University of Texas Bulletin
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THE SAN ANGELO FORMATION
THE GEOLOGY OF FOARD COUNTY

J. W. BEEDE AND D. D. CHRISTNER

BUREAU OF ECONOMIC GEOLOGY

J. A. Udden, Director **E. H. Sellards, Associate Director**

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

Sam Houston

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

Mirabeau B. Lamar

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THE SAN ANGELO FORMATION*

BY

J. W. BEEDE AND D. D. CHRISTNER

INTRODUCTION

The San Angelo formation is a mappable unit in the Permian system and has been traced from San Angelo in Tom Green County north to its crossing on Red River in Wilbarger County, and thence to Duncan, Oklahoma, where it is found to be continuous with the Duncan sandstone of that state. In its southernmost exposures in Tom Green and Coke counties this formation is composed of coarse, siliceous conglomerates of clay and sandstone. Westward and northward in Coke and Tom Green counties, the formation grades into sandstones and shales. Delta conditions, however, continue for some distance north of the Coke County line. The San Angelo formation rests disconformably upon the Clear Fork and is overlain by the great clay and gypsum series of West Texas. By reason of its distinctive characteristics it forms a very important stratigraphic unit upon which to base broad correlations. For this reason it is believed that the accompanying map indicating the outcropping belt of this formation in Texas will be of service in connection with further studies of the Permian formations.

HISTORICAL SKETCH

The importance of this formation as a horizon marker was first recognized by Cummins who considered it the base of the Double Mountain formation.[1] In his references he mentions the Clear Fork beds as being characterized by red clays while the base of the overlying Double Mountain beds is "composed of sandstones, limestones, sandy shales, red

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[1]Cummins, W. F., Geol. Surv. Texas, First Annual Report, pp. 188-189, 1890. Second Annual Report, p. 402, 1901.

*Manuscript submitted 1925. Publication issued June, 1926.

and bluish shales and thick beds of gypsum." The fact that he always mentioned sandstones first in these definitions is of importance since the beds immediately above the Clear Fork are sandstones, and these sandstones are the San Angelo sandstones. In the map (Plate XVIII) in the Second Annual Report of the Texas Geological Survey, he draws a short straight line across his route along Brazos River in the northeast corner of Stonewall County, demarking the base of the Double Mountain beds. This line coincides with the position of the San Angelo sandstone in that locality, and serves to make the present correlation certain.

Aside from being the first to define and locate the boundary between the Clear Fork and Double Mountain beds, Cummins, together with Dr. Lerch of San Angelo, was the first to define the San Angelo formation.[2] In the following year Lerch traced it farther north and studied its relationships more fully. But in his second paper Lerch tentatively referred the beds to the Triassic, since the conglomerates of the San Angelo formation and the Triassic were so similar.

Nothing further was mentioned regarding the formation until 1917 when Wrather described the northern extension of these beds as the Blowout Mountain sandstone from its occurrence in Blowout Hill in Taylor County.[3] At this time the San Angelo beds had not been recognized north of Colorado River. Wrather virtually placed them at the base of the Double Mountain beds but included with them a few feet of the Clear Fork beds which lie above the Merkel dolomite. Later the formation was mapped in Coke County by Beede and Bentley.[4]

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[2]Cummins, W. F. and Lerch, O., Amer. Geol., Vol. V, pp. 321-325, 1890. Map.

Lerch, O., Amer. Geol., Vol. VII, pp. 74, 77, 1891.

[3]Wrather, W. E., Notes on the Texas Permian. Bull. S. W. Ass'n. Petr. Geol. I, p. 87, 1917.

[4]Univ. of Texas Bull., 1850, p. 19, 1919.

NATURE OF THE NORTHERN EXTENSION OF THE FORMATION

During the season of 1922 the San Angelo formation was traced by the writers northward from Coke County to Red River in Wilbarger County, Texas, and since then the senior author has followed it some distance into Oklahoma where it has been possible to determine its position beneath the Blaine formation of that state, and to correlate it with the Duncan formation. As has been pointed out in the bulletin on Coke County, Texas, the southern part of the San Angelo formation exposed in Central Texas constituted a part of a large delta, probably with its central part, or debouchure of the stream, near Tennyson. As one goes up the Colorado River from the vicinity of Bronte, this formation gradually disappears below water level, but the sediments become less and less conglomeratic until at Robert Lee only a few thin sheets of rather small quartz pebbles are found at the surface. This change in the amount of pebbles is illustrated by two sections taken in order from the two localities about seventeen miles apart, given below.

Section on Mt. Margaret, at Tennyson, Texas

		Thickness Feet
10.	Sandstone, rather coarse, twenty feet thick at the place measured. Upper part very ferruginous, many small iron concretions, some large ones, conglomeratic in spots	25
9.	Conglomerate, contains some sandstone and shale lenses, coarsest about twenty-five feet above the base	65
8.	Sandstone, top conglomeratic	5
7.	Conglomerate, six inches to	4
6.	Sandstone, buff, locally a conglomerate with pebbles two inches long, some concretions	4
5.	Concealed	8
4.	Sandstone, white laminated	1+
3.	Shale, green, somewhat sandy, iron concretions, weathers buff in places	12
2.	Clay shales, red	3
1.	Sandstone, three layers with three beds of sandy maroon shale	7

Numbers 6, 7 and 8 of this section are all locally represented by conglomerate. It is impossible to state just what thickness of sandstone and shale lies immediately below this section. It is quite variable locally. Number 10 is the top of the conglomerate beds which constitute the top of the San Angelo formation.

A Section East of Robert Lee

At the Hester place north of Colorado River and east of Robert Lee the following sections occur:

		Thickness Feet
13.	Limestone, sandy, crystalline, with sandstone and shale, sandstone pinching out locally	5
12.	Shale, red, two feet to	5
11.	Shale, red, five feet to	15
10.	Sandstone, gray, five feet to	7
9.	Shale, blocky, sandy, red, two feet to	1–4
8.	Dolomite sandy, pink, two thin layers separated by a thin sheet of shale	1–5
7.	Shale, red blocky	6
6.	Sandstone, red conglomerate with whitish pebbles	0–6
5.	Shale, red	1
4.	Sandstone, gray, six inches to	1
3.	Shale, red	4
2.	Sandstone, fine-grained, six inches to two feet	1–3
1.	Shale blocky, red, sandy, about	3

The following section gives an idea of the formation as seen at Kickapoo Mountain:

Section at Kickapoo Mountain

10.	Shale, red	15
9.	Sandstone, brownish, very even bedded, eighteen inches to	2
8.	Shales, red and concealed beds	30
7.	Sandstone, buff-gray	2–3"
6.	Concealed	2–6"
5.	Sandstone, buff-gray, three feet to	4
4.	Shale, sandy, green and red, eight feet to	10
3.	Conglomerate, sixteen feet of conglomerate at base, larger pebbles inch or two in diameter, white and red quartz and black chert, and some yellow stained quartz pebbles. Matrix, buffish sandy material. This conglomerate grades down to chicken gravel at the top of the bed. The upper part contains iron streaks and sandstone weathering gray-brown	26

2.	Sandstone, eight feet thick locally, yellowish or brownish-buff, locally conglomeratic. Shales and talus below	26
1.	Shales, blue, green and brown with some sandstone bands	26

There is considerable material below the base of the section which belongs to this formation. Farther north and a half mile east, the thickness between the top and the base of the conglomerate is 277 feet. It appears that some allowance must be made for an east dip, which would leave from 200 to 250 feet for the thickness of the San Angelo formation at this place.

A similar transition is seen on tracing the formation northward. Near the big bend of Brazos River in the southeastern corner of Stonewall County the last of the fine quartz pebbles were seen, except for some rather large quartz sand grains on the north side of Salt Fork of Brazos River a mile or two above its mouth. The conditions that are found here are as follows:

Brazos River Section of the Lower San Angelo Formation, and Top of Clear Fork Beds Junction of Salt Fork With Double Mountain Fork of Brazos River

		Thickness Feet
11.	Shale and coarse pebbles of conglomerate four inches in diameter. No quartz except sand grains. Section continues higher	10
10.	Coarse conglomerate, pebbles of clay and dolomite three inches in diameter	5
9.	Red and green shales	10
8.	Sandstone, pink to greenish-gray	2–6
7.	Shales, reddish	6
6.	Sands and clays, less coherent than Number 5	4
5.	Sandstone, laminated, cross-bedded, some pebbles of clay or dolomite	7
4.	Sandstone, dolomitic, cross-bedded, greenish-gray containing small pebbles of dolomite or clay. This bed apparently represents the Merkel dolomite, two feet	5
3.	Light colored green dolomitic shale and light sandy dolomite, nodular appearance, 5 feet to	3
1.	Shale red and green, streaks of gypsum, green and light colored satin spar and nodular gypsum	35

The basal seventy-three feet of this section belong to the Clear Fork formation, and are composed of nodular gypsum and green and red shales, clays and sandy dolomite sheets. The remainder of the section belongs to the San Angelo formation.

Somewhat farther north the San Angelo beds are found between Brazos River and Kiowa Peak. The following section taken at this place shows the stratigraphic succession of the San Angelo formation and also the overlying Blaine formation.

