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OF THE
UNIVERSITY OF TEXAS

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Bureau of Economic Geology and Technology
WM. B. PHILLIPS, Director

Potash in the Texas Permian

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J. A. Udden

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The Mineral Resources of Texas. Wm. B. Phillips. Issued by the State Department of Agriculture as its Bulletin No. 14, July-August, 1910. (Out of print).

The Composition of Texas Coals and Lignites and the Use of Producer Gas in Texas. Wm. B. Phillips, S. H. Worrell and Drury McN. Phillips. University of Texas Bulletin No. 189, July, 1911. (Out of print).

A Reconnaissance Report on the Geology of the Oil and Gas Fields of Wichita and Clay Counties. J. A. Udden, assisted by Drury McN. Phillips. University of Texas Bulletin No. 246, September, 1912.

A Map Showing the Location of Iron Ore Deposits in East Texas; Blast Furnaces; Lignite Mines in Operation; Lignite Outcrops; Producing Oil Fields, etc. Wm. B. Phillips, September, 1912. (Out of print).

Eighteen Press Letters, dealing with various features of mineral production in Texas. (Out of print).

The Fuels Used in Texas. Wm. B. Phillips and S. H. Worrell. University of Texas Bulletin No. 307, December 22, 1913.

The Deep Boring at Spur. J. A. Udden. University of Texas Bulletin No. 363, October 5, 1914. (Out of print).

The Mineral Resources of Texas, by counties. Bull. 365 (in press).

Address all communications to

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PREFATORY NOTE.

By Wm. B. Phillips, Director.

During the last two or three years, this Bureau has examined a large number of samples, from different parts of the State, for potash. Excluding the isolated and commercially valueless deposits of nitrate of potash, described in a paper entitled "Investigation of Sources of Potash in Texas," published in Bulletin No. 98 of the American Institute of Mining Engineers, February, 1915, the present Bulletin and Bulletin No. 363 on The Deep Boring at Spur, of the Bureau, contain practically all of the definite information we now have concerning the existence of possibly workable beds of potash salts in Texas. The studies of the deep explorations here presented were made by Dr. J. A. Udden, geologist of the Bureau. The chemical analyses were made by Mr. J. E. Stullken, chemist of the Bureau. The commercial importance of the matter is well illustrated by the fact that during the five years ending with 1913, we imported into this country nearly $50,000,000 worth of potash salts from Germany, the sole source of supply. Taking one year with another, the annual value of our imports of potash salts is close to $10,000,000.

These importations have practically ceased and it is wholly uncertain when they can be renewed. The European war has completely unsettled this business.

Much before the beginning of this war, the United States Department of Agriculture and the United States Geological Survey had conducted extensive investigations, chiefly in Nevada, California, etc., with the hope of finding domestic sources of potash salts. Near the center of Carson Sink, Nevada, the United States Geological Survey sank a well to the depth of 985 feet, in the search for these salts.

It is not the purpose of this Introduction to review the matter of the search for potash salts in the United States during the last few years, but it is thought that some comparative figures might be given with reference to the discoveries elsewhere than in Texas.

Natural brines from Death Valley, California, have shown a maximum amount of potash (K_2O) of 3.43 per cent. in the

total salts, which comprised about 28 per cent. of the original sample. This amount was found in the ground water in the salt crust at the "sink."

In brines from the Saline Valley, California, the maximum amount of potash found was 1.56 per cent. In wells bored at Columbus Marsh, Nevada, the maximum amount of potash found was 25.18 per cent., expressed as percentage of the soluble portion of the sample, which was 6.30 per cent. of the original sample. This sample came from a depth of 27 feet. The borings at this place reached a maximum depth of 50 feet and the amount of potash found varied from 0.41 to 25.18 per cent. In saline residues from the drainage basin of Railroad Valley, Nevada, the amount of potash found, expressed as percentage of the soluble portion, varied from 0.89 to 12.19, the soluble portion in the first case being 25.24, and in the latter case, 55.20 per cent. of the original sample.

A sample of mud taken four feet below the surface of Jesse Lake, in western Nebraska, gave 28.92 per cent, of potash, expressed as percentage of the soluble portion, which was 4.63 per cent. of the original sample.

The highest percentage of potash in brines that has been noted in the preparation of this Introduction was 35.85, from a pond on the Star ranch, western Nebraska. In this case, however, the dissolved salts comprised only 3.21 per cent. of the original sample.

These references are from Bulletin No. 540, Part I, United States Geological Survey, 1914.

Searles Lake, in southeastern California, which appears to be an exceptionally favorable locality for potash salts, is described in Bulletin No. 580-L, of the United States Geological Survey, 1914.

There are two especially important features in the discovery of potash salts in Texas, which this Bulletin announces. The first of these is the discovery of potash-bearing "salt" in depth and the other is the extent of the area in which this "salt" occurs. The potash-bearing material is not a brine, but a solid. One of the wells is in Potter County, 23 miles northwest of Amarillo; the other one is in Randall County, 16 miles south and west of Amarillo. The distance between these two wells

is about 30 miles in a southeast direction, the well in Randall County being about 18 miles farther east than the Potter County well.

In the Potter County well, the highest amount of potash found, expressed as percentage of the soluble portion, was 9.23, from a depth of 875-925 feet. The soluble portion in this case was 87.24 per cent. of the original sample.

In the Randall County well the highest amount of potash found, expressed as percentage of the soluble portion, was 10.50, from a depth of 1700 feet. The soluble portion in this case was 51.72 per cent. of the original sample.

In concluding his observations, Dr. Udden says: "...the territory which appears from our present knowledge to give most promise is along the supposed axis of the basin, southward and a little westward from Boden, the Miller well and Adrian. From the sections already made, it is evident that tests should extend to the greatest depth at which it may be considered profitable to work, say, 2000 feet. The 'red salt' horizon in the Miller and the Boden borings will lie, it is believed, over most of the territory indicated, between 2000 and 2400 feet above sea-level, or from 800 to 1700 feet below the surface."

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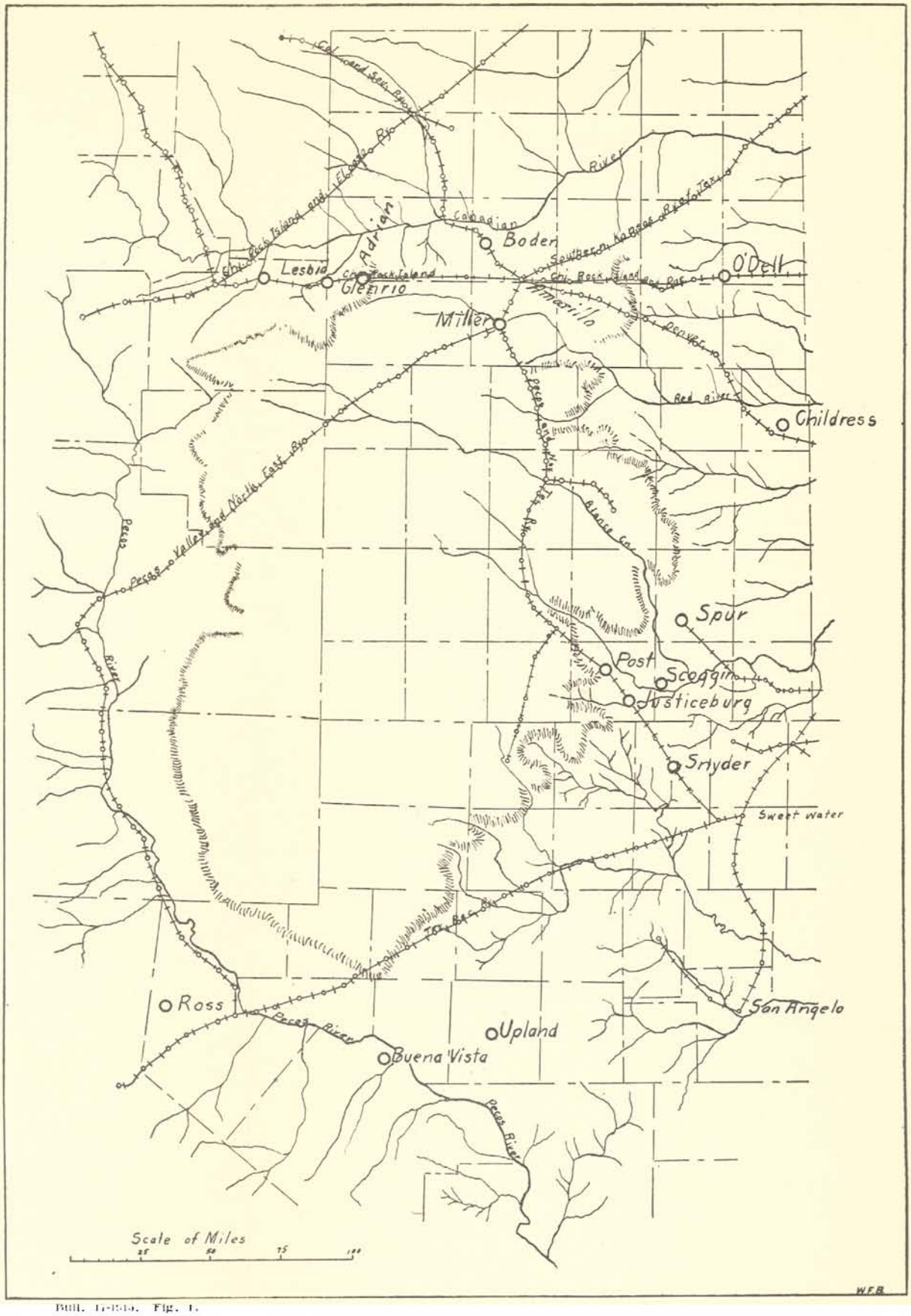


Bull. 17-3-5. Fig. 1.

INTRODUCTORY.

In an earlier publication* an account was given of the discovery of potash in a brine from the deep well at Spur, at the depth of about 2200 feet. The quantity amounted to 5.4 per cent. of potassium chloride in the total soluble solids, in one sample. After the publication of this report, the Bureau of Economic Geology and Technology of the University of Texas received samples of drillings from several other explorations in the western part of the state. Some of these drillings contained fragments of rock salt. Several samples of this rock salt have been analyzed and found to contain considerable quantities of potash. In two cases, it is believed that a potash mineral, such as carnallite, has been found. This is a bright salmon red substance containing about 14 per cent. of potassium chloride. It came, in one case, from a depth of about 900 feet below the surface, in a sample representing a fifty-foot bed of rock salt. This salt overlies three other salt beds, measuring jointly several hundred feet in thickness. In the other case, it was found in some rock salt coming from a depth somewhere between 1500 and 1700 feet. It is believed that this occurrence of potash in the form of a native mineral in association with salt deposits in the Permian redbeds at a moderate depth, warrants further explorations. In order that such explorations may be made as intelligently as possible, I wish to review some information which has been collected during the last three years and has a bearing on the geology of the Panhandle and the adjacent country, with special reference to the possible occurence of workable potash deposits in these beds.

Data From Borings.

The data secured consist of drill records and in some cases the determinations of contents of samples of cuttings from eighteen borings in the area of the Permian redbeds. The locations of these borings are shown in Figure 1. Ten of these borings extend in a belt from a little south of east, to north of west, across the north part of the Plains, following the drain-

*The Deep Boring at Spur, by J. A. Udden, Bull. of Univ. of Texas, No. 363.

age of Red River. The formations explored in these borings are shown in Figure 1. The other borings are located in a belt which is peripheral to the south end of the Llano Estacado, from Dickens county on the north, then south, southwest, and west, to Reeves county, west of the Pecos. The formations in these borings are shown in Figure 2. The data from which these sections were made are presented below.

Lesbia, New Mexico, Boring.

At Lesbia, New Mexico, a boring has recently been made for oil, 1414 feet deep, on land belonging to Mr. J. W. Lowing. Mr. Lowing furnishes the information that the first 1200 feet were in rock (probably mostly shale and sandstone). Below this depth, there was a bed of 100 feet of salt, followed by more rock, which was sufficiently indurated to be taken out in cores three feet long. Information from another source was to the effect that some salt had been penetrated at about 700 feet below the surface. This boring is on the east side of Arroyo Plaza, in the Triassic. Elevation of curb, estimated: 3950 feet above sea level.

The Glenrio Well.

Driller's Log.

Log of Rock Island Lines, deep well No. 2, at Glenrio, Deaf Smith County. Estimated elevation of curb, 3812 feet above sea level.

	Depth in feet below surface.	
	From	To
Red sand	1	8
Red sand and clay	8	32
Red shale	32	52
Hard red and blue shale, alternating layers	52	56
Red shale	56	120
Blue shale, mixed with sand	120	142
Red shale, mixed with sand	142	165
Gray sandstone	165	230
Water-bearing gray sandstone	230	255
Blue shale	255	262
Gray sandstone	262	280
Porous water-bearing gray sandstone	280	308
Blue shale	308	315
Porous water-bearing gray sandstone	315	324
Blue shale	325	334
Water-bearing gravel bed; "Tertiary gravels"	334	366
Blue shale	366	376
Red clay and sand-streaked red clay	376	466

Blue shale	466	476
Concretionary red clay with white calcareous concretions	476	515
Blue shale and limestone	515	541
Brown sandstone	541	561
Sand-streaked red clay with layer of brown shale at top and thin streak of soft brown sandstone at 585 feet	561	625
Brown sandstone	625	652
Red clay	652	657
Brown sandstone	657	660
"Carboniferous" limestone	660	667
Sand-streaked brown clay	667	675
"Carboniferous" limestone	675	700
Brown sandstone	700	702
Red shale	702	720
Hard white rock; "feldspar"	720	722
Red shale	722	742
Hard white rock; "feldspar"	742	746
Red shale	746	795
Hard white rock; "feldspar"	795	796
Red shale	796	800

Note.

Fresh water	230 to 255	in gray sandstone
Fresh water	280 to 308½	in gray sandstone
Fresh water	315 to 324	in gray sandstone
Fresh water	334 to 366	in "Tertiary gravels"
Small amount of salt water	585 feet	
Water, less salty	700 to 702 feet	

Samples.

Description of samples of cuttings from the Glenrio Well No. 2, made by the C. R. I. & P. Ry. Co. at Glenrio, Deaf Smith County. Submitted by Mr. Carl Scholz, Chicago, Ill.

