grades to 68-75 degrees C. in the normal quality, but may go as high as 84 degrees C. (marble wax)." The Thrall ozokerite (unrefined) has a melting point of 79.5 degrees C., while the refined material (the Thrall ceresine) has a melting point of 75 degrees C. The melting point of paraffin of the same consistency varies from 50 to 58 degrees C., and we found that of "Texaco" paraffin to be 55 degrees C. Thus the melting point does not only show this Thrall material to be ozokerite, but indicates that it is of fine quality.

According to Holde-Mueller, the specific gravity of paraffin (solidification point 44-58 degrees C.) is 0.867-0.915 at 15 degrees C., and of ceresine (solidification point 56-84 degrees C.) it is between 0.912 and 0.943. We found that the Thrall ceresine has a specific gravity of 0.926-0.928.

Various investigators have found that the indices of refraction of paraffin with melting points 50-58 degrees C. range from 1.4220 to 1.4275 at 90 degrees C., while the indices of refraction of pure ceresines range from 1.4212 to 1.4354, and even to 1.4415. We found the index of refraction of the Thrall ceresine to be 1.4414 to 1.4420 at 90 degrees C.

The purity of the Thrall ceresine (particularly the absence of paraffin in it) is established by "fractional" dissolution and precipitation which would result in yielding consecutive precipitates and a non-precipitable residue containing different proportions of ceresine to paraffin. This variation in the proportions of ceresine to paraffin can be ascertained by taking the indices of refraction of the consecutive precipitates and of the non-precipitable residue. With a pure ceresine, the indices of refraction of all the different precipitates should be well above the index of refraction for paraffin. On dissolution in chloroform, and precipitation with alcohol according to Holde-Mueller, page 246, the Thrall ceresine gave, on an average, the following indices of refraction:

First precipitate 1.4400
Second precipitate 1.4470
Unprecipitable residue 1.4520

This indicates that the Thrall ceresine is totally free from paraffin.

A sample of Galician ozokerite, which we had secured in the open market for purposes of comparison, showed itself to be less "doughy" or kneadable than the Thrall ozokerite, and it yielded a more flaky or brittle ceresine than the Thrall ceresine. Its melting point was low (55 degrees C.); its index of refraction, 1.4420 at 90 degrees C. This sample seems to be a less desirable material than the Thrall ozokerite, but we do not know that it is a fair sample of Galician ozokerite.

These determinations show, beyond the question of a doubt, that this Thrall material is ozokerite, free from paraffin, and of a fine quality.

Ozokerite owes its use and value to the fact that it combines the great chemical inactivity or resistivity of paraffin with the physical properties of beeswax—namely the property of being "doughy" or "kneadable." Its value is enhanced by the fact that its melting point is higher than that of paraffin or of beeswax.

Ozokerite and ceresine are used industrially in the manufacture of candles, in cable insulation, in shoe, stove and floor polishes. They are rather expensive, particularly at the present time, because ozokerite is mined chiefly in Galicia. One New York firm which buys large amounts of this material, stated that before the war, Galician ceresine was worth 25 cents a pound, and that at present it was probably worth three times that amount.

Ozokerite is also found in the Caucasus, and in the Wasatch Mountains, Utah. The Caucasian ozokerite is said to be inferior to the Galician ozokerite.

THE CHEMICAL COMPOSITION OF THE PETROLEUMS OBTAINED AT THRALL, TEXAS

BY E. P. SCHOCH AND W. T. READ

In the following examination of the petroleums found at Thrall, Texas, one sample bearing the Bureau number 2730 and designated hereafter as No. 1 was examined minutely, and then the others were examined sufficiently in detail to ascertain the fact that their composition is identical with that of No. 1. The petroleums discussed in this chapter are from the following wells, and they will be designated by the numbers assigned to them:

No.	Marked.
1	Bowers and Witherspoon Lease, Thrall, Texas.
2	Taylor Oil and Gas Company, number 44, Thrall, Texas.
3	Taylor Oil and Gas Company, well number 3, Thrall, Texas.
4	Corsicana Petroleum Company, well number 30, Thrall, Texas.
5	Corsicana Petroleum Company, well number 19, Thrall, Texas.
6	First Thrall Oil Company, well number 18, Thrall, Texas.
7	Corsicana Petroleum Company, well number 52, Thrall, Texas.

