REVIEW OF COAL PRODUCTION IN TEXAS

and

GYPSUM RESOURCES AND MINING ON THE HOCKLEY DOME, HARRIS COUNTY, TEXAS

By

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REVIEW OF COAL PRODUCTION IN TEXAS

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Coals were among the first of the many mineral resources of Texas to attract the attention of the early settler. In 1819 they were already exploited, although obviously on a small scale only. L. F. L'Heritier shows on the map accompanying his report "Le Champ-D'Asile, tableau topographique et historique du Texas, etc.", published in Paris, France, 1819 (second edition), a "mine de charbon de terre" [coal mine]. The location of that old mine is about 25 leagues east of Trinity River and about 27 leagues west-northwest of the presidio of Chichi on the branches of Sabine River in east Texas. This means that in 1819 the east Texas brown coals were known and exploited.

Coals are formed by geologic processes out of the remains of plants. Thus the nature and composition of a coal is dependent on the composition of the original raw material, that is, the plant remains, and the duration and character of the geologic processes which shaped the plant remains into those sedimentary rock-bodies that are called coal seams.

Using the duration and intensity of the geologic processes as a guiding line, one can classify the coals into a continuous series which begins with coals that were affected by geologic processes of short duration and low intensity only and ends with those that were affected for a long time and with high intensity. That series is roughly represented by the following classes of coal:

Peat——> Lignite (or Brown Coal)——> Bituminous Coal——> Anthracite——> Graphite

Among these the peat is least affected by geologic processes. In it the plant remains can be separated readily into individual strands and identified as to their botanical nature. Peat is also of very low specific gravity and has high primary porosity. On the other end of the series the graphite is a material so thoroughly altered that it does not contain any botanical structures; it is rather a mineralogical material composed of crystals of carbon and its organic origin can be surmised only from data other than botanical structures.

Lignite is near the beginning of this series of the classes of coal. It contains more or less clearly separable pieces of botanical material identifiable as lignitized roots, leaves, twigs, and tree trunks; but besides this material there is a considerable amount of earthy to dense, more or less friable material that can not be identified as a botanical entity by visual inspection without the aid of microscopes. The color of lignite is usually a very dark brown, and the color of the finely divided material, such as one obtains on a mineralogical streak plate, is characteristically dark chocolate-brown. For that reason it is perhaps better to call this kind of coal "brown coal," as the word lignite implies derivation from wood *(lignum)*—a derivation which is only partially consistent with the nature of the plant remains that went into the making of lignite. Most lignites are soft, friable, or crumbly, have low specific gravity, and comparatively high primary porosity. They contain large quantities of water. Some of the mine-fresh lignite from Texas was reported with a water content of 46.3 per cent. However, this seems to have been an extreme case as most of the fresh lignite from Texas was found to contain about 13 to 35 per cent of moisture.

Bituminous coal is usually brownish black to deep black in color, and the mineralogic streak is brownish to grayish black. The botanical structure is only rarely visible with the naked eye but can be detected under the microscope after preparation. The bituminous coals have considerable luster, on fresh cross-breaks approaching glassy or unctuous luster. They are also considerably harder than lignites and more coherent. Their natural porosity is low.

A special variety of bituminous coal is cannel coal, distinguished from bituminous coal by its dull waxy luster and lesser hardness. It is so rich in volatile constituents that pieces of this coal will burn with an unusually long and vivid flame like a candle, from which its name is derived.

Coal seams being derived from layers of accumulated plant remains are essentially very specialized kinds of strata. It is natural that such layers of accumulated plant remains can originate only in very special places and environments and only during certain special geologic times. Although plant remains may have been available in the geologic past in many different places, they were rarely accumulated with so little admixture of foreign substances as to form coal seams rather than impure carbonaceous sediments of little value as a fuel.

To illustrate this thought it is necessary to utilize the concept of geologic cycles. It is known that in the geologic past the sea has advanced over and retreated from the land repeatedly. The procession of geologic events from one advance of the sea to the next succeeding advance is known as a cycle, and the sediments deposited successively one upon the other at a place during an entire cycle are called a cyclothem. Such a series of sediments is composed of very different strata. There are the deposits of the sea such as calcareous shales, the deposits of the strand as beach sands, lagoonal deposits of carbonaceous shales, and many others. Among the multitude of strata of such a cyclothem, it is only the deposits of one definite stage of the cycle which can contain coal seams. At that stage the land surface must have been low and flat and the land must have been sinking slowly so that the deposits were being protected from erosion and oxidation. At the same time no large rivers were bringing in quantities of sand or mud to contaminate the organic deposits of plant remains. Such specialized conditions can have existed only rarely. One realizes from a study of such sedimentary cycles and their sediments that only a small portion of the Texas sediments can contain coals. And on the other hand such study can lead to the discovery of new and as yet undiscovered coal seams.

COAL DEPOSITS IN TEXAS

Lignite.—In Texas, lignites are present in the sediments of the Gulf Coastal Plain which are of Tertiary age. The lignites are widely distributed among the many thousand feet of thick sediments. However, most of these seams are either so thin or short that they have no commercial importance. Lignites of commercial importance are found only in two belts of strata. One of these is the Wilcox group (see map, fig. 55); much less important are those in the Yegua formation. Both are part of the Eocene deposits of the Gulf Coastal Plain Tertiary.

The Wilcox group of sediments enters the State in the south in Maverick and Webb counties and extends in a broad belt through the Coastal Plain country to Bowie County in the northeast. Another outcrop area is the so-called Sabine uplift, which centers around Panola and Shelby counties.

FORMATIONS CONTAINING COMMERCIAL BROWN COAL DEPOSITS IN THE GULF COASTAL PLAIN OF TEXAS

Tertiary	Pliocene		
	Miocene		
	Oligocene		
	Eocene	Jackson group	
		Claiborne group	*Yegua formation**
			Cook Mountain formation
			Stone City formation
			Sparta sand
			Therrill formation
			Weches formation
			Queen City formation
			Reklaw formation
			Carrizo sand
		*Wilcox group**	
	Paleocene		

*Indicates occurrence of commercial brown coal or lignite deposits.

The following counties are crossed by the belt of Wilcox outcrops and some have been or are producers of brown coal:

Anderson	Marion
Atascosa	Maverick
Bastrop	Medina
Bexar	Milam
Bowie	Morris
Caldwell	Nacogdoches
Camp	Navarro
Cass	Panola
Cherokee	Rains
Dimmit	Robertson
Falls	Rusk
Franklin	Sabine
Freestone	Shelby
Gonzales	Smith
Gregg	Titus
Guadalupe	Uvalde
Harrison	Van Zandt
Henderson	Webb
Hopkins	Williamson
Lee	Wilson
Leon	Wood
Limestone	Zavala

The Yegua formation is similarly disposed. It enters the State in the south in Starr County and extends in a belt less wide than the Wilcox outcrop through the Gulf Coastal Plain to Sabine County in the east. Lignites of the Yegua formation were mined by the Houston-Leon County Coal Company near Lovelady in Houston County.

Table 1 shows averaged analyses of brown coals from the deposits of Texas.

Bituminous coal.—Bituminous coal is found in Texas in strata older than Tertiary. In this State it is found in Cretaceous and Pennsylvanian beds.

Whereas the Upper Cretaceous formations are purely marine and devoid of coal in nearly all their extensive outcrops in Texas, in the Rio Grande region they are in part non-marine and contain coal seams. Commercial bituminous coal is present in the Upper Cretaceous formations in Brewster and Presidio counties near San Carlos and in Maverick County near the town of Eagle Pass. A prospect of bituminous coal is reported from the Eagle Mountains in Hudspeth County.

Table 2 shows some selected analyses of bituminous coal from the Eagle Pass coal field, Maverick County, Texas.

Table 3 gives some selected analyses of bituminous coal from the San Carlos coal field. This coal will coke.

Bituminous coal of Pennsylvanian age occurs in north-central Texas. Coal of this age has been found in the following counties:

Archer	Montague
Brown	Palo Pinto
Coleman	Parker
Eastland	Stephens
Erath	Wise
Jack	Young
McCulloch	

Of the various coal beds found in these counties, the most important are the Thurber, Bridgeport, and Chaffin coal.

The Thurber coal is the base of the Mineral Wells formation of the Strawn group. It was mined at Thurber, Gordon, Strawn, and Rock Creek. Its thickness is 18 to 28 inches. The thickness in the mine at Rock Creek, Parker County, is 22 inches; at the Strawn mines, in southern Palo Pinto County, it is 26 inches; and in the Thurber mines, in northern Erath County, the average thickness is 28 inches. The B.t.u. value of the coal ranges from 11,800 to 13,750, the fixed carbon percentage ranging from 40.8 to 52 per cent. The coal will coke.

The coal at Bridgeport, Wise County, occurs near the top of the Palo Pinto formation of the Canyon group. It is found from Bridgeport to the outcrop southwest of Perrin but does not extend far underground down the dip. In places limestone directly overlies the coal. The Bridgeport

FORMATIONS CONTAINING COMMERCIAL BITUMINOUS COAL DEPOSITS IN THE RIO GRANDE REGION OF TEXAS

Cretaceous	Upper	Navarro group	Escondido formation
			Farias formation
			*Olmos formation**
		Taylor group	*San Carlos beds**
		Austin group	
		Eagle Ford group	
	Lower		

*Indicates occurrence of commercial bituminous coal deposits.

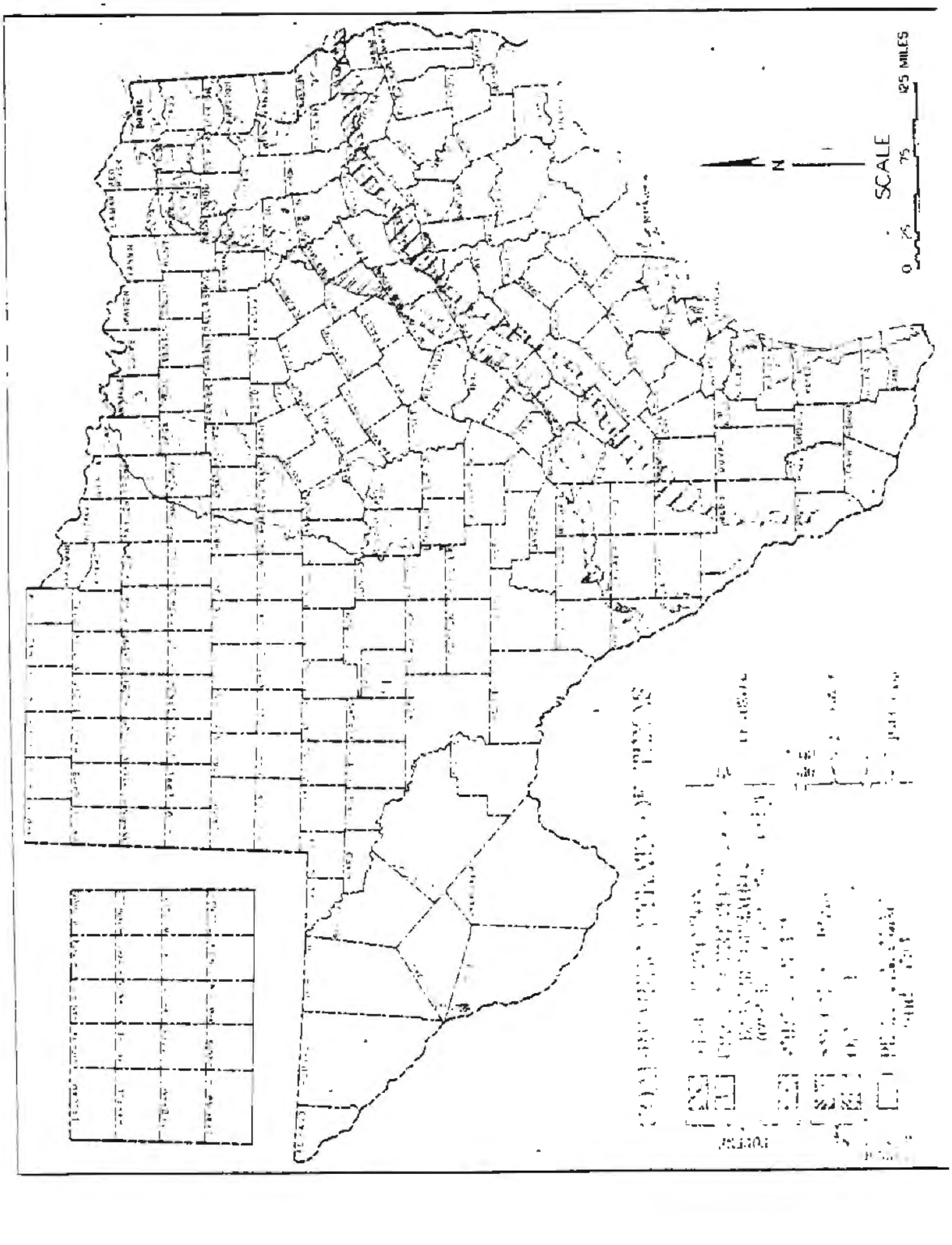
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Table 1. Analyses[1] of Texas brown coals.