	Depth in feet below surface. From	To
Red surface sand	1	8
Yellowish red marl and some gray to yellowish red limestone, like "tepetate," and fine sand, mostly from ½ to 1-16 mm. in diameter	8	32
Bright red marly clay, containing some quartz sand, in which mica was noted	32	52
Purplish, grayish red, marly clay, containing some sand	52	56
Light red marly clay, containing a few fragments of light blue clay, some fragments of calcareous concretions, and some sand	56	120
A gray sandstone. Some of the larger grains are well rounded. Mica conspicuous. Much clear quartz. Some dark quartz. Some fragments are from a red sandstone in which the sand is held together by a calcareous cement	120	142
Brown sandy marly clay containing included blotches of greenish gray marl of similar composition. Fragments of calcareous concretions. Mica present	142	165

Gray sand, mostly with grains from ⅛ to ½ mm. in diameter. Mica present. Some crystalline calcite noted. Sand mostly angular. Rock has a calcareous matrix	165	230
White sandstone, soft, micaceous, slightly cemented with calcareous material. Grains mostly angular, measuring mainly from ⅛ to ½ mm. in diameter..	230	255
A mixture of gray sand, silt, and clayey marl, containing some pebbles. Mica conspicuous. Some fragments of gray sandstone have a calcareous cement. A small part of red marl present	255	262
Gray sandstone with a calcareous matrix. Mica and pyrite present. Some of the quartz is pink in color. Size of sand mostly from ⅛ to 1 mm. in diameter. A few small pebbles noted	262	280
Micaceous gray sand and gravel. The mechanical composition of the sand is about as below: Diam. of grains in mm. — Percentages. 1-½ — 20 ½-¼ — 60 ¼-⅛ — 15 ⅛-1-16 — 5 Sand grains are not well rounded, are slightly rough, as from etching. Quartz is mostly transparent and white, also green, pink and yellow grains. Mica conspicuous. Gravel is rounded and consists mostly of vein quartz and chert	280	308
Greenish gray and red micaceous silt containing some sand, small pebbles, and fragments of a calcareous sandstone	308	315
White and gray sandstone, cemented with calcareous material, micaceous, and containing fine gravel. Most sand from ⅛ to 2 mm. in diameter. Not well rounded	315	324
Gray marly silt, slightly micaceous, and containing some sand	324	334
Sandy gravel. Coarsest pebble noted measured 1 inch. Material represented: white, black, yellow, chert; clear, white, and red vein quartz. Mica noted in sand	334	366
Greenish marly clay mixed with sand and pebbles, and containing fragments of a sandy limestone. Some quartz grains are very clear, some yellow, all are angular. Pebbles of white, blue, yellow and red chert. Mica and pyrite present	366	376
Brownish red and highly ferruginous sticky marly clay of fine texture, containing some sand and some fragments of red calcareous concretions and of concretions of limonite	376	466
Red marly clay of fine texture. Mica sparse. Fragments of red and white concretionary calcareous material noted. Small lumps of greenish gray clay present	476	515
A gray sandstone cemented with lime. Grains mostly from 1-16 to ⅛ mm. in diameter. Mica present..	515	541

A mixture of brown and gray marly and clayey silt and sand. There are fragments of a light gray calcareous sandstone. Mica noted	541	561
Reddish sand, mostly from ⅛ to ½ mm. in diameter. Sparsely micaceous. A small part of sample is red clay	561	625
Reddish sand, mostly from ⅛ to 1 mm. in diameter. Some of the larger grains are well rounded. Very little mica present. Slight quantities of clay and calcareous material present	625	652
Red marly clay. Mica not noted	652	657
A stony calcareous mud rock, dark brown and greenish gray, with some sand. Some poorly developed small quartz crystals noted. No mica seen	657	660
Cream-colored dolomite of very fine texture. In thin section it is seen to have minute angular porosities. Some of these have quadrangular shapes, indicating that they may be due to anhydrite crystals	660	667
Dolomite, cream-colored, fine-grained, finely porous.	675	700
Anhydrite	720	722
Anhydrite	742	746
Anhydrite	795	796
Bright red silty clay, hardly at all calcareous and containing no mica and very little sand. Some fragments of pure anhydrite present. The rock has greenish circular blotches several mm. in diameter.	796	800
Red sand, not micaceous. No label		....
Granular white anhydrite. No label		....
Red sand, slightly clayey. No mica noted. No label		....

Note.

The upper few hundred feet are in the Triassic red beds and sands. Below this are the Permian redbeds. The dolomite from 660 to 700 feet is probably the Alibates lentil. "Feldspar," used in the driller's record, is a misnomer for anhydrite.

The Adrian Oil & Gas Company Boring.

The Adrian Oil & Gas Company, of Adrian, a station on the Pecos Valley & North Texas Railway, began a deep boring at Adrian in 1909. This boring was abandoned in 1911 at the depth of 2825 feet. Mr. C. A. Hale, now residing in Vega, was the contractor of the boring. A standard rig was used. It was cased down to 337 feet with a 16-inch casing, with a 12½-inch casing down to 490 feet, with an 8¼-inch casing to 1530 feet, and with a 6⅝-inch casing to 2320 feet. The boring is located on the northwest edge of a flat depression in the land known as Rock Lake, near the center of Section 42, Block K11, in Oldham county, about two miles southwest of Adrian. Elevation of curb, estimated, 4050 feet above sea level.

Mr. C. A. Hale gives (1915) a memory record of the strata penetrated in this well. This is as below:

	Depth in feet below surface. From	To
"Red banks"	0	595
Dark shale	595	600
Soft honeycombed rock, looking somewhat like sandstone, and containing soft water, forming "soap suds"	600	640
Orange-colored mud	640	690
Gypsum and salt	690	750
Gypsum and salt, changing from one to the other every three to ten feet, or so	750	1185
Salt without break	1185	1370
Salt and gypsum	1370	1517
Sand like brown gas sand, no gas	1517	1547
Salt with gypsum	1547	2200
Dark rock (probably anhydrite)	2200	2240
Salt	2240	2440
Shale, red, dark and gray, and red mud	2440	2875

Note.

The sand containing soft water at 600 feet is evidently Triassic, and the gypsum and salt at 690 is no doubt the uppermost of the Permian redbeds, which seem to continue to the bottom of this boring.

The Adrian Townsite Company Well.

After water had been found in the Adrian well No. 1 at 600 feet, a well was drilled on high ground about one-half mile southeast of Adrian. Water was obtained at depths of from 678 to 750 feet in a "honeycombed" gray sand. There was a layer of limestone eight feet thick, between the depths 614 and 622 feet. The remainder of the ground penetrated is described by the contractor, Mr. C. A. Hale, as red mud. A sample of mud from the dump of this well consisted of yellow, red and gray sandy silt and clay, in which scales of mica were noted. This boring evidently did not penetrate all the Triassic. The elevation of the curb of this well is estimated to be 4140 feet above sea level. Some cuttings of salt, anhydrite and clay were examined from this boring.

The Boden Boring.

Driller's Log.

Log of boring at Boden (also known as Field), Potter County. Drilled by Layne & Bowler Company, contractors, for the Amarillo Petroleum & Gas Company. The boring is located in the northeast

quarter of Section 4, Block 21W, East Line & Red River Railroad. Drilling begun June 10, 1914, was finished Sept. 23, 1914. Elevation: near 3250 feet above sea-level. Pipe was set as follows: 24-inch at 20 feet; 12-inch at 690 feet; 8-inch at 1458 feet; 6-inch at 1700 feet. "Pulled all pipe, except separated the 12-inch pipe at 70 feet from surface; balance of 12-inch pipe was left in well."

	Depth in feet below surface. From	To
Soil	0	12
White clay	12	22
White sand mixed with charcoal	22	32
Blue clay	32	46
White sand mixed with charcoal, light flow of fresh water	46	50
Red clay	50	95
Gray rock	95	105
Red clay	105	115
Yellow rock	115	125
Red clay	125	165
Red sand with white shelly rock	165	190
Red clay	190	325
Red water sand (salt water), heavy flow, rose about 100 feet	325	340
Red clay	340	350
Red water sand (salt water)	350	390
White rock	390	400
Red sand	400	465
Red sand	465	565
Red clay	565	615
Blue clay	615	633
Red shelly rock and salt	633	640
Salt	640	645
Red sand	645	650
Salt	650	665
Hard white rock	665	695
Blue clay	695	698
Dark red clay	698	701
Salt	701	710
Hard white rock	710	720
Salt	720	730
Brown sand	730	745
Hard gray rock	745	765
Hard white rock	765	770
Hard gray rock	770	775
Salt	775	785
Hard white rock	785	795
Yellow rock	795	800
Salt	800	810
Hard gray rock	810	850
Hard brown clay	850	855
Hard white rock	855	875
Salt	875	925
Blue clay	925	930
Salt	930	950
Hard gray rock	950	955
Blue rock	955	975

Hard white rock	975	1005
Salt	1005	1230
Blue rock	1230	1290
Salt	1290	1460
Blue rock	1460	1475
Blue shale	1475	1485
Red sandy clay	1485	1680
Red sand rock	1680	1690
Hard brown rock	1690	1720
Red sandy clay, with occasionally thin strata of salt	1720	2010
Bubbles of gas noted	1900	2000

(Signed) T. H. LITTLE,
Superintendent, Layne & Bowler Company.

Samples.

Description of Cuttings from the Deep Boring at Boden, Potter County.

	Depth in feet below surface. From	To
Brownish yellow sandy adobe	0	12
Gray siliceous clay of fine texture. Does not effervesce in acid	12	22
Gray fine sand and some brownish red sandy shale. With this is a considerable quantity of lignitic wood, like that found in the Triassic beds	22	32
Gray clay, giving no reaction to acid. It contains fine siliceous sand	32	46
Gray sand, grains mostly from 1-16 to ½ mm. in diameter, of clear quartz, the larger sizes well rounded. Some red cherty fragments. Much lignite, showing woody structure	46	50
Red fine silt, slightly calcareous, containing red sand with grains mostly less than ¼ mm. in diameter	50	95
Gray dolomite of very fine texture, with a few fragments of white and pink gypsum. One fragment of sandy and gypsiferous dolomite had many small pale green grains, seen in thin section	95	105
White gypsum, coarsely crystalline, and some red sandy clay	105	115
Gypsum, white and pink in color	115	125
Red clay, somewhat open in texture	125	165
Brownish red silty clay and gypsum. The red silt has light greenish specks or blotches. Clusters of cubic pyrite noted	165	190
Sandy dark red silt. Minute flakes of mica noted	190	325
Red sand, with grains mostly from 1-16 to ¼ mm. in diameter	325	340
Red sandy and clayey silt, with some gypsum	340	350
Red sand of fine texture	350	390
White gypsum and some gray dolomite. Pyrite present and some salt. Potash, strong trace	390	400
Red sand, moderately fine in texture. Coarser grains rounded	400	465
Red sand, containing some silt	465	565
Light red silt showing some greenish gray blotches	565	615

Mostly gray dolomite of fine texture. The crystals are clear cut in outline and quite uniform in size. The sample contains some red silt, some white anhydrite and a few flakes of selenite. Potash, trace.....	615	633
A mixture of gray dolomite of fine texture, white anhydrite, red argillaceous sandy rock and gypsum. Potash, trace	633	640
Salt in original crystalline fragments, and red sand and silt. Some gypsum and anhydrite. Potash, trace	640	645
Red sand with some fragments of green shale of very fine texture	645	650
Rock salt, red sand and some lumps of dark red shale. Potash, trace.....	650	665
Pure white anhydrite.....	665	695
Gray, marly shale or clay. Heated in a closed tube, it gives very strong fumes of sulphur and a deposit of sulphur on the inside of the tube. The material contains no pyrite. With low heat in an open casserole, pungent sulphur fumes are given off. It is believed the sample contains some free sulphur very finely divided.....	695	698
Dark brownish red, sandy and silty clay.....	698	701
Much salt and some red sandy silt. There are some chips of a silty gray shale, which is slightly micaceous. Gypsum noted. Potash, trace.....	701	710
White and gray anhydrite of compact texture. Some red silty material.....	710	720
Mostly pieces of clear salt. Potash, trace.....	720	730
Salt, with some red silt and some blue silt. The sample contains several fragments of a red rock composed of a mixture of salt and silt. Potash, trace..	730	745
White anhydrite of moderately fine texture.....	745	765
White anhydrite.....	765	770
Grayish white anhydrite with some brownish gray silt	770	775
White anhydrite, with a few fragments of red silt. Potash, trace	775	785
White anhydrite.....	785	790
Yellowish white anhydrite.....	790	800
White and yellowish anhydrite of moderately coarse texture. Potash, trace.....	800	810
Gray anhydrite, mostly of compact texture.....	810	850
Brownish red silt and white and variegated anhydrite, with scattered fragments of dolomite.....	850	855
Bright white anhydrite.....	855	875
Clear salt, with a few fragments of salmon-colored salt. The salmon-colored salt was picked out and analyzed and found to contain approximately 9.23 per cent. potash (K_2O), equivalent to 14.81 per cent. potassium chloride. These fragments may be a mixture of potash-bearing minerals, with some common salt. The colorless salt contains 0.66 per cent. potash (K_2O). Another sample of drillings from this depth, received later, consisted of chocolate-colored clay, in which were seen surfaces covered with quartz crystals, in an incrusted plate; anhydrite containing small bodies of salt, rock salt with clouds of red silt, and a matrix of gray anhydrite,		

showing moulds of cubic crystals of salt a half-inch in diameter. In one of these moulds a salt-crystal remained undissolved	875	925
Mostly gray anhydrite, with some fragments of gray and red silt. Potash, trace,	925	930
Salt in fairly clear fragments. Potash, trace	930	950
Gray anhydrite	950	955
Dark, soft shaly rock giving strong fumes of sulphur when heated. With this is some anhydrite. No pyrite noted. Potash, trace	955	975
White, compact anhydrite, with some fragments of red and gray silt	975	1005
Pure salt. Trace of potash	1005	1230
Mostly gray, slightly impure anhydrite. In thin section one fragment shows the dark impurities distributed in a matrix, which incloses kernels of clear anhydrite of long straight crystals forming a network. One fragment showed thin laminae	1230	1290
Halite, anhydrite, red clay and silt and greenish-gray shale. The salt adheres to anhydrite in one piece, and to red silt in another lump. One piece of anhydrite has empty moulds of cubic form, evidently left by dissolved halite. Some of the red silt has blue blotches. When washed it is seen to contain small crystals of quartz. The anhydrite is fine in texture and gray in color. The greenish shale yields strong fumes of sulphur. Potash, trace	1290	1460
Gray anhydrite of fine compact texture. The gray color is apparently due to slight argillaceous impurity, which is present in streaks and blotches in some fragments	1460	1475
Gray, earthy, porous anhydrite of fine and uniform texture. It contains a small ingredient of silt and sand, and in this a few crystals of quartz were noted	1475	1485
Red sandy silt mingled with some anhydrite and containing a few clear pieces of halite. Octahedral pyrite noted. The sand contains small clear crystals of quartz. Most of the anhydrite is white and granular. Some is pinkish or gray and compact, some has a flaky character, and the flakes are composed of acicular crystals promiscuously oriented. Potash, trace	1485	1680
Red sand and silt with grains mostly from 1-16 to ⅛ mm. in diameter. In the coarsest sand, crystal of quartz were noted	1680	1690
Pure salt, mingled with some red silt. Trace of potash	1690	1720
Red silt, sand, and salt. The salt is in clear bodies in the sand. The red silty sand contains mica and also many small crystals of quartz. Potash, 0.14 per cent	1720	2010
One sample contains a lump of gray, very fine-grained anhydrite with an irregular 0.2-inch thick plate of red silt. One side of this lump shows cubic cavities, apparently places once occupied by salt crystals, 0.1 to 0.2 inch in diameter. The rest of this sample is lumps of red silt with irregular plates from 0.1 to 0.3 inch in thickness, of pure halite.		

Quartz crystals with two opposite pyramids and other more irregular quartz crystals occur among the larger sand **grains. Marked: "All salt found in this formation"**.....Depth not stated

Note.

This boring passes through some Cenozoic land drift, then Triassic material down to fifty feet or more below the surface. From ninety-five feet down to the bottom of the boring the formations penetrated belong to the Permian redbeds.

The Miller Ranch Boring.

Driller's Log.

Log of Miller Boring No. 1, Randall County. Dug by Will A. Miller & Sons, 18 miles S. W. from Amarillo, in bed of Palo Duro Canyon. Work stopped March 1, 1914. Location: 7 miles from Canyon City. Sec. 24, Block A, Tyler Tap R. R. Co., Randall County. Finished Feb., 1914. Located on the bank of Palo Duro creek. Elevation: near 3680 feet above sea-level.