Section of Kiowa Peak, Stonewall County

		Thickness Feet
28.	Dirt at top of peak	4
27.	Caprock of gypsum	40
26.	Shale red, some gypsum	20
25.	Shale, vari-colored gypsum	8
24.	Gypsum, some shale	15
23.	Shale, red and gypsum	15
22.	Gypsum	2
21.	Shale, greenish	5
20.	Shale and gypsum to top of first terrace of mountain	30
19.	Gypsum and thin fossiliferous dolomite	8
18.	Gypsum and shale, thin dolomite on top near horizon of fossils collected in 1909	25
17.	Gypsum	10±
16.	Concealed	45
15.	Dolomite, thin	1±
14.	Shale and gypsum	6
13.	Dolomite, occasional fossils	2
12.	Gypsum, shale and a dolomite bed	10
11.	Shale, red and green, dolomite, some gypsum streaks	15
10.	Gypsum, five feet to	10
9.	Shale, red	5
8.	Gypsum beds, three or four thin beds, separated by red shale, top bed thickens to three or four feet further on	10
7.	Shale, red, two feet followed by two or three-foot gypsum bed	5±
6.	Sandy layer, greenish, one foot to	3
5.	Shale, reddish with light colored streaks, five feet to	10
4.	Sandstone, greenish-white	17
3.	Sandstone white at base, followed by red shale	13

2.	Shale, red, cross-bedded sandstone and dolomitic clay and sand conglomerate. Locally cross-bedded sandstone twenty to thirty feet or more. Locally there is dark brown clay and sand between beds. Locally Numbers 1 and 2 are large whitish sandstone lenses	25±
1.	Dolomitic sandstone, gray, conglomeratic and cross-bedded	10

Numbers 1 to 6 of this section represent the entire thickness of the San Angelo beds. Perhaps it should be remarked here that a very considerable part of the beds immediately above Number 6 of this section may be of the same age as the upper part of the San Angelo formation as seen on the Colorado River. The work done in connection with this report was not in sufficient detail to determine this point. Hence, the top of the San Angelo beds cannot be positively defined in this section of northern Texas, nor can it be certain that the basal beds resting disconformably on the Clear Fork beds do not represent a gradual northward transgression of overlapping beds. However, this is an unimportant detail so far as the present discussion is concerned.

The characteristics of the formation north from this point to Pease River may be regarded as indicated in the section given in the part of this bulletin dealing with the "Geology of Foard County." The occurrence of copper ore in the formation, which characterizes it in Foard County, continues north to the west end of the Wichita Mountains in Oklahoma, though copper minerals are less abundant in the region north of Red River. A feature of the San Angelo formation north of Brazos River is the presence of a conglomerate composed of pebbles of clay and red sandstone. These are frequently of fairly large dimensions. With the loss of the siliceous pebbles the formation becomes thinner as it is followed northward, and diminishes from a section of some 400 feet in thickness on Colorado River to one much less than a hundred, probably considerably less than fifty feet—so far as the actual sandstone and conglomerates are concerned—at the northwest corner of the Wichita Mountains area.

While tracing the San Angelo formation northward account was taken of the underlying and superjacent beds. The Blaine gypsum which lies above the San Angelo is of equal importance as a horizon marker and must receive consideration. The relations of the Clear Fork and the Blaine formation are well shown in the geologic sections in the Foard County section of this report, to which the reader is referred. The section on the Oklahoma side is given by Gould in his paper on the Geology of Southwestern Oklahoma.[5]

Unfortunately only a part of the Blaine formation is found on Colorado River and it is not well developed there. The section is described in the bulletin on Coke County.

THE RELATIONSHIP OF THE SAN ANGELO SANDSTONE

In the light of the great lateral extent of the San Angelo formation, it is well to note briefly its relation to associated beds. It is found to underlie the first great gypsum series of the Permian rocks of the south-central United States, being separated from it by a layer of red clay of varying thickness. As previously noted the formation rests disconformably on the Clear Fork beds, apparently cutting out the Merkel dolomite near Sagerton, Texas, while on Colorado River south of Bronte, Coke County, Texas, its base is 270 feet above the Merkel dolomite. However, in its extension toward San Angelo it probably overlies older formations than in Coke County or Taylor County. As a result the western limit of the Clear Fork beds in Oklahoma is marked by the outcrop of the San Angelo formation, which extends in a rapidly narrowing strip past Altus, Oklahoma, skirting the west end of the Wichita Mountains as a narrow band of sediments, then widening eastward along the north flank of the mountains. In northern Oklahoma the Clear Fork formation occupies a wide area east of the outcrop of the

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[5]Gould, C. N., New Classification of the Permian Redbeds of Southwestern Oklahoma. Bull. Amer. Ass'n. Pet. Geol., VIII, pp. 322-341, 1924.

San Angelo beds. A similar correlation was made by Wrather[6] in his paper on the Texas Permian. The demonstration that rocks of Clear Fork age occur north of the Wichita Mountain regions raises the question of nomenclature in the region affected. Upon investigation we find that the names of the large divisions were first proposed in Texas. Thus Wichita, Clear Fork, and Double Mountain antedate any such terms used in Kansas or Oklahoma. On the other hand, the names of nearly all the minor formations, except San Angelo, were first used in Kansas and Oklahoma, and so far as these formations can be followed into Texas such names should apply. Among these are the Mangum dolomite, Blaine gypsum, and Whitehorse sandstone. A feature of considerable geological importance is the presence of a dolomite near the top of the Blaine series which carries a molluscan fauna of pelecypods, nautiloids, and ammonoids of great value in making wide correlations. Fossiliferous exposures of this dolomite are found at Acme in Hardeman County and at a number of other localities in northern Texas and southern Oklahoma. (See note on page 50.)

BROADER CORRELATION

A preliminary discussion of the correlation of the San Angelo formation has been given in previous publications by Böse[7] and by one of the writers.[8]

In this connection it is interesting to note that in general more extended stratigraphic researches seem to confirm correlations already expressed, namely, that the ammonoids of the upper Clear Fork beds of Runnels County are no lower than the uppermost Hess formation of the Glass Mountains and perhaps belong in the basal Leonard beds. The ammonoids from the dolomites near Acme, Hardeman

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[6]Wrather, W. E., Notes on the Texas Permian. Bull. S. W. Ass'n. Petr. Geol. I, section facing p. 96, 1917.

[7]Böse, E. Permo-Carboniferous Ammonoids of the Glass Mountains and Their Stratigraphic Significance. Univ. of Tex. Bull. 1762, pp. 208-210, 1919.

[8]Geology of Coke County. Univ. of Tex. Bull. 1850, pp. 49-50, 1921.

County, Texas, which were discussed by Böse[9] are now known to belong to the Mangum dolomite of the upper part of the Blaine series, already described. Thus, the fossiliferous zone of the Clear Fork with its basal Leonard or upper Hess fauna is from 350 to 400 feet below the rocks of the San Angelo formation, while the horizon of the Mangum dolomite of the top of the Blaine series of gypsum and dolomites, carrying an upper Leonard ammonoid fauna, is nearly the same distance stratigraphically above the San Angelo beds. This taken with the fact that its fauna was said to correspond in horizon "exactly"[10] with that of the upper Leonard formation, seems to indicate that the interval between the base of the San Angelo beds and the top of the Blaine should be correlated with the Leonard formation of Brewster County, Texas.

Later work may show the Mangum dolomite fauna to be well up in the Word formation.

Moreover, since the Blaine and the San Angelo formations extend across Oklahoma and into Kansas they form the basis for the correlation of the Permian rocks for the Mid-continent region from the Rio Grande to Kansas.

In this connection it is fitting to mention a correlation of higher beds of western Oklahoma and northwest Texas with beds in Trans-Pecos Texas. This correlation is that of the Whitehorse sandstone fauna with the Capitan or its equivalent west of Lakewood, New Mexico. This fauna[11] occurs in the Whitehorse sandstone which is separated from the Blaine formation below by a rather thick shale known as the Dog Creek shale, and by what is probably a profound disconformity. This same fauna has been found in a formation near the top of the Capitan limestone in New Mexico. This would place it higher in the Marathon section, probably in the Gilliam or Tessey.[12]

[9]*Loc. cit.*

[10]Böse, *loc. cit.*

[11]Beede, J. W., Advance Bull. 1st. Bienn. Rep. Geol. Sur. Okla., 1902. Univ. Kans. Sci. Bull, IV, pp. 115-168, 1907.

[12]Univ. of Tex. Bull. 1753, Plate 3, for the relative position of formations. The Gaptank is the uppermost Pennsylvanian formation.

Since the strata of the upper central part of the Permian rocks of the Texas-Oklahoma-Kansas regions have been traced through, it is of special interest to review the relation of these deposits and their faunas to the great Permian section of the Trans-Pecos region. In the accompanying chart the writers have indicated their present view as to the correlation of the Permian formations of the Central Texas, Marathon Texas, Oklahoma and Kansas areas.

CORRELATION CHART

Permian Formations of Texas, Oklahoma and Kansas

TEXAS (CENTRAL)	TEXAS (MARATHON)	OKLAHOMA	KANSAS
Quartermaster	?	Quartermaster	?
Cloud Chief	?	Cloud Chief	?
Whitehorse	?	Whitehorse	Whitehorse
Dog Creek	Word	Dog Creek	Dog Creek
Blaine	Leonard	Blaine	Blaine
Chickasha	Leonard	Chickasha	Chickasha
San Angelo	Leonard	San Angelo	San Angelo
Clear Fork	Upper Hess	Wellington-Enid	Wellington
Upper Wichita	Lower Hess	Marion-Enid	Marion
Lower Wichita	Wolfcamp-Lower Hess	Chase-Neva	Chase-Neva

PENNSYLVANIAN

NOTE.—Since this paper started through the press, evidence seems to be accumulating that the upper dolomites of the Blaine formation are probably equivalent in age with the Word formation rather than with the Leonard formation.

GEOLOGIC MAP

In the geologic map which accompanies this paper the subdivisions of the Wichita, Clear Fork, and Double Mountain series are not indicated. As explained in the text, the San Angelo is the basal formation of the Double Mountain group, varying in thickness from approximately 400 feet in Coke County to possibly scarcely more than 100 feet on Red River.

The Permian-Pennsylvanian contact shown on the map is based on Plummer's map in Bulletin No. 2132 of the Bureau of Economic Geology, the eastern limit of Plummer's Putnam formation being provisionally used as the boundary between the Permian and the Pennsylvanian. North of the area mapped by Plummer, this contact is taken from Gordon's map in United States Geological Survey Water Supply Paper 317. This part of the boundary is indicated on the map by a broken line. The line indicating the contact of the Wichita and Clear Fork for Runnels County is taken from University of Texas Bulletin No. 1816. North of Runnels County this line is compiled from various sources. The Double Mountain-Clear Fork contact representing the base of the San Angelo formation has been obtained largely by investigations made in connection with this paper.

The Triassic shown on this map is based largely on field observations made by the junior author whose summary of observations is as follows:

"The basal member of the Triassic was mapped hurriedly in reconnaissance in the summer of 1922. Since not more than four weeks were spent in this work, no detailed sections were made and only the main characteristics of the basal conglomerate bed noted.