	As Received							Dry Basis						Ultimate					
	Moisture	Vol. and Comb. Matter	Fixed Carbon	Ash	Total	Sulphur	B.t.u.	Vol. and Comb. Matter	Fixed Carbon	Ash	Total	Sulphur	B.t.u.	Carbon	Hydrogen	Oxygen	Nitrogen	Sulphur	Ash
Yegua Formation																			
Houston County (1290, 1293, 1294)	34.08	36.56	18.58	10.78	100.00	0.56	7,442							—	—	—	—	—	—
Wilcox Group																			
Atascosa County (1240–1242)	26.55	32.60	32.32	10.71	100.00	1.25	7,983	25.39	58.65	15.97	100.00	1.69	10,365			—	—	—	—
Bastrop County (1245–1246)	36.33	36.88	21.22	6.50	100.00	0.91		50.76	39.54	9.70	100.00	0.90	11,196		—	—	—	—	—
(1248–1248a)	28.50	28.96	32.18	6.36	100.00		7,325	45.12	44.17	10.71	100.00	0.80	10,894		—	—	—	—	—
Camp County (1255a)	20.74	37.26	28.60	13.40	100.00		8,416	47.01	36.09	16.90	100.00		10,618	—	—	—	—	—	—
Freestone County (1274–1276)	26.91	32.44	30.66	9.97	100.00	1.11	7,997	44.44	42.05	13.51	100.00	1.92	10,953	—	—	—	—		
Henderson County (1278–1280)	21.17	34.03	33.32	7.65	100.00			54.70	36.30	9.00	100.00	0.07	10,600	—	—	—	—		
(1282–1282a)	21.60	35.60	28.44	11.10	100.00	1.75	8,066	45.70	37.02	17.66	100.00	2.18	10,385	—	—	—		—	—
Hopkins County (1283–1289)	25.50	41.54	21.93	11.04	100.00	1.38	7,484	40.82	42.50	16.69	100.00	1.08	10,354	60.13	4.62	20.91	1.93	0.64	12.67
Leon County (1308–1316)	28.56	30.54	31.95	9.07	100.12	0.89	7,871	42.72	44.61	12.65	100.00	1.26	11,159	—	—	—	—		—
Medina County (1322–1327)	34.65	31.21	25.12	10.33	100.00	1.69	7,390					1.07	11,813	—	—	—	—	—	—
Milam County (1328–1347a)	28.28	31.19	26.55	8.86	100.00	1.02	8,057	46.05	41.73	12.14	100.00	1.31	10,658	60.77	4.33	21.65	2.01	0.91	10.32
Robertson County (1351–1374)	23.38	33.24	31.38	12.14	100.00	1.19	8,893	45.31	45.46	9.21	100.00	1.14	11,270	—	—	—	—	—	—
Titus County (1381)	34.50	29.96	29.04	6.50	100.00	1.28	7,403	45.74	[illegible]	7.52	100.00	1.95	11,298	—	—	—	—	—	—
Van Zandt County (1388)	27.20							56.18	37.20	6.62	100.00	0.65	10,540						
Wood County (1391–1409)	28.84	32.52	29.34	8.16	100.00	0.68	7,644	47.52	40.24	12.24	100.00	1.12	10,425	59.61	4.12	22.20	1.55	0.97	11.22

[1]Average of various samples analyzed for each county. These analyses are from published reports. Compare:
Schoch, E. P., Chemical analyses of Texas rocks and minerals. Univ. Texas Bull. 1814, 1918.
Phillips, W. B., and Worrell, S. H., The fuels used in Texas. Univ. Texas Bull. 307 (Scientific Ser. 45), 1913.
Phillips, W. B., Worrell, S. H., and Phillips, D. McN., The composition of Texas coals and lignites, etc.: Univ. Texas Bull. 189 (Scientific Ser. 19), 1911.
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Dumble, E. T., Report on the brown coal and lignite of Texas: Texas Geol. Survey, 1892.

Table 2. Analyses of bituminous coal from the Eagle Pass coal field.

	As Received							Dry Basis					
No.	Moisture	Vol. and Comb. Matter	Fixed Carbon	Ash	Total	Sulphur	B.t.u.	Vol. and Comb. Matter	Fixed Carbon	Ash	Total	Sulphur	B.t.u.
1,524	8.83	32.68	44.89	13.60	100.00	0.90	10,941	35.84	49.24	14.92	100.00	0.99	12,001
1,525	6.68	30.94	42.94	17.44	100.00	0.90	10,361	33.88	47.02	10.10	100.00	1.02	11,455
1,526	7.98	30.00	40.06	21.96	100.00	0.94	9,681	32.60	43.54	23.86	100.00	1.02	10,520
1,527	11.11	28.53	42.26	18.10	100.00	1.06	9,698	32.10	47.54	20.36	100.00	1.19	10,910
1,528	6.76	27.04	33.66	32.54	100.00	1.79	8,792	29.00	36.10	34.90	100.00	1.92	9,429

Table 3. Analyses of bituminous coal from the San Carlos coal field.

	As Received							Dry Basis					
No.	Moisture	Vol. and Comb. Matter	Fixed Carbon	Ash	Total	Sulphur	B.t.u.	Vol. and Comb. Matter	Fixed Carbon	Ash	Total	Sulphur	B.t.u.
1,554	4.60	39.20	50.10	6.10	100.00	0.62	12,157	41.43	52.47	6.40	100.00	0.64	12,757
1,555	4.90	32.80	43.04	19.26	100.00	0.85	9,663	34.19	45.26	20.25	100.00	0.88	10,164
1,556	2.47	34.84	32.36	30.33	100.00	1.61	8,348	35.72	33.18	31.10	100.00	1.65	9,585

coal is 18 to 22 inches thick, subbituminous with a fixed carbon ratio of 46 to 47 per cent and a B.t.u. value of 12.000. The Bridgeport mine was the last bituminous coal mine to cease operation in the State.

The Chaffin coal is in the Thrifty formation of the Cisco group. It is known only to occur at the Chaffin mine, 2 miles east of Waldrip, northern McCulloch County, where it is 20 inches thick and overlain by limestone. The coal was considered to be higher in grade than is usually found in this region, but the thinness of the bed and its distance from a railroad have prevented its being worked successfully commercially. There appears to be no analysis available.

The last production figures available are for the year 1943. In that year there was only one bituminous mine active in Texas. This mine, located in Palo Pinto County, produced only 9097 tons of an approximate value of $39.000; of this amount 7562 tons were shipped by railroad.

The following are some selected analyses of Texas Pennsylvanian coals:

Cannel coal.—The Texas cannel coal is found in Tertiary strata of the Rio Grande region. Commercial deposits occur in Webb County. The cannel coal of that area occurs in several seams of which only two were mined. These are the San Pedro and the Santo Tomas seams. The horizontal extent of these seams along their strike is small, because northward they split into several thin seams which are no longer commercial. Thus the useful deposits seem to be confined to Webb County, although the strata continue into the next adjoining counties to the north.

Table 5 shows selected analyses of the two coal seams.

The coal has an unusually low moisture content, which is obviously a desirable feature. However, the coal is also high in ash and sulphur. The coal is so rich in bituminous matter that in many places in the mines oil was found seeping from the rocks. In spite of some drawbacks in the composition of this cannel coal it is clearly a valuable material. The chief drawback in the use of this coal is the great distance of the coal from its potential markets.

Table 4. Analyses of Texas Pennsylvanian coals.

Coal Beds and Mines	Moisture	Dry Basis: Vol. and Comb. Matter	Fixed Carbon	Ash	Sulphur	B.t.u.
No. 7, Cisco, Eastland County	13.44	40.28	42.02	17.70	2.94	11.101
No. 1. Thurber, Erath County	2.70	11.95	50.08	7.97	1.98	12.526
No. 7, Jermyn, Jack County	10.21	38.18	39.01	22.81	1.84	10.510
No. 1, Strawn, Palo Pinto County	1.06	39.70	50.65	9.65	2.91	13,563
No. 1, Weatherford, Parker County	3.50	39.50	50.99	9.51	2.10	12.410
Bridgeport, Wise County	12.50	36.26	49.12	14.62	2.11	12,190
No. 7, Loving, Young County	18.00	37.70	49.00	13.30	1.35	12,709

FORMATIONS CONTAINING COMMERCIAL CANNEL COAL DEPOSITS IN THE GULF COASTAL PLAIN OF TEXAS

Tertiary	Pliocene		
	Miocene		
	Oligocene		
	Eocene	Jackson group	
		Claiborne group	Yegua formation
			Cook Mountain formation
			*Upper Mount Selman formation** (with Santo Tomas seam)
			*Bigford formation** (with San Pedro seam)
			Carrizo sand
		Wilcox group	
	Paleocene		

*Indicates occurrence of commercial cannel coal deposits.

Table 5. Analyses of Texas cannel coal.

			Proximate				Ultimate					
Mine or Locality	Bed	Condition*	Moisture	Volatile Matter	Fixed Carbon	Ash	Sulphur	Carbon	Hydrogen	Oxygen	Nitrogen	B.t.u.
Dolores shaft, mine sample	Santo Tomas seam	A	4.4	46.0	30.5	19.0	2.0	59.3	5.7	12.6	1.1	11,070
		C	...	48.1	31.9	19.8	2.1	64.0	5.5	9.1	1.2	11,580
		D	...	60.1	39.8	...	2.7	77.4	6.8	11.4	1.5	14,450
Dolores shaft, mine sample	San Pedro seam	A	3.9	48.8	34.9	12.2	1.9	65.5	6.2	12.7	1.2	12,230
		C	...	50.9	36.4	12.8	2.0	68.3	6.0	9.5	1.3	12,740
		D	...	58.3	41.6	...	2.3	78.2	6.9	10.9	1.5	14,600

*A, sample as received; C, moisture free; D, moisture and ash free.

OBSTACLES TO EXPLOITATION OF TEXAS COAL

Markets.—Although coal deposits of economic quality are widely distributed, their economic exploitation is severely restricted. Coal is a bulky material, and large quantities must be shipped to make a mine profitable. Therefore, ease of transportation is of great practical importance. To give an obvious example: Whereas brown coals are widely distributed in the Wilcox outcrops of Texas, only those places of that expansive outcrop area that are within easy reach of railroad lines or enjoy otherwise easy transportation have been exploited. The proximity of markets is also a determining factor. Some of the Texas coals, although of high grade, cannot yet be exploited profitably or on a large scale because they are far removed from markets. The cannel coal of Webb County, for instance, is one of the best as far as quality is concerned, but its exploitation suffers from the lack of a large dependable market at a reasonable distance. As the density of population increases in Texas and as the industrialization progresses, new and enlarged markets for these coals will be established. Then many deposits that are now dormant will become economically important.

Competition with other fuels.—Coal as a fuel—and for sometime to come its chief use will remain that of a fuel—is in competition with other fuels. In Texas it is in competition with fuel oil and gas. This is well illustrated by the influence of the great East Texas oil field on lignite production in east Texas. Before this great field came in, lignite was produced in many mines in east Texas, for instance, at Evansville and Bear Grass in Leon County and at Lovelady in Houston County. However, as the East Texas oil field began to produce oil so abundantly, these mines were forced to shut down, and some of the mine villages are now abandoned.

Production problems.—In many instances production methods in the Texas coal mines were primitive, and even today it is possible to produce coal by primitive and inexpensive means involving only a small capital investment. As yet the mining has not progressed to any great depth and has not moved far from the outcrop of the coal beds. One of the chief difficulties of underground mining in the lignite mines was the weakness of the strata. Thus difficulties with the elimination of water breaks were encountered in some cases. In most, if not all, underground mines the pillars of coal could not be removed because of early collapse. The mining methods have been described in the report on Leon County.

DEVELOPMENT—PAST AND FUTURE

The coals of Texas were discovered very early. A map of Texas published in Paris, France, in 1818 shows a coal mine in east Texas, indicating that the coal was at least known at that date. In 1839 Dr. J. L. Riddell described brown coal from the banks of Trinity River. Production and use of coal started around 1850 as some published reports indicate. However, this early production was very small and strictly local. Reliable production figures are available from 1888 on. (See fig. 56.)

Future production of Texas coals depends on very many economic factors. Coal as a fuel for home use has probably only a very limited future. At present this field is served by natural gas wherever the market is a concentrated one such as in the more populous settlements. These settlements will probably continue to be served by natural gas as long as this fuel is so abundant. This condition would tend to restrict the home fuel market considerably.