	Depth in feet below surface. From	To
To cellar	0	7
Red clay	7	40
Water and sand	40	55
Red shale	55	85
Blue shale	85	125
Red and blue shale	125	220
Water sand	320	360
Red shale	360	370
Water sand	370	435
Red shale	435	445
Yellow mud	445	460
Red shale	460	465
Yellow shale	465	485
Red shale	485	510
Gray shale	510	530
Red shale	530	550
Sand	550	565
Red shale	565	585
Sand	585	595
Red sand and shale	595	630
Salt water and sand	630	640
Red shale and sand	640	655
Light red mud	655	745
Sand	745	750
Limestone, hard	750	765
Light red shale	765	940
Salt and red shale	940	1170
White lime rock	1170	1185
Red sand, water, "gyppy," corrosive	1185	1280
Lime rock	1280	1292
Red shale	1292	1325
Brown sand	1325	1385

Red shale	1385	1390
Rock salt	1390	1430
Dark gravel shale	1430	1435
Solid salt	1435	1500
Lime rock	1500	1508
Rock salt	1508	1530
White lime rock	1530	1544
Blue shale, sulphur	1544	1565
Red shale and salt	1565	1570
Salt, some shale	1570	1585
Solid salt	1585	1610
Lime rock, hard	1610	1635
Salt	1635	1680
White lime rock	1680	1695
Blue lime rock	1695	1700
Blue mud, salt	1700	1710
Blue and brown salt	1710	1720
Blue lime and some water	1720	1740
Blue shale	1740	1745
Hard lime	1745	1825
Red mud	1825	1830
Salt	1830	1950
Lime rock, blue	1950	2015
Blue shale	2015	2018
Lime	2018	2025
Salt	2025	2205
Brown shale	2205	2210
Lime and blue shale	2210	2212
Salt	2212	2315
Lime	2315	2440
Salt	2440	2480
Lime	2480	2530
Red and blue shale, into a dark shale, very sticky	2530	2575

Samples.

Description of samples of cuttings from W. A. Miller & Sons' well, 18 miles southwest of Amarillo, Randall County, Texas.

	Depth in feet below surface. From	To
Red sandy silt and clay with bluish-gray small round blotches, and containing a few very small flakes of mica. Some porous white gypsum, partly as small perfect crystals of selenite. Some fibrous white gypsum. Above and at		1325
Fragments of light gray, medium gray, and almost grayish black anhydrite. Heated in closed tube it retained its color and gave off some moisture. In open flame the dark color disappears. The dark color is perhaps due to carbonaceous matter. In thin section it is seen to consist of a tangle of slat-like crystals. This resembles some anhydrite noted at from 2042 to 2047 feet below the surface in the boring at Spur. The sample has some salt and this contains 6.14 per cent. of potash (K_2O)	1500	1700
A sample of drillings consists of rock salt, dolomite and anhydrite. The bulk of the salt is in colorless		

broken crystals. This salt contains 2.79 per cent. of potash (K_2O). Two analyses were made of pink fragments occurring in this salt. One of these gave 1.72 per cent. and the other 3.23 per cent. of potash (K_2O) of the soluble portion. The anhydrite is white and granular. Some dolomite is quite pure, yellowish gray, some is mingled with anhydrite. In thin section two rock fragments were seen to consist of minute ill-defined rounded bodies of anhydrite imbedded in a sparse matrix of dark clayey and magnesian material. Some fragments were soft impure limonite.....1700 2100

One large rock fragment, coming from below 1700 feet, consists of bright red sandy silt, having small spherical light gray spots. Another large fragment consists of compact anhydrite containing imbedded irregular crystals of salt from 1-16 to ¼ inch in diameter. Red clay adhered to this fragment. The salt in this anhydrite contains 10.50 per cent of potash (K_2O), equivalent to 15.80 per cent of potassium chloride 1700

Note.

Most of the reported limestone is probably anhydrite. There was a heavy stream of fresh water at 40 feet, rising to within eight feet of the surface. Some gas was noted at 1325 feet.

Mr. C. L. Baker, of this Bureau, regards the uppermost 430 feet in this boring as Triassic. All below this depth is believed to be Permian redbeds.

The McLean Boring.

Log of the Panhandle Oil & Gas Company Boring No. 1, on the O'Dell farm, about one-half mile south of McLean, Gray County. Elevation, estimated: 2810 feet above sea level. Made in 1914. Rotary rig used.

	Depth in feet below surface. From	To
White seepage sand	10	20
Loose gravel	20	28
Bed of gravel, loose and hard in streaks	28	40
Hard running sand and gravel	40	80
White sand and some gravel	80	100
Light sand and pack	100	140
Water, gravel and boulders	140	170
Streak of clay and sand	170	175
Hard breaking rocks and gravel	175	180
Red sand rock	180	185
Soft "crested" rock	185	190
Red clay and sand	190	200
Soft sticky red shale	210	220
Hard light brown sand rock	220	231
Hard brown shale	231	240
Rock and hard lime	240	250
Dropping boulders and light brown rock	250	260

Soft lime and gypsum	260	285
Soft red shale	285	295
Hard brown shale	295	300
Soft sticky lime	300	310
Hard brown shale	310	330
Light gray quicksand	330	353
Sand, light brown and glassy	353	370
Soft shale and sand	370	390
Soft gypsum and sand	390	395
Loose gypsum and black shale	395	400
Hard gypsum rock	400	410
Hard rock, gypsum	410	420
Soft sand and gypsum	420	434
Hard white gypsum rock	434	444
Hard yellow sand and gypsum	444	450
Soft blue shale	450	465
Hard gypsum, sand rock	465	470
Soft white gypsum	470	480
Hard-breaking rock and boulders	480	490
Soft white gypsum and lime	490	523
Pure white gypsum and lime	523	530
Hard rock, blue shale and gypsum	530	535
Hard dark shale	535	550
Soft white and yellow gypsum	550	552
White gypsum	552	555
Coarse gypsum, sand and gas, and shale	555	560
Hard, clear and yellow rock	560	565
Hard gypsum, sticky clay	565	570
Hard sand rock	570	575
Hard, blue, gummy gypsum, clay	575	578
White chalk, gummy, paste, magnesia	578	583
Hard blue sand rock	583	585
Crystallized sand	585	586
Hard blue shale	586	590
Hard sand rock	590	593
Soft red shale and sand	593	597
Hard red and white "coral" rock	597	600
Hard sandstone and lime	600	622
Soft white rocky gypsum, mixed with shale and salt; also black mud	622	630
Loose shale	630	635
Soft white "chalk"	635	642
Soft white gypsum, streaked with red shale	642	645
Hard, dry, red shale	645	647
Hard-breaking gypsum rock	647	650
Hard blue shale	650	655
White gypsum rock	655	657
Sand rock	657	662
Blue sand rock	662	665
Sticky black mud	665	670
Sand rock	670	673
Red shale	673	682
Blue mud	682	703
Soft blue shale	703	712
Soft blue shale	712	722
Dark brown, dry shale	722	730
Blue shale	730	732
Dark sand	732	743

Blue shale	743	750
Soft red shale	760	766
Red shale and yellow sand	766	770
Soft gypsum and red shale	770	775
White yellow sand, shale	775	782
Red shale	782	800
Soft lime, red sand, isinglass	800	820
Gray lime, isinglass, soft red shale	820	830
Soft lime	830	840
Hard streak of salt, lime, sand and gray lime	840	865
Soft and hard gypsum and "isinglass"	865	883
Soft white gypsum and "isinglass"	883	900
Red shale and gypsum	900	940
(Gas sand.....902 to 903 ft.)		
Streaks of hard gray lime and gypsum	940	960
Streaks of hard gray lime and gypsum	960	965
Red shale	965	970
Shale and brown sand	970	1000
Soft white gypsum and lime	1000	1015
Brown shale and sand	1015	1036
Streaks of hard gray lime and gypsum	1036.	1070
Gypsum and lime, and red sand, crystallized	1070	1075
Isinglass, hard	1075	1090
Streaks hard blue lime and soft gypsum	1090	1150
White gypsum, lime and streaks of red shale	1150	1161

Casing set.

Red shale	1161	1175
White gypsum and soft blue lime	1175	1190
Gray lime	1190	1200
Limestone	1200	1215
Soft lime	1215	1218
Soft red shale	1218	1222
Pure white sticky gypsum	1222	1225
Brown shale	1225	1228
Red shale	1228	1230
Isinglass	1230	1233
Red shale	1233	1235
Hard gypsum and salt	1235	1240
Soft blue shale	1240	1275
Brown shale	1275	1280
Hard white gypsum	1280	1283
Soft red shale	1283	1290
Salt and white lime rock	1290	1300
Red shale and lime, blue shale and salt	1300	1350
Streaks of hard and soft lime, red shale and salt	1350	1355
Soft sticky lime	1355	1360
Hard blue limestone	1360	1362
Red sand rock	1362	1370
Isinglass	1370	1380
Soft red shale and lime	1380	1390
Isinglass and lime	1390	1395
Red sand rock	1395	1397
Yellow rock	1397	1405
Brown shale	1405	1410
Hard blue and gray lime	1410	1440
Loose gypsum	1440	1441
Breaking red sand rock	1441	1442

Hard yellow brown rock	1442	1445
Mica and hard brown shale	1445	1450
Blue shale	1450	1460
Hard gray lime	1460	1465
Soft gypsum and soft yellow shale	1465	1467
Hard blue lime	1467	1468
Red rock	1468	1480
Soft lime and gypsum	1480	1490
Gypsum and gray lime	1490	1500
Gypsum, gravel and lime	1500	1518
Gypsum and "isinglass"	1518	1520
Hard red and white rock	1520	1523
Hard sticky yellow rock	1523	1530
Hard limestone	1530	1532
Hard brown rock	1532	1533
Hard red rock	1533	1535
Hard white crystal rock	1535	1536
Red sand	1536	1538
Hard gray lime	1538	1541
Blue mud	1541	1543
Red mud	1543	1545
Soft limestone	1545	1546
Black sticky shale	1546	1550
Lime and red shale	1550	1555
Brown shale and shelly lime	1555	1560
Red shale	1560	1562
Soft gypsum	1562	1570
Hard white gypsum	1570	1575
Limestone	1575	1577
Shelly lime	1577	1587
White rock	1587	1589
Red brown shale and salt	1589	1593
Blue mud	1593	1600
Soft blue shale	1600	1610
Streaks of shelly lime and mixed shale	1610	1617
Soft gypsum	1617	1619
Hard lime	1619	1626
Lime, gypsum and red shale	1626	1630
Red shale	1630	1635
Soft mixture, red shale and shelly lime	1635	1637
Hard white and gray lime	1637	1645
Blue shale, soft, hard by streaks	1645	1665
Peculiar hard rock	1665	1670

Note.

An examination of thirty samples submitted from this boring by Mr. G. A. Anderson, and marked as coming from various depths between 673 and 1670 feet below the surface, in this boring, shows that they have an uncommon resemblance to each other, for samples representing different depths and presumably different deposits. Blue shale is comparatively rare in the samples between the depths 1000-1240 feet. It is the principal rock in a single sample labeled "1590 feet." Anhydrite is the principal material at four depths: 865, 1020, 1180, and 1200 feet. Anhydrite in the form of small free crystals or crystals in clusters which are partly or wholly free, is common in most samples, though not looked for in each case. They measure mostly from one-fourth to one mm. in diameter. Gypsum occurs in the form of fragments of thin fibrous

plates, from 1 to 2 mm. thick. Small crystals of selenite were common in the sample labeled 1590 feet. Red and greenish gray clay and silt was the principal material in the sample from 1650 to 1670 feet. The presence of bluish gray anhydrite suggests this was the rock in which the boring stopped, at 1670 feet. It was reported as hard rock.

It is evident that all the samples have been washed, and that heavy mud was used in drilling. All samples contain much iron from the bit and casing. None of the samples contains enough salt to be detected by taste. The unusual uniformity suggests that there has been much mixing of the returns. Perhaps the only conclusion that can with certainty be inferred from the examination of these samples is that the red beds extend down to 1650 feet below the surface, at the least.

Note.

In a letter dated Jan. 11, 1915, Mr. G. A. Anderson, of McLean, Texas, writes as follows: "We ran out of the salt before we reached the 1260-foot depth, and again before we reached the 1670-foot depth." Mr. Anderson was interested in watching the progress of the work at the time, and from his statement it is clear that beds of salt of considerable thickness were penetrated above the two depths he mentions. There was "oil show" at 550 feet, and at 1240-1260 feet.

The uppermost 180 feet is perhaps Tertiary and Pleistocene. The remainder of the boring is no doubt in the Permian redbeds.

Some Borings in and Near Childress.

1.

Log of the Fort Worth & Denver City Railway Company 2075-foot boring at Childress, Childress County, furnished by the Chief Engineer's office, Fort Worth, Texas. Boring finished in 1911. Elevation of curb: near 1877 feet above sea-level.

	Depth in feet below surface. From	To
Red dirt	0	125
Gyp rock	125	130
Blue clay	130	145
Gyp rock	145	160
Blue clay	160	165
Red rock	165	175
Gyp rock and dirt	175	270
Brown clay	270	275
Gyp rock with red streak	275	340
Red clay and gyp rock	340	430
Red clay	430	500
Red clay and light shale	500	570
Shell rock	570	572
Clay	572	650
Red mud	650	680
Red mud and gyp rock	680	725
Red clay and gyp rock	725	750
Clay	750	1045

Red mud	1045	1080
Red clay	1080	1255
Limestone	1255	1265
Hard rock	1265	1280
Red clay	1280	1300
Red mud	1300	1340
Shale	1340	1527
Limestone	1527	1615
Red clay	1615	1875
Red sandstone	1875	1900
Red sandstone and light clay	1900	1935
Sandstone	1935	2005
Hard blue formation	2005	2060
Light red shale	2060	2075

2.

Log of the U. S. Weddington Boring, located about six miles northwest of Childress, Childress County, in the southwest corner of Survey 644, Block H, Western & North Western Railroad. It is situated on a slope at the head of a draw draining east. A rotary rig was used. Boring completed in 1914. Elevation estimated at 1860 feet above sea-level.

	Depth in feet below surface. From	To
Record not given, mostly gypsum and red clay	0	423
Sand rock	423	428
Salt and sand rock	428	450
Sand rock	450	460
Gyp rock	460	465
Sand rock	465	469
Salt and sand rock	469	484
Salt and gyp rock	484	490
Gyp rock	490	494
Salt and gypsum	494	496
Salt and sand rock	496	501
Sand rock	501	503
Salt and sand rock	503	511
Sand rock	511	513
Gumbo	513	516
Hard rock	516	524
Salt and sand	524	530
Red and blue shale	530	564
Gyp rock	564	568
Gumbo	568	571
Shale	571	573
Hard rock	573	601
Hard sand rock	601	630
Soft sand rock	630	670
Rock	670	673
Gumbo	673	685
Rock	685	688
Gumbo	688	700
Red and blue shale with a little shell	700	764
Blue shale	764	776
Hard rock	776	782

Sand rock	782	790
Gumbo	790	799
Lime rock	799	811
Blue shale	811	814
Lime rock and red clay	814	848
Blue shale, some boulders	848	883
Lime rock	883	888
Soap stone	888	892
Hard rock	892	899
Lime, flint and honeycomb rock	899	909
Sand rock	909	919
Blue and red shale and boulders, light showing of oil.	919	958
Hard rock	958	961
Blue and red shale	961	968
Hard rock	968	983
Blue and red shale and shell	983	1030
Sand rock	1030	1045
Hard rock	1045	1072
Sand and shale	1072	1083
Hard rock	1083	1096
Shale and shell	1096	1114
Hard sand rock	1114	1135
Shale and boulders	1135	1140
Hard rock	1140	1143
Salt and sand rock	1143	1153
Hard sand rock	1153	1173
Soft sand rock	1173	1189
Hard sand rock	1189	1213
Soft sand rock	1213	1219
Brown shale, showing of oil	1219	1236
Hard sand rock	1236	1246
Soft sand rock	1246	1248
Hard sand rock	1248	1282
Soft sand rock, oil showing	1282	1300
Blue shale	1300	1319
Blue and brown shale	1319	1334
Sand rock	1334	1342
Black gumbo	1342	1352
Hard sand rock	1352	1394
Soft sand rock	1394	1398
Oil sand, oil showing	1398	1399
Shale and shell	1399	1412
Sand rock	1412	1424
Shale and shell	1424	1440
Lime rock	1440	1459
Hard rock	1459	1462
White lime	1462	1464
Hard shell rock and lime	1464	1478
Sand rock	1478	1481
Blue and red shale	1481	1492
Blue shale, shell rock and gumbo	1492	1507
Shale, boulders and red clay	1507	1527
Blue shale	1527	1535
Red mud	1535	1547
Red shale	1547	1557
Blue and red shale	1557	1587
Red shale	1587	1598
Soft lime rock	1598	1602

White flint rock	1602	1628
Soft sand rock	1628	1630
Black gumbo	1630	1635
Lime rock and yellow mud	1635	1656
Blue shale and shell	1656	1675
Shell rock	1675	1686
Lime rock	1686	1700
Soft lime	1700	1719
Soft sand rock	1719	1724
Hard rock	1724	1735
Sand rock	1735	1745
Black gumbo	1745	1748
Sandy lime rock	1748	1749
Shale and gumbo	1749	1766
Gray shale	1766	1774
Blue shale	1774	1777
Sand rock	1777	1784
Blue shale	1784	1785
Gray shale	1785	1788
Lime rock	1788	1796
Shell rock	1796	1800
Sandy limestone rock	1800	1811
Gray shale and shell	1811	1819
Sand rock, crystallized	1819	1822
White lime, blue and red shale, with little gumbo	1822	1896
Sand	1896	1900
Sand rock, red, crystallized	1900	1916
Hard limestone rock	1916	1933
Soft white lime	1933	1940
Red clay and limestone rock	1940	1955
Hard limestone rock	1955	1961
White muck	1961	1962
Dry red clay	1962	1970
Black shale, white muck, gumbo, shale and yellow sand, oil showing	1970	1990
Sandy limestone	1990	1992
Red muck, white lime	1992	2003
Sandy limestone	2003	2004

3.