"The locality where the basal Triassic conglomerate is best exposed is at Camp Springs, near the center of the east line of Scurry County. The name of 'Camp Springs Conglomerate' is proposed for this formation.

"As will be seen from the map, the area of the Triassic outcrop is much wider than shown on the general geological map of Texas accompanying Bulletin 44. Recently the writer has superintended detailed work over Garza, Kent, Borden, Mitchell, and Scurry counties, and is satisfied that no inliers of Permian occur within this area mapped as Triassic.

"The main characteristic of the Camp Springs conglomerate is that it is a coarse conglomerate exhibiting a brownish color wherever exposed, due mainly to the preponderance of brown quartz and chert pebbles. Also, in many localities the conglomerate contains much fossilized wood. In some instances whole tree trunks measuring from six inches to two feet in diameter and from six inches to ten feet in length were noted. There were also found in the conglomerate many bone fragments, especially from the vertebrae of reptiles.

"The base of the Camp Springs is marked by a very evident unconformity. In the few places where this contact was seen it showed a slight angular unconformity, the Triassic above dipping more gently to the west, than does the underlying Permian.

"The mapping of the basal Triassic-Permian contact in southern Mitchell County is approximate only. However, the contact is known to be located south of the town of Colorado. The Triassic-Permian contact from Dickens in Dickens County east and north is taken from the geologic map of Texas published in Bulletin 44."

THE GEOLOGY OF FOARD COUNTY

BY

J. W. BEEDE AND D. D. CHRISTNER

INTRODUCTION

This report on the Geology of Foard County is largely in the nature of a reconnaissance report. However, the geologic details were determined as far as could be economically done without the aid of a good topographic base or a plane table survey of the county, neither of which was available.

The stratigraphic succession and thickness of the beds occurring in the county were determined, the formations described and mapped, and the mineral resources studied.

We wish to express our obligation to the citizens of Crowell and other parts of the county, whom we met, for the courtesy and assistance so generously extended to us.

GEOGRAPHY AND PHYSIOGRAPHY

Foard County lies south of Hardeman County, whose northwest corner lies at the angle between Prairie Dog Town Fork of Red River and the southeast corner of the Panhandle of Texas. The area of the county is approximately 650 square miles.

The county, on the whole, is fairly rough. The "breaks" of the North Wichita furnish a subdued bad land topography throughout the eastern three-fifths of the south border of the county, while the rocks of the Double Mountain series produce a very rough topography in the northern and southern parts of the western portion of the county, and a region of rolling country of very considerable relief in the central-western portion. The region between the breaks of the North Wichita and Pease rivers, from the eastern part of the county to some distance west of Crowell, is a plain of very slight relief with few rock exposures. This region is

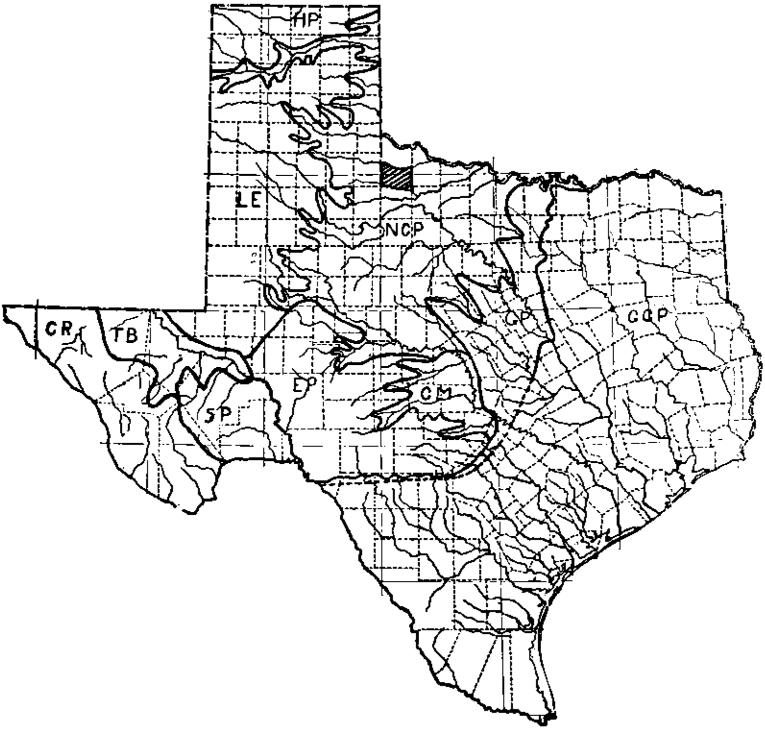

Figure 1. Map showing the location of Foard County and the physiographic divisions of Texas. Abbreviations: HP, High Plains; LE, Llano Estacado or Staked Plains; NCP, North Central Plains; GCP, Gulf Coastal Plain; CM, Central Mineral Region; GP, Grand Prairies; EP, Edwards Plateau; TB, Toyah Basin; CR, Cordilleran Region; SP, Stockton Plateau.

largely under cultivation while the rest of the county is largely ranch land.

Foard County is especially to be commended for its extensive, well planned, and well kept system of good roads.

The principal drainage lines of Foard County are North Wichita River with its South Fork in the south, and Pease River on the north. These rivers form the south and north boundary lines of the eastern half or three-fifths of the county. On the south side of the county a straight east-west line forms the boundary for a distance of twelve miles eastward from the southwest corner. On the north a straight line running in a northwesterly direction from the great bend of Pease River near the Johnson Ranch House, three miles west and seven miles north of Crowell, to the sharp southern bend of the river a little over two and one-half miles east of the northwest corner of the county, forms the border between Foard and Hardeman counties. There are some minor irregularities in the boundary of the extreme northwest corner, but for general purposes Pease River may be regarded as forming the boundary of the northwest corner.

The smaller drainage lines are North, Middle, and South Beaver creeks, in the southeastern part of the county, and Good Creek and South Fork of North Wichita in the southwestern part. The tributaries of Pease River are, from east to west, Mule Creek, Ragedy Creek, Canal Creek, Talking John Creek, and Catfish Creek.

Physiographically, the county lies in two topographic subdivisions of the North-Central Plains. The eastern part is in the nearly flat, Clear Fork Plain with its strips of bad lands bordering the larger streams, while the western part lies in the great, rough upland. The plain is a typical red beds plain developed on clay shale sediments, with buffalo grass and sparse mesquite growth. It is excellent grazing country and, much of it, relatively good farming country as well.

That part of the county containing the gypsum deposits falls into two topographic divisions. The first is the more rugged characterized by gypsum bluffs and canyons with the surface covered by cedar brakes. The other is grass covered rolling hills and shallow broad valleys on the plateau-like upland. The relief of this highland is older than that of the lowland and includes rugged scarps which are Pleistocene in age. Except for a single narrow belt shown on the geologic map, and some river sands, both the plain and the hills are noted for their lack of potable water. The streams at low water are especially salty, leaving upon evaporation crusts of salt, gypsum and other minerals in the sands of their beds and banks.

The stream channels have been cut more than a hundred feet below the level of the country, but have developed only small flood plains, or bottom lands.

However, coarse river gravels and sand occur high above the present rivers. These gravels, sands, and sandstones are evidence of two drainage cycles (drainage levels), represented in Foard County.

The first (Pleistocene) is represented by the plain of the eastern half of the county and the coarse gravels and sands (Seymour beds) along the bluffs of Pease River and Wichita River, which were then the stream beds. These gravels occur high above the present streams as in Sections 38 and 39 of Hardeman-Foard County, and other plains and along the top of the Wichita breaks, east of Tuscola, Knox County, and the north side of the Wichita west of the Orient Railroad bridge over Pease River. Of the old rivers, the flat valleys which are now under cultivation on the upland north and south of the Crowell-Paducah road, were then the valleys of the smaller tributary streams of Pease River and Wichita River.

The later cycle of erosion is represented by the entrenched streams, or canyons, in the western part of the county and the present valleys and low badland borders of the eastern part of the county.

According to Gordon, the gravel forms a thin bed beneath the soil of the whole eastern plain. After these valleys were developed, the region was uplifted and the rivers cut down again to their old level, which was relatively, about the present river level. Since that time they have developed such small bottom lands as are found along the streams, while the breaks have been formed by the erosion of the land, which was previously near stream level. In the rough country, this cutting down of the stream beds produced the canyons along the creeks running into Pease and Wichita rivers and the broader canyons of the rivers themselves.

In the high rough country of western Foard County the rocks are more resistant than the shales of the eastern part, with the result that the streams were unable to widen their valleys as rapidly as in the soft rocks of the eastern part of the county. As a consequence they flow in narrower canyons and have picturesque bluffs. This was true of the earlier drainage when the region was relatively lower than at present, as is shown by the masses of gravel and boulders now high above the present valleys of the streams, particularly the south bluffs of Pease River in the western part of the county.

At that time, too, the smaller streams had valleys of considerable size. These tributaries to old Wichita and Pease river valleys are now to be seen in the lower cultivated parts of the divide between Pease and Wichita rivers on each side of the Paducah road in the western part of the county. The higher hills in this region formed the low bluffs of these smaller streams and the flatter lower areas, the stream valleys.

HISTORY

The history of the geologic work done in Foard County was fully discussed by Gordon and will not be repeated in detail here. A bibliography is given at the end of this report.

In the water supply paper for the Wichita region of North-Central Texas, the Geology of Hardeman and Foard counties is considered under a single head.[1] Brief mention is made of the Double Mountain-Clear Fork and Seymour beds, a one-hundred and six-foot section of rocks seen between Crowell and Quanah, and the geology is discussed in a very general way. His discussion of the areal geology of Foard County is summed up in the following statement: "The uplands south of Pease River in the vicinity of Crowell and south to the breaks of the North Fork of the Wichita River are covered by fine black silt six to eight feet thick, underlain by gravel (Seymour) two to three feet thick. The gravels rest upon the red joint clay of the Permian."

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[1]Gordon, C. H., Geology and Underground Water of the Wichita Region, North-Central Texas. U. S. Geol. Survey. Water Supp. Paper 317, pp. 60-63, 1913.