The most promising outlet for the coals as fuel is in the industrial field and in the fuel supply of power plants in such areas where natural gas is not easily available,

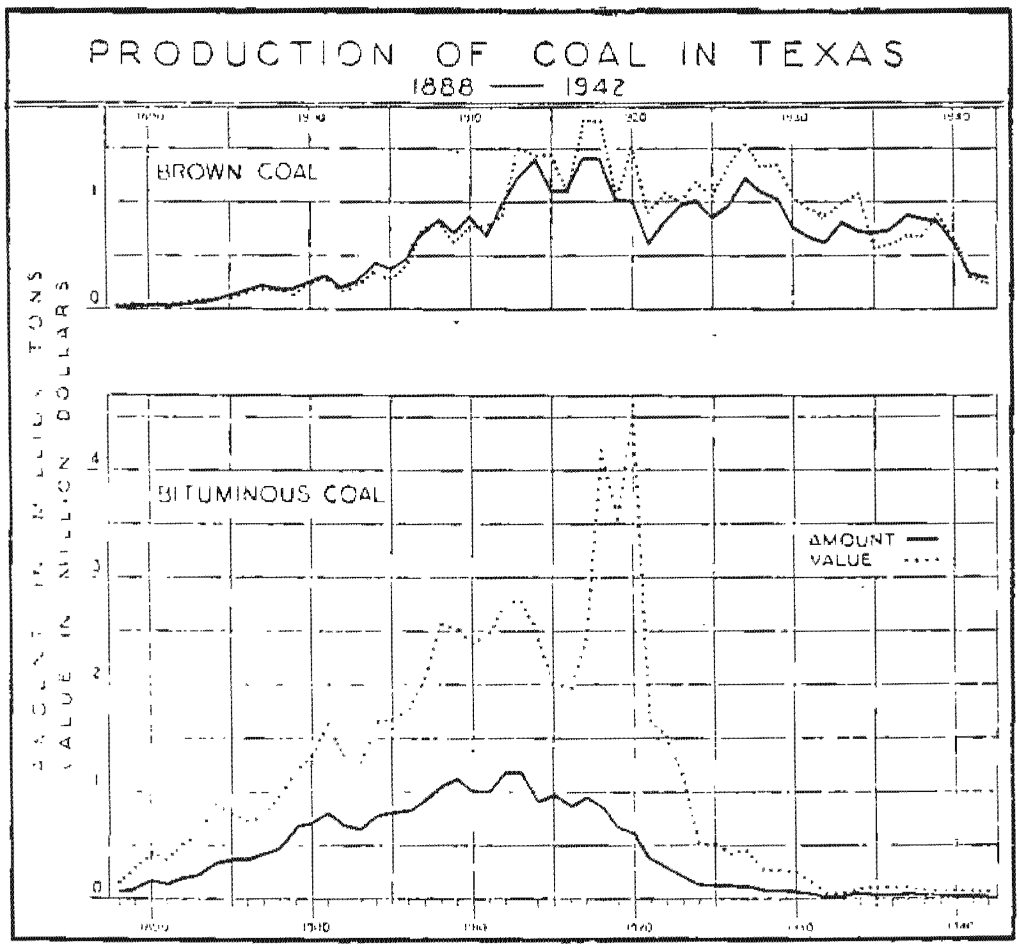

Fig. 56.

but where the coals are conveniently located. The successful operation of The University of Texas power plant in Austin with lignite is an example of this sort. Another possible future use of the coals is in conjunction with chemical extraction plants where the coals could be used not merely as fuel but as a raw material for chemical extraction. At present brown coal mined about 12 miles southwest of Marshall, Harrison County, is being used by a plant in Marshall for the manufacture of activated carbon.

However, should in the future the production of petroleum and natural gas not keep pace with the continuously rising demand for these products, then conditions for production of coals would change so much that a new era of economic exploitation of the coals might arise. Under such conditions coals might be produced again in quantities equal to or greater than were taken from the ground in the years 1917 to 1920.

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GYPSUM RESOURCES AND MINING ON THE HOCKLEY DOME, HARRIS COUNTY, TEXAS

H. B. STENZEL

The deposit of gypsum mined by The Hockley Gypsum Company of Houston, Texas, is located about 4 miles south of the settlement of Hockley in northwestern Harris County, Texas. The mine can be reached from Houston by the concrete highway U. S. No. 290 (Houston to Hockley, 35.3 miles) and improved county road (Hockley to mine, about 4.6 miles). The mine is connected by a spur with the tracks of the Southern Pacific railroad. The mine spur enters the main line of the Southern Pacific system (Houston to Waco) 2.75 miles east-southeast of the depot at Hockley.

The buildings, structures, and underground workings are on the land of the Warren ranch, John Warren estate, in the northwest corner of Thomas Coghill survey, northwestern Harris County, Texas.

SURFACE FEATURES

The area under discussion is in that part of the Gulf Coastal Plain which is known as the Coast Prairie. This is a region of very low, subdued relief sloping gently toward the Gulf.

The surface of the region around Hockley is covered by the Lissie formation. The upper portion of this formation, that is, the portion that occurs around Hockley, is predominantly a poorly bedded, clayey sand. However, clean and fresh exposures of this formation are rare on account of the low relief of the region. The surface soil produced by the formation is a light brownish-gray, clayey sand, loose and porous in many places. The subsoil is usually a coherent, dirty rust-orange-red, massive, clayey sand and may be 10 feet or more thick.

In the vicinity of Hockley the Lissie formation extends southward to the so-called Hockley scarp. This scarp is a well-marked, though gentle descent from a plain, the Alice terrace, standing near Hockley approximately at an elevation of 220 feet above sea level, to a lower plain, the Beaumont terrace, standing at an elevation of about 165 feet above sea level in this vicinity. As both terraces have a slope toward the sea, the Alice terrace a greater one than the Beaumont terrace, the descent immediately at the scarp is only about 30 feet and takes place in a distance of about one-half mile.[1]

The Hockley scarp may be seen along U. S. highway No. 290 about 5.8 miles southeast of Hockley railroad depot. From there it extends in nearly a straight line southwestward to the vicinity of the mine. Here it is rather irregular and outlying hills are present. These hills are clothed by the Lissie formation and rise from the Beaumont terrace about a mile from the Hockley scarp.

South of the Hockley scarp the surface of the ground is composed of the soils of the Beaumont formation. These soils are predominantly dark to black, deep, sticky, sandy clay.

GEOLOGY

SURFACE GEOLOGY

The two surface formations, the Lissie and the Beaumont, are composed of unconsolidated materials, and outcrops of hard rock formations are generally absent. An exception is the hard rocks exposed in Rock Hollow, a south-flowing creek draining the region around the mine. In the bed of this creek, just below the concrete crossing of the county road leading from Hockley to the mine, there is exposed a flat bench of jointed, hard, grayish-white, poorly bedded, very fine-grained sandstone. The abundant cement is whitish and porcellaneous in appearance. Occasional small open pores are in the sandstone; other pores are filled with bluish-white, translucent, waxy, opaline or chalcedonous cement. The age of this rock is not known, but it is probable that it is older than the Lissie formation. Alexander Deussen[2] thought that this rock was possibly a part of the Fleming formation.

[1]Compare the excellent topographic maps made by the U.S. Geological Survey: Hockley and Swanson quadrangles (Harris County, Texas), scale 1/31680, contour interval, 1 foot, 1920 and 1919, respectively.

[2]For references, see "Literature," pp. 214-215.

However, rocks of that type are not known from the normal Fleming formation outcrops. The presence of opaline cement seems to indicate a Catahoula age for this sandstone.

Subsurface Geology

Numerous test wells have been drilled in this area, and these wells have proved the presence of a shallow piercement-type salt dome centering in Thomas Coghill survey. This salt dome was named the Hockley salt dome and was described by Chapman and by Deussen and Lane. Additional local data were given by Teas.

The salt core of the dome, composed of rock salt, rises to within 1010 feet of the surface. The top of the salt is fairly flat and level at a depth of about 1010 to 1110 feet. The sides of the salt core are steep and descend to unknown depth. The diameter of the salt core at its top is approximately 2 miles. The salt of the core is being mined by the United Salt Corporation.

Above the salt lies the cap rock, which is of considerable thickness over the top of the dome but tapers to a thin edge at the margins. The greatest thickness penetrated by a test well is 995 feet in The Texas Company John Warren No. 1 in the northeastern part of the cap rock. The top of the cap rock is less flat than that of the salt core. The map of the cap rock (Pl. XIII) shows the configuration of the top of the cap rock by lines of equal depth to cap rock drawn at 1000, 400, 200, and 100 feet from the surface. The shallowest cap rock was encountered in Freeport Sulphur Company John Warren No. 17 at 74 feet and in the mine shaft of the United Salt Corporation at 76 feet. These data seem to indicate that the shallowest cap rock is in a north-northwest trending line through these two points and off center of the dome to the northeast. An area in which the cap rock lies at more than 100 but less than 200 feet depth is to the north of the center of the dome. The gypsum mine is near the east edge of this deeper area.

The cap rock is composed of several layers differing in lithologic composition. The bottom layer is composed chiefly of anhydrite rock. This rock is composed mainly of the mineral anhydrite ($CaSO_4$). The layer was studied by Teas in the salt mine shaft. Many joints cross this layer, and horizontal joints are common. The joint faces are slickensided and commonly carry a coating of fine pyrite (FeS_2). Horizontal bands of sandstone and irregular fragments of the same material occur in the anhydrite. The anhydrite layer is the thickest of the cap rock layers. In the salt mine shaft 885 feet of anhydrite rock are reported by Teas. This figure seems to be the maximum recorded thickness of the layer.

Above the anhydrite layer is the gypsum layer. This layer is composed chiefly of gypsum rock. The rock is composed mainly of the mineral gypsum ($CaSO_4 + 2H_2O$) with some minor impurities of silty shale and anhydrite. This is the layer that is being mined by The Hockley Gypsum Company. A more detailed description of the features of this layer is given below. The gypsum layer is present only over the central area of the cap rock and disappears towards the edge of the cap. Where the cap rock lies at 400 or more feet depth below the surface of the ground, the gypsum is absent as far as the well data indicate. Even in the central area there are some places where the gypsum layer is thin. In the salt mine shaft only 18 feet of gypsum rock were recorded.

The top layer of the cap rock is the limestone layer. This layer is rich in the mineral calcite ($CaCO_3$). It is brecciated and interwoven with veins of calcite and flecked with calcite vugs, many of which are oil-filled. Barite ($BaSO_4$) and strontianite ($SrCO_3$) are present in minor amounts. The thickness of this layer is variable. In the salt mine shaft 31 feet were recorded.

Above the cap rock there are unconsolidated deposits of sand and clay. Many of these beds are porous and water-bearing. The best description of these beds available at present is the one given from memory by Mr. J. M. Lloyd, at that time manager for the Tidewater Gypsum Company.

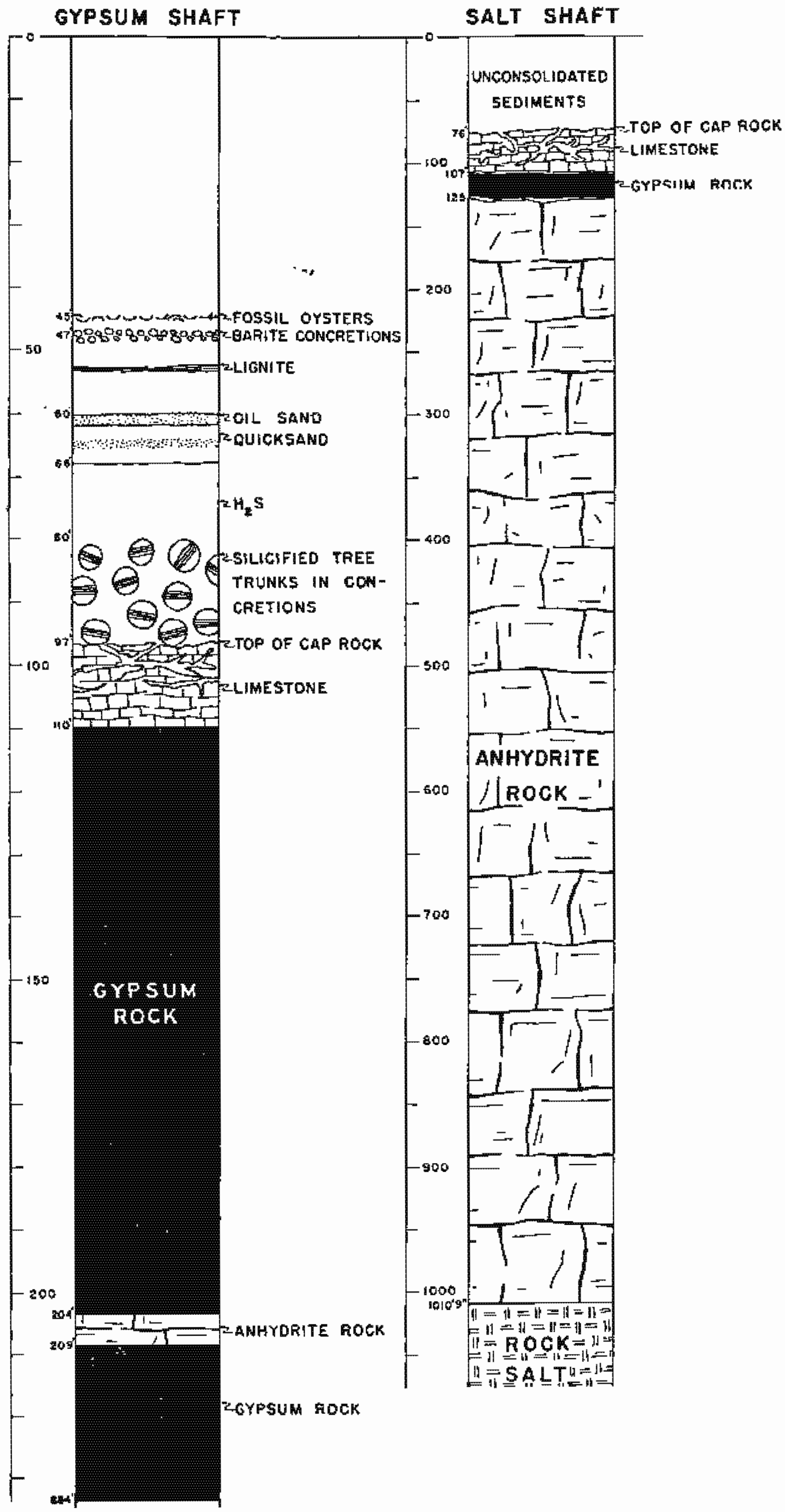


Fig. 57. The two mine shafts on the Hockley dome, Harris County, Texas.