Section of a shallow well made by the Fort Worth & Denver City Railway Company, at Childress, Childress county. From U. S. G. S. Water Supply and Irrigation Paper, 148, Pl. XXII, C. Elevation, near 1877 feet above sea-level.

	Depth in feet below surface. From	To
Red clay	0	50
Gypsum	50	70
Red clay	70	95
Gypsum	95	110
Red clay	110	130
Gypsum	130	140
Red clay	140	150
Gypsum	150	155
Red clay	155	298

Red beds	298	525
Blue clay	525	535
Red clay	535	655
Red clay	655	747
Flint	747	750
Red clay	750	754
Packsand	754	782
Red clay	782	786
Red rock	786	807
Packsand	807	844
Gypsum	844	848
Salt	848	1098
"Gyp" clay	1098	1118
Salt	1118	1138
Gypsum	1138	1148
Red and blue clay	1148	1163
Sticky clay	1168	1178
Salt	1178	1203
Gypsum	1203	1218
Salt	1218	1238
Red, blue clay	1238	1253
Joint clay	1253	1263

4.

Description of samples from the Cooper Well, about one and one-half miles east of Childress, Childress county. Made in 1914. Estimated elevation: 1810 feet above sea-level.

	Depth in feet below surface.
Gray shale and a little anhydrite. The sample contains a few fragments of oolitic dolomite, which is porous, the interiors of the ooliths being dissolved. In thin section, the ooliths are seen to vary much in size	1260
Some gray dolomite of fine texture, some gray silt, and some anhydrite. Honey-combed rock with drusy anhydrite noted. Some oolitic dolomite present. In thin section the ooliths are seen to be mostly filled with dolomite. A few are filled with anhydrite. A few are empty. The oolite is like some rock at 2264 and 2709 feet in the Spur well	1430
Gray sandy shale, red silt, and white and pink anhydrite	1445
Gray silty material and anhydrite, and fragments of oolite from which the interiors of the ooliths have been dissolved out, making the rock porous. These fragments resemble rock seen on the surface at Childress. In thin section of oolite, it is found to have some ooliths filled with anhydrite, as in samples at 2264, 2624, 2709 and at 3245 feet in the Spur well	1460
Gray sandy shale, red silt, and anhydrite	1470
Gray dolomite, some red and some gray sandy silt and anhydrite. Drusy anhydrite noted on some fragments	1475
Gray sandy silt, gray anhydrite, and gray dolomite, in about equal quantities. Some porous oolite noted.	

Some honey-combed rock fragments have surfaces covered by drusy anhydrite	1500
Gray sandy dolomite, with some anhydrite	1550
Pink and gray anhydrite and some gray silt	1560
Greenish gray silt and pink and white anhydrite. Much drusy anhydrite noted, incrusting the surface of some fragments	1600

Note.

Oolitic dolomite occurs in outcrops near this well, and it appears in the cuttings down to 1500 feet. In the Spur well, oolites of this kind were noted at intervals, from 1200 to 2673 feet below the surface. The section shown in this well probably corresponds roughly to the lower part of the redbeds in the Spur well, and extends some 1000 feet into the upper part of the Dolomite Beds in the Spur well.

The data obtained from the four borings from near Childress are interesting in that they illustrate the wide divergencies of interpretation by drillers when prospecting new and unknown ground made up of such poorly defined types of rock, as constitute the formations in this region. Some salt beds were evidently overlooked in the deep boring by the Ft. Worth & Denver City Railway Company, owing, perhaps, to the presence of silty matter in the salt. It is believed that salt beds are present from 848 to 1238 feet below the surface, that some of the limestone reported is anhydrite, and that the lower part of the deepest wells exends into the Dolomite Beds of the Spur well. Conjectures beyond this seem hardly warranted at the present time.

The Spur Boring.

For data on the Spur boring, a section of which is shown in Plate 2, the reader is referred to Bulletin of the University of Texas, No. 363, entitled "The Deep Boring at Spur.*"

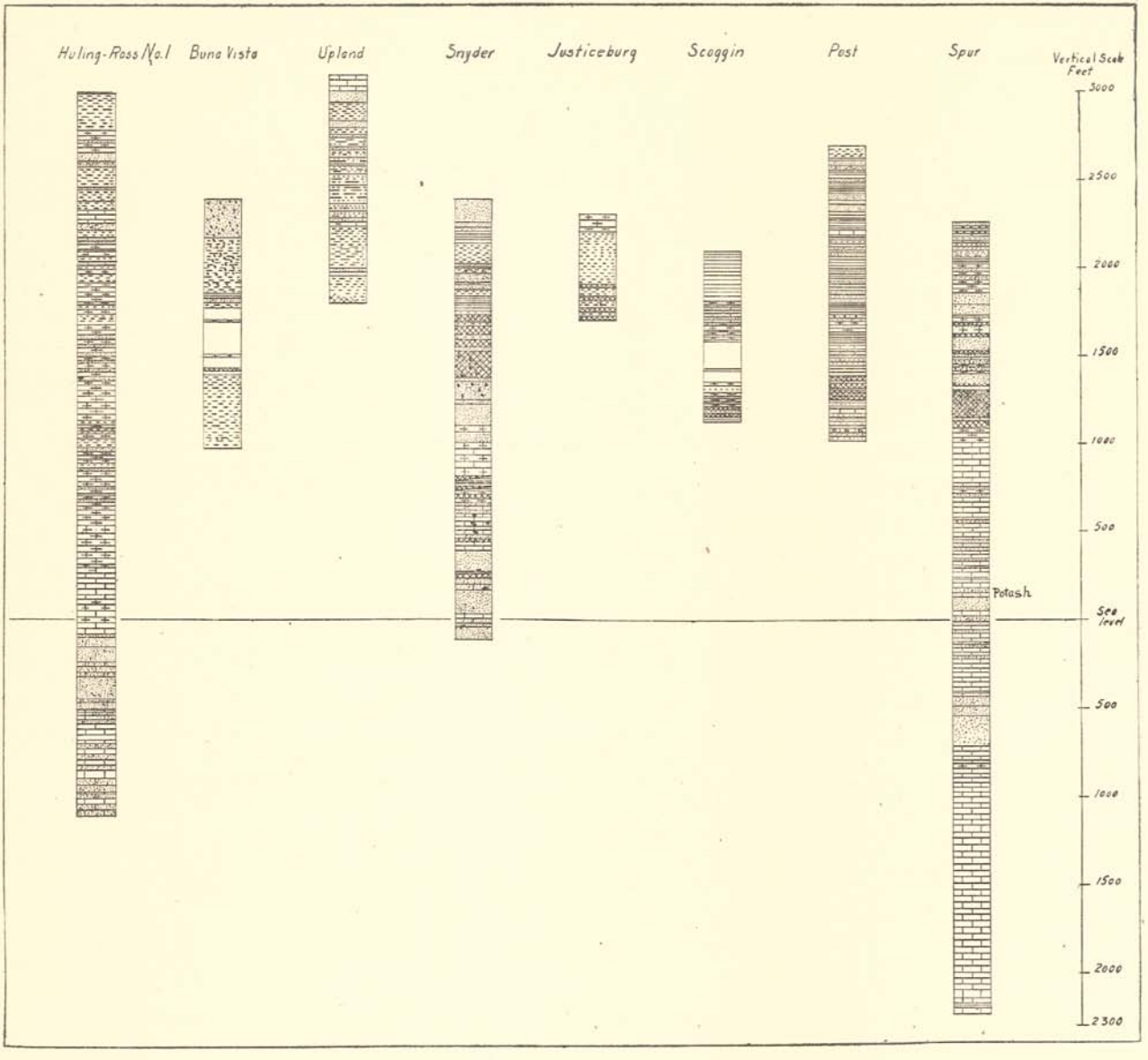
Boring at Post City.

Engineer's Log.

Log of Double U Company well No. 2, at Post City, Garza county. Estimated elevation: 2700 feet above sea-level. Log taken January 19, 1912.

	Depth in feet below surface From	To
Surface	9	21
White gyp	21	63
Red clay	63	78
Sand	78	83
Water sand	83	104
Clay	104	108
Clay and gravel	108	125

*This publication is now out of print.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Buna Vista
Upland
Snyder
Justiceburg
Scoggin
Post
Spur
Vertical Scale Feet
3000
2500
2000
1500
1000
500
Potash
Sea level
500
1000
1500
2000
2300

Gravel and sand	125	133
Red clay	133	187
10-inch casing set at 138 feet.		
Red and white rock, probably sand rock	187	207
Red plastic clay	207	264
Sand rock	264	310
Blue shale	310	331
Red sand rock	331	380
Red clay	380	484
Red rock	484	505
Red gumbo clay	505	545
White sand rock	545	547
Green clay shale	547	568
Same, and sand rock	568	629
Green clay shale	629	691
Red clay shale	691	754
Red and green clay shale	784	794
Red clay shale	794	815
Same, and sand rock	815	836
Sand rock and compact shale	836	857
Same	857	899
Hard compact red clay shale	899	964
Red clay, hardened. Well rounded pebbles, ¼ inch in diameter. Water came in at this depth, rose to within 100 feet of surface	964	968
Soft red shale, nodules of harder compact clay. Micaceous sandstone and crystalline gypsum	968	1000
Strata of crystalline gypsum, compact red clay shale	1000	1066
Dark red and green clay shale	1066	1140
Same, with streaks of calcite	1140	1145
Same	1145	1182
Dark red clay shale, greenish lime shale with narrow sandstone strata	1182	1217
Dark red clay shale with hard lime pebbles	1217	1234
Compact red and greenish clay shale	1234	1280
Same	1280	1284
Soft chalky gypsum	1284	1286
Hard compact gypsum rock	1286	1288
Compact red and greenish clay shale	1288	1296
Same, cored	1296	1298
Same	1298	1310
Fine grained red sandstone	1310	1314
Compact red clay, heavy with salt	1314	1318
Red sandstone, with streaks of satin spar, cored	1318	1324
Red clay shale with red (thin) sandstone and gypsum strata	1324	1336
Red sandstone and gypsum strata	1336	1344
Thin salt bed on red stone (sand)	1344	1346
Red clay shale, strata red stone (sand), 2-4 feet thick	1346	1368
Hard compact clay shale	1368	1374
Red clay shale with red sandstone and white lime and gypsum strata. Red clay shales heavy with salt above sand rock	1374	1394
Red clay shale with strata of red sandstone and salt-saturated clay	1394	1442
Red clay shale and red sandstone with small seams of white lime	1442	1468
Same as above	1468	1558

Red clay shale and red sand rock with occasional narrow strata of altered lime rock	1558	1604
Hard compact silicified lime rock	1604	1628
Red clay shale; red sandstone; less salt, small quantity gas	1628	1650
Hard red silicified lime rock; small quantity of gas noted	1650	1656
Red shale, heavy with salt	1656	1672
Salt rock	1672	1674

Samples.

Description of samples of cuttings from Double U Company well No. 2, Garza county. Samples furnished by the Double U Company.

	Depth in feet below surface. From	To
Pink and red marl, some quite argillaceous, some more calcareous; and gray imbedded sandstone	878	880
Red marly clay and some greenish gray clay	880	888
Red marly silty clay	894	896
Like the preceding	896	898
Like the preceding	898	900
Dark red slightly marly clay, with some green clay	900	902
Red marly clay, much pink calcite, apparently from concretions; greenish gray and red sandstone of fine texture	902	904
Red marly clay	904	906
Red and green clay, slightly marly, with some concretionary gray lime, in fragments	906	908
Pink and dull red marl containing some sand. Octahedral and cubic pyrite noted, octahedral crystals simple and nearly 1 mm. in diameter. Mica noted, some gypsum or anhydrite	908	910
Red marly clay and clayey sand. Pyrite, cubic, noted; also gypsum and fragments of pink calcareous concretions and mica	910	920
Red, slightly marly, clay	920	930
Red clay, slightly marly and sandy. Pyrite, gypsum, and quartz pebbles noted, also mica	930	936
Red silt, with occasional gray blotches	936	940
Like the preceding	950	964
Red marl, marked "Taken from the bit," at		966
Red clay of fine texture, with some gray calcareous blotches	964	968
Red marl, marked "taken from bit"	968	973
Red marl	973	980
Red marl with gray blotches. Mica noted	980	995
Red marly clay, with some concretions of gray lime	995	1000
Red silty marl, mica noted	1000	1005
Red marly clay, with some gray and red concretionary material	1005	1010
Red clay and red marl	1015	1030
Red marly clay and silt. Mica noted	1030	1040
Like the preceding	1040	1055
Like the preceding	1062	1077
Red silty clay marl, with green blotches	1077	1087
Red clay marl with some green marl	1087	1108

Red marly clay	1108	1120
Red marly clay, pyrite noted	1120	1130
Red marly clay, with some fragments of powdery and other gypsum, and some greenish gray marl	1130	1140
Red marly shale or clay	1140	1145
Red shale, dark red marly clay and some concretionary lime	1145	1148
Red and dark red shale and marly clay. Small quartz pebbles and gypsum present	1148	1150
Dark red clay and shale, in part marly. Concretionary lime noted	1150	1155
Red silty clay with small greenish gray streaks. Minute mica scales noted	1155	1160
Like the preceding	1160	1162
Like the preceding	1162	1164
Like the preceding	1164	1166
Red silty marl	1166	1168
Like the preceding	1168	1170
Like the preceding	1170	1172
Red shale and some greenish gray calcareous material	1172	1174
Red marly clay, with greenish gray blotches	1174	1176
Red marly clay with fragments of greenish gray concretionary limestone	1176	1178
Red marly clay	1178	1180
Red silty marl with some greenish fine sand and some red concretionary lime	1180	1182
Red marly clay, with fragments of greenish gray sandy rock	1182	1184
Dark red marly clay, and some fragments of greenish gray clay	1184	1186
Red marly clay	1188	1190
Like the preceding	1190	1192
Like the preceding	1192	1194
Like the preceding	1194	1197
Like the preceding	1197	1198
Like the preceding	1198	1217
Red marly clay, with rare greenish gray streaks	1218	1220
Red marly clay	1222	1224
Like the preceding, with some greenish gray fragments	1224	1226
Red marly clay, with some pink and some almost black calcareous concretionary fragments	1226	1228
Red marly clay with some lumps of dark purple clay and some fragments of sandy rock cemented with loose calcareous concretionary material	1230	1232
Red marly clay, and some light greenish gray calcareous rock	1232	1234
Like the preceding	1234	1238
Red marly clay	1239	1240
Like the preceding, and some fragments of greenish gray marl	1240	1242
Like the preceding, and some gray and purplish fragments of marly clay. Gypsum and pyrite noted	1242	1244
Red marly clay and fragments of light gray and dark gray calcareous material. Mica noted	1244	1246
Red marly clay with fragments of calcareous material	1246	1258