GEOLOGY

The surface rocks of Foard County are mostly of Permian age. The oldest beds outcropping in Foard are the red clays, with thin green bands of sand and dolomites, known as the Clear Fork stage of the Permian System.

Above the Clear Fork beds are the Double Mountain Series of rocks, of which two stages are represented in Foard County. These two stages are the San Angelo conglomerate and sandstone, and the gypsum and dolomite beds above it.

The only other rocks are the old river conglomerate of the high terraces, along the bluffs of the rivers, and the valley silts and sands of recent age. Considering these formations in the order of deposition, we first take up the Clear Fork beds.

CLEAR FORK

The Clear Fork beds are found over the eastern three-fifths of the county, and their character is shown in the section which follows. The beds are exceedingly uniform in character throughout their whole thickness and no layers were found among them that could be used as a basis to subdivide the stage into smaller formations, though such beds occur along Colorado River.[2]

In this northern region the Clear Fork is largely a series of delta beds, as has been pointed out by Case.[3]

They consist of clays with narrow sand beds, which were the bottoms of the channels of small streams or distributaries, or possibly shallower places in wide stretches of water where the more violent winds may have caused waves to reach the bottom, churn up sediments, and to remove the

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[2]Beede, J. W. and Waite, V. V., Geology of Runnels County. Univ. of Tex. Bull. 1816, pp. 146-149, 1920.

[3]Case, C. E., Bull. Amer. Mus. N. H., 23, p. 659, 1907; the Permian of Texas, Amer. Jour. Sci., 3 Ser. XLIII, pp. 9-12, 1892, etc.; Baker Origin of Texas Red Beds.. Univ. of Tex. Bull. No. 29, 1916; Udden, Univ. of Tex. Bull. No. 246, pp. 25–28, 1912.

fine clay, leaving the remaining sand in large bodies and disturbed beds. These sands, sometimes conglomerates of clay and sandstone, are usually green but where thicker than usual may be red, and are highly cross-bedded. The sands on the sides of these channels are green and ripple-marked and wave-marked. Still farther toward the shore, the "feather edges" of these beds are composed of sandy dolomite or dolomite plates or beds. These are rarely more than a foot thick, though some of the sandstone centers of the larger beds, which approximated ten feet in thickness, were noted on the south side of North Wichita River, opposite the eastern part of the county.

These channels or "green streaks" are sometimes persistent over several acres as shown in Figure 2, but they usually appear to "come and go," or to be lenticular when seen in section. For this reason the measuring of a continuous section along some of the streams is of somewhat uncertain accuracy, particularly where the exposures are poor or interrupted. None of these beds on the North Wichita can be recognized with certainty on Pease River

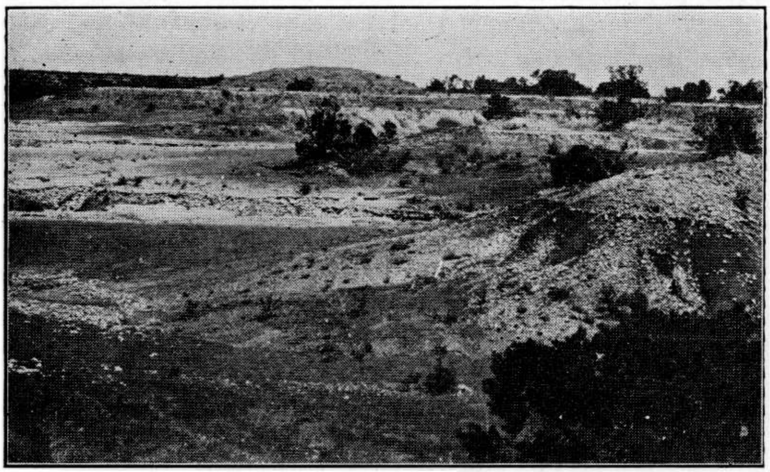

Figure 2. Clear Fork beds as seen on the South Fork of Wichita River. Red and light blue-green beds, the latter somewhat dolomitic.

since practically the whole intervening region is covered with soil or sand. For this reason, no attempt was made to subdivide the stage into smaller formations.

Stainings of copper are not uncommon in these green beds of the upper Clear Fork of this region, and unsuccessful attempts have been made to mine it.

Detailed Sections of the Clear Fork Stage

Section Beginning Near the North Wichita River, at the Round Knob on Its Western Side North of Southeast Corner of Foard County. Clear Fork Beds

Top of section.		Thickness Feet
105.	Red waxy clay, sandy at top	20
104.	Green streak, very micaceous two feet, six inches	2±
103.	Red shale and sandy shale, fifty per cent gypsum in lower fifteen feet, more sandy at top	35
102.	Red cross-bedded sandstone and sandy shale	12
101.	Red gypsiferous clay	5
100.	Sandy dolomite, nodular gypsum	1
99.	Red shale, light at top	6
98.	Dolomite, sandy, micaceous, shaly	2
97.	Red clayey shale, one green bed two inches thick, five feet from top	16
96.	Red clay cellular dolomite at top	5
95.	Green layer	3
94.	Red stuff, twenty-five to	20
93.	Red shale	35
92.	Red shale, lighter and more buff colored clay at the top	14
91.	Green streak	3
90.	Red shale	4
89.	Green streak	1
88.	Red shale and sand	25
87.	Green streak one foot six inches	1±
86.	Red shale	4
85.	Green dolomite zone	4
84.	Somewhat sandy red shale	28
83.	Green streak with very highly cross-bedded sandstone on top, some clay between	4±
82.	Red shale	13
81.	Slightly lighter red shale to top of first terrace	12
80.	Slightly lighter red shale, like No. 81	14
79.	Thin dolomite, one green streak	2

78.	Shale, dark red, dolomite three feet from top, comes 10 and goes	10
77.	Shale, dark red, thin gypsum streaks and two green streaks	3
76.	Green to pink nodular gypsum, six inches	—
75.	Water level to gypsum layer, dark red sandy clay with green spots nearly as large as dimes	10
74.	Dolomite	1
73.	Red shale	10
72.	Green streak	2±
71.	Red shale	10
70.	Dolomite below and green stuff above four feet	4
69.	Red shale, some green streaks, much gypsum	15
68.	Red shale, several gypsum beds, some thin dolomite layers	27
67.	Red shale, thin bedded dolomite at top	8
66.	Two sandy dolomite beds	1
65.	Red shale, two red dolomite layers	28
64.	Green band	1±
63.	Shale, red gypsum seams	20
62.	Two clayey dolomitic shale streaks, clay between	5
61.	Red clay	10
60.	Six-inch persistent dolomite bed followed by three feet five inches of red shale and two nodular dolomite beds	8
59.	Red shale, gypsum beds, one or two green streaks	30
58.	Green dolomitic material	2
57.	Shale, red	8
56.	Shale, sandy, or dolomitic birds-eye band	1
55.	Shale and red clay, much nodular gypsum	15
54.	Earthy dolomite, shaly, soft, some sand	3±
53.	Red clay shale, gypsum nodules at base	15
52.	Cross-bedded, beautifully ripple-marked, pinkish dolomitic sand	6–10
51.	Red shale	15
50.	Cross-bedded rippled sandstone	2
49.	Red clay and cross-bedded sandstone	5
48.	Sandy cross-bedded dolomite	1—
47.	Red shale	4
46.	Light colored sandy streak	1
45.	Red clay	2
44.	Cross-bedded rippled, spotted sandstone, six feet	12
43.	Red shale and gypsum	15
42.	Cross-bedded ripple-marked, speckled sandstone with two-inch hard dolomite at top	2
41.	Clay, red, and red and white cross-bedded sandstone	5
40.	Cross-bedded white sand eight inches	1—
39.	Red shale, selenite and nodular gypsum	6

38.	White sandy dolomite	1
37.	Red clay	3
36.	Red-speckled shale, red sandy shale at top	10
35.	Sandy dolomite	2
34.	Red clay with thin dolomitic streak in middle	18
33.	Hard sandy dolomite and spotted cross-bedded sandstone, rippled	6
32.	Red spotted clay, small nodules of gypsum and sandstone and seams of selenite, much cracked appearance	27
31.	Light colored cross-bedded sandstone, dolomite at top	2
30.	Red spotted shale, three light colored streaks disappear to west	14
29.	Cross-bedded, spotted, ripple-marked sandstone	1
28.	Red shale	5
27.	White dolomitic sand four inches	—
26.	Red shale, seam of gypsum	6
25.	Light colored sandy dolomite	1
24.	Red shale	8
23.	Sandstone, dolomitic cross-bedded	1
22.	Spotted, brick-red shale	10
21.	Pinkish-white mottled cross-bedded sandstone, locally dolomitic sandstone and boulders	10
20.	Red shale, several light colored streaks of sandstone four feet ten inches thick	25
19.	White to pinkish mottled sandstone	1
18.	Shale, red, several pale streaks, grades into sandstone farther west, locally cross-bedded	15
17.	Sandy streak, mostly light sandstone	1
16.	Dolomite and cross-bedded sandstone with dolomitic sandstone and clay pebbles	12
15.	Red shale	23
14.	Sandstone, shale and sandstone	10
13.	Shale, red, some crystalline gypsum	35
12.	Shale, red, two feet sand on top	17
11.	Green and red sandstone, some shale layers seven feet to	12
10.	Red shale, green and red sands	25
9.	Red shale, nodular, capped with about one foot of dolomite, conglomerate sandy green	2
8.	Red shale and red nodules three feet to five feet, red and green sandstone at top	20
7.	Shale, red, sand at top, selenite sheets	20
6.	Green and red sand	10
5.	Red shale	25
4.	Sandstone, red and gray	2
3.	Shale, red, some sand, sandstone bed ten feet below top	35

2.	Red shale thirteen feet, conglomerate sandstone two feet, some dolomite	15
1.	Red shale and sandstone, estimated, thin sandstone at top	30

SAN ANGELO FORMATION

Resting unconformably, or disconformably, upon the top of the Clear Fork shales is a series of sandstones, conglomerate, and shale beds, which have been named the San Angelo formation from its occurrence in Central Texas. This formation has been traced to Foard County. The reader is referred to a preceding part of this bulletin for a general discussion of the San Angelo formation. Its local development will be treated here.

