University of Texas Bulletin

No. 1850: September 5, 1918

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J. W. Beede and W. P. Bentley

Bureau of Economic Geology and Technology

Division of Economic Geology

J. A. Udden, Director of the Bureau and Head of the Division

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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

THE GEOLOGY OF COKE COUNTY

By

J. W. BEEDE and W. P. BENTLEY

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THE GEOLOGY OF COKE COUNTY[1]

By J. W. BEEDE and W. P. BENTLEY

INTRODUCTION

The geology of Coke County was worked out in connection with the study of the section of the Permian rocks as exposed along the Colorado River. This section and the larger structural phenomena encountered constituted the main work within the county. The areal geology received minor consideration and is somewhat generalized. The study of the Comanchean beds was general. However, it is hoped that the treatment of the county as a whole will prove to be of value, and that some contribution has been made to the knowledge of it.

Mention should be made here of the generous assistance given us by the people of the county and especially to Mr. Charles Escue who devoted much time to assisting us with his detailed knowledge both of the land surveys and of the geology of the county.

GEOGRAPHY AND PHYSIOGRAPHY

Coke County is situated just southwest of the center of the state in what is usually referred to as "West Texas." It is about twenty-six and one-half miles wide by thirty-three and one-half miles long and has an area of approximately 888 square miles. The Colorado River flows south of east through the central part of the county. The main tributaries of the stream from the north are: Kickapoo, Cow, Indian, Mountain, Messbox, Yellow Wolf, Rough, Meadow, Sand and Silver creeks. All these streams rise on the Callahan Divide and flow south into the river. Those on the south side rise on the Edwards Plateau and flow north into the river. They are: Mule, Live Oak, Wild Cat,

[1]Manuscript accepted December, 1920; published March, 1921.

Paint, Salt, Pecan, Rough, Gasconade, and Heifer creeks.

The surface of the county is, on the whole, rough. The "mountains" on the north and south sides of the river rise from 100 to 500 feet above their bases. The valley region between the mountains is fairly well dissected and has an immediate relief, from creeks to divides, of 50 to 150 feet. The lowest point in the county, on the Colorado River, is approximately 1700 feet above sea-level, and the highest known

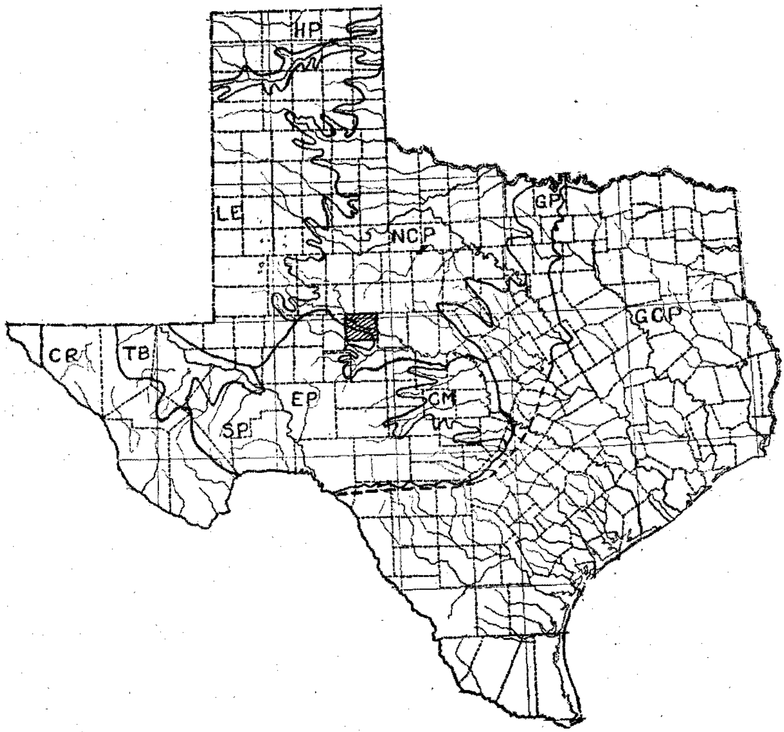

FIGURE 1

Sketch map showing physiographic regions of Texas, and location of Coke County. Abbreviations: HP, Panhandle High Plains; LE, Llano Estacado or Staked Plains; NCP, North Central Plains; CM, Central Mineral Region; EP, Edwards Plateau; TB, Toyah Basin; CR, Cordilleran Region; SP, Stockton Plateau; GP, Grand Prairie; GCP, Gulf Coastal Plain. The ruled area represents Coke County.

point, about 10 miles west of Blackwell in the eastern half of the county, has an elevation of 2558 feet. Higher points may occur in the western two-thirds of the county. This gives a total relief of at least 858 feet. The mountains south of the river are not so high as those on the north side of it, though they are composed of the same strata, which were

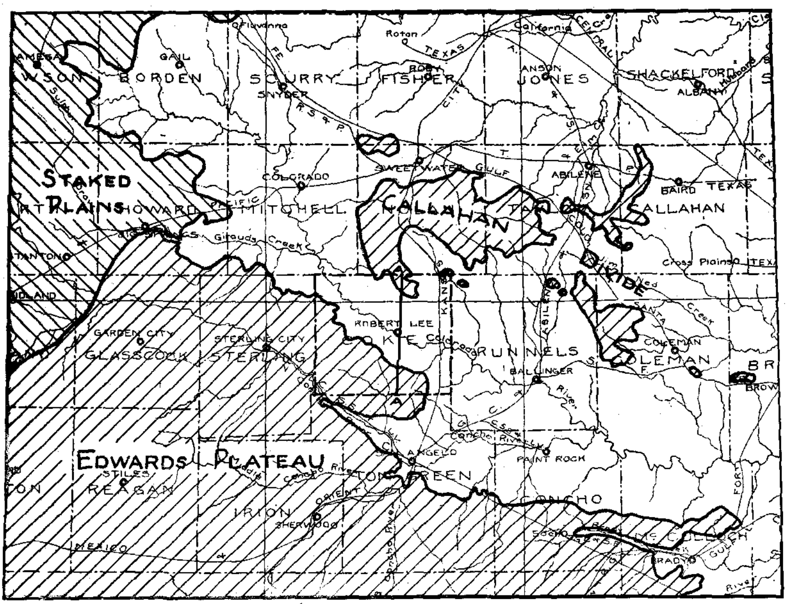

FIGURE 2

Sketch map of Coke County region showing Edwards Plateau, Callahan Divide, and the Colorado River Valley. A—A, location of the cross section shown in figure 3.

once continuous over the whole county. These upper (Comanchean) beds dip, or slope, to the southeast, making them higher north of the river.

The "mountains" in the south part of the county form the northwest part of the Edwards Plateau. This plateau is roughly bounded on the north by the Colorado River, on the south by the Pecos River, and extends from that section of the Balcones Fault scarp, or bluff, between Austin, San Antonio and Del Rio, northwest to the Staked Plains. The

North and South Section across Coke County near Robert Lee

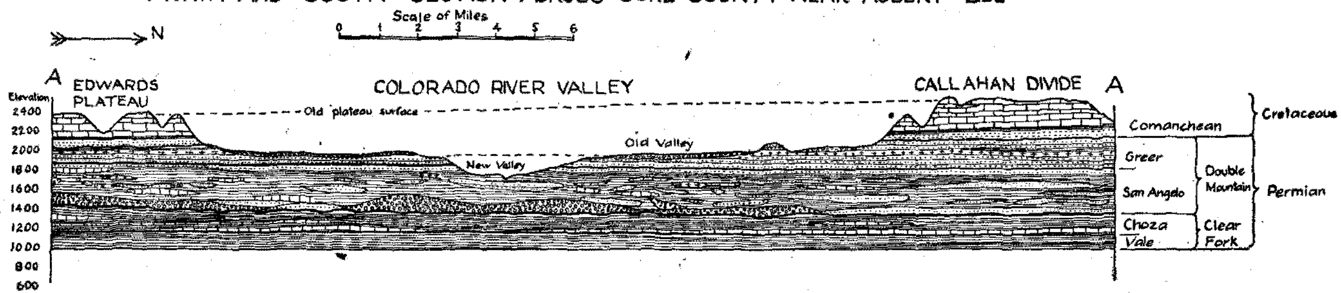

FIGURE 3

Section across Coke County near Robert Lee, showing Edwards Plateau, Callahan Divide, the old Colorado River Valley, and the new valley within it. It also shows a cross-section of the geologic formations of the central part of the county.

plateau was once continuous and unbroken over all of Coke County to the Callahan Divide and much farther both north and west to the Staked Plains. At that time the Colorado River flowed in the same general direction that it now does and probably near its present position. At any rate, it was over some part of the present valley between the mountains. In the course of time this river and its tributaries excavated a great wide valley which had a relatively even surface and was well drained. This valley is shown in the cross-section as the "Old Valley." In this way the northern part of the Edwards Plateau was cut away from its main body by the work of the Colorado River. The tributaries of the Colorado and Brazos rivers have cut the northern part of the plateau into a series of "mountains" or mesas, all of which have been called the Callahan Divide. They are remnants of the old plateau and are called "monadnocks." Moro Mountain and the Table Mountains in Runnels County, the Kickapoo Mountains, Hayrick Mountain, Cole Mountain and the Stepp Mountains of Coke County, are all monadnocks. A considerable part of the Callahan Divide forms the watershed between the Colorado River and the Brazos River.

The limestones of the Plateau and Callahan Divide are much more resistant to erosion than the soft red sandstones and shales beneath them. As soon as the Colorado cut through the firmer rocks into the softer beds below them, the river and creeks widened the valley rapidly by undermining the harder rocks. This process kept the bluffs steep and constantly crumbling in, with the result that the valley was widened much more rapidly than it would have been had all the rocks been firm.

After the old valley had been excavated, either the land was uplifted or else the Colorado River finally cut a deeper trench through the harder rocks farther east, so that the velocity of its current was sufficiently increased to cut a deep channel through Coke County. Even now, wherever the river runs on bed rock, it is still deepening it channel. Under these conditions the new valley was carved in the floor of the old valley. Small bottom lands along the river have been formed by the meandering stream. The creeks have cut deeply below the old valley and are still cutting down their beds in order finally to come into adjustment with the river.

In this manner the once relatively plane surface of the old valley has become quite rugged, and the larger creeks, like the river, have very little bottom land in their valleys. On account of the firmness of the Comanchean rocks of the Edwards Plateau and the Callahan Divide and the unresistant soft beds beneath them, the rise from the old valley to the plateau and mountains is abrupt, forming the steep walls of the Colorado River Valley.

SINKS

On the plateau are sinks and depressions which have no surface outlets. The open throats, or sinks, are frequently referred to as "blowouts" or "gas blowouts." In reality these holes or openings are simply solution holes dissolved at the cross joints, or cracks, in the limestone, by downward soaking rainwater. The water enters these cracks and slowly passes down until a horizontal plane between the layers is reached along which it may follow and below which the joint is closed. This water next comes out at the surface as a seep, or intermittent spring, in some canyon; or perhaps may continue as an underground flow beneath the gravel and boulders in the bed of the canyon without emerging as a surface stream. From the moment of its entrance into the rocks, the water begins to dissolve the limestone with which it comes in contact, until a vertical throat and horizontal channel are dissolved. These are called sinks, and caves, respectively.

(The accompanying illustrations show joints in the layers in Comanchean limestone in the mountains, and in Permian limestones on the lower plains. The latter rest upon soft clays which creep readily when wet, so that blocks are gradually pulled away from each other along the joint cracks and creep down the slope.)

A. Two monadnocks of the Callahan Divide. Kickapoo Mountain in the foreground, Hayrick Mountain in the left background. They are remnants of the Edwards Plateau.

B. One of the Table Mountains at Table Gap, Runnels County. Another relic of the former extent of the Edwards Plateau.

Pecan Creek running on bed rock and deepening its channel.

A. Joints in dolomitic limestone resting on clay shale. The larger (major) joints run from the foreground toward the background. The joint blocks are separating and creeping down the slope during wet weather. The minor joints run from right to left. Western Runnels County, Choza formation. Looking east.

B. Another view at the same locality, looking south. It shows the joints and joint blocks. The limestone here is creeping down the hill as in the other picture.

The water on entering the joints usually follows down the dip of the beds of the rocks. The normal dip of the Comanchean rocks of the plateau in Coke County is south of east. Probably much of this water ultimately finds its way into the underflow of the North Concho River. Sometimes these throats become sealed with clay, and the water stands in the basin of the sink for considerable lengths of time. In such cases the water may enlarge the sink basin by dissolving the rocks around its rim. In this way these upland lakes may grow to have a considerable area.

HISTORY

The first account of the geology of Coke County accompanied by a geologic map was given by Professor W. F. Cummins and Dr. Otto Lerch, in a paper entitled, "A Geological Survey of the Concho Country, State of Texas."[2] The "Concho Country" comprised Tom Green, Coke and Irion counties. In this article, the Permian, Cretaceous and later deposits were briefly described and mapped. In another article,[3] Lerch describes the San Angelo beds and gives their position between the Permian beds below and the Comanchean rocks above, also mentioning the fact that they are unconformable with both the Permian and Comanchean. His description of the formation, briefly, is as follows:

"Above this fossiliferous limestone (at Ben Ficklin) rests a quartz conglomerate about twelve feet thick. The pebbles are well waterworn, of small size and bound with a siliceous and irony cement. The conglomerate is stratified, dips toward the northwest under a steeper angle, however, than the underlying deposits, and is occasionally interspersed with large blocks of green and red speckled quartzite. The conglomerate is very hard, takes an excellent polish and is of a yellowish red color. Above it lies a series of red and yellow colored clays and sandstones, about one hundred feet thick, overlaid by lighter buff and whitish-colored thin beds of loose, friable sandstone and clays about fifty feet thick, followed unconformably by the Trinity sands." "I have traced this conglomerate for nearly twenty miles toward the north and its stratigraphic position with the beds above, below the Trinity sands...and propose for them the name 'San Angelo Beds'."

---

[2]Amer. Geol., Vol. V, pp. 321-325, 1890. Map.

[3]Amer. Geol., Vol. VII, pp. 74-77, 1891.