The Thrall petroleum is of light gravity, ranging from .819 to .825 or from 39.8°Be to 40.9°Be. The practical absence of unsaturated hydrocarbons in the distillates of all of these oils was shown by their uniformly low bromine numbers and the small amounts absorbed by concentrated sulphuric acid. Further, after treatment with sulphuric acid, the remaining oil is practically unaltered in properties, which would not be the case if some of the constituents had been removed. A small quantity of aromatic hydrocarbons of the benzol series was indicated by the formation of traces of nitro compounds on treating the various distillates with concentrated nitric and sulphuric acids. It is evident from these tests that the Thrall petroleum is composed almost entirely of the saturated hydrocarbons of the paraffin (C_nH_{2n+2}) and naphthene (C_nH_{2n}) series. The former consist of the open chain and the latter of the closed chain hydrocarbon complexes. No attempt was made to isolate individual hydrocarbons or to distinguish between the two series of saturated hydrocarbons. The higher boiling oils contain a soft paraffin with approximately the same index of refraction as the ozokerite which separates from the oil in the well pipes. Fine flakes of this ozokerite can be seen in the crude oil, but it is present in relatively small proportion. The distillation residues are soft, paraffin-like bodies, with low melting points, and they evidently consist of the higher hydrocarbons of the paraffin series. Their boiling points are so high that they would not admit of distillation without decomposition. The percentage of sulphur in these hydrocarbons is low, averaging about 0.50%. There is no indication of the presence of asphalt.

Examination of Sample No. 1:

Sample No. 1 was distilled as follows: Large amounts of distillates were obtained by distilling separately several samples of about one-half liter each of the crude oil from a copper still, and mixing corresponding fractions of distillates. Up to 100° C. a long LeBel-Henninger column was employed. From 100° to 150°, a short column was used. Above 150° an ordinary bent tube connected the still with the condenser. The first distillation was done merely to effect a rough separation, the receiver being changed every fifty degrees. These fractions of the distillate were then separately distilled from ordinary Engler glass flasks, with the flask supported in an iron funnel, the glass being protected from actual contact with the iron by strips of asbestos. The upper part of the flask was protected from cooling by an asbestos shield and the neck wrapped with thick asbestos cord. In this distillation, the receivers were changed every ten degrees, beginning with 40° and continuing up to 320.° Since there was no specially large volume of distillate obtained at any particular point, it is evident that no individual hydrocarbon is present in preponderating amount. These distillates were examined very carefully as to their gravities, bromine numbers, and indices of refraction. The values of the gravities and refractive powers of the consecutive fractions show a normal and regular increase, which confirms the observation that no one hydrocarbon is present in large proportion. The bromine absorption values are all very low, but they show a slight tendency to increase with rise in boiling point of the fractions.

In order to avoid decomposition, the portion of the oil boiling above 320° was distilled under reduced pressure (20 to 30 mm.). An electrically heated still was employed, by which the heat could be carefully regulated. The electric heater was constructed according to the specifications of I. C. Allen and W. A. Jacobs in Bulletin 19, Bureau of Mines. The heater consists of a mold in two sections, made of asbestos, magnesium oxide, sodium silicate and silica, and lined with asbestos insulated nichrome wire. The heat was controlled by the use of rheostats and an ammeter. The current was 110 volts, alternating, and the amperage employed varied from 1.5 to 3.0. By the use of various organic liquids of known boiling points, we found the amperage best suited to a particular temperature and rate of distillation. The flask used with this heater was of the Engler type, 500 cc. capacity. The condenser was in practically vertical position, and the condenser water was heated to facilitate the movement of semi-solid distillates.

Examination of Samples 2 to 7.