Red marly clay....1258 1262
Red marly silty clay, with fragments of concretionary calcite and some gypsum. Mica and pyrite noted. Some quartz sand....1262 1264
Red marly shale....1264 1268
Red marly clay....1268 1270
Red marly clay and some light greenish gray and white limey fragments....1270 1272
Red marly clay and shale and some fragments of red calcareous concretionary material....1280 1282
Red marly clay and some bluish calcareous material..1282 1284
Pure white anhydrite of microscopic crystalline texture....1284 1286
Anhydrite, taken from bit....1286 1288
Red silt, with some fragments of calcareous concretions....1288 1290
Red marly silt....1290 1296
Red micaceous silt and clay, with fragments of gypsum and lime and rounded grains of quartz....1306 1326
Red marly silt and clay with some fragments of bluish gray shale and some of anhydrite and limestone. Some coarse round quartz grains....1298 1384
Red marly clay and silt. Some fragments show layers of greenish gray color....1384 1386
Red marly clay and shale with some fragments of light gray lime and anhydrite, and gray rock....1386 1392
Red marly silt and clay....1396 1450
Red silty marl and clay with fragments of anhydrite, concretionary lime and rounded quartz grains....1450 1488
Red clay and sandy silt with calcareous fragments and crystals of gypsum and large fragments of anhydrite crystals....1488 1490
Red sandy and marly clay containing some anhydrite and some small selenite crystals....1490 1492
Pale red silty clay. The sample has caked apparently from the presence of anhydrite and salt. Small selenite crystals present....1492 1494
Like the preceding....1494 1518
Pale red marly and silty clay with anhydrite and selenite....1518 1536
Red marly and silty clay with anhydrite and selenite.1536 1538
Pale red marly and silty clay with crystals of selenite and fragments of anhydrite....1538 1570
Pale red marly and silty clay....1570 1572
Red silty and marly clay with fragments of anhydrite....1572 1576
Red sandy, silty clay with minerals as above....1576 1578
Red sandy, silty clay....1578 1616
Red silty and marly clay with selenite and anhydrite. A crystal of double pyramidal quartz noted....1616 1618
Red silty, marly clay....1618 1632
Red sandy and marly clay with crystals of gypsum and anhydrite....1632 1640
Red silty clay with minerals as above and a few green fragments....1640 1646
Red silty and marly clay....1646 1652
Red silty clay with crystals of selenite, fragments of anhydrite and clusters of quartz crystals....1652 1670

Red silty clay with crystals of quartz, fragments of anhydrite and radiating clusters of anhydrite....	1670	1672
Like the preceding, but with more anhydrite.....	1672	1674
Anhydrite, white, powdered and caked, second sample.	1672	1674
Red silty clay and anhydrite, with crystals of selenite, anhydrite and quartz.....	1674	1676
Red silty clay and some anhydrite.....	1676	1678
Like the preceding.....	1678	1694

Note.

Between the depths of 878 and 1694 feet no less than 108 samples of cuttings have been examined from this boring. These samples consist for the most part of mixtures of red marly silt, sand, anhydrite and gypsum, and verify the driller's log in several points. Pebbles of quartz and some sand are present at from 930 to 936 feet. There must be a conglomeratic sandstone near this depth. Quartz pebbles one-fourth inch in diameter are reported by the driller at from 964 to 968 feet. Calcareous material appears in the cuttings from 1150 to 1200 feet, where the driller reports several thin layers of limestone. A thin layer of gypsum shows in the driller's record at from 1284 to 1288 feet. The samples at this depth show that this was a layer of anhydrite, and that therefore the driller was right in differentiating it from limestone. The thin limestone layers reported by the driller from 1500 to 1558 feet seem from the cuttings to have been anhydrite. Both sources of information indicate the presence of some precipitated sediment, limestone or anhydrite, or a mixture of both at about from 1600 to 1630 feet below the surface. The hard, red, silicified limerock reported from 1650 to 1656 feet is represented in the samples by limestone. The salt rock reported at from 1672 to 1674 feet must have contained considerable anhydrite, which appears in the cuttings.

Pyrite was noted in the cuttings at 908-910, 1120-1130, 1242-1244, and 1262-1264 feet below the surface. Crystals of quartz, which seem to characterize the salt, anhydrite, and gypsum-bearing red beds, were noted in the cuttings at 1616-1618, at 1670-1672, and at 1674-1676 feet. Free clusters of anhydrite are often associated with these quartz crystals. They were noted in these samples at the three depths mentioned last. From the cuttings it appears that the ground contained some salt between the depths 1492 to 1518 feet. Small crystals of selenite were seen in the cuttings quite frequently from various depths, and the hydration of the anhydrite seems to extend to a greater depth in this boring than in most other explorations on the Plains.

The "white gyp" reported by the driller at from 21 to 63 feet, I take to be some soft, white, marly material, perhaps belonging to the Pleistocene. The clay gravel and sand reported at from 108 to 133 feet is doubtless the basal gravels of the Triassic. The beds below this are all to be referred to the Permian redbeds. The red rock, which is reported from 484 to 505 feet as separate from a red clay above and a red gumbo clay below, is in a horizon near that of the Alibates limestone lentil in the Glenrio well.

The Justiceburg Boring.

The Panhandle & North Texas Railway boring at Justiceburg, Garza County. Elevation: 2312 feet above sea-level.

The depth of this boring is 600 feet, and all is in the Permian

redbeds. These consist mostly of gypsum in the upper 100 feet, and below this of red sandy silt. Salt was noted in several places below 400 feet, and the last 15 feet were in rock salt. Information from Mr. C. L. Baker, of this Bureau.

The Snyder Boring.

Driller's Log.

Log of Snyder Development Company boring, located at Snyder, Scurry county. Elevation, estimated, 2400 feet above sea-level. S. K. Reese, driller to depth of 800 feet; Norwood Bros., to 1660 feet. Six-inch casing set at 1002 feet. Below this, the well was open. A rotary rig was used. The boring was made in 1912 as a test for oil.

	Depth in feet Below surface. From	To
Hard white sand	0	105
Hard red sand	105	115
Soft white sand	115	145
Hard white sand	145	155
Coal, 4 inches thick	155	165
Coal, 12 inches thick	165	170
Hard sand rock	170	185
Red clay	185	200
Red shale	200	250
Red rock	250	365
White sand	365	385
Red shale	385	390
Red rock	390	400
Gypsum	400	405
Red rock	405	410
Red clay	410	425
Red sand	425	440
Red rock	440	450
"Bed of lode stone"	450	485
Red sand rock	485	490
White rock	490	500
Oil sand	500	505
Same	505	510
Red sand rock	510	515
Red clay	515	520
Hard red rock	520	550
Red clay	550	640
Hard red rock	640	655
Salt water (and salt rock)	655	695
Salt rock	695	705
Red rock	705	720
Salt rock	720	765
Red rock	765	770
Salt rock	770	775
Red shale	775	785
Salt rock	785	800
Clay, gravel and salt	800	840

Red rock, sand	840	860
Sand rock	860	870
Clay, gravel mixed with salt	870	1020
Red sand rock	1020	1040
Gravel	1040	1140
Sand rock	1140	1160
Pack sand, red	1160	1285
White rock	1285	1315
Pack sand, red	1315	1330
Red rock, sand	1330	1345
Red sand	1345	1380
White rock	1380	1570
Salt, and shale	1570	1600
Shelly rock, mixed with shale	1600	1625
Red sand mixed with salt and shale	1625	1660
White lime rock and salt	1660	1725
Hard red sand, gypsum and salt	1725	1805
Gray lime rock	1805	1905
Gray lime, rock salt and sand	1905	1955
White rock	1955	2000
Red sand rock	2000	2120
Gray lime rock	2120	2130
Salt rock	2130	2160
Red sand rock	2160	2195
Red sand and gray lime	2195	2220
Hard sand and salt water	2220	2290
Red sand	2290	2360
Gray lime	2360	2385
Gray lime mixed with sand	2385	2430
Red sand rock	2430	2500

Samples.

Description of samples from the Snyder Development Company boring, Snyder.

	Depth, in feet, Below surface. From	To
Red clay shale and gray shale	Surface	
Red sand of fine texture, with some fragments of fine textured limestone, some fragments of selenite and some small crystals of quartz. Sample salty	1675	
A sample of anhydrite of light gray color and compact texture came up on the bit from depth of	1700	
Red sand, of fine grains, with some gray limestone, some granular anhydrite, and crystals of quartz. Sample salty	1725	
Mainly gray and light gray limestone, effervescence slow. Some of the gray limestone shows indistinct imbedded darker particles ⅛-¼ mm. in diameter, like fossil fragments or ill-shaped oolites. Some fragments of white and gray granular anhydrite noted. Some red sandstone of fine texture	1750	
Mostly gray limestone, having dark flexuous parallel streaks in some fragments; effervescing slowly. These may be of organic origin. Some red fine sandstone, and some fragments of dark shale. Several fragments of chert were noted, also some fragments of anhydrite	1790	

Gray and white limestone. Some of the gray limestone is like that at 1750 feet. With this is some red sandstone, fine in texture, some quartz crystals, some selenite and some granular anhydrite..... 1810

Mostly a gray limestone, characterized by imbedded dark gray fragments from ¼-¼ mm. in diameter. No fossils noted. With the limestone is some chert, some anhydrite, and some red sandstone..... 1865

Gray dolomite. Some fragments show a finely laminated structure. Some fragments are of a darker rock. Some grains of selenite and some granular anhydrite were noted, also some minute crystals of pyrite, some chert with microscopic straight spicules, red sand, drusy quartz, and one double pyramidal crystal of quartz. No fossils found... 1885

Mostly gray dolomitic limestone, some red sand and some anhydrite. There were also some quartz crystals, and some bluish white chert. The limestone is in some fragments characterized by exceedingly thin and wavy foliations..... 1900

Like the preceding..... 1905

Gray dolomitic limestone, in which are imbedded minute dark crystals of anhydrite. Considerable chert was present..... 1910

Like the preceding..... 1915

Like the preceding..... 1920

Gray dolomitic limestone. Some quartz crystals were noted 1925

Gray dolomitic limestone, with an admixture of red sand 1930

Like the preceding, but with less sand..... 1935

Gray dolomitic limestone with a considerable admixture of red sand. Some chert noted..... 1940

Like the preceding 1955

Like the preceding, but with more sand..... 1985

Like the preceding 1990

Gray dolomitic limestone, with some red sand..... 2000

Yellow limestone, some dark gray limestone, some red shale, and some fragments of anhydrite. The yellow limestone has irregular dirty black blotches and is dolomitic. The dark gray or black limestone is not dolomitic. The anhydrite is granular, white or bluish gray, translucent, in thin fragments. Some anhydrite is bright pink in color. Test for potash negative 2293

Largely quartz sand of fine texture, the grains being moderately rounded and incrusted with oxide of iron. Some fragments consist of sand grains imbedded in anhydrite. Fragments of limestone are also present. There are some clusters of small quartz crystals. Some soluble salts are present and some anhydrite..... 2335

A yellow dolomitic limestone. Some fragments show black streaky specks, and some contain imbedded crystals of anhydrite. Some chert was noted, near. 2400

Fine-grained sand, imbedded in a matrix of anhydrite. The sand grains are moderately rounded. In the depressions on their surface there is usually a coating of bright red hematite..... 2465

Fine red sand fairly well rounded. Some fragments of the rock show the sand imbedded in anhydrite. The material contains clusters of crystals of quartz of minute size. There were also some crystals of anhydrite	2475
Mostly fine red sand, fairly well rounded, like the sand in the preceding sample. There were also fragments of a gray limestone, with streaky specks of black, and clusters of microsocpic crystals of quartz	2485
Like the preceding	2500

Note.

The following is quoted from a letter from Mr. R. S. Jackson, Snyder Development Co., Snyder, Texas, May 24, 1912:

"I am sending you a sample of white rock taken from the well somewhere about 1700 feet. It is part of a piece that came out on the bit. When the drill went through it, the rock was ground up so fine it dissolved in the water and left no sediments. We passed through several strata of this rock. The water at times would be milk white. Another white rock passed through would ball up on the bit into a kind of gum. This latter rock was first found above the oil sand at a depth of 505 feet."

The uppermost 1700 or 1800 feet of this boring is in the Permian redbeds. Below this the formation is believed to be equivalent to the dolomites in the Double Mountain Formation, and to part of the Dolomite Beds in the Spur boring.

The Scoggin Boring.

Scoggin No. 1. Located about 800 yards east from the west boundary of Kent county, on the Yellow House Canyon. This boring was being made by the Yellow House Oil Company, of Dublin, in 1913. Elevation: near 2100 feet above sea-level.

The data on this well are not available from any authoritative source, but the fact seems well established that salt beds were encountered at 880 feet and continued at intervals from this depth down to 961 feet.

The Upland Boring.

Log of a part of a boring made at Upland, Upton county, in 1910. The boring is located in the west part of the town, and the curb has an elevation estimated to be near 3100 feet above sea-level.

	Depth, in feet, Below surface. From	To
Soil	0	2
Limestone	2	90
Red sand	90	135
White sand, with water	135	160
Red clay	160	262
White sand, with water	262	300

Red clay	300	340
White sand, with water	340	356
Streaks of red clay and sand rock	356	405
Water sand	406	415
Sand and clay. The clay is red and light gray, changing every two to three feet	416	510
Water sand	511	530
Sand and clay, changing from red to white and blue	530	700
Water sand	701	715
Sand and clay, red, gray and blue, changing every few feet	715	814
Sand rock	814	835
Limestone	835	860
Red sandy rock, shale or clay	860	1100
Water sand, with bitter and salt water	1100	1120
Red sandy rock, with streaks of clay. In this red clay are lumps of white material, which, when powdered by the drill, floats up on the water	1120	1300

Boring was being made deeper in 1913. Finished depth not known.

Note.

The limestone from 2 to 90 feet is Comanchean, as also the sandstone immediately below this. The presumption is that at least the upper part of the vari-colored clays with water-bearing sand reported from 160 to 835 feet also belong to the Comanchean, but it is quite possible that the lower part of this division may be Triassic. From 860 to 1300 feet is without doubt Permian redbeds. Salt and bitter water is reported from sand between 1100 and 1120 feet below the surface. At the depth of 1300 feet the driller reported that there had been very small returns of cuttings for some time, and it appeared likely that he was then drilling in a salt bed or in a salt-bearing red silt. A small sample was like the returns from such salt-bearing silt seen in other explorations.

The Buena Vista Boring.

Rocks explored in a part of a boring made by the United States & Mexican Trust Co., at Buena Vista, Pecos county, on Survey 23, Block 2, Houston & Texas Central Railway lands. Estimated elevation: 2400 feet above sea-level.