Twenty miles northward from San Angelo along the outcrop of these rocks would carry one to the vicinity of Mount Margaret, Coke County, where the best known exposures of the beds are to be found. There can be no question but that Lerch was following the prominent outcrop of these rocks from just north of San Angelo to the Mount Margaret region near Tennyson.

Since his formation closely resembled the Triassic conglomerate of the plains farther northwest, and appeared to be unconformable with both the overlying Comanchean and underlying Permian beds, Lerch referred them to the Triassic or "Jura-Trias," as described by Marcou. Lerch states that: "I am now inclined to think that this group of strata is of Triassic age and may be a southward continuation and thinning out of the strata 300 miles westward called Jura-Trias by Jules Marcou, the occurrence of which below the Staked Plains was announced many years ago by him." It is now found that in following these beds westward, they pass conformably beneath the Double Mountain beds of the Permian, as will be shown in the following pages. In the first of these papers Cummins and Lerch gave a section of the Comanchean rocks with a list of species of fossils, and discussed the later gravel, clay, and sand deposits.

The San Angelo beds rest upon the Clear Fork beds. In order that the significance of the terms "Clear Fork" and "Double Mountain" may be clearly understood in the following discussion, their original as well as later definitions as modified and more clearly stated in later work are reproduced here.

The first mention of the terms "Clear Fork" and "Double Mountain" beds was made by Dumble in the First Annual Report of the Geological Survey of Texas,[4] in which some of the characters of each were mentioned. Their first full definition was given by Cummins on pages 186 to 189 of the same report. They were more fully described later in the Second Annual Report[5] from which the following statements were taken.

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[4]Pp. lxix-lxx, 1890.

[5]Pp. 400-402, 1891.

Describing the Wichita, Clear Fork and Double Mountain beds, Cummins says:

> "I have separated the strata of the Permian into three divisions, under the names of Wichita Beds, Clear Fork Beds, and Double Mountain Beds. These divisions have been made more for the sake of convenience than for any other reason, especially the last two."

After giving the location of the Clear Fork Beds, his definition of the Clear Fork and Double Mountain beds is as follows:

> "The Clear Fork Beds are composed of limestones, clay and shale beds, and sandstones . . . The sandstones are not so abundant as in the Wichita Beds, and are not so massive, but generally thin-bedded. The clays are blue and red, the red occurring in thick, heavy beds . . ."

In defining the Double Mountain beds their features are thus characterized:

> "These beds lie in direct contact with the Clear Fork Beds throughout the whole length, and no attempt has been made to determine a line of division between the two divisions. The beds are composed of sandstone, limestones, sandy shales, red and bluish clays, and thick beds of gypsum. The limestones are generally of an earthy variety, and in places have many casts of fossils, the newer types being more largely represented than the older. The gypsum beds are numerous and many of them are very thick. All the clays and shales are impregnated with gypsum, and many of them carry a large per cent of common salt. The sandstones are generally very friable and of various colors, red, white, and spotted."

In short, the Clear Fork Stage is characterized by heavy shale beds, some sandstones and limestones. The Double Mountain stage is characterized by sandstones, thick gypsum beds, some sandy shales and earthy limestones. It should also be kept in mind that this differentiation was made in north Texas and not along the Colorado River. However, the definition holds very well for the Colorado River section. Indeed, the separation of the Double Mountain from the Clear Fork is much more definite and sharp than indicated by Cummins, both in the Colorado River region and in North Texas. This will be clearly shown in what follows.

STRATIGRAPHY

The oldest rocks exposed in Coke County are the upper 290 feet of the Clear Fork beds of the Permian system, found below Bronte along the Colorado River. Passing up the river from Cedar Mountain are the San Angelo beds, and a group of rocks between Robert Lee and the west line of the county, provisionally correlated with the Greer formation of western Oklahoma and the Panhandle of Texas. Both of these formations belong to the Double Mountain stage of the Permian system. In the northwest corner of the county is another formation, resting upon the Permian beds, which appears to belong to the Triassic system but which, as the point has not been determined with certainty, may well represent an unconformity at the base of the Quartermaster formation. The basal part of the formation is a very coarse quartz conglomerate, somewhat resembling the conglomerate in the San Angelo beds.

In most of northern and southern Coke County the rocks of the Comanchean system (or Comanchean division of the Cretaceous system) rest upon the Permian strata, while in the northwestern part of the county they lie upon the rocks just mentioned.

Over much of the Colorado River valley and the valley of the North Concho River are thick deposits of gravel, boulders and silt. These deposits are above the immediate valleys of the individual streams, usually 80 to 150 feet above the Colorado River, and a less distance above its tributaries. The age of this gravel and boulder formation is uncertain. It probably belongs to the late Tertiary or Pleistocene.

The soils, gravels and boulders of the lowest creek and river bottoms are of Recent age.

Permian

CLEAR FORK STAGE

The lowest rocks exposed in the county are the Merkel dolomite and about 270 feet of shales above it.

Choza Formation

The Merkel dolomite is excellently shown in the bluff of a creek west of Bullnose Mound across the line in Runnels County, and constitutes numbers 1 to 14 of the following section:

Section from Base of Merkel Dolomite as Exposed in Bluff West of Bullnose Mound and to the Base of the San Angelo Beds at Cedar Mountain.

		Feet	Inches
39.	Shale, red, with green sandstone streak which is a dolomite locally; 1 foot of coarse brown sandstone above; 2 feet of green shale on top....	11	
38.	Sandstone cemented with lime, 4 to 6 inches; shale, 3 feet; some platy, or nodular-platy, green shale	4	
37.	Shale, red	22	
36.	Shale, 5 feet; dolomite, 4 inches; shale, 15 feet; platy dolomite sheet on top..................	21±	
35.	Shale, 18 inches; dolomite, thin, pink............	1	1
34.	Shale, red, 4 feet; 1 foot rotten dolomite........	5	
33.	Shale, red, and 1 foot of dolomite................	20	
32.	Dolomite, 0 to..................................	0	6
31.	Shale, red	8	
30.	Dolomite, rotten	1	
29.	Shale, red	6	
28.	Dolomite	0	6
27.	Shale, red	14	
26.	Dolomite, 6 inches to...........................	1	
25.	Shale, red	44	
24.	Shale, red; some greenish thin dolomite on top....	16	
23.	Shale, red	12	
22.	Dolomite	1	
21.	Shale, red	8	
20.	Shales, variegated; dolomite on top..............	15	
19.	Dolomite bed	1	
18.	Shale, red	28	
17.	Dolomite streaks, crystalline limestone and some soft sandstone, 10 to.......................	12	
16.	Shale, red	14	
15.	Shale, red, with 4 inches limestone on top........	10	4
14.	Limestone, irregular	1	
13.	Shale	0	3
12.	Limestone	1	10

11.	Shale and granular limestone plate............	1	6
10.	Limestone in 3 beds, platy, ripple-marked........	0	9
9.	Shale with a 4-inch limestone in the middle......	1	
8.	Limestone, 3 beds; sheet of hematite on top.......	1	6
7.	Shale, olive	2	3
6.	Limestone, double bed, gray, 4 to 10 inches thick..	0	8
	thick	0	8
5.	Limestone, shaly, 9 inches to....................	1	6
4.	Dolomite, porous, coarse-grained, somewhat brecciated at the top; sheet of hematite 6 inches below the top............................	2	
3.	Shale, gray	0	4
2.	Limestone, gray, earthy, dense, rather hard, thin beds	1	3
1.	Limestone breccia in thin, warped beds, some of which are over a foot thick and cross-bedded..	4	

Numbers 1 to 14 of this section are the details of the Merkel dolomite bed as exposed in the bluff in a little creek west of Bullnose Mound near the county line.

Beginning at the top of this limestone as exposed at Teneyck Ford southeast of Bronte, numbers 15 to 38 constitute the section from the Merkel dolomite to the base of the San Angelo beds as exposed in Cedar Mountain. Most of the section is to be seen on the south side of the Colorado River. The top of this section forms the top of the Clear Fork beds, in which shales predominate and soft gray impure limestones and magnesian limestones are prominent in surface exposures. Sandstones are relatively rare, thin, and red.

An interesting feature in the Coke County exposures is the fact that as one goes west along an outcrop, thin dolomitic beds are seen to appear as parts of eastward pointing wedges. Somewhere in a shale exposure the end of a thin, light green band will be noticed, which gradually thickens toward the west. Careful examination of the point of it reveals a little calcareous cement in the sandstone or shale. If it is the latter, the streak is usually a little more sandy than the shale above or below it. Followed farther west the calcareous material increases and finally a thin bed of dolomite occupies the space. This is a phase of the change of much of the clay and sandy sediments into limestones in a southwesterly direction. If we could follow these beds for enough we would probably find the limestone or dolomite or dolomite band thickening and the shale between them thinning. These thin beds and some of the thicker ones appear as anhydrite in cuttings from the wells near Robert Lee. The total thickness of the Clear Fork beds in Runnels and eastern Coke Countis is approximately 800 feet.

DOUBLE MOUNTAIN STAGE

San Angelo Formation

The rocks of the San Angelo formation rest unconformably upon those of the Clear Fork beds. Thus there are 270 feet of shales and thin limestones between the San Angelo beds and the Merkel dolomite along the Colorado River, while near the Texas and Pacific Railroad only 25 feet of shale occur in this interval, according to Wrather.[6] The San Angelo formation varies lithologically from place to place. In eastern Coke County it is largely composed of coarse conglomerate and sandstone with some shales, while at other localities it is of finer-grained material and contains more shale. The following sections reveal to some extent these different phases.

Mount Margaret Section

		Feet	Inches
31.	Limestone, massive	1	
30.	Limestone, massive, weathers smooth, *Caprina*	5	
29.	Limestone and concealed interval	13	
28.	Limestone, hard	2	8
27.	Limestone, hard	5	
26.	Limestone, somewhat flaky	4	
25.	Limestone, very hard for these beds, fine-grained.	1	3
24.	Limestone, nodular, or hard nodular marl, quite fossiliferous, 10 feet 6 inches to	11+	
23.	Limestone with geodes and large gastropods, pelecypods, etc.; tends to weather into nodules	4	

[6]Proc. S. W. Petr. Geol. Assn. I, section, 1917.

22.	Limestone, less resistant than number 21........	4+
21.	Limestone, massive, rotten, fine-grained, weathers to a smooth surface........................	9
20.	Sandstone and sandy limestone..................	3
19.	Marls, fossiliferous	16
18.	Sandstone, buff, fine-grained, apparently calcareous	5
17.	Sandstones, algal, calcareous....................	2
16.	Clay, mostly olive.............................	23
15.	Concealed	60
14.	Sandstone containing concretions the size of small marbles, approximately in place.............	2±
13.	Float from Comanchean rocks..................	50
12.	Shales, red, and some soft, thin, sandstone, hardly noticeable; possibly 10 to 20 feet or more covered by float..............................	50
11.	Sandstone, pink, less iron than in the one below...	2±
10.	Sandstone, rather coarse, 20 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 25 feet above base......	65
8.	Sandstone, top conglomeratic....................	5
7.	Conglomerate, 6 inches to......................	4
6.	Sandstone, buff, locally a conglomerate, with pebbles 2 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 maroon sandy 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 the base of this section. This is quite variable locally. Number 10 is the top of the conglomerate beds which constitute the top of the San Angelo formation. On account of an inaccuracy discovered in the instrument used in measuring this section, some slight error may appear in the thickness of the beds, though this has been roughly corrected. The shales and sandstones between number 10 and the base of the Comanchean probably represent a higher formation of the Double Mountain stage.

Some of the coarser San Angelo conglomerate is cemented with iron, some has very little or no cement, and perhaps there are spots with calcareous-ferruginous, or even siliceous cement. Its appearance varies greatly from place to place. At Mount Margaret most of the large conspicuous pebbles are well rounded to subangular, iron-stained quartz pebbles. Associated with them are black and gray chert and other siliceous pebbles some of them rather intricately veined. There is some white and some reddish quartz. Some of the pebbles are 9 or 10 cm. in major diameter, and range from that down to fine sand. Some of the pebbles are coarse quartzite oxidized to a dirty dull brown and are thoroughly rounded. Most of the matrix of this conglomerate is sand.

A barometric section of these beds was published in the Runnels County report.[7] Later, a detailed section was measured for this report. At this locality and on Live Oak Creek east of the Humlong ranch-house the conglomerate is very coarse, containing quartz boulders, thoroughly rounded and iron-stained; rounded and subangular chert; some faulted and veined pebbles and boulders; and some quartzite. All minerals and rock less resistant to wear than silica are wanting. The size of grains and pebbles ranges from sand to cobbles.[8]

North of Bronte, one of the features of the lower beds of the formation is a series of layers of brownish sandstone conglomerates with rather soft yellowish pebbles of ocher-colored shale.

Permian Section at Kickapoo Mountain

	Feet	Inches
10. Shale, red	15	
9. Sandstone, brownish, very even-bedded, 18 inches to	2	
8. Shales, red, and concealed beds..................	30	

[7]Univ. Texas Bull. 1816, p. 50, 1919.

[8]Grabau. Principles of Stratigraphy, p. 287, 1913.

7.	Sandstone, buff-gray	2	3
6.	Concealed	2	6
5.	Sandstone, buff-gray, 3 feet to	4	
4.	Shale, sandy, green and red, 8 feet to	10	
3.	Conglomerate. 16 feet of conglomerate at the base, the larger pebbles an 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 has iron streaks in it and sandstone weathering gray-brown	26	
2.	Sandstone 8 feet thick in place, yellowish or brownish-buff, locally conglomeratic. Shales and talus below	26	
1.	Shales, blue, green, and brown, with some sandstone bands	76	

There is a considerable thickness of material below the base of the section which belongs to this formation. Farther north and a mile and a half east, the thickness between the top and base of the conglomerate is 277 feet. It appears that some allowance should be made for an east dip which would leave from 200 to 250 feet, or even more, for the thickness of the San Angelo formation in this vicinity. East of Blackwell, the conglomerate is still finer and there are very large joint blocks of quartzite present, the cement being siliceous. Farther north still, in the region of the Texas and Pacific Railroad, this formation is a sandstone, or a series of sandstones and shales.