Locally the San Angelo beds are largely composed of sandstone and sedimentary conglomerates, rather than of foreign siliceous material, while between the beds of sandstone and conglomerates are brown shales and clay. The formation is never very thick, having as defined here, a thickness in Foard County of 100 to 160 feet, usually nearer the smaller than the larger figure.

Two places were found where this formation could be measured with a reasonable degree of accuracy, one on the Wichita and one on Pease River. On the Wichita, the section follows, while on the Pease River section the San Angelo beds are contained in the interval between Numbers 52 and 68.

San Angelo Beds on North Fork of North Wichita River, Southwestern Part of Foard County

		Thickness Feet
12.	Red shale, twelve feet exposed, fifteen feet to twenty feet	15
11.	Green streak eight inches	1—
10.	Red shale	5
9.	Green streak	5
8.	Shale, red, much nodular gypsum, sandstone lens	14
7.	Sandstone, green to red, conglomerate at top	9
6.	Red clay with green streaks	3
5.	Green sandstone one foot six inches. More of it concealed	1+
4.	Red shale	10
3.	Conglomerate, pebbles of clay, dolomite and sandstone—red sandstone at top	16
2.	Concealed	15
1.	Concealed, two to four feet of whitish cross-bedded sandstone at top	15

One feature of the San Angelo formation is the fact that its basal beds are frequently composed of sandstone, while the conglomerate makes its appearance in somewhat higher beds. The sandstones are usually very dark colored, nearly of a chocolate color, sometimes of a buff hue, or even greenish or bluish. Locally a mass of sandstone may be seen cutting diagonally through shale beds. This is well shown in the section above the Johnson Ranch House on Pease River. The abundance of sandstone, its texture, its dark color, the absence of gypsum beds of considerable thickness, and the irregularity of its beds separates this formation from the Clear Fork beds below it and the rocks of the Blaine stage above it. This is most strikingly true of the quantity of sand which it contains.

This sand is sufficient to make sandy soil and even some dune sand near the outcrop unless the slope of the surface of the ground is sufficiently steep to cause the sand to be washed away.

In addition to the sand, which adds to the value of the soil by its capacity to retain water, the sandy beds are the source of a considerable amount of semi-potable water,

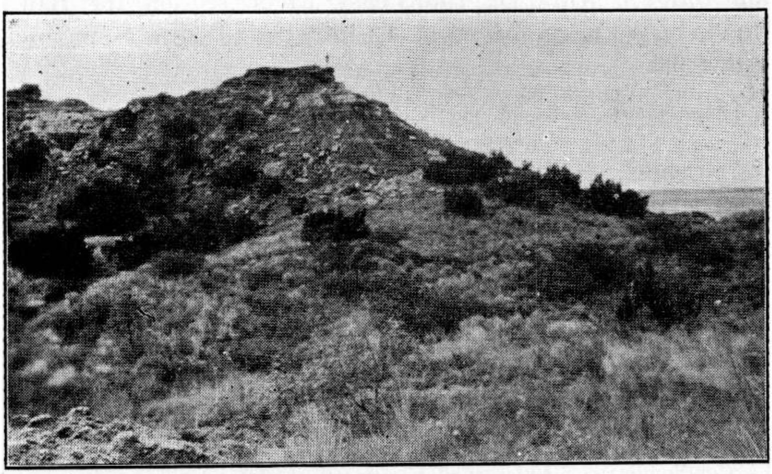

Figure 3. San Angelo Sandstone, Red River Bluff, north of Doan's Store, Wilbarger County.

which is used as stock and drinking water. This is a valuable asset, since water in the Clear Fork beds is scarce and impure, while the highly saline and gyppy water of the Blaine beds west of it cannot be used for domestic purposes.

Thus though the area of the outcrop of the San Angelo formation is but a narrow belt extending across the county, yet it is an important formation and has a definite place in the economy of the county.

BLAINE STAGE

Succeeding this formation is the series of thick gypsum beds with some shale partings and thin dolomites known as the Blaine beds, which were described by Gould in Oklahoma.

Pease River Section of Foard County Double Mountain Beds, Blaine Stage

		Thickness
102.	Dolomite, porous to very firm and fine-grained	4
101.	Shale with oolitic dolomite *Schizodus*	20
100.	Gypsum, dolomite at base	5
99.	Concealed, probably shale and gypsum	30
98.	Dolomite, six feet to ten feet	10
97.	Red shale, ten-foot gypsum lens, locally, or continuous bed	28
96.	Dolomite, thin-bedded to shaly	11
95.	Gypsum, locally two feet dolomite at base	24
94.	Shale	19
93.	Dolomite, coarse, earthy, cellular	2–3
92.	Shale, thin gypsum bed, very coarsely cellular dolomite, mud cracked stuff, crystals of bright red selenite	31
91.	Gypsum, six inches red shale at its base considerable shale in upper part	24
90.	Dolomite, hard, thin, platy layers, quite fossiliferous, only *Pleurophorus*	2
89.	Shale, green, and red gypsum	18
88.	Gypsum, white, massive five feet to	5–8
87.	Soft red and green shale, gyppy at top, two inches dull streak	15
86.	Green gypsum, pronounced cone-in-cone structure, one and one-half to	2
85.	Vari-colored gypsiferous shale	5
84.	Dolomite, very fine-grained, cellular, small gypsum geodes	1
83.	Massive white gypsum	15

82.	Yellowish hard dolomite, faint oolitic structure coarsely cellular, two beds, little shale, two feet to	3
81.	Green gyppy shale	7
80.	Soft gypsiferous shale, impure green gypsum	8
79.	Banded impure green gypsum	7
78.	White massive gypsum	6
77.	Shale, various shades, with thin, platy dolomite streaks twelve feet to	14
76.	Gypsum, shaly at top	10
75.	Red and green shale	5
74.	Gypsum	10
73.	Red and green shale	4
72.	Gypsum, massive with two or three green earthy gypsums	22
71.	Variegated gypsum and shale, some sandy green, earthy gypsum thin beds	20
70.	Dolomite, green, gyppy (anhydrite?) one and one-half feet to	2
69.	Shale, red and gypsum, occasional band of green earthy gypsum	20
68.	Gypsum, white, massive, nodular structure	5
	Top of San Angelo Beds	
67.	Shale, red, gypsum streak at top	13
66.	Green gyppy sandstone	1
65.	Shale, red	27
64.	Light green shale streaks, some red in middle	5
63.	Shale, red, sandy	5
62.	Sandstone, twenty-five feet to fifty feet, varies locally, some solid sandstone, very highly cross-bedded twenty-five feet to fifty feet	40±
61.	Shale five feet, sandstone lenses, cross-bedded chocolate-brown sandstone sheet six feet	11
60.	Chocolate colored sandstone, massive, conglomerate horizons in it. Sedimentary conglomerate	1
59.	Chocolate colored shales, sandstone lenses	3
58.	Sandstone, brown at base, streaked sandstone	4±
57.	Shale, red	3
56.	Green sandstone	7
55.	Shale red, green sandstone lenses	7
54.	Green cross-bedded sandstones three feet to	4
53.	Sandstone and shale, base of San Angelo formation in river, largely concealed at Johnson Ranch	20±

Base San Angelo Formation

(Exposed on Pease River east county line to base of San Angelo beds, distance east and west, about 18 miles.)

Top of Clear Fork at This Place

52.	Red sandy birds-eye clay, light colored in seam fourteen feet from base	24+
51.	White dolomitic sandstone	1
50.	Red clay	3
49.	Light sandy dolomite and sandstone sixteen inches	1+
48.	Shale, red, birds-eye, two-inch seam dolomitic shale twelve feet from base, two-inch seam dolomitic shale twenty feet from base, contains dolomite (vertical) and dolomitic sandstone dykes	26—
47.	Dolomitic sandstone, sandy, micaceous	1
46.	Shale, red, several green streaks, some gypsum	95
45.	Green dolomitic streak two feet	1
44.	Shale, red, little gypsum	83
43.	Heavy green band three feet to	4
42.	Shale, red	40±
41.	Dolomite, three feet to	1
40.	Shale, red	35
39.	Green streak	1
38.	Shale, red, estimated	20
37.	Sandstone, red, shaly at top, two green streaks, within it	25
36.	Green streak	1
35.	Sandstone, shaly, birds-eye shale, rusty colored	10
34.	Concretionary dolomite, chert forming terrace	1
33.	Shale, red, gypsum layer about a foot thick near the base	30
32.	Green streak, some green gypsum	1
31.	Shale, red, two thin gypsum layers	25
30.	Green streak, largely sand	1±
29.	Red and green shale and one dolomite streak near top	45
28.	Green streak	1
27.	Shale, red, ten feet to twenty feet	15
26.	Sandstone, dolomitic, and sandy dolomite	1
25.	Shale, red	6
24.	Green streak	1
23.	Dolomite one foot, wedging sandy shale over it	6
22.	Shale, red, six feet to	8
21.	Green sandy dolomite changing to sandstone. Three similar beds noted below it can be seen coming in on south side of bluff	15
20.	Shale, red, contains gypsum bed one foot thick	14
19.	Sandstone, birds-eye, light brown-red changes to gray	2±
18.	Shale, red, with faint pale streak	15±
17.	Clay, red, local pale band	10±
16.	Sandstone, birds-eye two feet, locally absent. In places there is a foot of dolomite in this bed	2
15.	Shale, red sandy	5
14.	Sandstone, birds-eye	2

13.	Clay, red, sandy in upper part	20±
12.	Gypsum, red clay and dolomite, one foot six inches	1+
11.	Shale, red	5—
10.	Sandstone, birds-eye, rather local, a short distance farther north gypsum replaces sandstone	2—
9.	Shale, red	8
8.	Green dolomite, sandstone streak, some of it flesh-colored, prominent terrace one foot six inches	1+
7.	Shale, red, two gypsum horizons, one with thin sheet of dolomite	13
6.	Gypsum, terrace, well marked	1
5.	Red shale, gypsum at ten-foot level	30
4.	Green streak, sheet of crystalline gypsum at top	2
3.	Shale, red, probably some gypsum streaks	10
2.	Sandstone, wave-marked and sandy dolomite, greenish-gray, two feet to	1
1.	Red stuff, apparently one thin gypsum sheet—from valley to bottom	23

In Bulletin No. 1850, University of Texas, on the Geology of Coke County, the gypsum series above the San Angelo beds was referred to the Greer stage and the San Angelo beds were correlated with the Whitehorse sandstone supposed to underlie the Greer beds. There are reasons for placing the gypsums of the southwestern part of Oklahoma west of Mangum in the Blaine series, hence the necessity of changing the correlation of the southern extension of these beds in Texas. The top of this group of gypsums is marked by the heavy dolomites of western Foard County.