	Depth, in feet, Below surface. From	To
Adobe soil	0	25
Sand and gravel	25	220
Red shale and clay, containing hard black pebbles, all through, and having a thin stratum of sand at 450 feet	220	531
Blue pyritiferous shale	531	555
Red sandstone	555	588
Red clay, containing layers of sandstone and white gypsum	588	620
Not known, except from two samples of cuttings of pure white gypsum, taken at 700 and 900 feet, and from statements by the driller that rock salt occurred at 962 feet and at 975 feet	620	1000

Mainly red silty gypsum-bearing shale or clay, with thinner beds of gray shale. Some cream colored and white limestone at 1377 feet and below. This part of the record is known from 23 samples of cuttings, taken from 4 to 95 feet apart. Some of the red clay had gray blotches. Some minute crystals of quartz were noted. A cream colored limestone was somewhat copious in a sample from 1377 feet, and twenty feet below this a silty clay contained minute spherical yellow calcareous concretions. Most of the samples contained some calcareous material. Pyrite was noted in some of the gray or bluish gray shale.....1000 1414

Note.

The uppermost 220 feet is believed to be Pleistocene, probably a river drift. From 220 to 588 feet is most likely Triassic. From 588 down as far as the record extends, is no doubt Permian redbeds. It is probable that these contain more salt than would appear from the two isolated mentions of rock salt by the drillers, who stated that cuttings from some parts of the boring were difficult to obtain, and seemed to "disappear" before coming to the surface.

Deep Boring Northwest of Toyah.

Driller's Log

Log of Producers' Oil Company well, Huling-Ross No. 1, located in west half of Section 16, Block 59, Reeves county. Drillers: A. Wood, E. W. Dodge, W. A. Nance, J. R. Dodge. Began drilling upper 2350 feet of well on December 5, 1910; finished June 23, 1911; cable rig used. Hole caved badly at 160 feet, water at 735 feet; oil and gas showing at 840 feet, showing very little oil at 1855 feet, very strong gas at 1875 feet, oil showing in 15 feet of hard sand. Stuck bailer and tools in hole at 2205 feet. Well was dry. Began drilling deeper on March 26, 1911; drilled to 4100 feet, with cable rig; well still dry; finished August 7, 1914.

Upper part of well:	Lower part:
284 feet 12½-inch casing.	337 feet 12½-inch casing.
754 feet 10-inch casing.	550 feet 10-inch casing.
878 feet 8-inch casing.	1070 feet 8-inch casing.
1226 feet 6⅝-inch casing.	2105 feet 6⅝-inch casing.

	Depth, in feet, Below surface. From	To
Gypsum	0	10
Gumbo	10	220
Gypsum	220	276
Water sand	276	286
Gypsum	286	340
Hard sand (water)	340	390
Sand and gumbo	390	420
Gumbo	420	490
Soft white gumbo	490	535
Sand, gumbo and rock	535	550
Red clay	550	620

Blue gumbo	620	670
Limestone	670	742
Sand	742	752
Red clay	752	757
Water sand	757	780
Blue gumbo	780	820
Crystallized gypsum	820	840
Water sand	840	860
Gumbo, limestone and gypsum	860	880
Gypsum and shale	880	900
Gypsum and limestone	900	930
Blue gumbo	930	960
Limestone, gumbo and gypsum	960	1030
Red bed (clay?)	1030	1060
Red bed and gypsum	1060	1100
Gypsum	1100	1200
Red bed and gypsum	1200	1260
Red bed, gypsum and shells	1260	1340
Gypsum and sand	1340	1650
Hard gypsum	1650	1680
Hard gypsum (white and black)	1680	1855
Gypsum, limestone and shale	1855	1875
Dark gypsum, shale and little sand	1875	2160
White gypsum	2160	2240
Sand and gypsum	2240	2335
Hard sand	2335	2350
Gypsum	2350	2695
Gypsum and lime mixed	2695	2725
Lime, gray	2725	2815
Gray lime	2815	2875
Gypsum	2875	2900
Lime and gypsum mixed	2900	3000
Dark gray lime	3000	3070
Sand and lime broken	3070	3082
Hard sand	3082	3130
Fine and soft sand	3130	3230
Black lime	3230	3235
Sand and lime mixed	3235	3315
Sand	3315	3445
Sand with trace of shale	3445	3455
Sand	3455	3500
Black lime	3500	3510
Sand	3510	3535
Lime	3535	3545
Lime and sand	3545	3575
Black lime	3575	3580
Sand	3580	3590
Gray lime	3590	3600
Black lime	3600	3615
Sand	3615	3616
Lime	3616	3695
Sand	3695	3700
Sand and lime	3700	3705
Sand and lime shells	3705	3715
Gray sand	3715	3730
Lime	3730	3745
Sand	3745	3760
Lime	3760	3790

Sand	3790	3805
Lime	3805	3830
Sandy lime	3830	3845
Lime	3845	3890
Sand	3890	3895
Sand and lime	3895	3923
Dark gray sand	3923	3970
Black lime	3970	3980
Sand and lime	3980	4000
Lime	4000	4040
Gray sand	4040	4055
Lime and sand	4055	4070
Sand	4070	4085
Lime, gray	4085	4100

Samples.

Description of samples from Huling-Ross No. 1 well:

	Depth, in feet, Below surface. From	To
A piece of impure gray sandstone collected when well was shot at 1800 feet, and judged by a driller to have come from the depth of from 1400 to 1500 feet. This is a gray sandstone consisting of grains mostly from 1-16 to ¼ mm. in diameter	1400	1500
A piece of rock taken when this well was shot and judged by a driller to have come from near 1800 feet, is a very compact dark brownish gray dolomite cut by joints or crevices which are filled with anhydrite. It is indistinctly stratified. In thin section, vertical, it shows indistinct stratification marked by yellowish irregular streaks		1800
Light gray anhydrite containing small streaks and specks of dolomite. In one thin section an area of dolomite is cut by a small vein of anhydrite. The dolomite bodies are not sharply defined in outline		2000
Gray anhydrite containing some dolomite		2050
Gray anhydrite containing dolomite which occurs in yellow layers and irregular tracts in a thin section. On heating in closed tube drops of oil appeared		2100
White granular anhydrite		2150
Thinly laminated gray anhydrite. Many of the cuttings are thin flakes, some parallel and some vertical to the lamination. Laminations are marked by the presence of yellowish dolomite		2200
Gray anhydrite		2250
Gray anhydrite. The larger pieces show lamination with darker and lighter layers. Oil was noted when heated in a closed tube		2300
Gray anhydrite. In thin section the larger pieces show laminations of yellow dolomitic material 4 mm. thick, alternating with transparent layers of anhydrite about 1.2 mm. in thickness. The dolomitic layers merge into the anhydrite on the sides and are crossed by many small veins filled with anhydrite, as if shrunk laterally		2350

Gray granular anhydrite showing laminations of darker and lighter layers, the darker containing more dolomite 2400

Granular anhydrite 2450

A thinly laminated gray rock consisting of granular anhydrite and carbonates, probably a mixture of limestone and dolomite 2500

Granular anhydrite. The larger pieces show lamination with alternate light and dark layers running at oblique angles to the longer diameter of some fragments 2550

Granular anhydrite. The larger pieces show light and dark laminations from 0.2 to 1 mm. in thickness. Bituminous fumes were given off, when heated in a closed tube 2600

Gray dolomite and anhydrite in intimate mixture. Bituminous fumes were given off when heated in a closed tube 2650

Gray, granular, laminated anhydrite containing some dolomite and apparently some shale 2700

Gray, granular anhydrite, containing some dolomitic material. Note on label says "Top of lime" 2715

Mostly soft yellow dolomite, and some anhydrite 2750

Gray, granular anhydrite, containing some calcareous matter. Label is marked "gas" 2785

Gray, granular anhydrite, some gray limestone, and some yellow dolomite showing small, peculiar reliefs on the bedding planes. Considerable pyrite is present, partly incrusting surfaces on some fragments. The gray limestone is foraminiferal, containing Textularia (?) sp., Nodosaria, and many perforated fragments of tests, also thin fragments of Ostracod shells. An almost entire valve of small pelecypod was noted 2800

Gray anhydrite and dolomite 2850

Laminated gray anhydrite and some soft yellow dolomite in large fragments 2900

Laminated gray anhydrite and some soft yellow dolomite in large fragments 2950

Laminated gray anhydrite 3000

Black silt, a thinly laminated limestone with vertical cleavage, and a soft granular sandy gray dolomitic limestone. A vertical section of the laminated limestone shows that the layers are separated by sharply marked stylolitic joints which are filled with a black substance. Heated in a closed tube, the sample yields drops of oil and fumes of ammonia. In thin section the black silt is seen to contain much bituminous material and shows some minute broadly elliptic bodies filled with a transparent material. The silt or sand is mostly from ¼ to 1-16 mm. in diameter 3050

Fine, gray, silty quartz sand containing rare scales of mica 3100

Gray, fine-textured quartz sand, mostly less than one-eighth mm. in diameter 3150

Gray sandy silt and some dolomitic material 3200

Sandy dolomitic silt with some impregnating black bituminous material. Strong fumes of sulphur and bitumen given off, when heated in closed tube. When ignited the black shale sustains a flame....	3250
Gray, fine sand and some dolomitic rock.....	3300
White quartz sand from 1-16 to ¼ mm. in diameter	3400
Dark, almost black, greenish shale containing dolomitic material and sand. Yields fumes of bitumen, sulphur, and ammonia, when heated in closed tube	3450
Fine light gray quartz sand with some dolomitic material	3500
A sandy gray silt, micaceous and containing some dolomitic material.....	3550
Black sandy dolomitic silt, and gray fine sandy rock. Heated in closed tube it gives much oil.....	3600
Sandy dolomitic and silty rock. Some is gray, some black. Scales of mica noted. The black rock distils much oil. The texture of the rock is fine and close	3650
Gray sandstone of fine texture, impregnated with some dolomitic material.....	3700
Shaly, dolomitic, fine gray sandstone, containing some mica scales.....	3720
Sandy and shaly gray dolomite.....	3725
Dolomitic and shaly gray sandstone, slightly bituminous	3730
A black rock consisting of fine sand cemented by bituminous and dolomitic material. Distils very much oil.....	3735
Dolomitic and shaly sandstone, some gray, some black. The black contains much oil, the gray, much dolomite	3740
Gray, fine sand, cemented by dolomitic material....	3745
Gray rock, consisting of fine sand in a cement of dolomite	3750
Sandy material, part of which is in a cement of mainly dolomite, and part in a cement of mainly bitumen. Oil drops were noted when heated in a closed tube.	3755
Dark gray rock consisting of quartz grains in a cement partly composed of dolomite, but mostly of bituminous matter. Oil distilled off in a closed tube	3760
Dark gray rock consisting of quartz grains, some in a cement of dolomite, but mostly in a cement of bitumen. Oil distills off in a closed tube.....	3765
Dark gray rock containing quartz grains, cemented together mostly by bitumen, but also by some dolomitic material. Effervesces briskly. Oil distills off when heated in closed tube.....	3770
Black rock containing quartz grains cemented together with bitumen and some dolomite. Distills off oil in closed tube.....	3780
Dark gray rock containing quartz grains cemented together. Most of the cement is bitumen and forms a black mass, some is dolomite. Oil is distilled off when heated in closed tube.....	3785

Dark gray rock containing quartz grains cemented together with bitumen and dolomitic material. Oil distilled off when heated in a closed tube..... 3790

Gray rock containing quartz grains cemented together by more dolomite than bitumen. Oil distilled off when heated in a closed tube..... 3795

Gray silt cemented together with dolomite and a little bitumen. Bituminous fumes were given off when heated in closed tube..... 3800

Dark gray silt cemented together with dolomite and bitumen. Oil was distilled off when heated in a closed tube..... 3805

Black silt cemented together with bitumen and dolomite. Oil is distilled when heated in a closed tube 3810

Dark gray silt cemented with bitumen and dolomite. Oil was distilled off when heated in a closed tube.. 3815

Black rock containing silt cemented together with bitumen and dolomite. Oil distilled off..... 3820

Dark gray silt cemented with bitumen and dolomite. Oil distilled off when heated in a closed tube. Pyrite and mica noted..... 3825

Fine yellow sand, and black silt cemented together with bitumen. Oil is distilled off when heated in a closed tube..... 3830

Gray and some black silt, cemented together by bitumen and dolomite. Oil is distilled off when heated 3835

Very dark gray silt cemented together with bitumen and dolomite. Oil is distilled off when heated in a closed tube..... 3840

Some dark and some light gray silt cemented together with bitumen and dolomite. Oil was distilled off when heated..... 3845

Yellowish gray sandy silt cemented together with dolomite and a little bitumen..... 3850

Gray silt, cemented together with dolomite and a small amount of bitumen. Bituminous fumes distilled out, when heated in a closed tube..... 3855

Sandstone cemented by dolomite. Bituminous fumes were given off when heated in a closed tube..... 3860

Black rock consisting of sandy silt cemented together with bitumen and a little dolomite. Oil was distilled off 3865

Black rock consisting of silt cemented together with bitumen and dolomite. Yields much oil when heated in a closed tube..... 3870

Almost black rock consisting of quartz grains cemented together with bitumen and some dolomite. Oil was distilled off when heated in a closed tube.. 3875

Very dark gray rock consisting of sand and silt cemented with bitumen and dolomite. Oil was distilled off when heated in a closed tube..... 3880

Black rock consisting of sandy silt grains in a cement of bituminous and dolomitic material. Oil was distilled off in a closed tube..... 3885

Some gray and some black rock, consisting of quartz grains in a cement of bitumen and dolomite. Oil was distilled off when heated in a closed tube.... 3890

Gray sandy silt in a cement of dolomite and some bitumen. Oil was distilled off when heated in a closed tube..... 3895

Light gray rock consisting of silt cemented together with dolomite and some bitumen. Oil was distilled off when heated in a closed tube. Mica noted..... 3900

Gray rock consisting of silt cemented together with dolomite and some bituminous matter. Oil fumes were given off when heated in a closed tube. Mica noted..... 3905

Gray rock consisting of silty sand slightly cemented with dolomite and some bitumen. Yields fumes of oil when heated in a closed tube..... 3910

Bluish gray rock consisting of silt in a scant cement of dolomite. A little mica was noticed. Sulphur and bituminous fumes were given off when heated in a closed tube..... 3915

Gray rock consisting of silt cemented together with a little dolomite. Some mica noted. Yields fumes of oil when heated in a closed tube..... 3920

Gray sandstone of fine silty texture containing a little dolomite and a few scales of mica. Yields oil fumes in a closed tube..... 3925

A gray silty fine sandstone containing a little dolomite. Mica was noted. Yields sulphur and bituminous fumes when heated in a closed tube.... 3935

A gray sandstone of fine texture containing dolomite and some mica. Yields bituminous and sulphur fumes when heated in a closed tube..... 3940

Black rock of fine texture consisting of sandy silt cemented together with bitumen. Some mica was noted. Yields much oil when heated in a closed tube. Rock burned when heated in the flame.... 3950

Black and dark gray rock consisting of sandy silt cemented together with bitumen and a little dolomite. Contains some mica. Yields oil when heated..... 3960

Dark gray rock consisting of silt cemented together with bitumen and some dolomite. Yields oil in a closed tube when heated..... 3965

Quartz sand, some grains of which are cemented tomented together with dolomite and some with bitumen and dolomite. Bituminous fumes were given off when heated..... 3975

Gray silty sandstone containing dolomite and a little mica. Yields bituminous fumes when heated in a closed tube..... 3970

Gray and black rock consisting of sandy silt cemented with bitumen and dolomite. Yields oil in a closed tube when heated..... 3985

Dark gray rock composed of sandy silt cemented with bitumen and dolomite. Yields oil when heated... 3990

Black rock of fine texture consisting of silt cemented with bitumen and dolomite. Yields oil when heated in a closed tube. Mica and pyrite noted. In thin section several imbedded pieces of thin shells, rounded concretionary (?) grains, spines, and a small Trochammina were noted..... 3995

A black rock consisting of calcareous silt impregnated with asphaltic material. Pyrite noted. Yields oil and burns with a flame. Pieces of thin small shells noted, one entire ostracod shell seen, one Endothyra and fragments of spines. In thin section the rock is seen to consist of angular quartz fragments imbedded in a calcareous and asphaltic matrix, in which appear fragments of spines, shells, Trochammina incerta d'Orbigny, and thin valves of ostracods 4005

Dark gray rock consisting of sandy silt in a cement of bitumen and dolomite. Yields oil when heated. 4020

Dark and light gray rock consisting of silt in a cement of dolomite and in bitumen. A few flakes of mica noted. Yields oil in a closed tube when heated 4025

Gray rock consisting of sandy silt in a cement of dolomite and some bitumen. Yields oil in a closed tube 4030

Dark and light gray sandy silt in a cement of dolomite. Bituminous fumes were given off when heated 4035

Gray rock containing sandy silt in a cement of dolomite and bitumen. Bituminous fumes were given off when heated..... 4040

Dark gray and light gray sandstone containing dolomite. Bituminous fumes were given off when heated 4045

Fine grained white sand and dolomitic material. Bituminous fumes were given off when heated..... 4055

Dark gray sandy silt in a cement of bitumen and dolomite. Yields oil when heated..... 4065

Dark gray rock of fine texture composed of silt in a cement of bitumen and dolomite. Yields oil when heated. In thin section, the quartz grains are seen to be angular, cross sections of spines or spicules were noted, and a flat Ammodiscus..... 4115

Note.