Log of gypsum mine shaft. Recorded by Mr. W. B. McCarter for the Bureau of Economic Geology, June 23, 1928. (Compare fig. 57.)

	Approximate depth *Feet*
Fossil oysters, which crumbled in the air	45
Barite concretions varying from ¾ inch to 2 inches in diameter, about 1.5 feet thick	47
Lignite bed	—
Oil sand, containing heavy petroleum, 1.5 feet thick	60
Quicksand	—
Hydrogen sulfide gas (H_2S)	68
Bed, 16 to 18 feet thick, containing silicified tree trunks forming the centers of 2-foot concretions	80
Limestone	97
Gypsum	110
Total depth	136

GYPSUM ROCK

The gypsum rock of the cap rock is now accessible in the 200-foot level of the gypsum mine. Several varieties of the rock are visible. One variety is banded with darker and lighter gray colors in nearly horizontal layers up to 4 inches thick. This banded variety is finely crystalline but may range up to medium-crystalline. It is visible in two places in the mine (see Pl. XII).

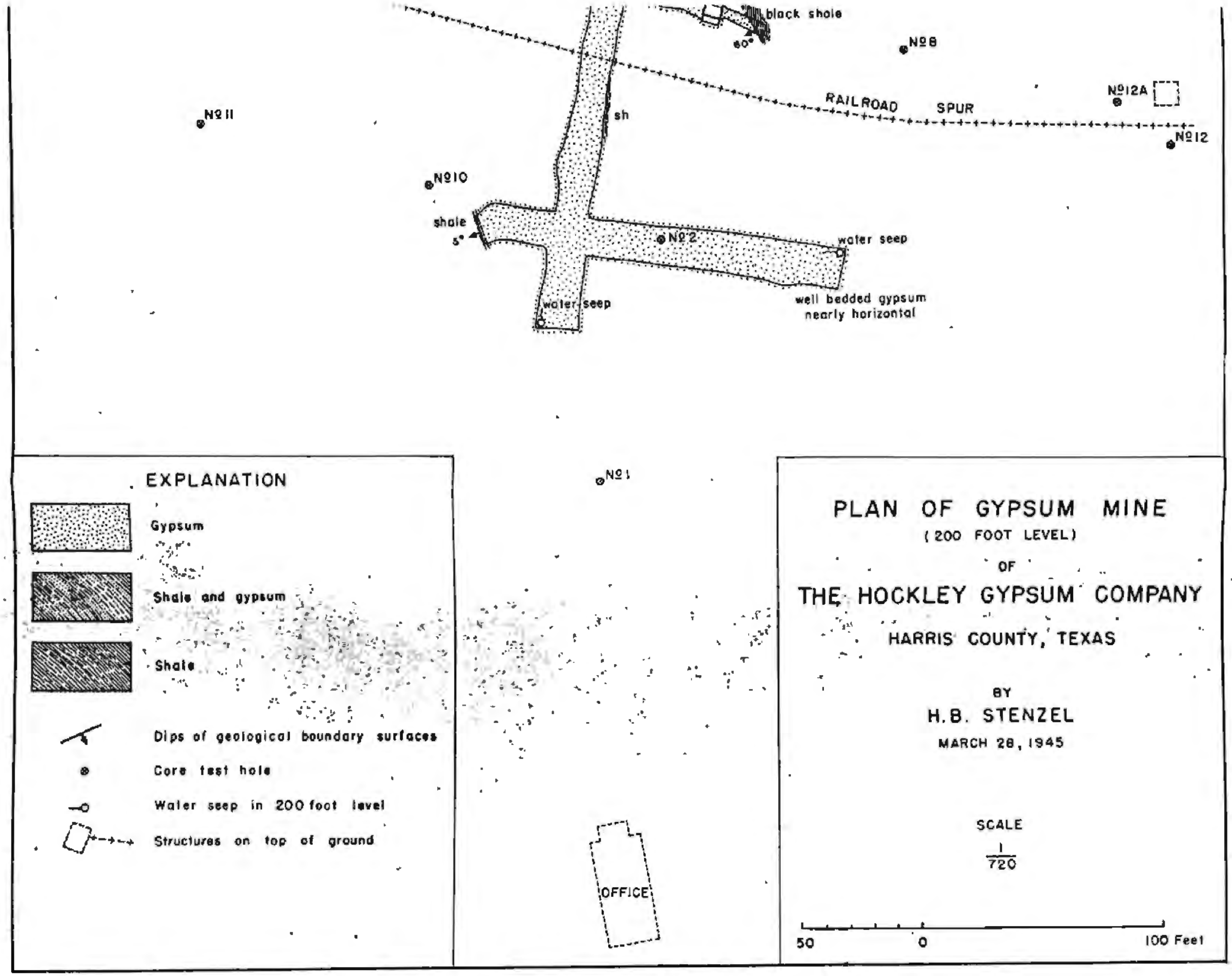
Another variety is finely crystalline, irregularly blotched with various shades of whitish gray and gray. This variety consists of irregular blocks of various shapes and sizes composing a breccia. Layering is discernible in some of the blocks and is in various directions depending on the position of the particular block in the breccia. The matrix in which these blocks lie is finely crystalline and thoroughly recrystallized and adheres firmly to the enclosing blocks. The whole mass, blocks and matrix, is so thoroughly welded together by recrystallization of the gypsum that it is difficult to find the boundaries of the various blocks and to recognize the mass as a breccia. It fractures as a unit and not along the boundaries of its components (Pl. XIV–B).

Locally vugs are found. These are usually lined with large, clear crystals of gypsum and filled with water. Their volumetric content is usually small and they do not seem to present difficulties in mining.

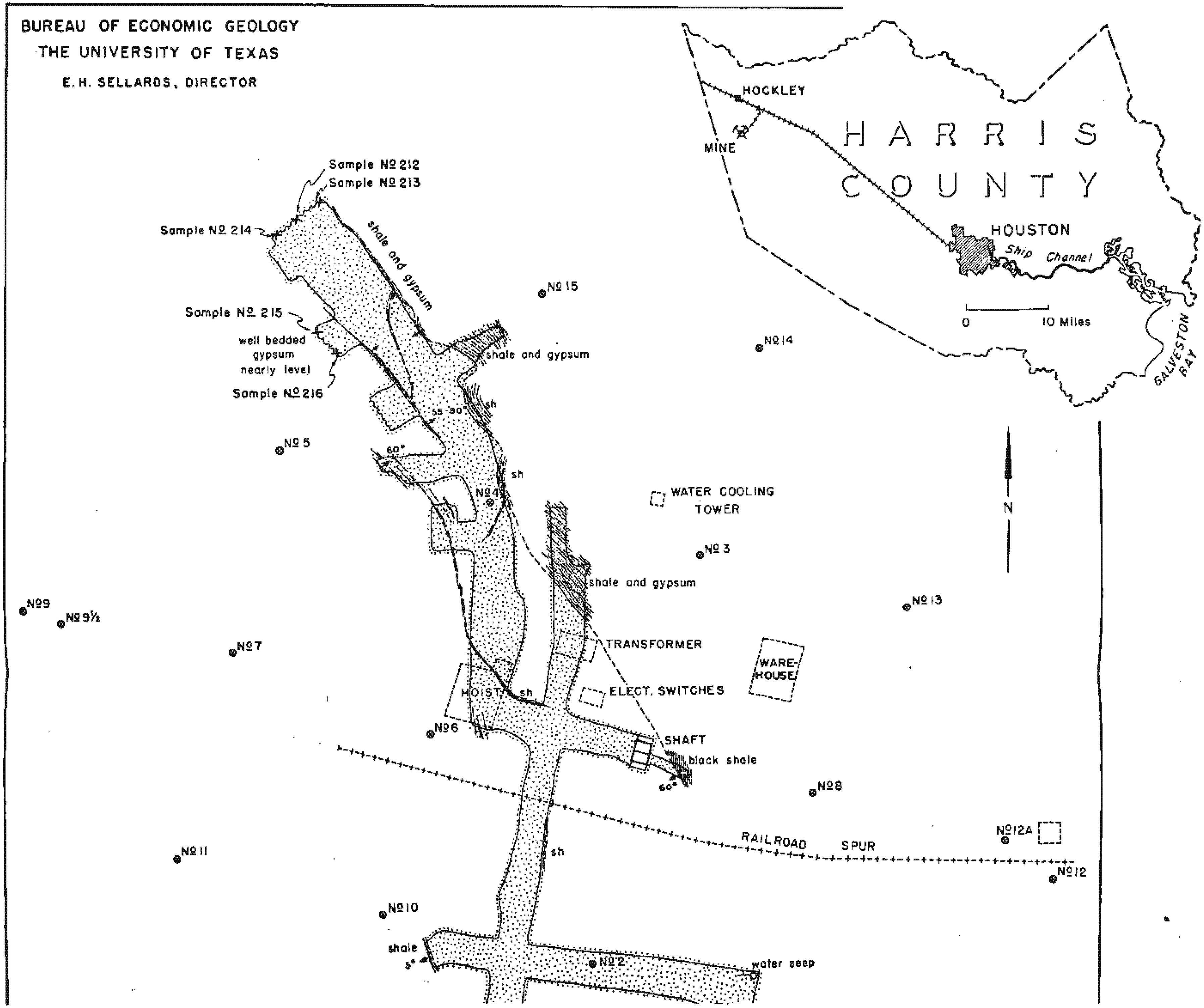
Along the latest planes of movement one finds coarsely crystalline gypsum, which fills completely or nearly so the cavities between the two walls of the break. In many instances the gypsum of these breaks is slightly twisted so that its cleavage planes are uneven. This indicates a slight movement after crystallization of the gypsum. The whole gypsum body is traversed by countless slippage planes. However, nearly all of these are tight and closed by recrystallization of the gypsum so that the mass is essentially impervious to the passage of water. This is evidenced by the dusty dryness of the mine in which, aside from the shaft, only few minor water seeps were encountered underground (see Pl. XII).

It is natural that gypsum rock should have the ability to recrystallize readily and so to close any breaks or pores. Gypsum is slightly soluble in water. At 21° C. one part of gypsum is soluble in 420 parts of water. If a sufficiently long period of time is available, gypsum would be taken in solution and redeposited by the moisture present in the pore space and openings of the rock. In this fashion open breaks or pores would tend to clog and the breaks would gradually weld together by recrystallization.