The rocks of the Blaine stage rest conformably upon the San Angelo formation. They are at once distinguished from the San Angelo beds by the regularity of stratification, the very small amount of sandstone which they contain, the numerous thick strata of gypsum, and the presence of many relatively thin fossiliferous dolomite beds. These beds underlie the western third of the county, and are responsible for its rough topography. The rocks are best seen in the picturesque cliffs of Pease River, in which the red shales and white gypsum beds form very striking landscapes. These beds are also excellently shown north of Aspermont on the Salt Fork of Brazos River, and, indeed, wherever large streams cross the formation.

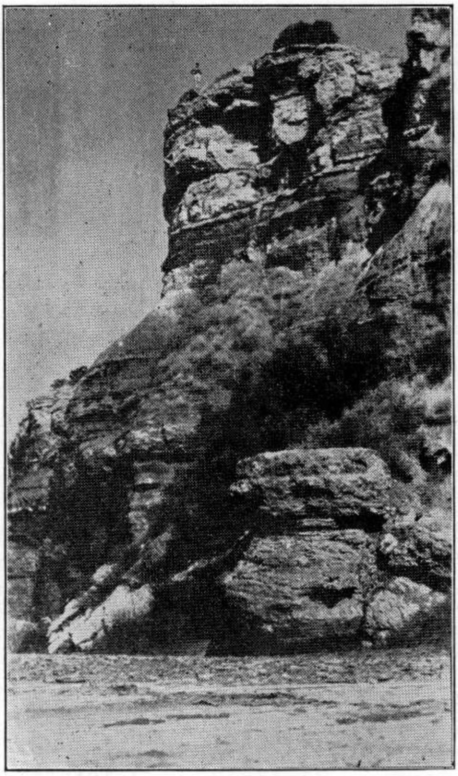

Figure 4. Gypsums of the Blaine stage, north bluff of Pease River, in northwestern part of Foard County.

In Oklahoma the various gypsum beds and dolomites have been named, but these names cannot yet be safely applied to the Texas beds until more detailed work has been done in tracing them through to determine, with certainty, the identity of each of the Texas beds with the individual beds of Oklahoma. However, there can be no doubt that the big gypsum series of Texas is identical with the great gypsum series (the Blaine stage) of Oklahoma. In western Oklahoma, the succession is as follows:

"Greer" 275 feet	Mangum dolomite Collingsworth gypsum Cedar top gypsum Haystack gypsum Kiser gypsum Chaney gypsum	= Blaine formation

All of these beds are separated by thicker or thinner red and bluish shale beds.

If this is compared with the section of the Blaine beds of Foard County a general similarity between them is apparent. This similarity is probably as close as could be expected when the lenticular nature of some of the gypsum beds is taken into account. The presence of dolomite beds below the gypsum beds, in Texas, is significant, though occasionally some thin gypsiferous shales may intervene. This is more noticeable in Texas than in Oklahoma.

Gypsums are soluble in rain water, and here solution is aided by the jointing of rocks. The beds are broken into joint blocks, by two systems of intersecting nearly vertical cracks, which break the beds into great masses or blocks, and which permit water to flow along these joints. The water dissolves the gypsum along the sides of the joints and forms caves, which are rather common in Foard County.

Sometimes a dolomite occurs above a gypsum bed. When this occurs, the dolomite, broken into small joint blocks, permits free access of the rain water to the gypsum bed below which dissolves away unevenly, leaving the dolomite covering irregular shaped hillocks, usually more or less circular or curved in outline. This is well shown in the region a few miles north and northwest of Vivian and is a good illustration of this peculiar type of surface, which sometimes occurs on a much larger scale.

The Foard County section of the Blaine stage is represented in beds numbered 68 to 102 of the Pease River section, on preceding pages.

The rocks of the Blaine stage are the youngest, or latest, of the thoroughly lithified rocks of Foard County, though beds of vastly more recent date occur in the forms of gravels, sometimes conglomerates, and sands of former river beds. These beds are called the Pleistocene beds or the Seymour beds.

PLEISTOCENE

Over much of the plain of the eastern half or two-thirds of the county there is present, locally at least, a gravel composed of large, unpolished, rounded pebbles and boulders beneath soil of greater or less thickness. These gravels were mentioned under the subject of Physiography and the result of Gordon's studies of them noted. Fossil bones of horses and mammoths found in them show the gravels to be of Pleistocene age.

They occur along the rivers, high above their banks, in the western part of the county, while the breaks of the Wichita and Pease rivers have been etched back from the stream and disclose them nearly at the level of the plain. Usually more or less sand and sandstone accompanies these gravels and they furnish a small amount of water for wells.

These boulders consist of quartz, quartz-mica-schist and many other rocks including Comanchean limestones and fossil *Gryphaeas*.

Their precise occurrence has not been shown on the map since nearly all the region where they occur is covered with later soils or sands, or, frequently, they have been carried away by the rivers.

RECENT

Rocks of still later age form the surface sands near the eastern edge of the outcrop of the San Angelo beds, and also sands and dunes in northeastern Foard County, and in the valleys, together with the river bottom silts which come under this head. Over considerable distances the rivers have not yet developed extensive bottom lands and for this reason the recent deposits are quite limited in extent. The principal value of these deposits lies in their adaptability for agricultural purposes. At the old ford across

Pease River in the northeastern corner of the county, a large spring occurs in the gravels, and at other points shallow water is to be had in them.

ECONOMIC GEOLOGY

Sand and Gravel

An abundance of sand is found along the streams and over some of the uplands along the outcrop of the San Angelo formation, and in regions where streams may formerly have been; as south and northeast of Uralia. The sands of the river beds may need washing to remove the salts deposited by evaporation of the river and seep water before using, but the blown sand does not.

The finer Pleistocene and gravel of the high terraces and breaks of the rivers forms an excellent surfacing material for roads. It is found on the western part of the county along Wichita River, on the northwestern part along Pease River, and also along Pease River in the eastern part of the county.

Building Stones

There is little first-class building stone in the county. There are occasional beds in the San Angelo sandstone, which could be used for this purpose, but then only in a limited way. They would make fair dwellings and barns if properly selected. These rocks will be more or less surface hardened by weathering. Some beds occur which could be easily worked, but the grains are too poorly cemented together to last for a great length of time. Dolomites, which could be used for foundations, occur in the western part of the county.

Clay

Throughout the eastern half or two-thirds of the county poorer grades of clay may be found, which would burn a fair grade of ordinary building brick. No clays were seen which would burn to make higher grade clay wares.

Gypsum

Western Foard County contains an enormous amount of gypsum, as is shown by the preceding sections of the rocks of the Blaine stage. However, gypsum is so common over West Texas, western Oklahoma and southern Kansas that it is of little value except under favorable conditions of transportations to market and moderately cheap fuel. In case Foard County could secure a railroad through the western part of the county connecting with those reaching the active markets, it might be possible to develop the plaster industry. This would be particularly true if cheap fuel in the way of oil or gas could be found in the county.

It is likely that the gypsum industry will, in the course of time, become one of the great industries of the State, and under favorable fuel and transportation facilities Foard County should have a large share in it, on account of the accessibility of the deposits which are high above the country level and quite thick and extensive, assuring ease and economy of mining.

Copper

There has been considerable prospecting and even mining of copper ore, malachite, in this county. This is true of the whole northwestern outcrop of the San Angelo formation. Localities the scenes of these operations are the mouth of Croton Creek southwest of Benjamin, Cedar Mountain west of Benjamin, and especially in Section 35 in northern Foard County, where several cars of concentrated ore are said to have been mined and shipped. Similar deposits in two or more localities north of Pease River in Hardeman County have been similarly exploited.

Figure 5 illustrates the extent of the work done on this mine in Foard County.

The main ore is malachite and is associated in its main aggregations with fossil wood and plants, which are largely charcoal-like masses of trunks and stems. Only two of the specimens collected may be identifiable. The most of the

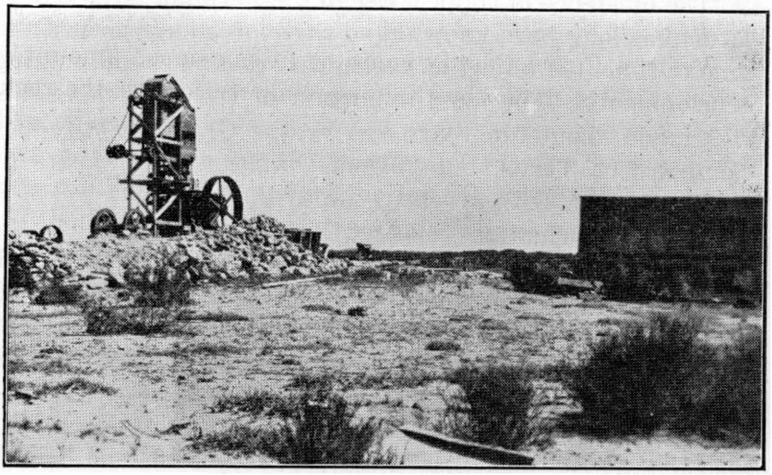

Figure 5. Crusher and Tank, copper mine in western Foard County.

remains appear to be accumulated in drifts in their present position, in which the ore is most abundant or richest. The main difficulty is that the conditions favorable to such segregation of the copper ore are so small and so erratic that one cannot hope to make a profitable industry of it. Some of the associated sands are cemented with malachite. About the only other copper mineral noted was occasional pieces of azurite. One specimen was a beautiful mixture of azurite, malachite, and selenite crystals.