It is worthy of note that the sandstones of the Clear Fork beds below the San Angelo formation which are of little importance in Runnels and eastern Coke counties, are largely red in color. In the San Angelo formation on the Colorado River they are buff or yellowish-brown and of quite different texture. If the outcrop is followed northward across the Callahan Divide, the sandstones are found to be red.

Above the San Angelo beds are 65 feet of the overlying Greer formation—numbers 4 to 10 of the section.

Cedar Mountain Section

		Feet	Inches
10.	Conglomerate and standstone, 20 to 30 feet.......	30	
9.	Shales, sandy and clayey, containing small calcareous nodules. Upper 2 or 3 feet of shales buff, carrying brown nodules, 10 feet to......	20	
8.	Sandstone conglomerate composed of fine-grained sandstone fragments, pebbles lighter colored than the matrix, followed by finer and less resistant sandstone beds. In the upper part some of the beds are pale crimson to dark red-brown tinged with purple. The sandstone contains much iron in the south end of the mountain	42	
7.	Shale, green	2	
6.	Shale, red, includes a 2-inch dolomite bed at 15 feet and another at 17 feet......................	27	
5.	Shale, red, 5 feet; dolomite, drab, 4 inches; breaks into 70 degrees parallelopipeds, somewhat finely crystalline.	5	4
4.	Dolomite, shaly or platy, shows strongly the impression of sun cracks in the shale below. Forms top of main flat-topped hillocks. Another thin bed above it......................		3+
3.	Shale, red, gray streak at top, sun-cracked.......	8	
2.	Dolomite; quartz or barite present. Ledge prominent near here.............................	0	4
1.	Shale, red	16	

Numbers 8 to 10 are the partial section of the San Angelo beds. They vary at the two ends of the mountain.

Sections from Cedar Mountain to Robert Lee

Section West of Cedar Mountain and East of the Mouth of Cow Creek

		Feet
4.	Shale, red, exposed in bluff 48 feet. Full thickness	50+
3.	Sandstone, cross-bedded, buff, and gray, 10 to....	20
2.	Shales, sandy, white and red. A few rods farther east they appear twice as thick as here.......	15±
1.	Conglomerate, sandstone, and shale. Sandstone, which contains some quartz pebbles as large as quails' eggs, is buff; contains lens of white sandy shale at foot of hill..................	38

At the time this section was studied the Colorado River was too high to permit the tracing of the beds along its banks and as a result it is impossible to state whether the conglomerate of number 1 of the section is the upper or lower conglomerate of the Cedar Mountain section.

Section on West Side of Cow Creek Near its Mouth

		Feet
4.	Sandstone conglomerate. No quartz pebbles. Over this is a 5-foot bed of sandstone.............	10
3.	Sandstone, soft, buff, some yellow sandy conglomerate and some concretions, upper part quite shaly, 20 feet to..........................	7
2.	Shale, sandy ferruginous, upper 2 feet leached......	17
1.	Sandstone in ravine near the river................	10

Number 1 of this section is the same bed as Number 3 of the previous section, and varies from 0 to 10 feet in thickness. It is probably a local lens. Number 2 varies from 0 to 25 feet, allowing Number 3 and Number 1 to come into contact locally. Number 3 is locally quite thin and in other places is thicker than the figures given. Number 4 varies from 0 to 10 feet, and in many places is absent from the section.

Section near creek above Cow Creek

		Feet	Inches
5.	Terrace conglomerate of variable thickness.		
4.	Sandstone, buffish, cross-bedded, shale parting in lower part	7	
3.	Shales, maroon, to base of next sandstone. Two sheets of sandstone in the shales, upper part of shale with dark crusty sandstone sheet. Upper part of shales greenish-gray...............	25	
2.	Sandstone, cross-bedded, stained red on outcrop, buff to brown within. Somewhat pitted. Exposed.	2	6
1.	Concealed, probably containing base of Number 2..	10	

Just east of this exposure the two sandstones come together, cutting out the shale bed between them. Farther on they separate again. This is characteristic of these two beds, as shown in the outcrop along the bluff. Between this locality and the Hester place, the following section is passed over:

		Feet	Inches
12.	Shales, red, sandy, 30 feet to	28	
11.	Sandstone, 10 to	20	
10.	Shale, red, 25 to	15	
9.	Sandstone and foliated gypsum	4±	
8.	Shale, red.	8	
7.	Sandstone with foliated gypsum in pieces	3±	
6.	Shale, red; some light-colored streaks	18	

Number 6 rests on top of Number 4 of the previous section.

Section at the Hester Place

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

Traced westward from Bronte these formations vary somewhat at different places, the sandstones and dolomites showing a tendency to pinch out locally, but by carrying a section of considerable thickness the horizons may be followed fairly well in a general way. None of the sections of the San Angelo formation can be duplicated in detail at any place other than the one measured.

GENERALIZED SECTION ON THE NORTH SIDE OF THE RIVER NEAR ROBERT LEE

A little farther west of the last section, at the road going east from the Halbert Place, the green material below the dolomite becomes sandy and a dolomite sets in at its base. Still farther west the sandstone is less than a foot thick and practically pinches out. Four feet above it is a 2-inch dolomite layer, 15 inches of red shale and nearly black shale, and another thinner dolomite. Over this is a thin sheet of calcareous material and more dark red shale. Up the hollow from this place the following section was taken:

		Feet	Inches
5.	Sandstone, cross-bedded, gray, oil showing in places. A lens from 6 inches to	20±	
4.	Shales, gypsiferous, sandy and clayey, scarlet to vermilion, yellow, and red in upper 3 feet and at the base, 6 feet to	8	
3.	Dolomite, two layers, 2 to 6 inches apart, gray shale parting with gypsum crystals. (These are the beds crossing the road east of the Pecan Mott.)	..	10
2.	Shales, gypsiferous, sandy, variegated	3	
1.	Sandstone, even-bedded, oil-impregnated	3	3

Section of bluff facing Mountain Creek below road crossing at Pecan Mott Farm

		Feet	Inches
10.	Recent conglomerate.		
9.	Sandstone like those below, 8 feet to	0	
8.	Shale, red, 5 feet, and beds of sandstone 6 and ½ to 8 feet	13	
7.	Dolomite, two layers, separated by thin shale	1	6
6.	Shale, lavender and other colors, 2 feet to	3	
5.	Sandstone, brownish to snuff-colored	2±	
4.	Shale, red, 5 feet to	7	
3.	Dolomite, two beds a foot apart separated by lavender shale. Lower bed twice as thick as the upper bed.	1	8
2.	Shale, red.	10	
1.	Sandstone, oil-bearing, very dark grayish-brown	2	

At the large dam on the Halbert place (Pecan Mott farm) sandstone Number 5 of this section is exposed. It thickens and thins considerably in short distances. The dolomite, Number 3 of the section, is below the sandstone at the west end of the dam. The heavier dolomite above the dam is Number 7 of the section. The lower of these two dolomites is only two feet above the sandstone. From this point upward, the lake section is as follows:

	Feet	Inches
7. Sandstone and crystalline calcareous material....	7	
6. Shale, red, green, sandy bed 6 feet below the top	20	
5. Shale, green, sandy	1	
4. Shale, red.	5	6
3. Dolomite, double bed	1	
2. Shale, red.	15	
1. Dolomite, two thin beds and some underlying shale	5	

Thirty feet above the dolomite, Number 7 of the section preceding the one above, is a 6-inch dolomite, and another is found three feet above that. The sandstone, Number 5 of the same section, is two feet to 10 feet thick. Thirty-five feet above Number 1 of the same section is a 2-foot bed of soft sandstone. Twelve feet above this sandstone is another dolomite four to five inches thick, followed by eight feet of shale to the base of a 20-foot sandstone, with a sheet of crystalline calcareous material on top, which, in places, is rather thick. Some of the lower beds are conglomeratic. The upper bed of sandstone is persistent and may be the one which passes under the divide to the west and appears on the east side of Mountain Creek north of the Bronte road.

The sandstone which forms the top of the hills at the lake (above Number 7 of the lake section) is lenticular. It is quite thick at the "Bridges Well" exposure on Mountain Creek. It is well exposed beneath the bridge over Mountain Creek on the Bronte Road.

The preceding sections are believed to cover the whole thickness of the San Angelo beds as exposed from Cedar Mountain to their top near Robert Lee. They are taken along the north side of the river and are so selected as to show as nearly as possible the most typical section of the formation.

Most of the San Angelo beds are wedges rather than lenses. The conglomerates and sandstones grow thinner and finer toward the west and appear to split up in that direction. The result is that the shales and thin dolomites wedge out toward the east and irregularly dovetail into the coarser beds.

In the western part of this region there are long crooked channels, of varying width and thickness, filled with cross-bedded sandstones. Some of these are hardly 40 feet across and some are quite large. One of these channels extends nearly west and is rather crooked where erosion gullies and valleys have revealed it. Such beds appear as sections of lenses of sandstone in the faces of the bluffs which cut across them. The sandstone filling these channels is always buff or yellowish-brown, as are the more massive sandstones of this whole formation. They may be thought of as fossil creeks, or delta channels.

Rarely can a section in the San Angelo formation be duplicated a short distance away, but when all the details are worked out it is readily seen that the sandstone and shale beds follow certain horizons quite closely thereby aiding in the construction of a section up the river.

The shales appear to set in as wedges with points to the eastward or southeastward, and thicken to the westward and northwestward. They thicken faster than the sandstones and conglomerates thin out, and in this way increase the thickness of the whole formation. It would seem that this is a delta with its crooked channels filled with sandstones, some of which are in regular cross-bed strata. The gravel becomes smaller westward and northward until but relatively few very thin sheets of conglomerate occur near Robert Lee, and none of much consequence seems to have been encountered by the drill in either the Locke or Stroud wells. The whole San Angelo formation in these wells seems to have been 400 feet in thickness.

The whole section may not be exposed at Mount Margaret, but it probably does not exceed 200 feet at that place, although in the region of the northern part of the Kickapoo Mountains it is thicker.

It seems likely that well records farther west will show this formation to contain more and more limestone, gypsum, and dolomite, less and less sand, with decreasing amounts of shale as these deposits merge with the calcareous deposits of the central part of the basin in West Texas.

This formation crosses the Texas and Pacific Railroad to the northward and in all probability forms the base of the Double Mountain formation as described by Cummins. It can possibly be traced to the Red River. To the south and southwest it is buried beneath the rocks of the Edwards Plateau.

Eskota or Greer Beds

On top of the San Angelo beds is a series of soft, evenly bedded, clayey, fine-grained sandstones and fine sandy shales provisionally referred the Greer stage. As a rule the sandstones and shales are dark red. Locally they are leached to a buffish or greenish shade, and there are occasionally persistent light-colored beds. In this formation are many heavy gypsum beds. Throughout its extent in Coke County only one thin sheet of limestone has been seen, and that is of very peculiar crystalline texture which locally is found to be very sandy. It is correlated by Wrather with the dolomite in the Eskota gypsum. Along the Colorado River the Greer formation, on account of its even bedding and finer composition, is sharply separated from the San Angelo formation, though it is probably conformable with it. The shales are of darker color and carry very fine sand, and the sandstones are even-bedded and persistent for red-beds strata. They occur at Mt. Margaret and Kickapoo Mountains and continue up the Colorado River to the west line of the county.

Section at "Hill Number 1"

		Feet	Inches
9.	Interval with some red sandy shales	12	
8.	Sandstone, laminated, light red-brown	2	6
7.	Interval, sandstone near top	4	
6.	Sandstone, blocky	1	
5.	Shales, red	8	
4.	Sandstone conglomerate, quartz pebbles, mostly fine	5	
3.	Sandstone and shales, ferruginous	47	
2.	Sandstone	7	
1.	Interval in which occurs sandstone, sandy shale, and some irony material	18	

Number 8 has the same appearance as the first even-bedded sandstone above the top of the San Angelo formation elsewhere, and is in all probability the same bed.

Section near first house on Sterling City auto road, after leaving the pike

		Feet	Inches
9.	Limestone conglomerate, Tertiary or Recent.		
8.	Shales, sandy, red	6	
7.	Sandstone, dark brick red, massive to laminated, very evenly bedded throughout	9	
6.	Shale, red, sandy, green band at top	11	
5.	Sandstone, laminated, dark brick red, a little shaly red sandstone on top	22	
4.	Sandstone, blocky, red, irresistant	3	
3.	Shales, sandy, green and red	2	
2.	Sandstone, platy, red, green streaks at base	1	
1.	Shale, red, blocky, somewhat sandy	2	

This section appears to be above the San Angelo beds.

LOWER WILDCAT CREEK

The basal part of this section is nearly as low as the beds in Hill No. 1 or near the base of the Greer formation.