The gypsum rock visible in the mine encloses numerous fragments, tatters, and blocks of shales. Many of these enclosed blocks are sooty black to gray-black, laminated, micaceous or silty, in some cases very silty shale. These blocks are traversed by countless, small, slickensided slippage planes, and their bedding is contorted and twisted so that they do not show lamination readily but appear to be black mud rather than a shale. Many of the blocks are dry and as a consequence break into brittle fragments. Only one shale body was found to be plastic. This is the shale 15 feet east-southeast of the shaft on the 200-foot level. These shales are fragments of older sedimentary rocks penetrated by the salt core of the dome and brought from greater depth to this level. The outside boundaries of these shale pieces are very irregular and cut at any angle across the bedding of the shale. Usually the shale fragments are bounded by slippage planes and are drawn or smeared out into long tatters along these



black shale
60°
№8
№12A
RAILROAD SPUR
№11
sh
№12
№10
shale
5°
№2
water seep
water seep
well bedded gypsum
nearly horizontal
№1
EXPLANATION
Gypsum
Shale and gypsum
Shale
Dips of geological boundary surfaces
Core test hole
Water seep in 200 foot level
Structures on top of ground
OFFICE
PLAN OF GYPSUM MINE
(200 FOOT LEVEL)
OF
THE HOCKLEY GYPSUM COMPANY
HARRIS COUNTY, TEXAS
BY
H.B. STENZEL
MARCH 28, 1945
SCALE
1/720
50
0
100 Feet


BUREAU OF ECONOMIC GEOLOGY
THE UNIVERSITY OF TEXAS
E. H. SELLARDS, DIRECTOR
HOCKLEY
MINE
HARRIS
COUNTY
HOUSTON
Ship Channel
0 10 Miles
GALVESTON BAY
N
Sample Nº 212
Sample Nº 213
Sample Nº 214
shale and gypsum
Sample Nº 215
well bedded gypsum nearly level
Sample Nº 216
shale and gypsum
sh
55-80°
60°
sh
Nº 15
Nº 14
Nº 5
Nº 4
WATER COOLING TOWER
Nº 3
shale and gypsum
Nº 13
Nº 9
Nº 9½
Nº 7
TRANSFORMER
WARE-HOUSE
HOIST
sh
ELECT. SWITCHES
Nº 6
SHAFT
black shale
60°
Nº 8
RAILROAD SPUR
Nº 12A
Nº 11
sh
Nº 12
Nº 10
shale
5°
Nº 2
water seep

planes (see Pl. XII). In featuring the shale on the map it had to be exaggerated somewhat to allow representation of the smaller, thinner bodies. Many of these are so small and so mixed with gypsum that they are not objectionable. It has been found impossible and unnecessary to map all minute minor shale inclusions.

At the present status of mining, shale is present in sufficient quantities to be objectionable only to the east of the shaft and along the east side of the cross cut. It has been broken into in several places, but as can be seen from the map it has been skillfully avoided in the newer workings active at the time of the investigation. Future effective mining will depend on continued skillful avoidance of the larger shale bodies guided by continuous underground mapping.

QUALITY

The gypsum rock is intimately and in varying proportions mixed with impurities, of which the above described shale seems the most important at present. Through skillful mining operation the more obviously impure portions of the gypsum rock and the larger shale bodies may he avoided and left uutouched nnderground. In addition, by chemical tests it is possihle to check and guide mining operations so that only gypsum rock of desired quality is mined.

Numerous analyses are available of the underground gypsum rock. These analyses are from the various core tests and give a representative picture of the composition of the gypsum layer as a whole. It must be pointed out that this picture includes also such portions of the layer as are not pure enough and which under normal, skillful mining procedure are left underground. Certain portions of the layer will have to be left untouched underground under any circumstances, because pillars must be left standing to support the roof of the mine. By choice the less valuable portions of the layer may be left standing as pillars and only a very small amount of useless material, if any, need be removed.

In summarizing the analyses given in the appendix, it is evident that an extensive body of high-grade gypsum is present and that the minable gypsum rock meets specifications.

QUANTITY

Through the core tests made by various companies it is possible to outline (1) the extent of the cap rock, (2) the depth at which it lies, (3) the extent of the gypsum rock layer of the cap rock, and (4) the quantity of gypsum rock available to mining.

The extent of the cap rock was first shown by Deussen and Lane. Somewhat improved but in essential features similar data are given on the accompanying map (Pl. XIII). Wells and core holes known to have reached the cap rock are shown on that map. It may be seen that outside the 1000-foot line the cap rock descends very rapidly down the sides of the salt core and in many places it also thius out completely. In other words, the 1000-foot line comes very near to being a fairly representative outline of the margin of the cap rock. The size of the area enclosed by this line is 2.5 by 1.8 miles and the shape is ovoid with the longer axis from N–NW to S–SE and the lesser axis goiug through the north-central part of the outline.

Depth of the cap rock is shown on the map hy the 1000, 400, 200, and 100-foot lines. Each of the lines denotes depth to the top of the cap rock measured from the surface of the gronnd. The elevation of the surface of the ground varies from 203 to 162 feet above sea level, although as a whole the ground is very flat. As these lines are constructed from depth data without regard to sea level elevation, they are not contour lines of equal elevation above sea level. Rather they are in the nature of isopach lines giving the thickness of the overburden above the cap rock.

From the configuration of the lines it may be inferred that the top of the cap rock is flat, although somewhat uneven, and that toward the margin it descends with increasing steepness. The 100-foot line indicates a broad and shallow basin, open to the north, situated in the north-central part of the cap rock area and flanked in the east and west by broad ridges.

As has been explained above, the gypsum rock layer is only one of the several composing layers of the cap rock. Therefore, its extent is either equal to or smaller than the cap rock. The greatest thickness of the gypsum rock, 128 feet, was encountered in The Hockley Gypsum Company core hole No. 11, located west of the gypsum shaft. This core hole is in the north-central part of the cap rock area. However, in a general way the greatest thickness of this layer is over the mid-portion of the cap. In radial direction from the mid-portion the layer gradually pinches out before reaching the 400-foot line. There are several test holes near this line which show the gypsum to be absent. However, there are too few of these marginal data to establish accurately the thin outer edge or the actual margin of the gypsum rock layer. In view of the fact that along the 400-foot line the gypsum is either absent or of negligible thickness that line can be assumed to be the outer margin of the gypsum rock layer for all practical purposes.

Within the 400-foot line the gypsum is of varying thicknesses. In some places there seems to be a rapid change of thickness. For instance, the salt mine shaft disclosed gypsum rock of only 18 feet thickness but The Hockley Gypsum Company core hole No. 11 disclosed 128 feet plus; both are in the north-central part of the cap rock area within a short distance from each other. In other places the changes in thickness are not so extreme as that, for instance, in the area covered by The Hockley Gypsum Company core holes in the vicinity of the mine.

The quantity of gypsum available and recoverable may be calculated from the various core hole data. It is very large and sufficient to sustain the local industry.

MINING

Mining and Production Methods

The shaft used at present was originally sunk by the Tidewater Gypsum Company of Texas in 1928. The shaft had remained unused since about that year and was cleaned out and repaired in 1944. Originally it was only 136 feet deep. It has been deepened to 234 feet. It is a two-compartment shaft 8 by 14 feet in cross section. Only one of the compartments is in use at present.

Mining is done at present only on the 200-foot level. However, a lower level is contemplated and can be opened up readily, because the shaft is already excavated to 234 feet depth. Drilling is done by Chicago pneumatic stoker and Sullivan and Ingersoll-Rand jackhammers supplied with compressed air by a 315-c.f.m. Ingersoll-Rand compressor. It is planned to use electric auger drills later on. At present loading of the gypsum rock is done by hand shovel and larger blocks are broken to convenient size by hammer. The rock is loaded onto buckets.

The bucket lift hoists the rock and discharges it into a hopper, which is above the crusher. The crusher is a 7-inch Allis-Chalmers Newhouse gyratory primary crusher. This crusher reduces the rock to the size which is desired by cement plants. A belt-bucket elevator discharges the crushed rock to an Allis-Chalmers 2-deck Aerovibe screen of 3 by 10-foot size. A horizontal belt conveyor carries oversize material back to the gyratory crusher (Pl. XIV–A).

A belt conveyor carries the material to a Stephens-Adamson box car loader, which distributes it in the box cars. Shipment is by box car and open gondola. A stock pile operated by scraper-hauler system is near the tracks.

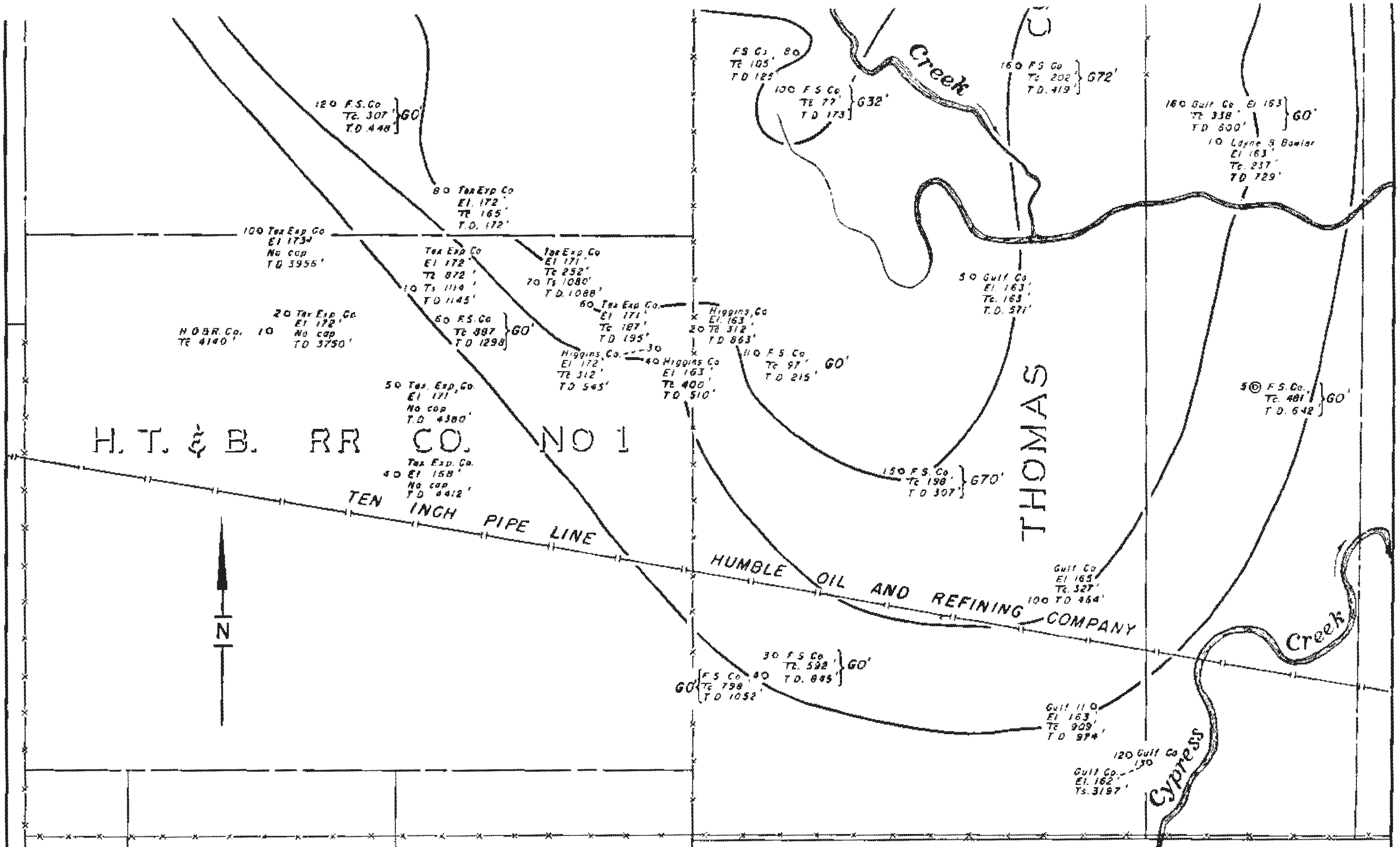
At present all gypsum sold is used as a retarder in Portland cement manufacture.

Mining Hazards

In the course of refitting the shaft and opening up the 200-foot level some difficulties were encountered. These comprise ground water leaks and presence of hydrogen sulfide gas.

Ground water occurs in the unconsolidated sediments which overlie the cap rock. In undisturbed condition only the uppermost portion of the cap rock, the limestone layer, is cavernous and permeable to water. The lower portions of the cap rock including the mass of the gypsum layer are water tight or very nearly so. This is evidenced by the dry condition of the 200-foot level, in which only minor water seeps are present and where nearly all the walls and the roof are dry.