The accumulations of ore are too small to be of much value and the small plant drifts in the San Angelo, or other red bed formations, are too small and sporadic to make it worth while to attempt to exploit the ore.

Of the many papers on Texas red beds copper ore, the one by Schmitz[4] may serve as an example. He states:

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[4]Schmitz, E. J., Copper Ores in the Permian of Texas. Trans. Amer. Inst. Min. Eng., XXVI, pp. 97-108, 1896. Ex. Simonds, Record of Geol. of Texas, 1887-1896. Trans. Tex. Acad. Sci., III, 1900, pp. 220-221.

"The existence of copper ores in the Permian measures of Texas has long been known, and these ores have been, from time to time, the object of geological researches and mining developments. The most important of these developments was made about ten years ago by the Grant Belt Copper Company of Texas, but it ended, after several years of fruitless labor, with an entire failure. . . .

"From information collected by me, it seems that the geological adviser of the company assumes the copper ore (or at least the copper) to be of Plutonic origin, and was directing his efforts toward the depths for the mother lodes or deposits. The diamond drill was employed for this purpose, and at one point, in Knox County, a hole was sunk to a depth of 1,000 feet. How an engineer could conceive of the idea that these copper ores of the bedded Permian, which is bare of Plutonic lodes, dikes or intersections, must be of eruptive origin, is rather hard to understand. I have been told that indurated water worn clay, mistaken for volcanic scoria, suggested or supported the hypothesis. . . .

"The occurrences of copper ore are scattered over a large area . . . and the ore . . . appears principally in the marls, clays, and shales as pseudomorph after wood (cuprified branches of trees, to a thickness of several inches in diameter), most all of which are of fossiliferous origin.

"Copper ore is also found in irregular amorphous masses, intermixing with and impregnating the marl of clay-slate. In a third form it occurs 'as numerous small pebbles in a hardened cupriferous marl conglomerate.' And finally I found such nodules of copper ore seated in hardened clay-slate and even in sandstone. The copper ore consists principally of green-blue and dark siliceous carbonates of highly varying percentage. The cuprified wood runs mostly high in copper, generally between twenty and sixty per cent, and the same is true of the nodules. When impregnating or intermixed with the clay and marl, the ore mostly contains less than twenty per cent of copper; so does the conglomerate, etc.

"No matter in what form the ore appears, it always shows its neptunic (laid down in water) origin. The pseudomorphs of wood, as well as the nodule ores, occur in entirely separate and distinct pieces of irregular form, and are scattered irregularly through the clay or marl matrix, forming nests or pockets of uncertain extent and size. The ore occurrences in the conglomerate marl and cupiferous clays all show decided pocket-form, and give indisputable evidence of the origin of the copper ores by precipitation during the deposition of the copper-bearing stratum, or by replacement and metamorphosis shortly after deposition of the strata."

Oil and Gas

So far as known this region has never received a sufficient test for oil and gas possibilities. Several wells have been started or completed, but none have been carried sufficiently far to thoroughly test the possible oil resources of the county. The logs at hand are appended to this discussion.

In a large way the most significant feature of the structure of the region is the change of strike of the San Angelo beds from north to northeast, which implies a broad structural ridge or terrace. Whether this change in strike is due to a flattening of the dip in the northern part of the county, or whether it is due to a changed direction of dip cannot be positively stated. However, at the outcrop on Red River the dip appears to be somewhat north of west. A change of direction of dip would be a surer, more effective structure than a mere flattening of the dip. To whichever cause it may be due, minor structures are likely to be found upon it. Without a topographic base it was impossible to work out the levels and structure except by plane table, which was impossible in the time available. This must be done to secure accurate results. For this reason the structures are not considered in detail in this report. There are considerable variations of dip in some localities which may prove to be structures worthy of development. Aside from the structures implied in this change of dip, no large structures were noticed, aside from the increased dip in the southwestern part of the county where the San Angelo beds come in near the Clear Fork beds. It is not certain that this increased dip is not due to unconformity.

With our present knowledge of the subsurface geology, it is by no means impossible that oil sands might be found beneath Foard County. This change of strike of the San Angelo formation is suggestive of oil possibilities. However, accurate plane table mapping over wide areas is necessary in order to make intelligent selections of the better drilling sites.

The depth to the Pennsylvanian rocks cannot be stated accurately. The Wichita stage is estimated at 2,000 and the Clear Fork 1,300 feet. If these estimates are accurate the top of the Cisco should be reached at 3,300 along the eastern edge of the outcrop of the San Angelo beds as shown on the map, and at a considerably lesser depth in the eastern part of the county. In the western part of the county two to five hundred and fifty feet more should be added. These figures are supposed to be maximum depths.

In the western part of the county the results of the Herring well show that any well to be a real test should be prepared to go to a depth of 4,500 feet or deeper.

Log of the Herring No. 1 Well, Emerald Oil Company, Foard County, Texas. J. E. Sweet, Driller; Wm. McNab, Superintendent, Emerald Oil Company, Winfield, Kansas

	From Depth in	To Feet	Thickness
Soil, brown	0	3	3
White lime	3	43	40
Red rock	43	47	4
Pink shale	87	107	20
White lime	107	122	15
Pink shale	122	160	38
Red rock	160	200	40
Lime	200	205	5
Shale	205	215	10
Red rock	215	275	60

	Depth in Feet From	To	Thickness
Red mud	275	420	145
Pink shale	420	465	45
Red mud	465	515	50
Red rock	515	590	75
Lime	590	610	20
Blue slate	610	640	30
Red rock	640	685	45
Red mud	685	840	155
Pink mud	840	880	40
Pink mud, tinted with streaks of blue, very cavey	880	914	34
Set 12½″ at 914′			
Greenish shale	914	1,000	86
Red bed	1,000	1,040	40
Lime	1,040	1,044	4
Red bed (cave)	1,044	1,150	160
Set 10″ at 1,100′			
Lime	1,150	1,155	5
Red bed (cave)	1,155	1,175	20
Lime	1,175	1,177	2
Red beds	1,177	1,281	104
Lime	1,281	1,284	3
Red beds	1,284	1,330	46
Lime	1,330	1,335	5
Red bed	1,335	1,385	50
Lime	1,385	1,505	120
Set 1,428′ 10″			
Dark lime	1,505	1,700	195
Blue slate	1,700	1,775	75
White lime	1,775	1,810	35
Broken lime	1,810	1,870	60
Light colored lime, very hard	1,870	1,890	20
Broken lime	1,890	1,940	50
Dark lime	1,940	2,000	60
NOTE.—Just a very little show oil at 1,950. Showed very little grit (ss.) at 1,950′			
Dark lime, very hard	2,000	2,125	125
Light lime, softer	2,125	2,160	35
Sand and water (500′ water in four hours.)	2,160	2,175	15
White lime	2,175	2,225	50
Blue shale	2,225	2,233	5
White lime	2,233	2,237	4

	Depth in Feet From	To	Thickness
Blue shale	2,225	2,223	8
White lime	2,243	2,248	5
Blue shale	2,248	2,255	7
White lime	2,255	2,258	3
Blue shale	2,258	2,262	4
White lime	2,262	2,270	8
Red rock	2,270	2,275	5
White lime	2,275	2,282	7
Blue shale	2,282	2,287	5
Lime	2,287	2,290	3
White lime	2,290	2,297	7
Light sand (water)	2,297	2,303	6
Lime	2,303	2,313	10
White shale	2,313	2,325	12
Lime	2,325	2,333	8
White shale	2,333	2,336	3
White lime	2,336	2,416	80
2,388′ of 8″ casing.			
Water at 2,375′.			
Blue lime	2,416	2,423	7
Black lime	2,423	2,430	7
Very light showing of gas at 2,430′.			
Some gas at 2,430′ in lime.			
Black lime	2,430	2,450	20
Blue shale	2,450	2,452	2
Black lime	2,452	2,457	5
Blue shale	2,457	2,460	3
Gray lime	2,460	2,475	15
Blue shale	2,475	2,480	5
Gray lime	2,480	2,500	20
Blue slate (caving)	2,500	2,502	2
Hard gray lime	2,502	2,538	36
Soft blue shale	2,538	2,540	2
Hard gray lime	2,540	2,546	6
Black soft shale	2,546	2,549	3
Black hard lime	2,549	2,576	27
Hard gray sand	2,576	2,583	7
Light show of gas 2,583′.			
Red soft shale	2,583	2,605	22
Blue soft shale	2,605	2,640	35
(Rainbow at 2,460′ in blue shale.)			
Hard lime	2,640	2,644	4
Soft blue shale	2,644	2,680	36
Soft red shale	2,680	2,720	40

	Depth in Feet From	To	Thickness
Soft blue shale	2,720	2,750	30
Blue mud	2,750	2,760	10
Blue shale	2,760	2,764	4
Blue shale, soft and cavy	2,764	2,782	18
Very bad caving. Fishing tools and casing. Hole measured, 2,732′—(50′ short) Set 6⅝″ casing at 2,698′. U/R 6⅝″ to 2,732′.			
Blue shale (caving)	2,782	2,745	?
White shale (caving)	2,745	2,753	8
White lime (caving)	2,753	2,762	9
Gray lime, very hard (caving at 2,773′)	2,762	2,773	11
Black shale	2,773	2,797	24
Gray lime	2,797	2,800	3
Blue shale	2,800	2,810	10
Lime shell	2,810	2,812	2
Blue shale (caving and leaking water)	2,812	2,817	5
Black shale. U/R 6⅝″ to 2,812′			
Blue shale	2,817	2,838	21
U/R 6⅝″ to 2,836′.			
Shale	2,838	2,840	2
Blue shale (caving)	2,840	2,861	21
Pulled 6⅝″ casing. Run new string. Set 2,859′.			
Light lime	2,861	2,864	3
Blue shale	2,864	2,874	10
Black shale—caving badly	2,874	2,918	44
Water leaking through casing.			
Shale and lime	2,918	2,924	6
Shale and thin lime shell	2,924	2,929	5
Shale	2,292	2,955	26
Shale and light shells	2,955	2,965	10
Light shale	2,965	2,970	5
Shale and lime shells	2,970	2,990	20
Light shale containing small streaks of coal (caving)	2,990	3,000	10
Light shale, caving	3,000	3,020	20
Blue shale	3,020	3,090	70