Twenty-three samples, representing the rocks penetrated from 2000 to 3000 feet below the surface, consist of anhydrite, in the main, intimately associated with more or less dolomite, and having mostly a thinly laminated structure, such as is seen in parts of the Guadalupian formation. Some fragments showed that this rock has in places been brecciated.

At 2700 there is some nearly pure dolomite. Near 2800 there is a gray limestone containing some foraminifera and fragments of small shells and other fossils. In this part of the section the rock is otherwise uniform in character, being anhydrite and dolomite. Below this depth the samples from 3050 to 4115 feet consist of a rock which may be described as dolomite containing more or less fine sand, silt and clayey material. The range of variation in the composition of this rock is from nearly pure dolomite containing only a small amount of siliceous material to pure sand, as at 3100, 3150, 3400, and 3500 feet below the surface. At various depths, this rock has been impregnated with much bituminous material, so as to be black. This condition was noted at 3050, 3250, 3450, 3600, 3735, 3755-3785, 3805-3820, 3840, 3860-3885,

3950, 3990-4000, 4065, and 4115 feet, making a thickness of nearly 100 feet of black asphaltic rock. Much of the other sandy dolomite is to a less degree impregnated with hydrocarbons, so that nearly all the samples from this part of the well will yield bituminous fumes and even drops of oil when heated in a closed tube.

A mixed sample of this black rock taken from five different depths has been distilled to determine the hydrocarbon content. It was found to contain 14.2 per cent. of volatile combustible hydrocarbons. This includes an amount of oil equivalent to 2.4 gallons per ton of the rock.

The uppermost several hundred feet of this boring, possibly a thousand feet, are believed to be the Comanchean. The strata from 1030 to 1315 feet below the surface is probably to be referred to the Permian redbeds. The 2785 feet of strata below this are all believed to be in the Delaware formation, and are probably to be correlated with the Dolomite beds in the Spur well, Dickens county.

DISCUSSION OF THE DATA.

Indications of Desiccation.

The existence of extensive salt beds is conclusive proof of general desiccation in the redbed sea. For the precipitation of potash salts in any natural water, extreme desiccation is required. The geographical conditions necessary for such concentration of sea water is the separation of smaller basins from the main body of the sea. It is not at all likely that the concentration in the open sea has ever in the past approached a condition near the limit of saturation for potash salts. In the finding of natural potash salts, there is, therefore, a presumption that their location is in an ancient isolated basin.

Indications of An Isolated Basin.

There are several other circumstances which suggest that the Staked Plains are located in a place where an isolated basin existed when the salt beds were formed. Several circumstances indicate, at any rate, that the west half of the Panhandle is near the central belt of a geosyncline whose axis runs nearly north and south.

A mild suggestion of the existence of such a geosyncline (a belt where the earth's exterior has been relatively settling more, or elevated less, than in the surrounding country, and where possibly this condition of secular relative movement has long existed and is still to some extent maintained) is to be found in the great topographic feature known as the Llano

Estacado. This is a level plain, from 100 to 150 miles wide, into which the drainage lines on all sides have made slow progress as compared with other regions farther north, similarly situated with regard to the larger features of our continent. Erosion on the Llano Estacado has, during a part of the Pleistocene and perhaps also Tertiary time, been at a standstill. This condition has permitted the accumulation of a considerable thickness of Pleistocene, and possibly some Tertiary, material, while the surrounding land has been eroded. The suggestion is that a contributive cause to this condition may have been that the Llano Estacado has not been lately elevated as rapidly as the surrounding parts of the Great Plains. The suggestion is given for what it may be worth. Much importance can not be assigned to it, owing to our lack of knowledge of the relative value of other factors, which must also be taken into consideration in the interpretation of the physiographic features of the plains.

Conclusive evidence of the existence of a geosyncline in this belt is, however, not wanting. All geologists who have studied the region on either side of the Llano Estacado, east or west, have found the general dip in the adjoining country to be in toward the Plains. East of the Staked Plains, the dip is to the west; and on the west side, the dip is to the east. The west dip on the east side is extensive, and quite high for its extent. Along some lines, in places, it amounts to at least thirty feet per mile, and it continues for nearly two hundred miles. Lower and lower strata come up to the surface in this direction. On the west side of the Staked Plains, the dip is known to be to the east, away from the mountains in New Mexico. Cummins noted that the dip decreases as the plains are approached from this direction, and he was probably the first to note that "the Staked Plains may be said to be in a Permian basin."

In the well data already presented, the only clear evidence of the existence of this geosyncline at the south is found in the fact that in the Huling-Ross well, the redbeds, if present, do not extend deeper down than to 1615 feet above sea-level; while in the Buena Vista well, they certainly continue down to 985 feet above the sea-level.

In the northern wells, the basin structure is less conspicuous. Correlations of the well sections are somewhat uncertain, owing to the variability of the redbed deposits. For the major divisions of the well sections, the Pleistocene, and possibly Tertiary, the Triassic, the Permian redbeds, and the Permian dolomites, some correlations are given in each case in the notes on these borings. It does not seem possible to more than surmise what any of the equivalencies are between different members within the redbeds. There seem, however, to be two zones of salt beds. In the Childress boring, only one of these zones is represented; no doubt the lower. This begins at a depth of 800 feet and may be said to extend down to the bottom of the more shallow boring, No. 3 of the boring at Childress. In the McLean boring, salt was noted at 625, 845, and at 1250 feet. Another salt was passed through at 1650 feet. In the Miller well there were some salt beds at from 940 to 1170 feet and another series of heavy salt beds from 1390 to 2480 feet. In the Boden boring the salt beds seem to merge into one continuous series of close-lying salt beds, extending from 640 to 1460 feet, and beginning again at 1690 feet. In the Snyder boring, several salt beds occurred between 655 and 1020 feet. These probably correspond to the lower salt beds farther north. A still lower group of smaller salt beds was recorded at depths from 1570 to 1940 feet. In the Post boring, the curb of which is about 600 feet above that of the Scoggin boring, the salt reported between 1300 and 1440 feet apparently represents the upper group in the Snyder boring. The salt in the Scoggin and Justiceburg borings is to be referred to the upper of these groups. In the Spur boring there was only one group of well developed salt beds, from 570 to 1174 feet.

Small reliance can, however, be placed on a correlation of these groups between the different explorations, except for borings located near together. It appears that in the Adrian boring, salt deposition suffered but little interruption throughout the making of 1700 feet of sediments. It is to be observed, also, that the upper group of salt beds seems best developed in the Boden boring, and the lower group is better developed in the Miller boring. As already stated, the two groups seem to coalesce, or run together in the Boden boring, and this may

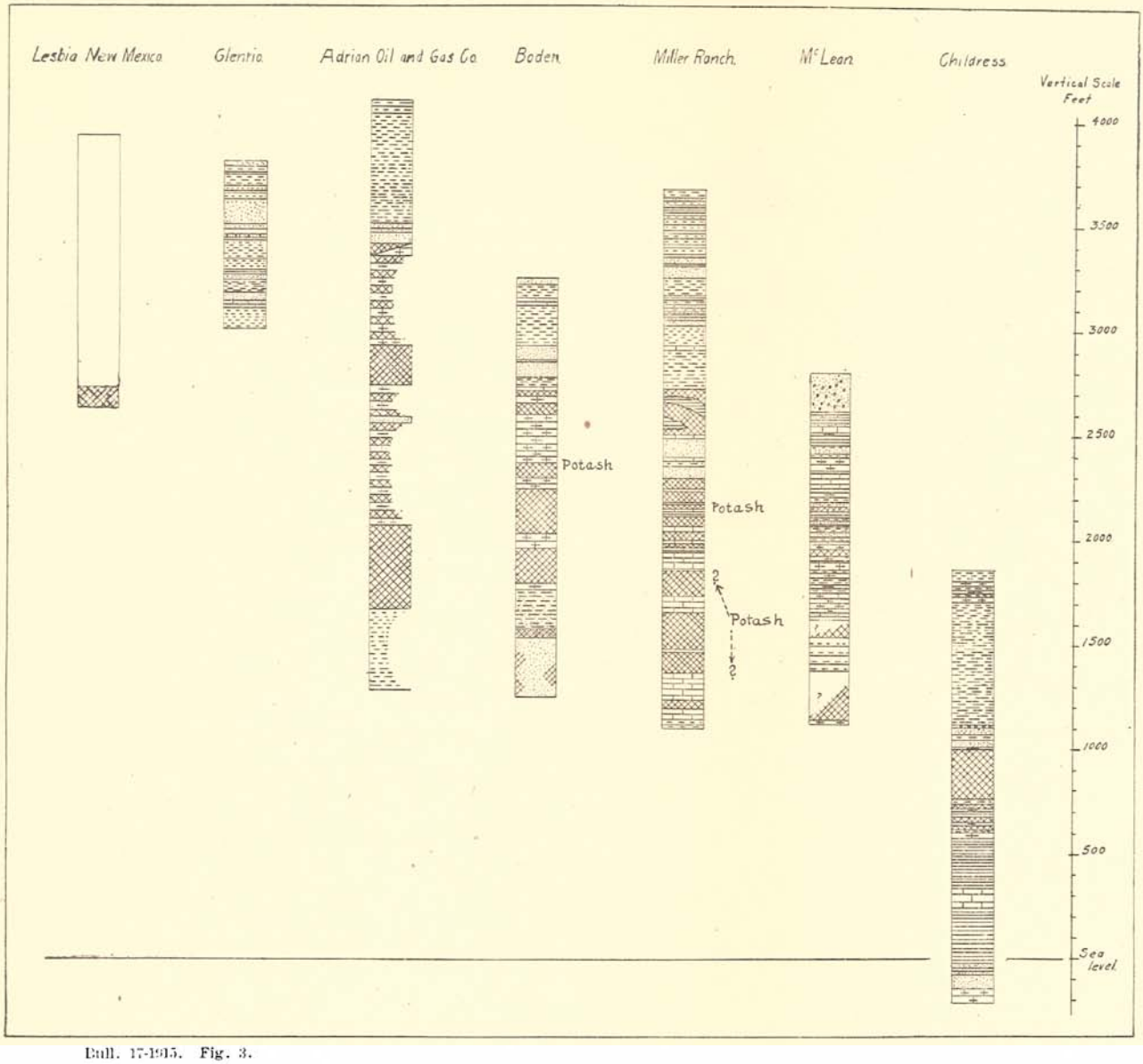
be said also to a lesser extent to be the case in the Miller boring. Such a condition would be most likely to result near the center of a basin undergoing gradual desiccation. It is possible that the uppermost salt beds in the Boden and Miller borings are not represented in the borings farther south. But with the few records in hand, a correlation of the salt bed groups in the northern explorations with those in the region farther south, is hardly warranted.

Tilting of the Basin.

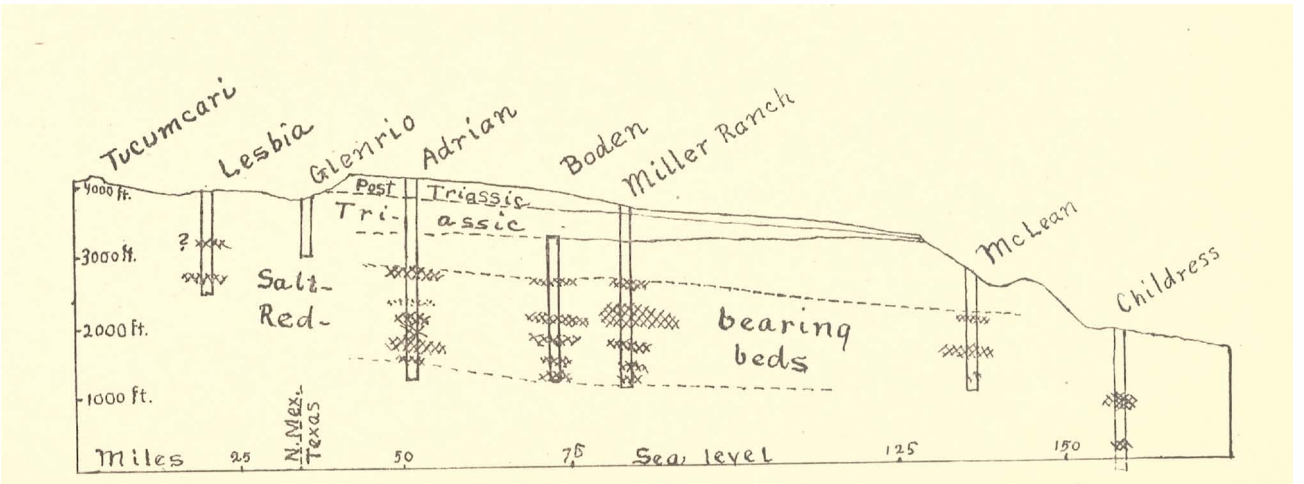
Another circumstance that obscures the view of the basin structure in the well sections in the north, is the fact that the geosyncline in this region is itself tilted to the east. As we proceed westward from Childress, we go up a high gradient; from 1877 feet above sea-level at this place, to 4100 feet at Adrian. The dip between these two points appears to be easterly, everywhere. But east of Amarillo, this dip is probably smaller than to the west of Glenrio. Referred to the present land surface, the Triassic, at any rate, plainly descends as we go west from Childress until we come to Amarillo. Westward from the west boundary of the State, this formation is believed to run more nearly parallel with the general slope of the surface of the land. The geosynclinal structure is manifest mainly in a difference in the rate of the east dip of this formation. The north to south axis of the basin is, then, located where the change in this rate is greatest. This change is evidently quite gradual. With the data from borings now at hand, it appears that the Adrian, the Boden, and the Miller borings are nearer the center of this basin than any of the other explorations reported.

It is evident, as already stated, that the Permian basin itself has been tilted to the east. This feature of the structure is further elucidated in Figures 3 and 4.

The present writer does not know if Cummins held the view that the Permian basin was a basin in the Permian age, or if he had in mind a solely structural basin, due to a synclinal flexure formed at some later time than the Permian. There is some evidence in the drill records that the Staked Plains region was a basin in the Permian sea, and that this geosyncline



Bull. 17-1915. Fig. 3.