However, in sinking the original shaft insufficient care was taken to wall off the water horizon and water leaks from the overlying unconsolidated and porous sediments. The amount of water entering is not serious as it is being handled success-



EXPLANATION

El 163'	Elevation above sea level
Tc 312'	Top of cap rock
T D 3750'	Total depth
G70'	Thickness of gypsum rock layer of cap rock

SUBSURFACE MAP OF HOCKLEY SALT DOME

HARRIS COUNTY, TEXAS

BY

H. B. STENZEL

MARCH 28, 1945

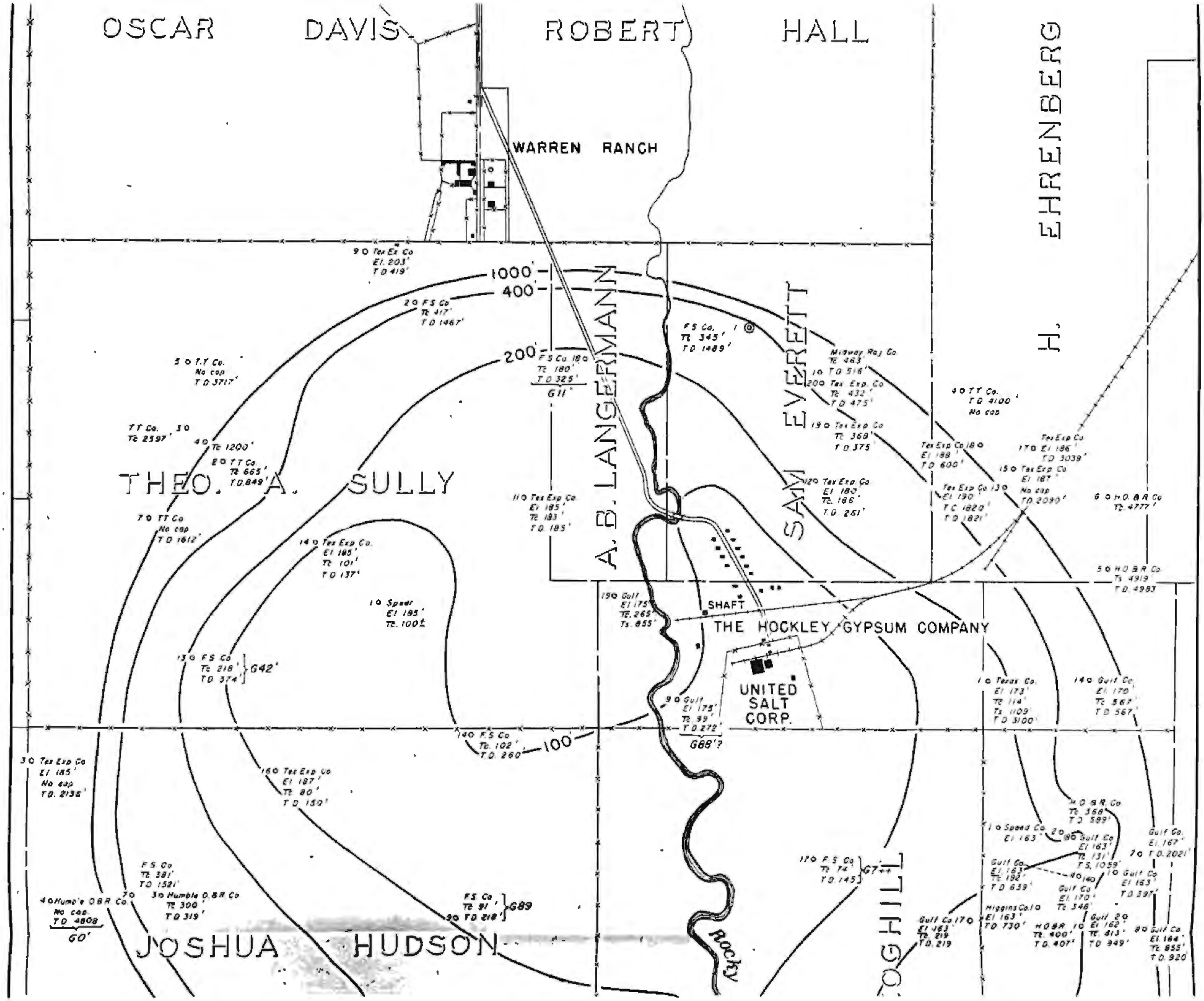
Scale 1/15,000

500 0 3000 FEET

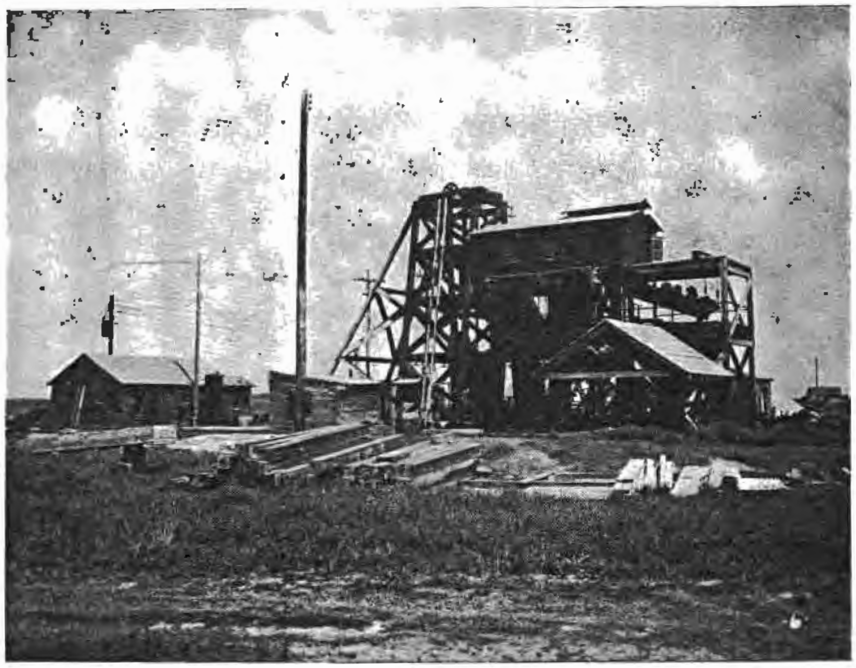
0 ½ MILE

EXPLANATION

1000', 400' — Lines of equal depth to top of cap rock


OSCAR DAVIS
ROBERT HALL
H. EHRENBERG
WARREN RANCH
A. B. LANGERMANN
SAM EVERETT
THEO. A. SULLY
THE HOCKLEY GYPSUM COMPANY
SHAFT
UNITED SALT CORP.
JOSHUA HUDSON
HILL
Rocky
1000'
400'
200'
100'

The University of Texas Publication 4301 **Plate XIV**



(A) Shaft and plant of The Hockley Gypsum Company, near Hockley, Harris County, Texas.

(B) Gypsum rock in the mine.

fully by pumping for short periods. Although it may not be found necessary, it is probable that methods can be devised by which the shaft can be made to stop leaking. The mine levels should prove dry or nearly so and very little difficulties are to be expected from that source provided sufficient care is taken and core hole exploration is preceding the mining operations.

The roof of the present level appears sound on examination and the strength of the cap rock is such that it should support a roof under the present conditions and procedures of mining. It is obvious that care must be taken not to weaken the roof in any way.

Hydrogen sulfide gas is present in the mine and in some of the ground water. The gas is obnoxious but is readily removed by proper ventilation. No difficulties should be encountered under the present system of ventilation.

HISTORY OF DEVELOPMENT

The first well at this locality to penetrate to hard rocks was drilled in 1902 by Lee, Napier, and Spears in the Theodore A. Sully survey. This well entered hard rock, probably sandstone, at 13 feet continuing in this to 60 feet. A small quantity of oil was found in this rock and black shale was found below. The presence of a salt dome at this locality was first suspected by Mr. Patillo Higgins in 1905 on the basis of gas seeps in shallow auger holes and hydrogen sulfide-bearing water seeps. The first six wells were drilled by Mr. Higgins in 1906 to 1908. These wells entered cap rock at shallow depth and proved the existence of the salt dome. Later exploration showed in many instances that part of the cap rock was composed of gypsum rock.

In 1928 Mr. Howard W. Kenyon of Houston became interested in the possibilities of gypsum mining near Hockley and investigated the cap rock. For testing and exploration, 9 wells and a shaft were dug proving the presence of an extensive gypsum rock deposit. The shaft was 136 feet deep. The shaft entered gypsum rock and its bottom was in that rock. A prospectus entitled "A new source of potential wealth in Harris County, Texas" and dated October 1, 1928, was printed and a company, Tidewater Gypsum Company of Texas, was formed for the exploitation of the lease. It is not known whether this company produced gypsum commercially except on an experimental basis. Due to the depression years of 1929 to 1932 no further work was done and the property remained dormant.

Later exploration was taken over by the Texas Gypsum Mining and Construction Company. It is not known how much exploration this company conducted.

In 1937 Mr. Kent B. Diehl, then president of Gulf Portland Cement Company in Houston, became interested in the gypsum mine. The first report on the deposit was made for Mr. Diehl by Mr. Thorald Field of Superior, Wisconsin. Then in 1942 Mr. Diehl and his associates formed The Hockley Gypsum Company. This company obtained leases covering the salt dome area and proceeded with exploration. In the course of exploration 15 core holes were drilled in the vicinity of the old shaft. The old shaft was cleaned out and deepened to 234 feet. This proved a very difficult task on account of considerable water leakage around and through the old shaft and on account of the poor original construction of the shaft walls. However, the difficulties were overcome in 1944 and the shaft is now in continuous operation. At first operations were in charge of Mr. Axel F. Peterson and Mr. A. J. Ragel, superintendent. The present superintendent is Mr. Matthew P. Rowe. The mining of gypsum has now passed the experimental stage and is on a commercial basis. The gypsum is being shipped to Houston and other places. Some of it even goes overseas.

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APPENDIX

This "Appendix" contains analyses of the gypsum rock from the Hockley salt dome and drillers' logs of the cap rock. These data are presented as a substantiation and documentation of the subsurface geology of the Hockley salt dome cap rock.

ANALYSES OF GYPSUM ROCK FROM HOCKLEY SALT DOME

The following 5 analyses were made by Mr. R. M. Wheeler of the Bureau of Economic Geology from samples submitted by H. B. Stenzel. The samples were taken by Mr. Matthew P. Rowe in presence of H. B. Stenzel. They were taken vertically down the exposed working face of the 200-foot level at the places indicated on Plate XII. The samples were obtained by chipping off small pieces with a pick at few inches intervals. Samples 212 to 214 cover 10 feet and samples 215 and 216 cover 12 feet vertically, in each case the entire exposed working face.

Number	Sample	Description	Free H_2O	Combined H_2O	Acid insol.	R_2O_3	CaO	SO_3
212	202 XCN	Center 259'	0.03	18.54	1.57	0.0X	33.30	45.66
213	202 XCN	East side 259'	0.03	20.24	0.87	0.0X	32.35	45.35
214	202 XCN	West side 259'	0.02	20.42	1.06	0.0X	32.35	45.15
215	213 DW	North side 12'	0.02	20.00	2.37	0.0X	32.20	45.22
216	213 DW	South side 12'	0.02	20.11	2.17	0.0X	32.00	45.02

Remarks: Carbonate reaction noticed with cold, dilute HCl.

Date: May 12, 1945.

The data presented in the next pages consist of analyses of samples taken from cores of the Freeport Sulphur Company core holes. These analyses were made by the Lone Star Cement Corporation, Houston, Texas. The analyses are followed by drillers' logs and analyses of the core holes of The Hockley Gypsum Company made chiefly by the Colorado Assaying Company, Denver, Colorado. At the end is appended a report made to Mr. Howard Kenyon by J. N. Gregory containing information about the shaft and analyses of samples taken therein.

LONE STAR CEMENT CORPORATION
Houston Plant

Freeport Sulphur Company—Hockley, Texas, Well No. 9
Samples taken from cores at Freeport, Texas, April 28, 1939

Feet from surface From	To	SiO_2	Al_2O_3	CaO	SO_3	H_2O	Total
92	96	0.92	0.04	32.16	46.00	20.63	99.75
96	102	1.84	0.24	31.88	45.60	20.44	100.00
102	108	1.56	0.06	32.02	45.80	20.54	99.98
108	109	26.00	0.40	26.60	32.61	14.30	99.91
109	116	0.16	0.12	33.60	45.51	20.60	99.99
116	126	1.68	0.20	31.92	45.60	20.49	99.89
126	131	4.56	0.36	30.74	43.97	19.73	99.36
131	136	3.76	0.20	31.21	44.64	20.03	99.84
136	142	1.12	0.08	31.88	45.58	20.45	99.11
142	152	1.20	0.28	32.05	45.82	20.56	99.91
152	162	0.56	0.16	32.30	45.18	20.72	99.92
162	172	0.48	0.08	32.37	46.27	20.77	99.97
172	182	0.96	0.28	32.13	46.00	20.62	99.99
182	192	0.32	0.34	39.70	55.57	4.00	99.93
192	202	0.44	0.40	37.70	52.00	9.00	99.54
202	208	0.92	0.42	41.20	54.81	2.30	99.85

Well No. 9 drilled by Freeport Sulphur Company is about 4200 feet southwest of Tidewater mine shaft.

From 92 to 182 feet from surface is a fair grade of gypsum. There are spots of very hard silica balls scattered through the cores. Silica is noticeable in lump form from 96 to 109 feet and from 116 to 152 feet in these cores.

Anhydrite is found at 182 feet and continues as far as we have tested, which is 208 feet.

Gulf Portland Cement Company tested some of these cores with the following results:

Feet from surface From	To	SiO_2	Al_2O_3	CaO	SO_3	Loss
102	108	...	......	33.03	46.21	21.10
136	142	——	——	32.43	45.80	22.17
172	182	——	——	33.43	45.70	23.16

Houston, Texas
May 10, 1939.