		Feet	Inches
19.	Shaly, sandy, material, dark red	15	
18.	Sandstone, greenish-white	10	
17.	Sandstone and shaly dark chocolate beds. 8 to	10	

16.	Sandstones and shaly streaks, green, hard white layer 2 feet below top changes to laminated bed here	10	
15.	Sandstone, hard, red-chocolate	1	8
14.	Sandstone, massive, chocolate, shale at base, green blotches	4	6
13.	Sandstone, two beds, shale parting, chocolate-colored with green blotches, upper bed massive and thicker than the lower bed	6	
12.	Sandstone, soft, green, firmer than No. 11	0	6
11.	Sandy bed, mottled, shaly	4	6
10.	Sandstone, hard, red	2±	
9.	Sandstone, laminated, red and greenish (all stained red on outside)	1	6
8.	Shale, red, blocky, in part laminated, sandy	2	6
7.	Sandstone, green		6
6.	Shale, sandy, and shaly sandstone	9	
5.	Sandstone, hard bed, shaly, red, 8-inch hard bed	3	3
4.	Sandstone, green		9
3.	Sandstone, soft, massive, red, green specks	4	
2.	Sandy layer, green, 6 inches to	1	
1.	Shale, blocky, red	6	

Section on Wild Cat Creek
Above Bridge on Sterling City Road

32.	Sandstone, salmon-colored	2	6
31.	Sandstone, firmer than the one below	15	
30.	Shaly material, soft, dark red	20	
29.	Sandstone, soft, laminated, brick-red	16	
28.	Interval, mostly red shale	20	
27.	Sandstone, evenly-bedded, soft, salmon-colored	8	
26.	Shaly sands, red	4	
25.	Sandstone, massive, red	2	6
24.	Shale, sandy and shaly sandstone, dull red to green	3	
23.	Sandstone, rather soft, evenly-bedded, dark brick-red	9	6
22.	Shale, sandy, red, 2 feet to	3	
21.	Gypsum, pink, in nodules and crystals	0	1
20.	Sandstone, laminated, green and salmon-colored	7	

Section of Colorado River Bed
Below the Wagon bridge West of Robert Lee

		Feet	Inches
7.	Sandstone, green, shaly, top not seen	2—	
6.	Shaly, red, green on top	3	
5.	Sandstone	0	3
4.	Shale and thin sheets of sandstone	8	

3.	Shales, red, containing gypsum. 14 inches to.....	4±	
2.	Sandstone, shaly, gypsiferous, 4 inch denser, sandstone at base	2	4
1.	Shale, red, many sheets of satinspar, blocky shale	8	6

Section of the Seaton Keiths Bluff,
Three Miles West of Robert Lee

		Feet	Inches
18.	Conglomerate, Tertiary or Pleistocene............	40	
17.	Sandstone, evenly-bedded, friable, massive, red, some greenish specks and masses near the bottom and at the top............................	15	
16.	Earthy beds, blocky, clayey, and sandy material with few signs of stratification...............	20	
15.	Sandstone, reddish, polka-dotted, friable, very irregularly bedded, 3 feet to...................	2	
14.	Sandstone, soft, blocky, green, friable............	6	
13.	Sandstone, very friable, blocky, dark red.........	9	
12.	Sandstone, greenish gray, stained red on outside, 7 feet to	6	
11.	Shale, sandy, blocky, red, or impure sandstone.....	9	
10.	Sandstone, two or three beds, firmer than beds below, greenish, stained red, shaly locally.......	6	
9.	Shales, sandy and soft sandstone. The top of this bed and the base of the one above form a dominant line along the west cliffs, 20 feet to.....	16	
8.	Sandstone, two beds, slightly gypsiferous (three beds in west part of bluff), forms light red-brown double band along bluff, with greenish beds below it..............................	8	
7.	Shaly material, mineralized, greenish.............	2	
6.	Shales, somewhat lenticular, contain some gypsum	8	
5.	Sandstone, laminated, red, thickening from a few inches to	3	
4.	Shale, red, some gypsum, contains some sandstone	8	
3.	Sandstone, shaly, friable, red, much gypsum......	2	
2.	Sandstone, laminated, red, some gypsum..........	1	8
1.	Gypsum, massive, with masses of crystalline gypsum scattered through it. The upper 5 feet contain some shale. Base shaly, with satinspar	12±	

The basal part of this section may duplicate the base of the previous section, which is probably near the gypsum horizon above Wildcat Creek bridge.

Section of Bluff on East Side of Second Creek
East of John Saul's place.

		Feet	Inches
5.	Sandstone, red-brown	20	
4.	Sandstone, shaly, pale red........................	15	
3.	Sandstone, gray	7	
2.	Sandstone, soft, red........................	45±	
1.	Sandstone in creek (below recent conglomerate) cemented with gypsum and containing gypsum masses	5±	

Rough Creek Section, near Meneille House

		Feet	Inches
14.	Sandstone, massive, light red........................	5	
13.	Sandstone, soft, gray, and shale........................	1	
12.	Sandstone, massive, quite friable, red............	48	
11.	Sandstone, greenish-gray, prominent, apparently same green bed seen in Seaton Keiths Bluff (Number 12 of that section)........................	7	
10.	Sandstone, massive, reddish........................	3	
9.	Shale, red	1	6
8.	Sandstone, massive to shaly, parti-colored, quite gypsiferous, masses of gypsum in upper part..	7	
7.	Shale, very gypsiferous........................	2	6
6.	Sandstone, salmon-colored very gypsiferous.....	7	
5.	Shale, red and gray, small masses of gypsum......	4	6
4.	Sandstone, parti-colored, gypsiferous.............	4	
3.	Gypsum, sandy, or gypsiferous sandstone.........	5	
2.	Sandstone, red and green, shaly, sheets of gypsum	5	
1.	Sandstone with gypsum streaks.................	20	

South Pecan Creek Section, Bluff Above Graveyard

		Feet	Inches
10.	Limestone conglomerate, Pleistocene?		
9.	Sandstone, rather evenly-bedded, red, joints and cracks filled with calcareous material from conglomerate above	12	
8.	Sandstone, evenly-bedded, nodular, gray to deep red. Some small gypsum crystals...........	6	
7.	Sandstone, massive, evenly-bedded, harder than that below, salmon-colored	5	6
6.	Sandstone, darker and more friable than number 5	3	
5.	Sandstone, relatively hard, massive, gray to salmon	3	
6.	Sandstone, salmon-colored very gypsiferous......	7	
3.	Sandstone, massive, soft, weathers into large rounded nodules	10	
2.	Sandstone, massive, soft........................	12	
1.	Concealed from creek bed........................	12	

Farther down, the following section is shown in the creek:

		Feet	Inches
3.	Sandstone, soft	2	
2.	Shale, hard, purple, and thin plates of white sandstone	0	6
1.	Sandstone, poorly stratified, soft	18	

The purple shale is rather persistent and in places comes in over a gypsum bed which has been dissolved away in this immediate region. This accounts for the peculiar slumped-faulted appearance of the section.

A little farther down South Pecan Creek the following section is exposed:

		Feet	Inches
4.	Packsand, as in previous section, residual from dissolved gypsum beds, 4 feet to	10	
3.	Sandstone, red and gray, slump at top, 2 feet to	3	
2.	Shale, sandy, and shaly sandstone	4	
1.	Sandstone, massive, quite friable, red	7	6

Number 1 of this section is 10 feet thick with two feet of yellow or red shale beneath it, as shown by other nearby exposures. Beneath it are seven feet of quite petroliferous sandstone.

Section of the Rocks of the Bluff on South Pecan Creek, Just Above the Junction of North and South Pecan Creeks

		Feet	Inches
10.	Sandstone, thinner-bedded than number 9	25±	
9.	Sandstone, amorphous residual material from dissolved gypsum layers, 10 to 20 feet	15±	
8.	Shale, with sheet of ripple-marked sandstone, 2 feet to 6 inches	1	6
7.	Sandstone, even bed	3	6
6.	Shale, red	2	8
5.	Sandstone, massive, red, cross-bedded, green at south end of bluff	5	6
4.	Shale, sandy, thin sandstone in the middle	4	6
3.	Sandstone, green or gray, at south end of bluff, red near the north end	6	6
2.	Shale, yellow or gray	2±	
1	Sandstone, yellow and gray, 5 feet showing above creek bed	5±	

The thickness of the two upper beds is estimated. Beds 9 and 10 are crumpled due to the solution of gypsum from the rocks of Number 9. The latter bed is thinned cor respondingly.

Section of the Rocks and Conditions from Mouth of Pecan Creek to Base of Last Section

		Feet	Inches
16.	Sandstone, gray	10	0
15.	Shale, red	1	0
14.	Sandstone, gray to red	1	8
13.	Red shale	1	8
12.	Sandstone with shale and nodular sandstone in lower part	7	5
11.	Sandstone, massive, salmon-colored	4	0
10.	Shale, and sandstone containing boulders	3	0
9.	Interval, 5 to 15 feet	10±	
8.	Sandstone and shale; 25 feet of new beds; 15 feet of shale at east end reduced to 5 or 6 feet	25	
7.	Sandstone, massive to shaly, somewhat mottled mostly dark red. Rests on Number 6, just above Arlitt ranch-house. Lighter-colored blocky bed at top may be white-washed from caliche	45	0
6.	Sandstone, three beds, massive to cross-bedded, light-colored and red, about	20	0
5.	Sandstone, red to mottled, massive, with 6 inches to 1 foot of mottled shale at the top	4	6
4.	Next section half mile upstream, right bank, unexposed interval between sections, 5 feet to	15	
3.	Sandstone, massive, cross-bedded, gray, some salmon-colored masses, resistant, has general appearance of gray layer on opposite side of river	4	0
2.	Sandstone, massive, shaly at base, red, some gray spots	6	0
1.	Sandstone, massive to knotty, red and mottled, two beds	5	0

Section of Bluff on south side of creek at bend

		Feet	Inches
8.	Shale.	5	
7.	Sandstone, massive bed below	7±	
6.	Shale.	2±	
5.	Sandstone.	5—	

4.	Shale.	1—
3.	Sandstone.	25±
2.	Shale.	1
1.	Sandstone in creek bed.	2+

Number 3 of this section is probably Number 16 of the previous section and is the base of the next bluff on the west side of the creek.

The beds of lower Pecan Creek are nearly the same hori zon as some of the upper beds in Seaton Keiths Bluff section. There is a persistent greenish-gray bed traceable along the north bluffs of the river from Seaton Keiths Bluff to Rough Creek, nearly opposite the mouth of Pecan Creek, and this may be represented by Number 3 of the section at the mouth of Pecan Creek. The massive sandstones of the bluff below forms the base of the following section on the Parsons place.

		Feet	Inches
19.	Sandstone.	2	
18.	Shale.	2	6
17.	Sandstone, massive red or greenish.	8	
16.	Shale, red, sandy	4	
15.	Sandstone, massive, red, green locally.	6	
14.	Shale.	3	
13.	Sandstone, massive yellowish gray bed.	4	
12.	Sandstone, 4 or 5 thin beds.	6	6
11.	Sandstone, massive.	14±	
10.	Shaly gypsum	3	
9.	Sandstone (equals No. 3 of previous section). . . .	4	6

This section is numbered continuously with the second one above.

Section on river at mouth of Gulch, N 28° E from Millikan Mountain

		Feet	Inches
18.	Sandstone, red, knotty, green and gray, locally shaly, all very irregular.	20	
17.	Shale, yellowish and soft sands. Across canyon this bed is red and apparently gypsiferous.	20	
16.	Sandstone, red, and red shale, all very uneven; platy conglomerate of sandstone and other material	4±	

15.	Sandstone, dark red, top very uneven............	4	6
14.	Shale, sandy.	5	
13.	Sandstone, massive, red.	4	6
12.	Shale, red, fine sand...........................	6	
11.	Sandstone, green below, red above...............	12	
10.	Shale, soft, sandy and red sandstone............	7	
9.	Sandstone, soft yellowish, "gyppy?"	5	
8.	Shale, yellowish-gray, sandy, gypsum?............	10	
7.	Sandstone, soft, red	3	
6.	"Gyppy" material, red-gray	6±	
5.	Sand, soft, gray, gypsum	10	
4.	Shale, soft, red and greenish sandstone, shale below	5	
3.	Sandstone, rather shaly, greenish-gray............	4	
2.	Sandstone, massive, greenish-gray...............	20	
1.	Shales, green, red, and gray, grading into sandstone	3	

Much gypsum has been dissolved from beds of this section, especially beds Nos. 6 to 10, and probably beds Nos. 16 to 18. It existed as beds of gypsum, or gypsum in small masses, while some of it formed the cementing material of the rock.

In order to bring out the changing aspect of the beds from place to place—even though the beds are much better stratified and more persistent than those of the San Angelo beds—the part of the section from Number 5 of this river section to its top is repeated in fresh exposures at the head of the canyon.

		Feet	Inches
33.	Limestone, siliceous	2	0
32.	Shale, mottled (probably top of river section, 6-10 feet) only 5 feet visible.....................	5	0
31.	Sandstone, red	4	4
30.	Shale, red, or shaly sandstone....................	23	
29.	Crusty material, calcareous appearance. Horizon of platy conglomerate; equals number 16 of river section	5	0
28.	Sandstone, red	11	0
27.	Shale, red	5	
26.	Sandstone, soft, earthy, red; basal part of this bed is main upper firm bed of the river section....	20	
25.	Shale.	5	
24.	Sandstone, largely soft..........................	10	

23.	Sandstone, very irregularly bedded; equals No. 7 of river section...........................	7	
22.	Shales, purple, sandstone above and below........	0	6
21.	Sandstone, earthy, and soft material (gypsum dissolved out)	10	
20.	Sandstone red, and calcareous material (gypsum dissolved out)	8	
19.	Gypsum, massive; equals No. 5 of river section....	7	

Beds Nos. 19-24 of ravine section and Nos. 5-9 of the river section represent Nos. 9 and 10 of the Pecan Bluff section. In the last mentioned locality, solution of the gypsum from between the sandstone and shaly layers has produced the peculiar wavy appearance of the face of the bluff. The purple shale well up in this formation, seen above the bluff of South Pecan Creek associated with sandstone, comprises Number 22 of the ravine section.

Number 33 of the section is of very peculiar appearance and often has a crystalline cellular structure, sometimes sandy, and is very persistent from the high bluffs of upper Pecan Creek region to the west side of Wilson Mountain where it dips into the river. It is the only calcareous bed so far seen in the upper part of the Double Mountain beds of Coke County. For this reason it is particularly valuable as a base on which to work out structure in this region.

Section Southwest Side of Wilson Mountain

		Feet	Inches
4.	Shales, red, some shaly sandstone and probably some gypsum lenses or beds..................	78	
3.	Gypsum, massive, interstratified with larger and smaller amounts of shale and sandstone.......	78	
2.	Pseudo limestone or dolomite....................	2	
1.	Shales, red, filled with intersecting thick sheets of satinspar, lenses of gypsum 1 to 2 feet thick at top on side mountain.....................	34	

Farther northwest, heavy gypsums occur immediately below the dolomite as well as above it. Farther west a greater thickness of similar beds comes in below the base of the overlying formations.

Quartermaster Formation (?)

In the northwest corner of Coke County occur some deposits of uncertain age. They are composed of coarse quartz, quartzite, and chert conglomerates, in a brownish sandy matrix associated with very dark maroon shales and impure sandstones. Locally these conglomerates and even the maroon sands are nearly black. Rocks of Comanchean age rest upon them. At the present writing it is impossible to state whether they are of Triassic (Dockum) age, or whether they are a formation similar to the San Angelo, occurring well up in the Double Mountain beds. If the last is the case, as seems probable, then they may represent an unconformity between the Greer and Quartermaster beds. These beds are best developed in the Panther Gap-Stepp Mountain region.