Bull. 17-1915. Fig. 4.

is like many others, in that it is situated in a place where the earth's exterior has suffered, on the whole, a slight downward flexing for a long period; dating, in this case, perhaps, as far back as before the Permian age itself. This evidence is in the data we possess on the relative size of the salt beds at different points. It may be taken for granted that the salt beds are thickest where the sea in which they formed was deepest. It may also be assumed that the several salt beds represent the total salt deposits in one major basin. The latter assumption may or may not be entirely true. Another assumption whose validity is not quite certain, we may also make: that the wells reaching 1800 feet, or a little more, have penetrated the greater part of the salt beds. If we then sum up the total thickness of the salt beds in the explorations which are on the east of the axis of the basin, we find that salt deposition has been notably greater near the supposed center of the basin than farther east. This is suggested by the following table:

Table showing the estimated combined thickness, in feet, of salt beds penetrated by some borings in the Panhandle.

Names of Borings:	Adrian.	Boden.	Miller.	O'Dell.	Childress.
Explored thickness of salt beds	900*	579**	897	400***	315

*Partly estimated.
**Fifty feet in this amount is estimated to have been penetrated in the lowermost 200 feet, which the log describes as being "red sandy clay with occasionally thin strata of salt."
***Estimated.

This westward thickening of the salt beds is so far evident only in that part of the Staked Plains which is in the Panhandle. For the south extension of the Plains, no records of any borings near the central axis of the basin have yet been obtained. The Buena Vista and the Upland borings both went below the depth of the records secured, and from conversations the writer had with the drillers, his impression was that at both places more salt had been penetrated than the records indicate. The drillers at each of these places stated that from much of the holes in the red clays and sands, there had been very little silt or sand in the water carrying the returns. The returns had seemed to disappear.

The form, extent and direction of the Permian basin of the Plains can be conjectured mainly only from what is known

of the physiography and the general geological structure in the surrounding country and in the Plains country itself. The longer axis of the basin evidently extends in a general direction from north and south. It probably lies in a belt reaching from near the southwest quarter of the Panhandle at the north, to near Andrews county at the south. The axis of the Marathon anticline, already rising in Permian times, intersects the axis of the Plains basin not far to the south of the Pecos river. The old basin certainly did not extend south of this axis. Its north limit is less evident. From the southwest part of the Panhandle it may have extended northeast, north, or northwest; or perhaps the barrier separating this basin from the northern waters in the redbed sea lay near this region. At any rate, it is recognized that this part of our present continent was near the southwest limits of the Permian sea, which here made a wide detour to the south.* It is in just such an angle of the sea that the geographical conditions would exist, which might result in the isolation of a minor basin where desiccation might be complete, or might reach saturation for potash salts.

The Finding of Potash-bearing Salt.

In some of the cuttings coming from the Boden boring, I found small fragments of salt having a salmon red color. These were submitted for analysis to Dr. Phillips, the Director of the Bureau. The quantity was small, so that the result is to be considered approximate only. The analysis is, however, no doubt substantially correct. This "red salt" contained 9.23 per cent. potash (K_2O) of the soluble portion. It contained very little insoluble material. The rock salt from which these red fragments were picked, gave only 0.99 per cent. of potash (K_2O). After these analyses had been made I looked for like red salt in the rock salt obtained from the Miller boring at from 1500 to 1700 feet below the surface. A small quantity was found also here, and this material showed 6.14 per cent. of potash (K_2O) in the soluble portion. The quantity used in this analysis was likewise very small, and was obtained from cuttings which contained much insoluble material, mostly

*Compare Paleogeography of North America, Charles Schuchert, Bull. Geol. Soc. Am., Vol. 20, Plate 85.

anhydrite. Two additional small lots of red salt were later picked from the cuttings marked as from 1500 to 1700 feet below the surface from the Miller well. These gave, respectively, 1.72 and 2.79 per cent. of potash (K_2O) of the soluble portion. The red fragments in these last lots were not red all through, but consisted in part of colorless salt.

In order to obtain more material, a visit was afterward made to the parties from whom these samples had been obtained. Seven samples from known depths in the Miller boring were secured. Some of these were duplicates of the samples already examined. In addition to these samples, ten lots of rock salt mixed with other cuttings were collected from the dump at the Boden boring and nine similar samples from the dump at the Miller boring. At the latter place, the dump had been exposed to rains for a year, and to overflows. At Boden, the dump had been exposed to the weather for less than a year, and there had been no overflow, as the boring is on ground lying above high water.

One sample of rock salt coming from between 875 and 925 feet below the surface in the Boden boring gave 1.16 per cent. of potash (K_2O) in the solubles. Other parts of this salt gave 0.99, 0.45, 0.94 and 0.98 per cent, respectively. In at least one of these lots, minute fragments of red salt were noted. The salt giving 0.45 per cent. was imbedded in anhydrite rock. Salt from between 1240 and 1290 feet below the surface gave 0.43 per cent. Some salt from 1290 to 1460 feet gave 0.70 per cent. Only one small lot of grains of red salt was secured from the new samples obtained from known depths in this boring, and most of the fragments making this picked lot contained mixtures of red and colorless salt. On analysis this picked lot showed 2.07 per cent. of potash (K_2O) of the soluble portion.

Two analyses of some salt taken from below 1300 feet in the Miller boring contained, respectively, 0.62 and 0.91 per cent. of potash (K_2O). A sample of the salt imbedded in anhydrite from below 1700 feet was found to contain 10.50 per cent. of potash (K_2O). This salt had no unusual color.

Some salt samples were taken from the dump of these borings. A large part of the dump at each place consists of fairly clean cuttings of salt. The material which lies uppermost was

separately sampled in a place where it was known to have come from the deeper part of the boring at the Miller Ranch. At Boden different parts of the dump were identified, by a gentleman who had closely watched the progress of the drilling, as representing the lower, the middle and the upper part of the boring.

Undoubted red salt was not found in any of the samples from the dump at the Miller boring. Some fragments showed a rusty red color, probably due to the presence of some very fine red silt or to rust derived from fragments of the steel of the bit. The percentages of potash (K_2O) in nine samples of salt from the dump of this boring vary from 0.31 to 0.64 and average 0.45. In the dump from the Boden boring a small lot of fragments containing undoubted red salt were found. These gave 1.74 per cent. of potash (K_2O). Some salt containing doubtful red material gave 0.71 per cent. Eight other samples contained from 0.25 to 0.68 per cent., averaging 0.44 per cent., practically the same amount as in the salt from the dump at the Miller boring. It is believed that this figure (0.44%) approximates the average potash contents of the main salt beds in the region.

A visit was also made to Adrian, where a deep hole was bored several years ago. When this boring was made, a number of samples of cuttings were taken and preserved in bottles. One of these bottles was found. It had been preserved by Mr. O. Olson, a farmer living in the vicinity. This bottle contained nine layers of different cuttings, representing, no doubt, separate strata of rock salt, anhydrite, and some shale, each about a half-inch thick in the bottle. The depth where this lot was taken was not known. Evidently it represented some salt beds, no doubt below the depth of 700 feet. An analysis of a mixed sample for the lot gave 0.31 per cent. of potash (K_2O). By diligent search a single fragment of red salt was found in this salt, less than a millimeter in diameter, and too small for analysis. All analyses made for this report are presented, for more ready reference, in the following tables:

Table I.

Contents of potash (K_2O) in percentages of soluble portion of rock salt from the Boden boring, Potter County.

Number of Analysis.	Nature and condition of sample.	Depth in feet below surface, or inferred part of the boring.	K_2O in percentage of soluble portion.
2193	Rock salt	875-925	0.99
2257	Rock salt	875-925	1.16
2258	Crystals of rock salt in anhydrite	875-925	0.45
2280	Rock salt containing some red fragments	875-925	0.94
2271	Rock salt	875-925	0.98
2282	Rock salt	1290-1460	0.70
2283	Rock salt	1290-1460	0.43
2235	Rock salt, in part red, from dump	Upper part	0.71
2273	Rock salt, from dump	Upper part	0.31
2251	Rock salt, from dump	Upper part	0.68
2275	Rock salt, from dump	Upper part	0.25
2276	Rock salt, from dump	Middle part?	0.43
2284	Rock salt, from dump	Lower part	0.26
2278	Rock salt, from dump	Lower part	0.49
2285	Rock salt, from dump	Lower part	0.68
2279	Rock salt, in a matrix of anhydrite	Not known	0.43

Table II.

Contents of potash (K_2O) in percentages of soluble portion of small fragments of red or pink salt (carnallite?) picked from samples of rock salt from the Boden boring, Potter County.

Number of Analysis.	Nature and condition of sample.	Depth in feet, below surface, or inferred part of the boring.	K_2O in percentage of soluble portion.
2281	Some colorless salt present	870-930	2.07
2193	All red salt	875-925	9.23
2236	Taken from dump, some colorless salt present	Middle	1.71

Table III.

Contents of potash (K_2O) in percentages of the soluble portion of rock salt from the Miller boring, Randall County.

Number of Analysis.	Nature and condition of sample.	Depth in feet below surface, or inferred part of the boring.	K_2O in percentage of soluble portion.
2293	Cuttings of rock salt, no color	1300+	0.62
2295	Cuttings of rock salt, some yellowish	1300+	0.91
2296	Cuttings taken on dump	Middle?	0.37
2297	Cuttings taken on dump, some reddish fragments	Middle?	0.37
2294	Cuttings taken on dump, some reddish fragments present.	Lower	0.33
2287	Cuttings taken on dump	Lower	0.31
2292	Cuttings taken on dump	Lower	0.64
2289	Effloresent salt on surface of dump	Unknown	0.49
2298	Cuttings taken on dump	Unknown	0.47
2291	Cuttings taken on dump, much shale present	Unknown	0.49
2288	Cuttings from dump, (some red salt present?)	Unknown	0.55

Table IV.

Contents of potash (K_2O) in percentages of soluble portion of small fragments of red or pink salt (carnallite) picked from samples of rock salt, and of one sample of colorless salt contained in anhydrite from the Miller boring, Randall County.

Number of Analysis.	Nature and condition of sample.	Depth in feet below surface, or inferred part of the boring.	K_2O in percentage of soluble portion.
2215	Picked red salt fragments	1500-1700	6.14
2220	Picked fragments containing some red salt	1700-2100	1.72
2216	Picked fragments containing some red salt	1700-2100	2.79
2290	Colorless rock salt in anhydrite	1700+	10.50

Significance of the Find.

It is to be noted that all samples of salt from known depths in the Boden boring containing more than 0.70 per cent. of potash (K_2O) are from somewhere between 870 and 930 feet below the surface. The red salt from the dump representing the middle part of the well may have come from this depth also. The percentages of potash noted in salt from this depth are as follows: 0.94, 0.98, 0.99, 1.74, 2.07, 9.23.

It will also be noted that the red salt containing the greatest percentage of potash in the Miller boring comes from between 1500 and 1700 feet below the surface. The significance of these two occurrences becomes apparent when we find that the formations lie about 500 feet deeper under the surface at the Miller ranch than at Boden. Before entering the formation lying at the surface at Boden, some 500 feet of overlying material had to be penetrated at the Miller ranch. It is evident that red salt occurs at the same formational horizon in the two explorations. It all comes from the upper part of the second salt beds. The red salt found in the salt from 1700 to 2100 feet in the Miller boring may, to be sure, belong higher up, but this is unlikely. There may or may not be a corresponding lower potash bearing salt in the Boden boring. Observations on this point are wanting.

In the Miller boring a colorless salt containing 10.50 per cent. of potash (K_2O) is found in an anhydrite rock below the depth of 1700 feet, its exact position being unknown. The association of the two precipitation products of salt and anhy-

drite suggests that the potash may have come from the upper part of a salt bed, close to an overlying bed of anhydrite.

One very significant feature of the occurrence of the red potash-bearing salt is that it is found near or in the upper part of the principal salt beds explored. Six hundred feet of salt underlies the red potash-bearing salt in the Miller boring and five hundred feet underlies the same material in the Boden boring. This circumstance suggests that the deposition of potash was preceded by a long period of progressive concentration of the sea water, at the end of which the point of saturation for potash salts was reached, and these salts, also, began to separate out from the brine in the sea. It seems very unlikely that this condition should have been reached at the same time in two places thirty miles apart—this being the distance between the Boden and the Miller borings—without resulting in the deposition somewhere of considerable quantities of potash salts. With evidence that saturation for potash salts was attained in two places, and perhaps in three (Adrian), so far apart, this condition may be presumed to have been quite general.

Mineral Nature of the "Red Salt."

It is to be regretted that enough of the "red salt" was not secured for determining its mineral nature. The fact that it contained, in one case, as much as 9.23 per cent. of K_2O, and that it differs in color from the other salt with which it is mingled, suggests that it is a real mineral such as carnallite, or polyhalite. In the case of all the analyses containing a percentage of potash notably higher than most of the rock salt, this percentage evidently increases with the quantity of the "red salt" present, excepting the case of the colorless salt found in anhydrite below 1700 feet in the Miller boring. A mineralogical determination of this colorless salt as well as of the "red salt" must await the procuring of more material. In the meantime, the present writer is inclined to the belief that we have in this instance a natural mineral containing potash. So far as the present writer is aware, the occurrence of natural potash salts in association with rock salt in the Permian red-beds has not before been observed, although the salt beds in

this formation have been quite extensively explored all the way from Kansas and across Oklahoma to southwest Texas.

Prospecting for Potash.

The finding of potash-bearing salt in the Boden, the Miller, and also, as believed, in the Adrian boring, was a fortuitous incident attendant on the making of some tests for oil or potable waters. Had potash been looked for at the time these explorations were made, we would no doubt now have much more definite information on the quantity of potash in the salt beds of the Plains. We are now limited to qualitative knowledge only. From the few samples taken—four from a 2600-foot hole, a half-hundred mostly from the barren beds in a 2000-foot hole, and nine samples from a 2825-foot hole—no estimate on the quantity of existing potash deposits can at all be made. One of the samples containing the potash is labelled as representing fifty feet of salt. It no doubt was collected from a single bucket and represents, at most, some five feet of the bed. What there was in the other forty-five feet, we do not know. Do the fragments of "red salt" in the samples from 825 to 925 feet in the Boden boring represent small segregations in the five feet of salt from which they probably come, or do they represent a larger deposit of such material passed through somewhere in the other forty-five feet of this salt bed? The tendency of potash is to diffuse. The latter supposition seems therefor the more plausible. But we do not know which may be the case.

Everything considered, the present writer believes that the problematic existence of utilizable potash in association with the Permian salt beds in the southwest is, by these finds, rendered sufficiently probable to warrant the beginning of explorations to settle the question of its presence or absence. From the evidence now in hand it would appear most profitable, perhaps, to make the first test in the vicinity of the localities where potash salts have already been discovered. The data presented show that extensive salt beds underlie not only the greater part of the Panhandle, but that they extend south to Upton county and west into New Mexico. Where in this extensive territory the Permian waters were most effectively

isolated from the main body of the ancient sea and most nearly or wholly desiccated, can not well be made out by any examination of the superficial features of the region, except so far as it may be possible to make conjectures on the basis of the general structure as already indicated and on the basis of the nature of the sediments themselves as revealed by the drill. Such conjectures as it may be possible to make will lack the definiteness regarding localities that actual drilling tests will give. Leaving the region of the three wells already known to contain some potash salts, the territory which appears from our present knowledge to give most promise is along the supposed axis of the basin, southward and a little westward from Boden, the Miller Ranch, and Adrian.

From the explorations already made, it is evident that tests should extend to the greatest depth at which it may be considered profitable to work, say 2000 feet. The "red salt" horizon in the Miller and the Boden borings will lie, it is believed, over most of the territory indicated, between 2000 and 2400 feet above sea-level, or from 800 to 1700 feet below the surface.

Successful prospecting will necessitate the employment of drillers experienced in the coring of salt, and of the services of competent technical help to watch and determine the results as they appear.