LONE STAR CEMENT CORPORATION
Houston Plant

Freeport Sulphur Company—Hockley, Texas, Well No. 10
Samples taken from cores at Freeport, Texas, April 28, 1939

Feet from surface From	To	SiO_2	Al_2O_3	CaO	SO_3	H_2O	Total
108	110	3.40	0.20	31.37	44.89	20.12	99.98
110	120	4.22	0.12	31.14	44.54	19.97	99.99
120	130	1.08	0.32	32.08	45.90	20.58	99.96
130	140	7.08	0.24	30.16	43.14	19.34	99.96
140	150	0.92	0.12	36.92	52.82	9.00	99.78
150	160	1.00	0.16	39.18	56.05	3.55	99.94
160	164	0.80	0.32	40.36	58.45	0.07	100.00
164	173	0.36	0.20	39.76	56.87	2.75	99.94

Well No. 10 drilled by Freeport Sulphur Company is about 4600 feet south-southwest of Tidewater mine shaft.

Gypsum is found from 108 to 140 feet with some silica balls scattered throughout.

Anhydrite is found at 140 feet and continues as far as we have tested, which is 173 feet.

Gulf Portland Cement Company tested some of these cores with the following results:

Feet from surface From	To	SiO_2	Al_2O_3	CaO	SO_3	H_2O	Total
115	118	———	———	32.43	46.37	20.97	———
130	140	———	———	32.43	45.39	20.85	———

They evidently had some pieces without silica balls.

Houston, Texas
May 11, 1939.

LONE STAR CEMENT CORPORATION

Houston Plant

Freeport Sulphur Company, Hockley, Texas, Well No. 14

Samples taken from cores at Freeport, Texas, April 28, 1939

Feet from surface From	To	SiO_2	Al_2O_3	CaO	SO_3	Loss	Total
104	108	Not determined			0		
109	115	38.72	3.28	33.30	0	23.85	99.15
115	124	0.72	0.08	32.26	46.14	20.71	99.91
132	141	0.52	0.08	32.90	47.00	19.45	99.95
141	148	1.48	0.18	31.98	45.77	20.18	99.59
148	153	1.48	0.20	40.00	56.87	1.45	100.00
153	161	0.72	0.08	39.40	53.23	6.45	99.88

Well No. 14 drilled by Freeport Sulphur Company is about 2700 feet southwest of Tidewater mine shaft.

Sandy limestone from 104 to 115 feet.
Gypsum from 115 to 124 feet.
Anhydrite and gypsum from 132 to 141 feet.
Gypsum from 141 to 148 feet.
Anhydrite from 148 feet to as far as we have tested, which is 161 feet.

Gulf Portland Cement Company tested some of these cores with the following results:

Feet from surface From	To	SiO_2	Al_2O_3	CaO	SO_3	H_2O
115	124	———	———	33.13	45.58	21.50
132	141	———	———	33.03	47.07	20.91

Houston, Texas
May 12, 1939.

LONE STAR CEMENT CORPORATION
HOUSTON PLANT

Freeport Sulphur Company—Hockley, Texas, Well No. 16
Samples taken from cores at Freeport, Texas, April 28, 1939

Feet from surface From	To	SiO_2	Al_2O_3	CaO	SO_3	Loss	Total
204	212	1.52	0.24	33.00	43.15	21.59	99.50
212	221	1.60	0.32	33.50	42.05	21.95	99.42
221	229	2.52	0.32	33.00	42.74	20.72	99.30
229	238	1.08	0.20	33.20	45.21	20.40	100.09
238	246	14.24	0.36	29.00	36.29	18.28	98.17
246	250	4.76	0.12	32.20	42.33	20.12	99.53
250	258	10.48	0.16	30.80	40.06	18.70	100.20
258	263	15.32	0.20	28.40	37.73	17.85	99.50
263	271	8.80	2.08	28.98	41.45	18.59	99.90
271	274	22.88	0.40	24.95	35.60	16.00	99.83
274	282	1.44	0.44	38.70	55.36	4.00	99.94
282	290	0.80	0.52	40.50	58.60	1.38	100.00

Well No. 16 drilled by Freeport Sulphur Company is about 4800 feet south-southeast of Tidewater mine shaft.

Gypsum is found from 204 to 274 feet with hard silica balls scattered throughout.

Anhydrite is found at 274 feet and continues as far as we tested, which is 290 feet.

Houston, Texas
May 13, 1939.

LONE STAR CEMENT CORPORATION
HOUSTON PLANT

Freeport Sulphur Company—Hockley, Texas, Well No. 17
Samples taken from cores at Freeport, Texas, April 28, 1939

Feet from surface From	To	SiO_2	Al_2O_3	CaO	SO_3	Loss	Total
127	135	0.72	0.16	56.00	0	42.86	99.74
135	145	1.80	0.60	54.80	0	42.58	99.78

Well No. 17 drilled by Freeport Sulphur Company is about 2850 feet south-southwest of Tidewater mine shaft.

These tests showed this to be limestone between 127 and 145 feet.

We are doubtful of the 135 to 145 feet sample being representative of this depth, as the log of the well lists gypsum from 138 to 145 feet; however, there was no gypsum in the broken core which we made our analysis from.

Houston, Texas
May 13, 1939.

Hockley Gypsum Company core hole No. 1 on John Warren Estate lease. Location: 00 E & W—200 S. Commenced 3–25–1943; completed 4–20–1943.

Driller's log:		Driller's log:	
Surface sand and boulders	0–62	Gypsum	188–198
Limestone streaks in sand	62–65	Gypsum	198–208
Water sand	65–99	Gypsum	208–218
Limestone, solid	99–105	½ foot cavity at 224′, gypsum	218–228
Shale and limestone	105–118	1 foot cavity at 232′, gypsum	228–238
Limestone	118–119	Small cavity at 247′, gypsum	238–248
Limestone and sand	119–129	Gypsum	248–258
Sand	129–130	Gypsum	258–268
Limestone, solid	130–152	Gypsum	268–270
Sand and shale, hard	152–154	Anhydrite and gypsum	270–278
Limestone	154–163	Anhydrite	278–287
Anhydrite and gypsum	163–168	Anhydrite	287–297
Shale	168–169	Anhydrite	297–308
Gypsum	169–178		
Gypsum with shale streaks	178–180	Total depth	308
Gypsum	180–188		

Detail of first 62 feet from graphic log of core hole No. 1:

Surface material	0–10
Clay	10–20
Quicksand	20–27.5
White clay	27.5–40
Water sand	40–62

Cored	Recovery	Cored	Recovery
118-128	0	208–218	8.75
128–138	1 foot	218–228	8
138–148	2	228–238	5.25
148–154	1.5	238–248	7
154–158	1.5	248–258	8.5
158–163	0	258–268	5.75
163–168	4	268–278	9.5
168–178	6	278–287	8.25
178–188	6	287–297	10
188–198	9	297–308	10
198–208	9.5		

Analyses	% SO_3	Analyses	% SO_3
168–175	45.21	225–240	41.44
175–185	41.96	240–255	42.24
185–195	42.08	255–270	44.58
195–205	50.02	270–290	51.80
205–215	46.72	290–308	54.72
215–225	39.62		

Hockley Gypsum Company core hole No. 2 on John Warren Estate lease. Location: 100 S—00 E & W. Commenced 4-2-1943; completed 5-20-1943.

Driller's log:		Driller's log:	
Surface	0–42	Broken shale	132–135
Sand and broken formation	42–60	Shale and anhydrite	135–138
Water sand	60–90	Shale	138–146
Soft shale	90–100	Gypsum	146–169
Limestone	100–101	Gypsum and shale	169–179
Broken limestone	101–111	Gypsum	179–279
Hard shale	111–132	Total depth	279

Analyses:

Feet from surface From	To	SO_3	CaO	Insoluble	Combined H_2O
149	163	42.75	31.10	4.60	19.05
163	176	44.40	32.15	1.95	19.55
176	201	41.65	32.35	4.00	18.35
201	208	45.35	33.20	1.05	18.90
208	213	50.25	38.15	0.65	7.95
213	227	40.95	32.48	4.60	18.10
227	237	39.95	35.35	1.05	17.50
237	255	50.65	38.57	0.35	7.50

Denver 1, Colorado, June 24, 1944
The Colorado Assaying Company
By Edmund Phillips

Hockley Gypsum Company core hole No. 3 on John Warren Estote lease. Location: 100 N—00 E & W. Commenced 5-21-1943; completed 6-2-1943.

Driller's log:		Driller's log:	
Surface	0-47	Broken gypsum	109-119
Oil sand	47-52	Gypsum, 1' of shale	119-129
Shale and sand	52-75	Gypsum with shale seams	129-159
Limestone	75-78	Gypsum 1' shale 9'	159-169
Shale	78-85	Gypsum 1' shale 9'	169-179
Hard sand and limestone	85-93	Gypsum 1' shale 9'	179-189
Shale and hard sand	93-103.5	Gypsum	189-216
Shale and hard sand	103.5-106	Anhydrite	216-236
Anhydrite and gypsum	106-109	Total depth	236

Analyses:

Feet from surface From	To	SO_3	CaO	Insoluble	Combined H_2O
129	139	44.00	31.80	2.95	19.55
139	145	45.20	32.43	1.05	20.00
145	159	44.50	32.23	2.00	19.70
159	179	40.00	28.80	11.30	17.90
179	199	39.90	30.45	9.40	17.20
199	207	51.25	36.62	0.40	11.00
207	215	43.05	32.70	2.50	19.05
215	236	55.15	39.85	0.55	3.50

Denver 1, Colorado, June 26, 1944
The Colorado Assaying Company
By Edmund Phillips

Hockley Gypsum Company core hole No. 4 on John Warren Estate lease. Location: 100 N—100 W. Commenced 6-2-1943; completed 6-16-1943.

Driller's log:		Driller's log:	
Surface	0-42	Shale streaks, 3' gypsum	165-175
Oil sand	42-48	Gypsum	175-208
Sand	48-61	Gypsum 2' broken sand	208-218
Black shale	61-85	Shale and gypsum	218-228
Shale	85-150	Gypsum	228-246
Limestone	150-155		
Limestone, anhydrite and gypsum	155-165	Total depth	246

Analyses:

Feet from surface From	To	SO_3	CaO	Insoluble	Combined H_2O
155	170	43.20	32.45	3.70	18.60
170	210	43.80	32.10	3.75	18.90
210	226	40.80	30.90	6.75	17.95
226	244	51.05	37.80	0.55	8.30
155		42.05			
165		44.25			
175		44.20			
185		44.50			
195		35.40			
205		46.65			
215		11.72			
225		41.60			
235		47.50			
245		52.40			

Denver 1, Colorado, June 26, 1944
The Colorado Assaying Company
By Edmund Phillips

Hockley Gypsum Company core hole No. 5 on John Warren Estate lease. Location: 100 N–200 W. Commenced ——; completed ——.

Driller's log:		Driller's log:	
Surface	0–65	Gypsum	152–177
Oil sand	65–70	Shale 6½′ gypsum 3½′	177–187
Hard sand	70–75	Gypsum	187–197
Shale	75–128	Broken shale and gypsum	197–207
Shale	128–137	Gypsum	207–247
Hard white shale	137–147	Broken core catcher	247–257
Anhydrite	147–152	Oil sand and gypsum	257–267

Analyses:

Feet	% SO_3	Feet	% SO_3
148	45.7	208	44.8
158	45.2	218	46.5
168	44.4	228	44.2
178	42.6	238	37.7
188	45.3	258	52.6
198	44.3	267 bottom	55.6

Denver 1, Colorado, July 14, 1943
The Colorado Assaying Company
By Edmund Phillips

Hockley Gypsum Company core hole No. 6 on John Warren Estate lease. Location: 100 W–14 S. Commenced 7–8–1943; completed 7–25–1943.

Driller's log:		Driller's log:	
Surface	0–39	Gypsum 7′ shale 3½′	168–178
Oil sand	39–45	Shale 5′ gypsum 3½′	178–186
Water sand	45–72	Shale 4′ gypsum streaks	186–190
Lignite shale	72–114	Shale streaks	190–198
Hard black shale	114–120	Gypsum	198–208
Hard sand	120–132	Broken core catcher	208–218
Broken limestone and shale	132–135	Gypsum	218–248
Gypsum	135–148	Gypsum 7′ anhydrite 2′	248–258
Gypsum and shale	148–158		
Shale streaked with gypsum	158–168	Total depth	258

Cored	Recovery	Cored	Recovery
136–148	8	198–208	9
148–158	10	218–228	9½
158–168	4	228–238	9¼
168–178	10	238–242	4
178–186	8	242–248	6
186–190	4	248–258	8
190–198	4		

Analyses:

Feet	% SO_3	Feet	% SO_3
138	45.4	219	46.1
148	44.2	229	45.0
158	45.4	239	40.1
168	44.0	249	44.0
199	44.8	258	53.2

Denver 1, Colorado, July 31, 1943
The Colorado Assaying Company
By Edmund Phillips

Hockley Gypsum Company core hole No. 7 on John Warren Estate lease. Location: 200 W–00 N & S. Commenced 7–30–1943; completed 8–7–1943.