The values for gravity, bromine absorption and refractive power having been determined very carefully for Sample 1, the remaining six samples were examined somewhat less in detail. For the separation of the gasolines and kerosenes from the crude oils, we used a 500 cc. Engler flask, protected and heated in the same manner as the flask first described above. The residues from these distillations were distilled further under reduced pressure from the electrically heated still also described above. The distillates were fractionated at the following points of temperature at atmospheric pressure: ordinary temperature to 100°. 100°-125°, 125°-150°, 150°-175°, 175°-200°, 200°-225°, 225°-250°, 250°-275°, 275°-300°. Then at an average pressure of 30 mm., the distillates were fractionated at the following points of temperature: room temperature to 200°, 200°-225° 225°-250°, 250°-275°, 275°-300°, 300°-325°. The corresponding fractions from all six oils were examined with reference to indices of refraction, specific gravities, bromine numbers, colors, odors, etc. These values indicate that all of the oils are of approximately the same chemical composition. Further, the percentage by weight of the various distillation fractions, the heating values, content of water, content of sulphur, and gravities of the crude oils were determined in order to give an idea of the commercial values of these petroleums.

TABLE I.

AVERAGE SPECIFIC GRAVITIES, INDICES OF REFRACTION, BROMINE ABSORPTION NUMBERS, AND COLORS OF DISTILLATES FROM SAMPLES 1 TO 7 OF THRALL PETROLEUM.

Atmospheric Pressure	Gravity at 15.5°C	Index of Refraction	Bromine Number	Color
Up to 100°C	.7145	1.3909	0.6	Water White
100°-125°C	.7275	1.4037	1.1	Water White
125°-150°C	.7453	1.4123	0.9	Water White
150°-175°C	.7649	1.4230	1.9	Water White
175°-200°C	.7797	1.4299	2.6	Water White
200°-225°C	.7932	1.4370	2.4	Water White
225°-250°C	.8090	1.4428	3.0	Water White
250°-275°C	.8171	1.4482	1.6	Cream White
275°-300°C	.8280	1.4550	3.8	Cream White
Reduced pressure (20 to 30 mm.)				
200°-240°C	.8496	1.4645	4.3	Cream White
240°-275°C	.8608	1.4719	3.4	Extra Pale
*275°-300°C	.8739	1.4780†	4.0	Extra Pale
*300°-325°C	.8874	1.4853†	3.3	Lemon Pale

*Semi-solid vaselines.
†Calculated from value at 60°C.

TABLE II

RESULTS OF DISTILLING SAMPLES 2-7. PER CENT OF TOTAL OIL OBTAINED AS DISTILLATES BETWEEN CERTAIN TEMPERATURES

Sample No.	2	3	4	5	6	7
Napthas or Gasolines up to 150°C	13.5%	11.7%	12.5%	13.6%	15.2%	12.3%
Lamp Oils or Kerosenes from 150°C to 300°C	39.4	40.1	37.4	38.2	37.0	39.2
Lubricants from 300°C atmospheric pressure to 325°C, 30 mm. pressure	15.5	19.6	27.1	25.0	18.6	23.6
Residues	31.0	26.8	19.7	22.4	26.7	23.6
Distilling losses	0.6	1.8	3.3	0.8	2.5	1.3
	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

TABLE III

OTHER DATA CONCERNING THE THRALL CRUDE PETROLEUM

Sample No.	1	2	3	4	5	6	7
Specific gravity at 15.5°C	.8195 40.8°Be	.8246 39.8°Be	.8227 40.1°Be	.8204 40.6°Be	.8214 40.4°Be	.8191 40.9°Be	.8241 39.9°Be
Heating value in British thermal units, per pound	19330	18950	19600	19225	19310	19250	19220
Water	None	None	None	None	None	None	None
Sulphur	0.44%	0.48%	0.57%	0.54%	0.45%	0.44%	0.41%

Comparatively little work has been done on other Texas oils. The literature of industrial chemistry for the past twenty years contains five different reports on oils from the Corsicana, Sour Lake, and Beaumont fields.