On the south side of the river, southwest of Wilson Mountain, similar beds appear, which are covered by the old river conglomerate. Because the slopes of the scarps below the soft basal Comanchean are covered with its debris, it is difficult to find a clear contact at the exposures visited. Until this section is carried farther up the Colorado River, and its position accurately determined, it is better to leave further discussion of the age of these beds in abeyance. One of the best sections seen is at Panther Gap.

Panther Gap Section

15.	Limestone, nodular, more above it	5±
14.	Concealed	15
13.	Limestone, nodular	7
12.	Marl, yellow, filled with fossils, *Exogyra texana*, gastropods, etc.	4
11.	Limestone, dark buff, a fossil conglomerate, *Exogyra* and *Gryphea*	2
10.	Sandstone and sand. Gray to dark buff	12
9.	Conglomerate, coarse, white, quartz, etc. in it. Sand just below it. Comanchean	4
8.	Concealed	25
7.	Sandstone, pink and buff, like Trinity but firmer	25±
6.	Conglomerate, sandy, firm	10

5.	Shaly material	5±
4.	Sandstone, light brownish, 5 feet to.............	10
3.	Conglomerate resembling that at Mt. Margaret....	25
2.	Sandstone, yellow, purplish, and green............	20
1.	Shales, gray-green	5

Numbers 9 to 15 are certainly of Comanchean age, while Nos. 1 to 6 appear to be older. No fossils have been collected from these lower beds. The conglomerate, Number 3, is made up of several components.

Beds Nos. 1 to 6, inclusive, are quite different from the usual exposures of the Comanchean sands of Runnels and Coke counties. There is a locality near Nipple Peak south of Bronte which contains somewhat similar gravel but this is apparently reworked and forms the base of the Comanchean beds.

The conglomerate in beds Nos. 1 to 6 is composed of larger and smaller pebbles of quartz and chert. The quartz is usually thoroughly rounded and the chert less so, much of it being subangular. The matrix is sand which is sometimes cemented with iron oxide.

This conglomerate is on the average finer than the San Angelo conglomerate at Mount Margaret, but pebbles an inch to five inches across are to be found in the region east of the Gap and north of the road. There are two varieties of quartz at Mount Margaret, white and red. The white is more common. There are fewer pebbles of quartz than of chert in the Panther Gap conglomerate, while the sand of the matrix contains much more quartz than chert. Some beautifully veined pebbles have been seen. The cherts are black, green, and gray. The green chert is quite prominent in some spots. It has the appearance of the green cherts of the Caballos formation of the Marathon region.

LOGS

Driller's Log, Stroud No. 1 Well
Robert Lee Oil Co.
Located Three Miles West of Robert Lee, Texas, on Wild Cat Creek
December 30, 1918

	Depth of feet below surface From	To
Surface	0	20
Sand rock	20	46
Gravel and red clay	46	78
Pack sand	78	160
Red shale. Oil and gas showing at 175 feet	160	320
Hard red shale	320	420
Rock	420	422
Red shale	422	454
Soft sand rock with a little lime	454	500
Hard sand and lime rock	500	560
Red shale boulders	560	650
Hard rock with lime gypsum	650	690
Variegated shale boulders with lime	690	834
Lime rock	834	850
Variegated shale	850	877
Gumbo	877	879
Hard sandstone	879	881
Hard variegated shale	881	975
Hard shale, thin strata rock	975	1038
Sandstone, hard	1038	1049
Shale, thin strata hard lime rock	1049	1182
Blue gumbo	1182	1184
Hard variegated shale	1184	1202
Gray limestone	1202	1356
Blue gumbo	1356	1361
Limestone	1361	1373
Shale	1373	1378
Limestone	1378	1404
Black gumbo	1404	1407
Limestone	1407	1419
Variegated shale, blue below 1502	1419	1557
Hard limestone	1557	1589
Dark blue shale	1589	1678
Light colored limestone, fairly soft	1678	1697
Black gumbo	1697	1699
Limestone	1699	1744

Blue shale	1744	1821
Dark blue limestone	1821	2020
Blue shale and lime	2020	2152
Rock, very hard and rough drilling	2152	2166
Shale	2166	2189
Gumbo	2189	2191
Blue shale and lime (quite a lot of lime)	2191	2197
Hard limestone	2197	2324
Hard limestone with soft strata	2324	2411
Hard limestone	2411	2448
Hard limestone with thin soft strata	2448	2506
Limestone with strata of soft lime shale	2506	2625
Hard grayish limestone	2625	2733
Soft limestone, very light color	2733	2785
Hard limestone	2785	2825
Soft limestone	2825	2845
Hard limestone	2845	2875
Sand, salt water	2875	2890
Hard limestone with many shells	2890	2986
White sand, salt water, some gas	2896	3004
Limestone. hard, with pyrites	3004	3028
Limestone and pyrites: hardest drilling yet encountered	3028	3068
Coarse sand, salt water	3068	3078
Hard limestone, pyrites	3078	3093
Pyrites of iron. Solid strata, very hard	3093	3108
Sand, salt water	3108	3123
"Little lime and lots of shells"	3123	3131
Limestone and lime shells	3131	3156
Hard limestone with pyrites of iron	3156	3231
Limestone with coal	3231	3250
Limestone with pyrites	3250	3270

Driller's Log of Westbrook No. 1 Well, at Tennyson, Coke County, Texas. Completed in December, 1919.

	Depth below surface in feet	
	From	To
Red rock	0	120
Lime, hard. Water, eight bailers per hour	120	135
Shale, brown, caving	135	171
Lime, gray	171	200
Missing	200	290
Red rock	290	320
Lime, gray	320	332
Red rock, lime shells	332	410
Lime, gray hard	410	436

Slate, blue, and mud	436	500
Slate, blue, and shells	500	540
Lime, hard, gray	540	595
Sand, white, soft (quartz)	595	597
Red rock	597	640
Shale, blue, soft	640	685
Shale, brown, soft	685	735
Shale, blue, soft	735	750
Lime, white hard	750	790
Shale, white, soft	790	795
Lime, white, hard	795	855
Lime, black	855	860
Lime, white, hard	875	887
Shale, blue, soft	887	893
Lime, white, hard	893	922
Shale, soft, white	922	933
Lime, white and gray	933	1022
Shale, white	1022	1032
Slate, limy	1032	1075
Lime, hard, white	1075	1095
Shale and shells, white	1095	1115
Slate, dark	1115	1125
Lime, dark, broken, sulphur water at 1195	1125	1205
Shale, white	1205	1220
Lime, dark	1220	1320
Shale and lime, dark	1320	1384
Lime, gray	1384	1470
Shale, light	1470	1485
Lime, dark blue with shale breaks	1485	1632
Shale, brown	1632	1638
Lime and shale, gray, gas sand, sulphur water at 1850, water up to 250 feet from collar	1638	1850
Lime, gray	1850	1970
Lime, dark, water, 4 bailers	1970	1985
Lime, water, hole full	1985	2025
Lime, break at 2145 feet. Parafin scum	2025	2145
Lime, gray	2145	2330
Lime	2330	2375
Lime, sandy, 2 bailers water	2375	2385
Lime	2385	2420
Shale, broken, and lime shells	2420	2438
Lime	2438	2450
Shale, blue	2450	2460
Shell	2460	2465
Shale, blue, caving	2465	2500
Lime, gray, sandy	2500	2510
Shale and brown shell	2510	2570

Brown shale, light	2570	2600
Hard shell	2600	2602
Lime, broken, and shale	2602	2610
Lime, hard	2610	2620
Shale, blue	2620	2622
Lime	2622	2625
Shale, white	2625	2628
Shell	2628	2630
Shale, white, caving	2630	2645
Shell, sandy	2645	2650
Red rock	2650	2652
Shale, blue	2652	2660
Lime	2660	2680
Shale, blue	2680	2683
Lime	2683	2695
Lime, broken	2695	2705
Shale, blue	2705	2710
Shale, white	2710	2715
Lime, hard, black	2715	2720
Lime, gray	2720	2730
Lime, white	2730	2745
Shale, blue	2745	2800
Slate, blue, and shells	2800	2815
Lime and slate	2815	2850
Shale, blue	2850	2860
Lime and shells	2860	2930
Shale, black, blue, caving. At 2930 feet a small coal seam	2930	2950
Slate, white and blue, and shells	2950	3005

Log of the Cain Well, No. 1, San Angelo, Texas. By H. H. Jones, Superintendent. Elevation 1890 Feet

	Thickness	Depth
Red sandstone and chert	0	8
Boulders	5	13
Hard sandstone	12	25
Red clay	20	45
Boulders	5	50
Red clay	45	95
Blue shale	16	111
Limestone	9	120
Sandstone, water, salt	3	123
Limestone	6	129
Sandstone	54	183
Red clay	6	189
Limestone	5	194

Sandstone, pyrites, mica	11	205
Flinty rock	4	209
Hard sand rock	3	212
Blue shale	59	271
Hard shell	1	272
Blue shale	33	305
Hard limestone	31	336
Hard sandstone	5	341
Water sand, salt, sulphur	5	346
Hard shell	1	347
Gray shale	25	372
Hard lime	8	380
Blue clay	12	382
Sandstone	8	400
Limestone	12	412
Sandstone	8	420
Hard sandstone, pyrites	22	442
Blue clay	5	447
Very hard lime	23	470
Limestone, pyrites	7	477
Blue clay	2	479
White gypsum	3	482
Blue clay	4	486
Hard gray shale	2	488
White gypsum	5	493
Blue clay	6	499
Gypsum and blue clay	4	503
Blue clay	6	509
White crystal gypsum	3	512
Blue clay	6	518
Hard shell	3	521
Blue clay and gypsum	2	523
Hard shell	3	526
Blue clay	6	532
White gypsum	4	536
Blue clay	1	537
White lime	8	545
Blue clay	55	600
Hard gray lime	10	610
Gray lime	20	630
Blue gumbo	5	635
Hard gray lime	35	670
Blue clay and shale	180	850
Light blue sandy shale	7	857
Blue gumbo	11	868
Lihgt blue shale	56	924
Black shale	4	928

Blue shale	57	985
Blue gumbo, satinspar	10	995
Blue gumbo	65	1060
Hard shell lime	7	1067
Shales, light blue, dark blue to very dark	323	1390
Black limestone	27	1417
Light blue shale	19	1436
Blue gumbo, bituminous	2	1438
Gray lime	39	1477
Shale, light sandy	41	1518
Gray lime	60	1578
Blue gumbo	3	1581
Light blue sandy shale	14	1595
Gray lime	64	1659
Blue gumbo	2	1661
Gray lime	107	1768
Dark blue shale	2	1770
Gray lime	50	1820
Blue shale	11	1831
Gray lime	71	1902
Black gumbo	3	1959
Gray lime	51	1956
Black gumbo	3	1559
Gray lime	102	2061
Blue gumbo pyrites	4	2065
Gray lime	38	2103
Black gumbo	3	2106
Light blue shale	80	2186
Black lime	20	2206
Blue gumbo	25	2231
Sandy gumbo	25	2231
Sandy shale	11	2242
Dark blue gumbo	61	2303
Limestone, light to gray	522	2825
Black shale, pyrites	1	2826
White lime	16	2842
White and light blue shale	4	2846
Dark shale, fossils	4	2850
Black lime	14	2864
Streaks shale, lime, pyrites	19	2883
White lime	12	2895
Dark shale, lime concretions	7	2902
White lime	88	2990
Dark blue shale	9	2999
Gray lime	27	3026
Dark shale	1	3027
Gray lime	38	3065

Dark shale	1	3066
Gray lime	7	3073
Dark blue shale	29	3102
Gray lime	4	3106
Light blue shale, fossils	152	3258
Limestone	5	3263
Black shale, coal seam	42	3305
White silica sand, water	10	3315
Gray lime	6	3321
Dark shale, lime concretions sandstone lentils	529	3850
White lime	1	3851
Dark shale	9	3860
Limestone, mottled, fossils	37	3897
Black rotten lime and shale	23	3920
Black arenaceous limestone very hard	10	3930
Black shale	4	3934
Black lime	6	3940
Black lime	4	3944
Black lime	16	3960
Black shale	10	3970
Black lime	3	3972
Black shale	3	3975
Black lime	4	3979
Black shale	5	3984
Black lime	3	3987
Black shale	3	3990
Black lime	2	3992
Black shale	3	3995
Black lime	15	4010
Black shale	35	4045
Gray lime	3	4048
Black flinty lime	4	4052

Log of Texas Elkhorn Syndicate Well, Richardson No. 1
Sterling County. Elevation 2200 feet
Log Kept by H. H. Jones, from 3735 Feet to Bottom. Above That It Was Kept by other Drillers

	Feet	
	From	TO
Soil	0	12
Gravel	12	80
Lime	80	85
Red rock	85	120
Red rock	120	330
Hard lime	330	336
Red rock	336	485

Lime	485	490
Red rock	490	500
White lime	500	540
White lime	500	500
Red rock	540	550
Blue slate	550	760
Red rock	760	790
Shell lime	790	795
Red rock	795	985
Shell lime	985	990
Red rock	990	1170
Lime	1170	1185
Slate and lime blue in shells	1185	1425
Hard gray lime	1425	1450
Blue shale	1450	1550
Sand; hole, full water	1550	1580
Blue shale	1580	1633
Lime	1633	1682
Sand, salt water	1682	1696
Pure lime	1696	1730
Sand, water	1730	1780
Sandy lime	1780	1822
Sand, salt	1822	1896
Sandy lime	1896	2381
Sand, water	2381	2387
Sandy lime	2387	2447
Sand, water	2447	2459
Sandy lime	2459	2760
Sand, sulphur water	2760	2778
Gray shale and lime	2778	2816
Gritty lime	2816	2852
Lime and shells	2852	2935
Hard gray lime	2935	3092
Dark shale	3092	3150
Hard, close dark gray lime	3150	3185
Dark calcareous shales	3185	3540
Sand (?)	3540	3558
Gritty lime	3558	3638
Blue shale	3638	3657
Shale and lime	3657	3750
Black lime	3750	3798
Shale, slate and lime	3798	3830
Gray lime, turning black	3830	3865
Soft gray lime, 5 gallons 40 degree oil	3865	3668
Light gray lime	3868	3918
Brown to black lime	3918	3924

Gray lime	3924	3940
Dark lime	3940	3966
Gray lime	3966	3980
Light gray fine-grained lime	3980	4000
Dark lime	4000	4005
Light yellow lime	4005	4023
Black slate	4023	4030
Slaty lime	4030	4043
Dark mottled lime	4043	4112
White fossiliferous lime	4112	4153
Salt water with sulphur odor, beginning about	....	4140

CORRELATION

Before taking up the details of correlation, two general facts must be considered: First, that the Coke County beds are an upward continuation of stratigraphic succession described in Runnels County[9]; second, that an unconformity exists between the Choza and San Angelo formations which may be of very great extent.