Driller's log:		Driller's log:	
Surface	0–45	Broken limestone	125–128
Oil sand	45–48	Solid limestone	128–134
Water sand	48–65	Broken limestone and hard sand	134–151
Sandy shale	65–75	Cavity lost returns	151
Shale	75–92	Hard sand	151–157
Lignite shale	92–98	Shale or hard sand	157–160
Shale	98–115	Gypsum	160–172
Sandy shale	115–125	Total depth	172

Hockley Gypsum Company core hole No. 8 on John Warren Estate lease. Location: 100 E–00 N & S. Commenced 8–9–1943; completed 8–14–1943.

Driller's log:		Driller's log:	
Surface	0–49	Sandstone and gypsum	177–179
Oil sand	49–58	Water sand	179–182
Water sand	58–72	Sandstone and gypsum	182–188
Shale	72–161	Gypsum	188–208
Gypsum streaks	161–162	2' Gypsum 4' anhydrite	208–214
Shale and streaks of gypsum	162–168		
Gypsum streaked with shale	168–177	Total depth	214

Hockley Gypsum Company core hole No. 9 on John Warren Estate lease. Location: 300 W–00 N & S. Commenced 8–14–1943; completed 8–25–1943.

Driller's log:		Driller's log:	
Surface	0–41	Sandy shale	95–102
Blue shale	41–55	Shale and boulders	102–135
Oil sand	55–65	Sand rock	135–146
Water sand	65–87	Washed down after hole stood 24	
Shale	87–90	hours; lost hole by cave in.	
Lignite and sand	90–95	Total depth	146

Hockley Gypsum Company core hole No. 9½ on John Warren Estate lease. Location: 300 W–20 foot offset E. Commenced 9–1–1943; completed 10–8–1943.

Driller's log:		Driller's log:	
Surface	0–45	Blue shale	144.5–147
Shale	45–80	Hard sand	147 –152
Oil sand	80–90	Broken formation	152 –158.5
Lignite	90–98	Gypsum	158.5–174.5
Shale	98–112	Broken formation	174.5–184.5
Shale and sand	112–126	Gypsum	184.5–203.5
Shale and boulders	126–141	Anhydrite	203.5–204.5
Anhydrite	141–143		
Water sand	143–144.5	Total depth	204.5
Cored	Recovery	Cored	Recovery
158.5–164.5	8	194.5–203.5	9
164.5–174.5	10	203.5–204.5	1
184.5–194.5	10		

Hockley Gypsum Company core hole No. 10 on John Warren Estate lease. Location: 100 S–100 W. Commenced 10–13–1943; completed 10–29–1943.

Driller's log:		Driller's log:	
Surface	0–17	Broken gumbo	143–149
Shale	17–20	Anhydrite	149–154
Sand and boulders	20–30	Anhydrite 8″ break	154–159
Shale	30–42	Gypsum	159–178
Oil sand	42–50	Broken gypsum and gumbo	178–188
Shale	50–53	Broken formation gypsum, shale and boulder	188–198
Sand and boulders	53–60	Gypsum formation	198–209
Lime rock	60–66	Anhydrite	209–217
Sand and shale	66–88	Gypsum	217–223
Sand and shale 5″ anhydrite	88–93	Anhydrite	223–233
1.5′ anhydrite and gumbo	93–103	Gypsum	233–278
Gumbo	103–123	Anhydrite	278–288
2′ anhydrite 8′ broken formation	123–133	Total depth	
Hard anhydrite	133–143		

Analyses:

Feet	% SO_3	Feet	% SO_3
168	45.3	238	40.1
178	43.1	248	36.1
188	45.8	258	39.5
198	42.8	268	43.5
218	54.7	278	45.7
228	56.6	288	0.62

Hockley Gypsum Company core hole No. 11 on John Warren Estate lease. Location: 100 S–200 W. Commenced ——; completed ——.

Driller's log:		Driller's log:	
Surface	0–20	Igneous shale	91–96
Soft lime rock	20–22	Sand and boulders	96–120
Water sand	22–24	Hard sand	120–121
Soft lime rock	24–30	Anhydrite	121–124
Shale	30–46	Hard sand	124–125
Oil sand	46–51	Anhydrite	125–130
Shale	51–70	Shale	130–133
Water sand	70–76	Anhydrite	133–141
Shale and sand	76–79	Broken formation sand, shale and boulders	141–155
Lime rock	79–84		
Lignite shale	84–90		
Sand rock	90–91	Total depth	283

Analyses:

Feet	% SO_3	Feet	% SO_3
155 top	42.80	233 top	46.60
165 top	43.90	233 bottom	51.60
165 bottom	38.20	243 bottom	43.10
175 top	46.80	243 top	46.40
175 bottom	45.30	249 top	46.20
185 top	40.10	249 bottom	39.80
185 bottom	46.40	259 top	44.30
195 top	40.00	259 bottom	45.60
205 top	41.20	269 top	38.20
205 bottom	40.20	269 bottom	41.40
215 top	49.40	279 top	43.90
215 bottom	40.90	279 bottom	39.00
223 bottom	47.60	283 bottom	43.90
228 top	55.90	No mark	56.10
228 bottom	46.40		

Denver 1, Colorado
The Colorado Assaying Company
By Edmund Phillips

Hockley Gypsum Company core hole No. 12A on John Warren Estate lease. Location: 200 E. Commenced 2-4-1944; completed 2-26-1944.

Driller's log:		Driller's log:	
Surface sand	0–27	Shale	80–87
Clay	27–35	Sand	87–102
Sand	35–42	Shale	102–112
Sticky shale	42–56	Broken gypsum	112–116
Sand and gravel	56–70	Gypsum	116–122
Shale and sand	70–80	Total depth	300

Analyses:

Feet from surface From	To	SO_3	Combined H_2O	CaO	Insoluble
122	138	40.65	17.10	34.62	1.90
138	142	29.17	12.55	40.35	1.90
142	152	37.60	16.20	36.60	1.20
152	162	42.10	18.00	34.00	1.30
162	172	45.80	19.10	32.45	0.20
172	182	44.30	18.60	33.65	0.35
182	192	53.55	6.50	38.50	0.20
192	201	55.10	3.70	39.83	0.20
201	211	54.55	4.15	39.48	0.35
211	219	55.75	4.10		
219	229	56.10	3.70		
229	240	55.05	4.50	39.55	0.30
240	256	55.80	4.35		
256	266	55.90	3.75		
266	276	54.85	4.20		
276	286	55.45	4.05		
286	300	56.15	2.70		

Hockley Gypsum Company core hole No. 13 on John Warren Estate lease. Location: 180 E-100 N. Commenced 3-4-1944; completed 4-4-1944.

Driller's log:		Driller's log:	
Surface clay	0–20	Shale with streaks of lime rock	80–102
Sand	20–30	Gypsum	102–132
Clay	30–45	Broken gypsum	132–142
Shale	45–67		
Lime rock	67–80	Total depth	300

Analyses:

Feet from surface From	To	SO_3	Combined H_2O	CaO	Insoluble
142	162	42.20	18.10	31.07	7.05
162	177	43.92	18.30	32.87	3.10
177	189	51.75	6.85		0.50
189	199	51.33	8.30	38.00	0.40
199	219	46.85	16.40	34.64	0.30
219	240	54.35	5.15		0.30
240	300	56.30	3.10		

Hockley Gypsum Company core hole No. 14 on John Warren Estate lease. Location: 200 N–00 E & W. Commenced 4–12–1944; completed 5–22–1944.

Driller's log:		Driller's log:	
Surface	0–20	Limestone	72–73
Clay	20–27	Shale	73–74
Hard sand	27–31	Limestone	74–85
Clay	31–60	Shale	85–88
Sand and shale	60–70		
Shale, streaks of hard sand	70–72	Total depth	300

Analyses:

Feet from surface From	To	Combined H_2O	Insoluble	CaO	SO_3
88	115	18.60	6.05	31.00	43.40
122	136	17.65	10.80	29.10	40.30
136	142	19.55	1.20	32.40	46.05
142	152	18.00	3.40	32.60	43.05
152	162	11.30	1.55	36.65	47.15
162	164	5.90	3.25	37.30	53.05
164	174	4.85	0.85	38.90	54.65
174	184	5.05	0.80	39.35	52.20
184	189	5.15	12.30	33.55	47.10
189	198	6.25	2.55	37.65	52.40
198	209	18.55	1.00	33.25	44.40
209	219	18.50	0.95	33.20	45.35
219	229	9.45	5.25	35.05	48.60
229	246	4.75	1.30	38.65	54.05
246	256	18.15	2.35	32.35	45.80
256	270	4.20	8.10	36.15	51.20
270	300	2.25	14.45	34.15	48.55

Denver 1, Colorado, May 31, 1944
The Colorado Assaying Company
By Edmund Phillips

Hockley Gypsum Company core hole No. 15 on John Warren Estate lease.

Analyses:

Feet from surface From	To	Moisture	SO_3	CaO	Insoluble	Combined H_2O	Total
96	124	5.8	39.44	30.87	16.70	12.58	99.59
124	134	0.0	45.11	32.66	4.95	19.10	99.85
134	140	0.30	24.42	18.56	43.64	10.80	97.42
140	169	0.5	43.70	32.99	4.05	18.75	99.49
169	183	0.0	43.40	31.27	4.51	19.35	98.53
183	195	0.45	45.34	33.74	4.40	15.88	99.36
195	215	0.0	45.24	32.88	3.36	17.60	99.08
215	230	0.15	50.78	33.92	7.50	4.25	96.45
230	255	0.25	52.99	35.24	6.65	3.50	98.38
255	275	0.0	53.99	35.69	3.60	4.55	97.83

Houston, Texas
September 17, 1928

Mr. Howard Kenyon
Houston, Texas

Dear Sir:

I submit herewith the results of chemical tests made by the Houston Laboratories, Houston, Texas, on five samples of gypsum taken from the Tidewater Gypsum Company's development shaft on the Hockley Dome, Harris County, Texas.

Samples No. 1, No. 2, No. 3 and No. 4 were cut by me on September 11, from the walls of the shaft, while sample No. 5 represents an average of the samples held in the Foreman's office, and taken by him from the bottom of the shaft at the end of each day's work of shaft sinking.

The following description of the shaft is necessary to understand the value of the samples taken:

Vertical two-compartment shaft, 163 feet deep, timbered and lagged to a depth of 127 feet, dimensions about 5 feet 8 inches by 12 feet 8 inches in the clear. Below the timbering the shaft has penetrated thirty-six feet of gypsum in a massive, unbroken bed. Entrance to the shaft is made with an electric hoist and prospector's bucket. The gypsum is very hard and was sampled with an air-cooled jackhammer.

Sample No. 1. Cut from the four walls at the bottom of the shaft.

Sample No. 2. Cut from three walls, eighteen feet above the bottom of the shaft. The fourth wall was inaccessible from the bucket.

Sample No. 3. Cut from three walls of the shaft about two feet below the bottom of the timbering. Fourth wall inaccessible.

Sample No. 4. This sample represents an average of cuttings taken every foot out of the two closer walls of the shaft, from the point where the timbering ends to the bottom of the shaft.

Sample No. 5. Foreman's samples.

Each sample was quartered and crushed until it was reduced to about one-half pound of powder and particles not over one quarter of an inch in size.

The weights of the unquartered samples were approximately as follows:

No. 1. Three pounds.
No. 2. Three pounds.
No. 3. Three pounds.
No. 4. Fifty pounds.
No. 5. One pound.

Samples No. 1, No. 2, and No. 3 were designed to compare by analyses the uniformity of the gypsum at three points throughout the thirty-six feet of its exposure; sample No. 4 to show the average analysis of the exposure; while sample No. 5 represents the average analysis of the exposure as made from samples taken by the Foreman.

The results of these analyses show the exposure of gypsum in the shaft to be of an extremely pure quality.

Respectfully submitted by

(signed) J. N. Gregory, Mining Engineer
4007 Montrose Blvd.

Attached Chemical Memo.

Certificates of Analysis

Submitted by Houston Laboratories, Houston, Texas
September 17, 1928

To J. N. Gregory, Houston, Texas

Samples of GYPSUM				Received from:	9–13–1928
	No. 1	No. 2	No. 3	No. 4	No. 5
Sulphuric anhydride	44.60	45.28	45.55	44.92	45.12
Silica and insoluble	3.60	1.80	2.00	3.20	1.70
Water of combustion	20.10	20.41	20.52	19.96	20.34
Hypothetically combined:					
Gypsum	96.15	97.70	98.28	95.50	97.36
Anhydrite	0.0	0.00	0.00	1.05	0.00
Silica and insoluble	3.60	1.80	2.00	3.20	1.70
Total	99.75	99.50	100.28	99.75	99.06

Per: F. R. Robertson