	Depth in Feet From	To	Thickness
White water sand. Hole full water, impossible to get on bottom to "fighting cave." Impossible to get on bottom on account cave 80 feet off bottom. U/R at 2,940	3,090	3,091	1
2,962′ of 6⅝″ casing. 3,092′ of 5 3/16″ casing.			
Hard gray lime	3,091	3,093	2
Blue shale	3,093	3,096	3

Log of Halsell Well No. 1, Foard County, Texas. Block "A," H. & T. C. R. R. Section 378. Drilled by the Texas Petroleum Company, About 8½ Miles South and 5 Miles East of Crowell

	Depth in Feet From	To	Thickness
Red mud	0	850	850
Blue shale	850	930	80
Blue shale with shells	930	1,188	258
Blue shale with shells, 5′ apart	1,188	1,290	172
Lime (salt water 1,430′)	1,290	1,550	260
Blue shale shells	1,550	1,600	50
Lime	1,600	1,630	30
Salt water, sand	1,630	1,660	30
Lime shells	1,660	1,705	45
Lime	1,705	1,740	35
Blue shale	1,740	1,760	20
Gritty shale, some gas	1,760	1,785	25
Blue shale	1,785	1,815	30
Lime	1,815	1,915	100
Blue shale (caves)	1,915	1,955	40
Lime	1,955	1,960	5
Pink shale	1,960	1,965	5
Lime (gritty)	1,965	1,980	15
Shell	1,980	2,020	40
Blue shale (caves)	2,020	2,050	30
Red shale (dark brownish-red, caves)	2,050	2,073	23

Description of Samples from Halsell Well No. 1, Foard County, Texas, Near South Line of County not far from Truscott. Depths, 550–2050 feet

	Depth in Feet
Red marly clay, containing several large fragments of white and red dolomite. Some sand present, most of which is much worn and etched. No fossils noted	550

	Depth in Feet
Red shale, containing some fragments of red and gray dolomite, and some fine sand which is worn and etched. A slight quantity of gypsum also present	690
A large fragment of brownish-red shale, with spherical concretions or nodules of a light green shale, mostly about one-tenth of an inch in diameter present throughout. Some gypsum present, as are grains of quartz. Driller's note: "Typical birds-eye clay"	725
The sample is in part a dark gray shale, in part anhydrite, and in part gypsum, the proportion being about forty per cent shale, about twenty per cent gypsum, and about thirty per cent anhydrite. There are several fragments of veins of gypsum of a vertical prismatic structure. No fossils noted	850
The sample consists of a mixture of shale and gypsum, with a little anhydrite present. The shale, about forty per cent of the sample, is a dark gray, hard and rather fine-textured material. No fossils noted	900
Dark gray shale, with some gypsum and a quantity of brown dolomite. The latter comprises nearly half the sample, and is rather fine-textured. No fossils noted	950
Light brownish-gray, very fine-textured dolomite, together with some gypsum, some coarser textured, dark dolomite, and some dark gray shale. No fossils noted	1,000
Light gray, fine-textured dolomite, with some fragments of black dolomite, and a little gypsum. No fossils noted. Driller's note: "Blue slate and shells"	1,050
Brownish-gray dolomite, some dark blue-gray shale and some gypsum in small fragments. No fossils noted. Driller's note: "Blue slate and shells"	1,100
Brownish-gray dolomite of fine texture and dark blue-black shale, in equal parts, together with some fragments of gypsum. No fossils noted. Driller's note: "Blue slate and shells"	1,150
Dark grayish-black, indurated shale with some brownish-gray and some pink dolomite, and a few fragments of gypsum. Several large fragments of pyrite and several small fragments of small sponge spicules noted	1,200
Black shale, with some gray dolomite and gypsum. Several small fragments of pink or red crystalline gypsum noted. No fossils noted	1,250
Light gray, fine-textured dolomite, together with almost equal quantities of black shale, slightly indurated and gypsum. Several fragments of pink gypsum noted. No fossils noted. A small fragment of pyrite adhered on the side of a fragment of pink gypsum	1,300

	Depth in Feet
Gypsum, with black shale in abundance. Some dolomite of a brown color is also present. The gypsum is mostly white, but several pink fragments were noted. No fossils observed	1,350
Dark grayish-brown dolomite of very fine texture, and a few fragments of gypsum, also a very little black indurated shale, some of the dolomite is almost black. No fossils seen	1,400
Dark gray-brown dolomite of very fine texture, with a few fragments of gypsum. Many fragments of black dolomite observed. Strong odors of bitumen are noted when the dolomite is heated in closed tube. No fossils noted.	1,450
Very light gray, fine-textured dolomite, containing some dark gray dolomite. The light dolomite is soft, but the dark gray dolomite is harder and of fine texture. Some gypsum present. No fossils noted	1,500
Light gray-brown limestone of fine texture, with some anhydrite and a few fragments of white chert. Several fragments of irregularly formed Ammodiscus were noted in black limestone fragments. A small *Fusulina* was seen in thin section	1,550
Soft white limestone of fine texture, with chert in profusion. The chert splits in thin fragments and is rather coarse-textured. Pyrite noted. Brown limestone also present. A thin section of the limestone shows a *Nodosaria* of six segments and many unidentified organic fragments of jaws and annelids (?) noted. In thin sections, the limestone is seen to be fine-textured, and to contain a great many needle-like sponge spicules filled with a white opaque material, also many fragments of various unrecognizable fossils	1,600
A mixture of gray and white fine-textured limestone, with white siliceous material. Fragments of *Fusulina* and *Productus* spines in abundance were noted. Pyrite present. A fragment of what appears to be a crinoid stem also was seen	1,650
A fine-textured white, siliceous material mixed with an equal quantity of hard black shale and containing many fragments of dark brown limestone, some of which show black parallel markings, probably organic. Many fragments of *Fusulina* and some *Productus* spines present. Sponge spicules noted. A fragment of what is apparently a crinoid stem was also seen and an *Archaeocidaris* plate.	1,700

	Depth in Feet
Dark, gray crystalline limestone, very hard, and slightly siliceous in composition. A small fragment of a silicified shell, probably *Productus*, was observed, and a few very small spines. Most of the very fine material is sand grains, rounded and highly etched	1,760
Dark blue-gray shale, of very fine texture, and well indurated, the shale shows joints and fracture surfaces of all shapes and at various oblique angles with the bedding planes. Pyrite is abundant, and the shale contains many fragments of soft, vari-colored concretionary materials and fragments of *Productus* spines	1,800
Dark gray, hard, fine-textured limestone and blue-gray shale. The limestone contains a soft chert in small veins and concretions, some white and some black. A fragment of shell of a brachipod was noted. Pyrite present. *Productus* spines, some siliceous, were noted. Sand grains and calcite also present	1,860
Dark gray and white limestone together with hard blue-gray shale. The limestone is partially crystalline, of fine texture, and of considerable hardness. *Productus* spines present, and considerable pyrite noted. Fragments of a brachiopod noted	1,900
Dark blue-gray shale, containing a few concretionary limestone fragments of brown and gray colors. Fragments of *Productus* shells and spines, and the basal knob of a spine noted. Two varieties of *Ammodiscus* were noted, one having a few coils of a tube of large diameter irregularly spiral, and one having a large number of coils of small tube wound to a perfect spiral. A fragment of *Trochammina* and an *Endothyra* noted. Pyrite present. Black carbonaceous fragments are profuse. Sponge spicules occur frequently, and the whole sample has a decidedly carbonaceous aspect	1,950
Black shale, with dense, fine-textured limestone of white and brown colors. Sponge spicules were noted frequently. *Trochammina incerta* and *Trochammina gordialis* noted infrequently. Carbonaceous organic material abundant. Pyrite and marcasite present and also black and green chert. A fragment of small gastropod was noted	1,960
Light gray, fine-textured sandstone, containing some concretionary hematite, concretionary ferruginous red limestone, and some pyrite and marcasite. The matrix of the sandstone is only slightly calcareous, and the stone contains few carbonaceous fragments. Some siliceous reddish-black and some blue-black shale was present in the sample	2,000

	Depth in Feet
Dark red-brown shale of very fine texture, and quite indurated. Many fragments of a very dense, fine-textured dark red limestone and sone fragments of gray limestone present. Vari-colored chert fragments are common. Pyrite and hematite occur infrequently, as do *Productus* (?) spines and fragments of shells. An *Endothyra* (?) also noted	2,050

NOTE:

At the time the San Angelo conglomerate was first studied by the senior author it was believed to be of Permian age for the reasons presented in the Bulletin on Runnels County, and later on Coke County.

The following conditions can be interpreted as evidence for that conclusion: First, and the strongest reason, is that at all places it occupies the same stratigraphic horizon throughout its extent as does the Blowout Mountains sandstone of Taylor County, and the Duncan sandstone of Oklahoma. This of course, could be explained as a fortuitous accident, though the air line length of the coarse conglomerate outcrop is fifty-five miles, but it seemed difficult to postulate this conglomerate to be part of a Triassic apron since it conformed so closely to the outcrop of Permian beds. Second: the sandstones and conglomerates of the whole section are nearly free from mica and fossil wood and there is a difference in the mineralogical composition of the Triassic and the San Angelo conglomerates. Third: such an extensive unconformity as that extending from the Colorado River to Central Oklahoma and Kansas forms an excellent setting for just such an occurrence as the San Angelo conglomerate.

Evidence against the Permian age of the San Angelo conglomerate is found in its general resemblance to the Triassic conglomerates farther west. This is especially true of the yellow-stained quartz gravel and larger pebbles, which certainly would argue for a similar origin.

Another reason of greater or less importance is the lack of other similar Permian deposits in this region. Anyone casually viewing the two conglomerates would regard them as being of the same age. So far as I am personally concerned, I leave the question open until further evidence accumulates which will clearly decide the matter. I am solely responsible for originally referring these beds to the Permian and for this note.

J. W. BEEDE.

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