Near Bronte, for instance, there are 270 feet of the Choza formation above the Merkel dolomite, while near the Texas and Pacific Railroad in the next county on the north, this interval is reduced to 25 feet. This difference, amounting to 245 feet, is probably erosional.

There appears to be evidence to the southward, the details of which have not yet been worked out, which suggests a strong erosional unconformity or a considerable overlap by the San Angelo formation.

The Middle or Upper Middle Choza formation of the Clear Fork Stage, when correlated by its ammonoids, may represent the basal Leonard formation, according to Böse. who states:[10] "But our horizon 3 (Choza formation, Runnels County) may possibly correspond with the lower part of the Leonard formation (horizon of *Perrinites*); at least, the difference in age cannot be very great."

However, fossil ammonoids have been found in the overly-

[9]The Geology of Runnels County. Univ. Texas Bull. 1816, 1919.

[10]The Permocarboniferous Ammonoids of the Glass Mountains, West Texas, etc. Univ. Texas Bull. 1762, p. 207. 1919.

ing Double Mountain beds which show that "Our horizons 4 and 5 certainly correspond exactly to the Horizon of *Perrinites vidriensis* or upper Leonard formation"[11] of the Glass Mountains region.

If the nautre of the Leonard formation is taken into account we find that throughout its thickness it is to a very considerable degree composed of conglomerate,[12] and that it overlaps thousands of feet of strata to the southward. In the Mount Ord Range, some miles south of Lenox, it is largely a conglomerate and rests upon Pennsylvanian strata which are older than the Gaptank. Passing northeast from here the Hess, Wolfcamp and Gaptank formations come in beneath it before reaching the north end of the Marathon basin. These three formations as exposed have an aggregate thickness of more than 4600 feet and their southern extermities are completely bevelled by erosion. It is now apparent from Böse's correlation that the San Angelo conglomerates lie below the upper Leonard and that their base is at least near the base of the Lower Leonard formation of the Glass Mountains, making it possible that the unconformity at the base of the San Angelo beds may be a continuation of the Leonard unconformity. The probability of this being true is heightened to some extent by the fact that less erosion occurred in the Central Texas region than in the region of maximum disturbance in the Glass Mountains; and that higher beds referable to the underlying Hess formation would be left in Central Texas than would remain in the Glass Mountains. Hence, forms of ammonoids more closely related in time and form to those of the Leonard than are any known in the Hess formation of the Glass Mountains, might be expected in Central Texas. Another possibility is that the unconformity of Central Texas, as shown in Coke County, may represent some of the horizons of the Lower Leonard itself. In either case we would expect to find preserved in Central

[11]Loc. cit.

[12]Udden, J. A., Notes on the Geology of the Glass Mountains. Univ. Texas Bull. 1753, Bureau Economic Geology, p. 46. 1917.

Texas beds below the unconformity carrying younger faunas than would be found in the region of maximum disturbance, where a larger amount of the higher beds of the Hess formation were probably removed by erosion. At any rate it is reasonably safe to assume that the unconformity at the top of the Clear Fork beds is referable to the one at the base of the Leonard formation in the Marathon region. .

Followed still farther northward we find the Clear Fork largely composed of shales with some gypsum beds, and the Double Mountain sandstones very thick, with gypsum deposits coming in above them. This is the basis for Cummins' separation of the two, as he points out in his papers in the Reports of the Texas Geological Survey.

It is worthy of note that Gould records some 200 feet of Whitehorse sandstone followed by beds with very heavy gypsum deposits in the Panhandle region. These gypsums and associated rocks he calls the Greer formation. It is reasonably certain that the gypsums of the Double Mountain formation correspond in a general way to those of the Greer formation, and the succession is similar in Oklahoma and Central Texas, as Wrather pointed out.[13] There is also strong reason for regarding the fossil-bearing beds of Whitehorse sandstone seen at its type locality at Whitehorse Spring, 18 miles west of Alva, Oklahoma, as being unconformable with the beds upon which the sandstone rests.

Thus it appears that this unconformity represented by the base of the San Angelo formation is of great extent and is probably the most valuable horizon marker in the Permian of Texas. If this conclusion is correct, the Clear Fork and the upper part of the Wichita formations are equivalent to the Hess formation of the Glass Mountains. The lower part of the Wichita beds would probably represent the basal Hess formation and Wolfcamp formation, if the Wolfcamp is represented in central Texas.

The *Schwagerina* horizon is doubtfully represented in the

[13]Bull. S. W. Assn. Petr. Geol., p. 103. 1917.

central part of Texas. We know of no reference to these fossils, though they may exist and have been overlooked. There is one specimen of *Fusulina* from the base of the Wichita beds representing a species that occurs in the *Schwagerina* horizon in Kansas and Oklahoma. It may be that the horizon is present and the *Schwagerina* wanting, or that there is an elision of the formation in central Texas. It may be noted here that Böse and also Martin found some evidence of disconformity near Moran, in Shackelford County. Its extent and significance have not been determined. The horizon in the Wichita stage in which *Omphalotrochus* occurs on the Colorado River is high enough above the base of the stage as now considered to make it likely that the *Schwagerina* beds are present; but that the fossils are absent or have not been observed. For the present, the base of the Wichita formation is to be considered as tentatively defined. The main *Schwagerina* horizon of the Marathon region includes the topmost part of the Gaptank and part, at least, of the Wolfcamp beds. In Kansas and Oklahoma this horizon is represented by the Neva limestone and immediately associated rocks. A feature to be held in mind is the fact that in the great limestone sections of extreme West Texas many species have a much greater range than in the interrupted limestone-shale succession of the central and northern parts of the state, or in Kansas.

The rocks above the San Angelo beds comprise the second formation of the Double Mountain stage. Wrather traced some of the Texas gypsums through to the Red River and in his paper on the section from Abilene to Sweetwater he placed the rocks from the top of the San Angelo formation (Blowout Mountain sandstone) to the top of the heavy gypsums, in the Greer formation of Oklahoma and the Texas Panhandle.[14] The rocks above this gypsum he referred to the Quartermaster formation of the Panhandle. The heavy Coke County gypsum beds would then belong to the Greer formation. As has already been stated, Wrather tenta-

[14]Wrather, W. E., Notes on the Permian. Bull. S. W. Assn. Petr. Geol., p. 103. 1917.

tively refers the limestone or dolomite in these gypsums to the Eskota dolomite.

The conglomerate at the top of the red beds in the northwest corner of the county may well represent the base of the Quartermaster of Gould, so far as our present knowledge goes. There is a similar thickness of shales above the top of the massive gypsums of the Greer in the Coke County section to correspond with the interval between the gypsums and the sandstones of the Greer and Quartermaster beds of the Panhandle. The green chert abundant in some parts of this conglomerate probably comes from the Caballos formation of the Marathon region.

It seems that the Coke County region was sufficiently close to the region of major movements to the southwest in early Permian times to have the unconformities with their overlying conglomerates clearly developed, which are now revealed in exposures on the northern edge of the Edwards Plateau. This fact will be of great importance in interpreting the age of the Permian formations of north Texas.

Comanchean

Section at Mt. Margaret

		Feet	Inches
31.	Thin ledge at top of hill	1	
30.	Limestone, massive, full of *Caprina*, weathers smooth	5	
29.	Limestone and concealed	10	
28.	Limestone, hard bed	2	8
27.	Limestone, hard	5	
26.	Limestone, somewhat flaky	4	
25.	Limestone, very hard, fine grained, 11 inches to	1	3
24.	Limestone, nodular, marly, or hard nodular marls, quite fossiliferous	10	6
23.	Limestone with geodes and large gastropods, pelecypods	4	
22.	Limestone, less resistant than one below	4	
21.	Limestone, massive, rather fine-grained, weathers smooth	8	
20.	Sandstone and sandy limestone	3	
19.	Clays—Walnut?	15	
18.	Sandstone, buff, fine ,apparently calcareous	5±	
17.	Sandstone, algal (?) about this horizon	2	

16.	Clay, olive, occupies most of interval	20
15.	Soncealed	15
14.	Sandstone, concretionary, concretions about the size of marbles, at about this level	2∓
13.	Concealed, apparently wash from higher up	45
		79

This section rests upon the Permian section given in the preceding pages.

Comanchean Section of Small Southeast Peak of Kickapoo Mountains

		Feet	Inches
13.	Limestone, somewhat nodular below, poorly exposed at base, 5 feet, followed by 13 feet 2 inches of massive limestone which weathers cellular in upper part. All one bed	18	
12.	Concealed	10	
11.	Clays and marls lower part more buff and clayey than upper part. *Exogyra texana.* There is a limestone of considerable thickness partially exposed above the clays and making the whole interval 17 or 18 feet	17±	
10.	Limestone, fossil conglomerate, *Gryphaea, Exogyra texana,* large and small pelecypods; weathers into small lentils below, upper part weathers into blocks and is lighter colored and firmer than the lower part of the bed	11±	
9.	Clay, sandy, calcareous, some concretions	5	
8.	Sand, loose, fine-grained, buffish	6	
7.	Sandstone, with some fine pebbles, rather dark-colored	5	
6.	Conglomerate, buff, more or less concretionary, calcareous, 7 feet to	8	
5.	Sands, ashy, apparently some clay	12	
4.	Sand, soft, whitish and buff, and covered slope	25	
3.	Clay, and yellow sand streaks, 6 feet to	8	
2.	Sands, ashy and soft sandstones, 2 feet of fine concretionary sandstone at top	16	
1.	Shale, green, and sandstone nodules, some sandstone and fine iron concretions	11	
		152±	

Comanchean Section of Northeast End of
Kickapoo Mountains

11.	Limestone, chalky, very cellular, higher beds back in ridge	8
10.	Limestone, chalky	8
9.	Limestone, chalky, seven or eight layers	10
8.	Limestone, chalky, upper part cellular, chert	6
7.	Limestone, upper part filled with chert	12
6.	Concealed	10
5.	Limestone, massive	21
4.	Limestone, nodular, and concealed, very fossilifeous	15
3.	Limestone, nodular, base a fossil conglomerate	12
2.	Clays, *Exogyra texana*, *Gryphaea*	5
1.	Sand. Trinity, and material like it	114
		221

Section at "Mount Q." "Butterfield" is given on an old map but it is uncertain whether this refers to the name of the mountains or the survey. In our notes it is given the designation "Mount Q." It is a high outlier just in front of the plateau escarpment in Surveys 10 and 11, south of the oil well being drilled by Mr. Tucker.

		Feet	Inches
43.	Limestone, top of section, almost completely composed of foraminifera, some gastropods. Possibly	1	
42.	Concealed	7	
41.	Limestone, concealed	2	
40.	Limestone, coarsely crystalline, about	1	
39.	Interval	1	
38.	Limestone, hard, resistant, in four layers	12	
37.	Limestone, massive, hard, white, weathers to cellular surface, in three or more layers. about	9	
36.	Interval	1	6
35.	Limestone, massive, weathers cellular. Layers 5½ feet above base with numerous gastropods	11	
34.	Concealed	6	
33.	Limestone, laminated, yellowish white		8
32.	Concealed	1	
31.	Limestone, rotten. cherty	2	
30.	Concealed	2—	
29.	Limestone, chalky, white. with yellow streak	1—	
28.	Concealed	8	
27.	Limestone. nodular, white, occasional geodes, about	6	

26.	Limestone, white, platy, bottom half soft, top hard and resistant	2	
25.	Concealed	5	
24.	Limestone, nodular, rather soft. sandy	4	
23.	Limestone. white, foraminiferal	1	6
22.	Concealed	2	
21.	Limestone. hard. white	10	
20.	Concealed	2	
19.	Limestone, hard, sponges?	3	
18.	Concealed	2	
17.	Limestone, massive, weathers into nodules, lower ten feet soft, upper part hard, dense. Foraminifera, *Pecten*, etc.	22	6
16.	Interval. Upper 3 or 4 feet marl	11	
15.	Limestone. nodular	10±	
14.	Concealed, some shale	6±	
13.	Sandstone, yellow	9±	
12.	Concealed	30	
11.	Sand, yellow, soft	6	
10.	Clay, soft dirty-white	18	
9.	Sand, soft, yellowish	7	6
8.	Sandstone, soft, gray, shot-like concretions	3	6
7.	Sand, loose, yellowish-white	5	
6.	shale, reddish	5	
5.	Concealed	4	
4.	Sandstone, gray, fine shot-like concretions	4	
3.	Sand, soft, yellowish	11	4
2.	Concealed	10	
1.	Sandstone dark-buff, fine-grained	10	

The entire section is composed of Comanchean rocks. It is uncertain whether or not the section reaches the base of them.