In the American Chemical Journal, Vol. 22, p. 489, F. C. Thiele reports the results of one analysis each of oils from Corsicana and Sour Lake. Regarding the former, he states that it resembles very closely the oil of the Lima-Ohio field, but without its disagreeable ordor. It shows a gravity of .8296, yields 11 per cent gasoline, 55 per cent kerosene, and appears to contain some asphaltum bodies. Later Clifford Richardson reported in the Journal of the Society of Chemical Industry, Vol. 19, p. 121, that he had found the Corsicana oil to be predominatingly a paraffin base, but does not report asphalt. His other results practically check those of Thiele.

Sour Lake.

Both the authors referred to above discuss in the same articles just cited the general nature of the oils from the Sour Lake field. Thiele finds it to be of .963 gravity, distilling very little below 200°, and giving over seventy per cent residue. He estimates the asphaltum at about twenty per cent and states that the oil contains aromatic hydrocarbons. Richardson finds no evidence of paraffin in this oil and confirms Thiele's work regarding asphaltum and general characteristics.

Beaumont.

Two articles by Dr. Chas. F. Mabery, the great authority on American petroleums, cover the oils from the Beaumont field, the references being American Chemical Journal 22, 553, and 23, 264. In the first he does not state the exact source of the oil. The gravity is .950, and the sulphur 0.94 per cent. The oil is very high boiling, there being no distillate below 240° C. He identifies several of the hydrocarbons as belonging to the C_nH_{2n-2} series, which he considers as derivatives from double methylene rings and therefore saturated. In the higher distillates he finds unsaturated hydrocarbons of the C_nH_{2n-4} series. In the second article, he investigates the oil from the Lucas well. This he finds to be of .920 gravity, containing 2.16 per cent sulphur, which he states is the highest sulphur content he has ever found in any oil. Here he identifies only double methylene hydrocarbons as in the lower distillates of the first oil. He states further that the Lucas oil is lower in asphaltum.

A brief report from the Chemical Trade Journal, March 1901 states that Beaumont oil is an asphalt base, in gravity and odor below that of the Lima-Ohio oil, that its viscosity is too low for lubricants, the odor too disagreeable for lamp oils, and that it is only suitable for fuel oil.

As far as we can judge with our slight knowledge of other Texas oils, the Thrall oils are quite similar to the Corsicana oils, and quite different from all other oils now obtained in Texas.

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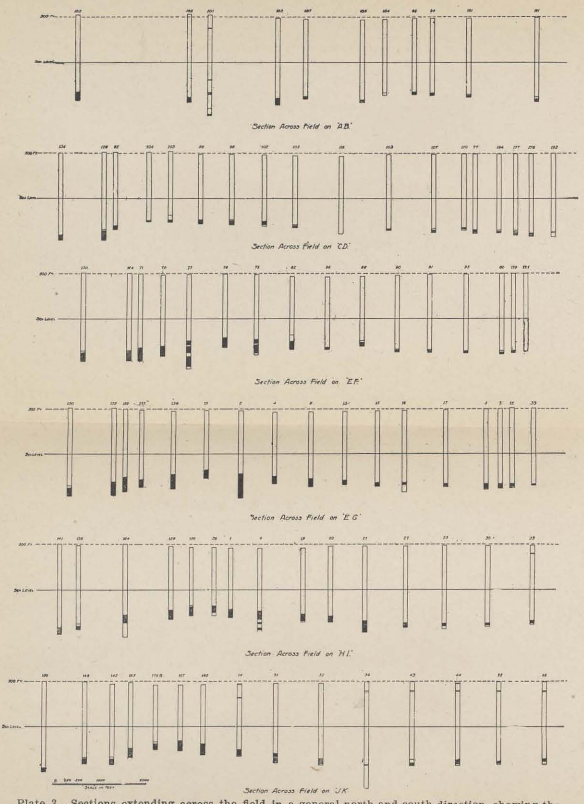

Plate 3....Sections extending across the field in a general north and south direction, showing the position of the oil-bearing rock, as known from well records, in solid black. Locations of sections shown in Plate 1. Horizontal scale shown on plate 1. Vertical scale is 500 feet to the inch.