Section, Southwest Corner of Cole Mountains

44.	Limestone, massive, even-bedded, composed of small fragments of shells, forms top of mountain	10	
43.	Limestone, soft, chalky, weathers into large blocks, especially the basal part. Chert nodules and layers, more chert in the lower part. Top much harder	42	
42.	Limestone, fine-grained	6	
41.	Concealed	3	4
40.	Limestone, hard, fine-grained	16	4
39.	Concealed	8	5

38.	Limestone, hard, massive, resistant, numerous gastropods. Weathers into spalls from 7½ feet above the base up for the next 5 feet; next 12 feet *Radiolites*	38	
37.	Concealed. Lower 5 feet yellowish white clay. *Exogyra texana* (in place?)	117	
36.	Concealed, partly, mostly red sandy shale, upper part red shelly sandstone	19	
35.	Concealed.	5	
34.	Sandstone, red, thin-bedded, shelly	6	
33.	Shale, greenish-yellow.	1	
32.	Sandstone, shelly, yellowish-white, fine-grained	2	4
31.	Shale, red, sandy, streaks of greenish-white sand, upper 12 inches nearly all sand	2	6
30.	Sandstone, yellowish-white, thin-bedded, fine-grained, jointed	5	5
29.	Sandstone, red, shelly, upper three inches greenish-white	0	9
28.	Sandstone, yellowish-white, fine-grained, thin-bedded, jointed	10	
27.	Sandstone, red, shelly, thin streaks greenish-white sand	1	9
26.	Shale, yellowish-green, calcareous, crusty	1	
25.	Sandstone, yellowish-gray, fine, thin-bedded, much jointed, cross-bedded	7	
24.	Sandstone, like No. 20, upper part more massive	5	6
23.	Sandstone, like No. 21	1	
22.	Sandstone, reddish, shelly, like No. 20	0	6
21.	Sandstone, gray-white, yellow streaks, cross-bedded	1	
20.	Sandstone, fine-grained, reddish, with white streaks, cross-bedded	1	7
19.	Shale, red, shelly, sandy, with greenish-white sandy streaks, gypsum	6	
18.	Sandstone, alternating red and greenish white, at top, lightly cross-bedded. Thin, massive gyp sum layers	6	6
17.	Sandstone, greenish with alternating thin beds of massive gypsum	4	0
16.	Shale, red, sandy, with streaks of greenish sand and layers of massive gypsum	6	6
15.	Gypsum, massive.	4	2
14.	Shale, red, with greenish-white streaks of fine sand, joints filled with foliated gypsum	3	2
13.	Sandstone, fine, greenish-white	2	6
12.	Shale, red, sandy	1	0
11.	Gypsum, massive	1	4

10.	Sandstone, red, with greenish streaks, joints filled with gypsum	6	8
9.	Sandstone, greenish, with gypsum streaks	1	9
8.	Shale, red, sandy, with gypsum streaks		9
7.	Sandstone, greenish-white, with nodules of gypsum, joints filled with gypsum	4	6
6.	Shale, red, satinspar in thin plates filling joints in all directions	12	
5.	Sandstone, greenish-white, with gypsum in vertical and transverse joints	11	
4.	Partly concealed, upper 15 feet red shale with massive gypsum and thin streaks of greenish white sand	39	
3.	Concealed	30	
2.	Shale, red	5	
1.	Concealed	15	

This section gives a clear idea of the local condition of the Greer beds at this place. The gypsum beds seem to be thinner than in some other places. It is difficult to say how much represents the gypsiferous beds above the limestone in the Grubbs Canyon and Wilson Mountain sections. The limestone is either absent or was not especially distinct in this section. This limestone bed is locally quite inconspicuous and looks like a secondary crust of little importance. It had not been studied at the time this section was measured and it may have escaped attention. The Greer beds here may reach to the top of Number 36 of this section. Number 37 is apparently the base of the Comanchean.

It is quite possible that some of the sandstone below Number 37 may belong to the beds above the Greer, which are represented but a short distance farther north by conglomerates which extend to the Panther Gap section.

The Comanchean section is well developed here and is excellently exposed. On the Edwards Plateau along the Robert Lee–Carlsbad road, the barometer shows a thickness of approximately 350 feet of Comanchean rocks.

Section of South End of West Stepp Mountain
Near Northwest Part of Coke County

		Feet
27.	Limestone, even-bedded, massive, 1 to 3 beds	15
26.	Limestone, somewhat laminated, porous, top quite craggy	6

25.	Limestone, marly	3
24.	Limestone, massive bed, top of cliff..............	4
23.	Limestone, brecciated	10
22.	Limestone massive, *Caprina* and larger fossils....	12
21.	Limestone, darker colored bed, weathering into quite rough blocks with geode-like pits........	4
20.	Limestone, massive, much like lower bed but firmer	25
19.	Limestone, marly, to massive-nodular, *Exogyra texana*, slim gastropods.....................	25
18.	Concealed	65
17.	Sandstone, buff-brown, calcareous, *Gryphaea*, grading into limestone at top, total thickness probably	10
16.	Sands ashy and sandy clays probably much thicker than seen	15
15.	Shale light-colored red..........................	5
14.	Sandstone dark maroon	5
13.	Shales deep maroon, somewhat sandy, with thin sheets of sandstone.........................	5
12.	Sandstone, laminated, buff-gray..................	10
11.	Conglomerate and coarse sandstone, chert and quartz pebbles	5
10.	Shale, one sand bed...........................	6
9.	Sandstone, more evenly and thinly bedded than those below, soft..........................	15
8.	Sandstone, cross-bedded, coarse, large lenses of coarse conglomerate which contains slabs of sandstone 2 feet across, yellowish............	20
7.	Shales, greenish	10
6.	Sandstone, coarse, soft, friable, buff to light red or pink; much of it very coarsely conglomeratic, iron-cemented, very dark brown to gray......	10
5.	Shale, buff to olive...........................	6
4.	Shale, gray to red, more or less platy and sandy..	15
3.	Sandstone, gray to maroon, slabby, ripple-marked	5
2.	Shale, gray to greenish, and red, more or less ferruginous, in places sandy......................	5
1.	Concealed	20
		336

Tertiary (?) Pleistocene (?)

The floor of the old valley between the Edwards Plateau and the Callahan Divide is covered with coarse conglomerate, some sands and silt. The age of this deposit has not been determined. It is probably Late Tertiary, or Pleistocene.

These deposits vary in thickness from a thin veneer to 60 feet, and in elevation from 90 or 100 feet above the river to probably 150 feet near the margins of the old valley. Much of this material is a coarse limestone conglomerate, locally loose boulders, but in other places well cemented. Some of it is rather fine, while other parts of it carry pebbles as large as hens' eggs, and at still other localities buolders a foot or two in diameter. The stones are usually well rounded. Most of the boulders and pebbles are the hardest of the Comanchean limestone mingled with some chert from the Edwards limestone. Frequently these limestones are almost entirely composed of foraminifera.

Where these deposits are favorably located they are very often tightly cemented with caliche and contain sufficient amounts of iron oxide or red clay to form a dense, whitish- to reddish-mottled conglomerate. Otherwise the beds are white.

There is, in many places, a considerable layer of silt or soil over this conglomerate.

Recent

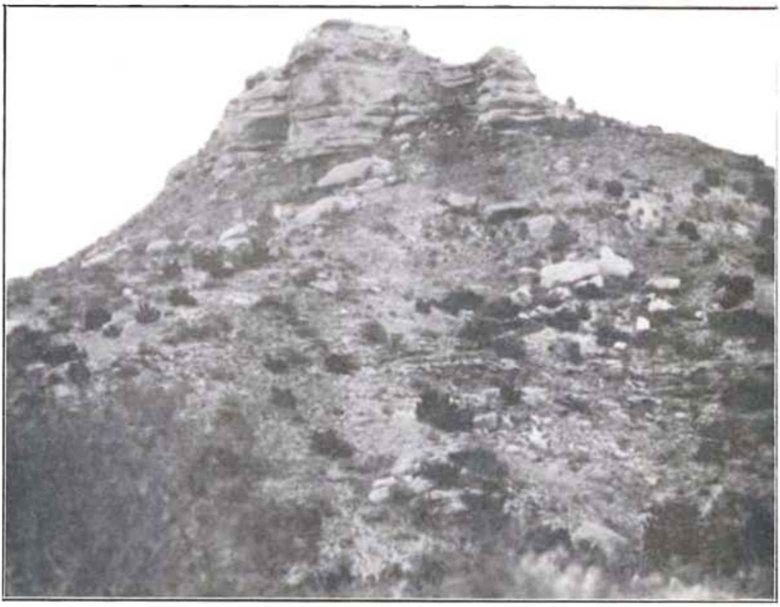
The clay and sand beds along the present first and second bottoms of the river, and in the river bed, and the soil of the first bottom with some gravel beds, constitute the recent deposits. They are very limited in this county and are shown approximately on the map.

ECONOMIC GEOLOGY

Sand

Probably the most notable sand deposit in the county is on Sand Creek, south of the "Colorado Road," in the northwestern part of the county. The sand here is largely dune sand. It is present in great quantities though it is distant from points where it could be extensively used, and is not on any transportation line.

There are sand beds which occur as bars and similar



A. Stepp Mountain. The lower part is Quartermaster(?) and the upper part is Comanchean.

B. Undercut rock, Comanchean, on north side of Grubbs Canyon.

deposits along the Colorado River of sufficient size and purity, if carefully selected, for local use.

Occasionally three are sand beds in the old valley such as the one in the road west and north of Bronte. Sometimes these beds contain considerable clay.

Another source of sand is that found in the basal part of the Comanchean rocks at the foot of the Edwards Plateau and the Callahan Divide. These sand beds are indicated in the sections of the Comanchean deposits. On the whole, the county is well supplied with sand. Should cheap fuel be developed in the county it may be that beds of sand of sufficient purity may be found in the basal Comanchean formations, to make a good glass sand.

Clay

In the study of the rocks of Coke County only low grade clays were encountered, that is, clays suited only for the manufacture of building brick, drain tile, etc.

The alluvial clays of the county are quite limited and impure. They are the soil of the first and second bottoms of the Colorado River. The shales of the Choza formation in the eastern part of the county, and of the San Angelo formation near Robert Lee, are of most importance. The former outcrop along the bluffs on the south side of the river as far north as the Kansas City, Mexico and Orient tracks and a short distance beyond. These beds also occur on the north side of the river as far as Bronte. The outcrop of this formation is shown on the map.

Near Robert Lee and eastward in the exposed bluffs along the river and main creeks are beds of clayey shales in the San Angelo beds and in the base of the Greer beds. Clay will be found among these shales which are suitable for the manufacture of ordinary brick.

Some of the lighter-colored clays of the lower part of the Comanchean rocks exposed in the base of the mountains north and south of the Colorado River may be of such a constituency as to burn a light-brown brick suitable for ordinary use, should cheap fuel be available.

Lime

About the only source of limestone for lime in Coke County is the limestone of the Comanchean formations found in the mountains of the county.

This limestone occurs in abundance and many of the beds are of sufficient purity to burn excellent "hot" or "fat" or quick-setting limes, such as as are most used for ordinary purposes. They would have no superior for "hard wall finish," if ground and made into the hydrated limes of commerce. Distance from market, and costly fuel preclude their manufacture except for local use. A less important but more accessible deposit would be the Comanchean limestone boulders of the old valley.

Limestone

The limestone resources of the county are the same as those just mentioned for lime. These Comanchean limestones outcrop in the mountains in such a way that but slight work is necessary in quarrying them. The rocks from many of the beds can be readily shaped into large-sized blocks with but little work and many of them can be sawed into any desired shape. This work can be done at times when farm work is slack or other work is not pressing. Work of this character can go on for several years and the rock can be accumulated until a sufficient amount is at hand which, with very little cash outlay, can then be used in erecting buildings. The lime can be burned from the spalls and the sand for the mortar is readily available. These are the best buildings that can be constructed, as well as the cheapest.

Many fine houses have been built in this way in other parts of the country and give very satisfactory results. They are permanent improvements that add materially to the value of any property.

Three precautions are necessary to good results. First, a firm foundation which will permit of no settling of the walls is necessary . Excavation must be carried deep enough to secure a firm foundation; and then it is a good plan to place a layer of good concrete one or two feet thick and a foot or so wider than the wall. Second, only large-sized blocks should be used. Third, the rocks should not be blasted in quarrying, as it fills them with invisible cracks that shorte the life of the stone as well as weakening the building. If blastnig can not be avoided, the smallest charges capable of doing the work should be used. The explosive should be a slow burning coarse black powder. Dynamite should never be used in quarrying rock to be used for building or other structural purposes.

Gypsum

The gypsum resources of the county are large. The available deposits are located in the western half of the county. Their occurrence is given in the description of the sections in this report. The easternmost point where gypsum is likely to be available in commercial quantities is the Seaton Keiths Bluff, three miles west of Robert Lee. The thickness of the beds is given in the section of the bluff on page —, and in the general section of the county.

Another bed is found near Grubbs Canyon, which is good pure gypsum. A still higher deposit should occur under the mountains west of Grubbs Canyon. This is the same general deposit, composed of the several beds, found near Wilson Mountain in the northwest part of the county where the beds have an aggregate thickness of about 80 feet.

Very little advantage can be taken of the deposits at present, owing to lack of fuel, transportation, and market. However, should it happen that gas in quantity should be struck in the terrace of western Coke County, the material could be quarried and burned with that fuel so cheaply that these deposits might become of economic importance. The products made from these gypsums might include plaster of Paris, dental plaster, and the "cement plasters." The process of manufacture of these products is simple.

Road Metal

One of the resources likely to prove to be of much value to the county is the material for road construction. There are two kinds to be had. First, there is the gravel from the San Angelo beds in the eastern part of the county. These gravels or conglomerates occur from the Tom Green county line along the Kansas City, Mexico and Orient Railroad to Tennyson around Fort Chadbourne, in the Kickapoo Mountains, Cedar Mountain, and in lower Live Oak Creek on the Humlong ranch. This is essentially a quartz gravel with sand. Some of it is firmly consolidated into a conglomerate or "concrete" and would require crushing, while at least a fair amount can be had as free gravel. This deposit has been described under the head of the San Angelo formation. "In the western part of the county the quartz found conglomerate at Panther Gap on the Colorado City road, and heretofore described, is equally useful as a road metal."

This gravel lacks binding cement to a considerable extent, but treated with a foreign binder would make the best of modern gravel roads if they are properly constructed.[15] From the section given it is evident that there is an ample supply of it for local use, as well as for shipping. There should be a demand for it. It is one of the best gravels for heavy traffic in all West Texas, and nearly all of the deposit is in Coke County. Two photographs of this material are reproduced on Plate 8.

The other deposit of road gravel is good for the side roads of the county and it is much more widely distributed along the broad valley of the Colorado River. It is the limestone gravel or "concrete" of the old valley floor. It extends entirely across the county and from the mountains on one side of the valley to those on the other. There are considerable areas without it, but there are few places where it can not be reached economically. The larger areas are shown on the map, in black shading.

One of the best exposures known is in the top of the

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[15]Univ. Texas Bull. 1839, pp. 151-159. 1919.

A. San Angelo conglomerate at Kickapoo Mountain.

B. San Angelo gravel at Mount Margaret.

Seaton Keiths Bluff, three miles west of Robert Lee. Here there are about 50 or 60 feet of it, 40 feet showing in the face of the bluff. The bluffs of Pecan Creek are covered with it, as is much of the region near the foot of the Edwards plateau, where it is cemented with caliche. All the highlands between the creeks in the "Old Valley" of the river, especially between Bronte and Robert Lee, carry deposits of it. It caps the low mesas east of Bronte and the longer one on the east side of the railroad between Bronte and Tennyson. In these latter localities it is accessible to the railroad. Its composition varies from place to place. As a rule it is coarse, and the boulders range from fine material to pieces a foot in diameter. Much of it is composed of the hardest of the Comanchean limestone rolled and ground in the old river until the large as well as the small pieces are well rounded. All the softer stones have been ground up to powder and most of it washed away. However, in many places this gravel is relatively fine and closely cemented into a hard conglomerate which would make an excellent road metal for the most of the roads of the county. It would have to be crushed before being used. Some of the better roads of the county are roadbeds crossing natural deposits of the material. An example of this is the highland with the white road between Bronte and Robert Lee. In such localities the roads need but little attention except to provide drainage.

The limestone and marls of the mountains make a good road for very light traffic, but are too soft for heavy traffic. This material is available for most of the county.

Oil and Gas

STRUCTURE

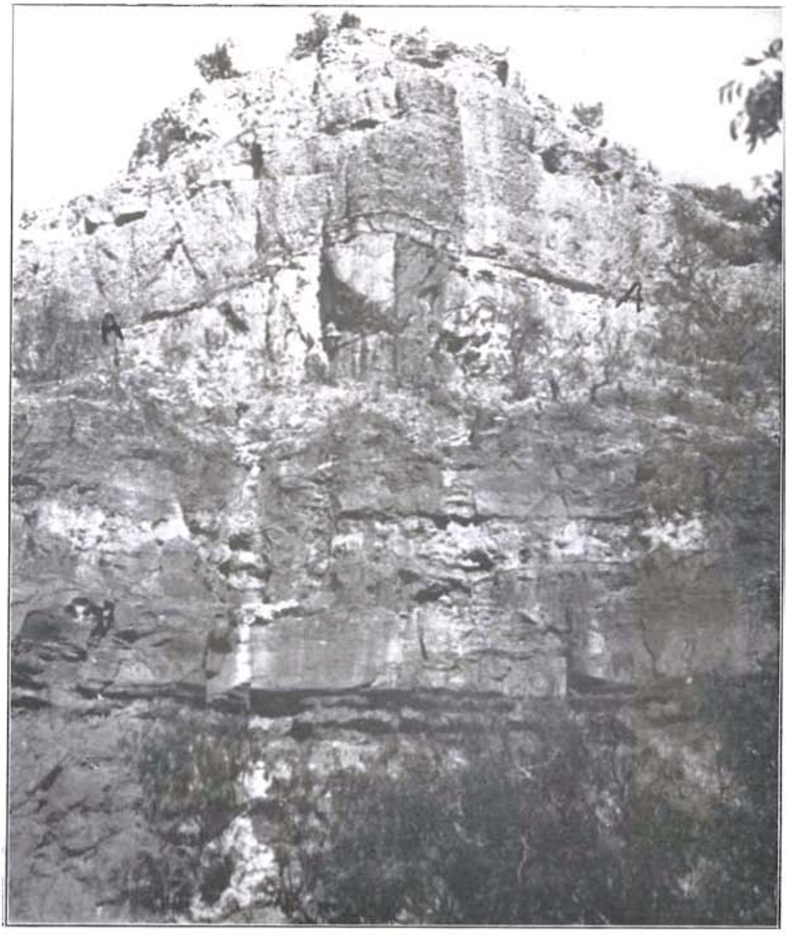
After studying the Pennsylvanian and lower Permian along the Colorado River in Coleman and Runnels counties one does not find the structure of the rocks in Coke County as simple one would expect.

Dip

The general dip of the Permian beds is in a direction north of west. It is much more nearly west than is the case in Runnels County where over a large part of the county it is about northwest. In a general way, the dip is approximated up the Colorado River. In the eastern part of the county the dip is approximately 50 feet per mile; locally it is more than that. From Robert Lee westward it is slight and may be level and even locally reversed for some considerable distance; near the west edge of the county, however, a steeper dip is resumed. The average dip of the Permian rocks up the Colorado River for the whole county will probably not exceed 30 feet to the mile, and may be less. The general dip of the Comanchean beds is to the southeast.

Major Structures

The interruption of the normal dip noted above forms the major structure of the county. It is really a terrace with minor structures upon it, consisting of both faults and folds. The real axis of this terrace has not been determined but is assumed to be nearly north and south in the northwest part of the county. It is most apparent and most easily studied on the south side of the river from Edith to Wilson Mountain which is located in the large northward loop of the river near the northwest corner of the county. The best horizon marker is a peculiar dolomite bed, part of the way quite sandy, frequently cellular and crystalline, with black spots in it. Its appearance hardly suggests a limestone. It varies from about a foot to two feet in thickness, and is exposed from the hills just east of the junction of North and South Pecan creeks to the west side of Wilson Mountain, above which it enters the river. On the north side of the river this limestone is found exposed in Silver Creek at the Colorado Road crossing, and thence eastward, at numerous points on either side of this road for several miles.. Its position with respect to the Panther Gap con-



Seaton Keiths Bluff, three miles west of Robert Lee. 80 feet of Greer sandstone followed unconformably by 40 feet of limestone conglomerate shown above the line A—A. The conglomerate is the old river bed conglomerate of the Colorado. It is 60 feet thick just back of the cliff.

glomerate is clearly seen in the Gap. It is possible that an east dip due to faulting or folding will be traced on this limestone east of Panther Gap. A series of heavy gypsum beds set in on top of this limestone bed and these have been dissolved away, leaving the horizon of this bed forming the top of the general plain near the river between the points mentioned.

One of the most interesting features of this structure is that it seems to overlie a much stronger and steeper structure beneath the unconformity at the base of the San Angelo formation. Another matter of interest is the fact that the minor structures visible at the surface are much sharper and more broken on the eastern part than on the western part of the terrace. Indeed, there seem to be few disturbances on its western part. The structural features of the terrace as a whole will be discussed along with other smaller folds and faults.

Minor Structures

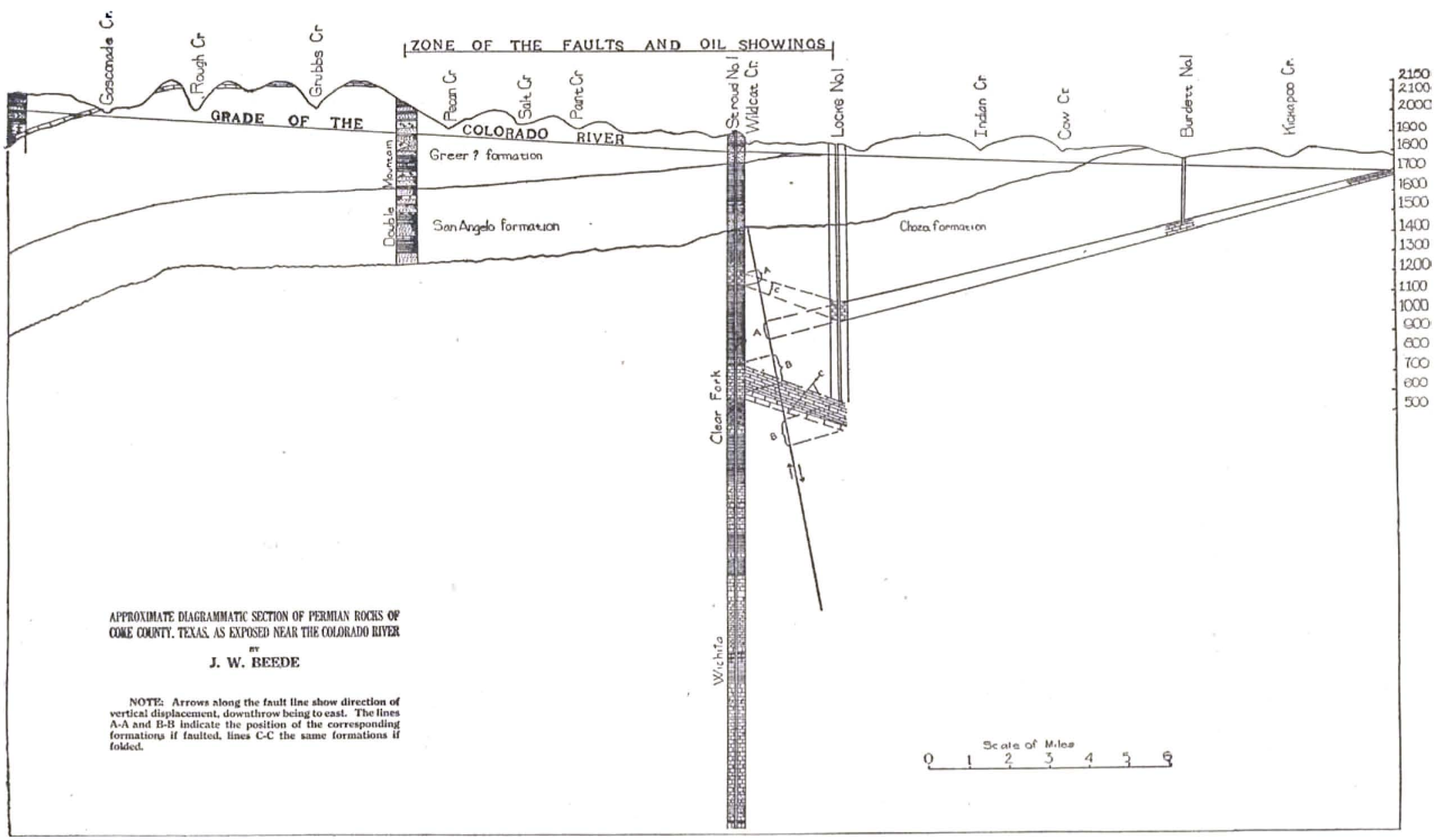
Structures on the major terrace fall into two classes: Folds and faults. The folds are noted east and west of Robert Lee, near Edith, and probably will be found at other localities. One of the features that must be considered here is the fact that at Robert Lee and the mouth of Pecan Creek the Colorado River appears to be synclinal. The same thing is true east of Robert Lee as far as Cedar Mountain. There is little likelihood of its being synclinal west of the mouth of Pecan Creek. These small synclines along the river may be regarded as saddles on the larger terrace. Aside from these somewhat local sags there are also arches, one on Wildcat Creek, and one on Pecan Creek near the junction of North and South forks, another on the side of Mountain Creek just northeast of Robert Lee. Others are probably present. Apparently there is one on the north side of the river near Rough Creek. It is to be regretted that funds were not available to detail the structures of the Colorado River Valley from near Robert Lee to the west line of the county. No attempt has been made to locate all these structures.

On the eastern third of the terrace are numerous faults and zones where the rocks are locally crushed. These zones probably represent slight faulting with some lateral pressure which crushed the rock in vertical zones six to 50 feet or more in width. There is usually a slight displacement of the beds vertically on the sides of the crushed zone, and the crushed beds themselves show slight downward displacement. This crushing passes below the rocks in the beds of the creeks.

The sandstones and sandy shales of these regions are soft and friable. The sand grains are fine and cemented with clay and fine iron oxide, and the shales are but little less sandy than the sandstones. These rocks would stand only a slight lateral compression or strain without rupture.

Crushed zones are associated with normal faults, though the faults themselves are usually well separated. Frequently they are found a quarter of a mile apart, with even-bedded undisturbed rocks between them.

The faults are best seen on Pecan Creek. The other examples seen were located in the bluffs of Pecan Creek. The accompanying photographs illustrate the appearance of these features. They occur from just above the old Arlitt ranch-house to a point a quarter of a mile above the road which crosses the creek just below the junction of North and South Pecan creeks. One of the first bluffs above the house shows a crushed zone. The next shows a reversed fault of almost four feet, and a little forther upstream the same bluff shows crumpled light and dark shale, slightly faulted, between the sandstone layers. Some distance above this are more crushed zones and faults. The largest fault of the number discovered on the creeks is of the normal type. The largest block in htis fault is shown in the accompanying photograph. The fault is open above the creek level and closed below it, but the middle part contains an eight inch sandstone dike. The upper part is filled with sand and clay of surrounding beds and a triangular block of sandstone of considerable dimensions occupies the fault in the top of the exposure. There are several smaller faults on the right of the main fault, one with a displace-

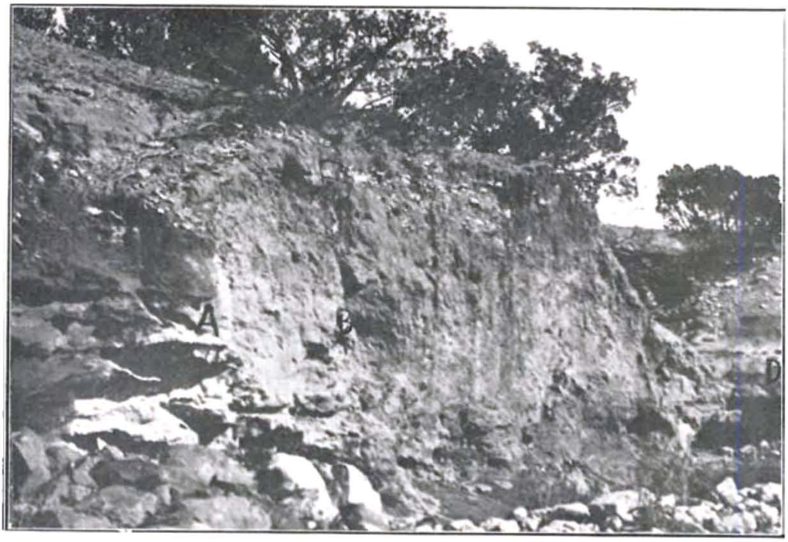


APPROXIMATE DIAGRAMMATIC SECTION OF PERMIAN ROCKS OF COKE COUNTY, TEXAS, AS EXPOSED NEAR THE COLORADO RIVER

BY

J. W. BEEDE

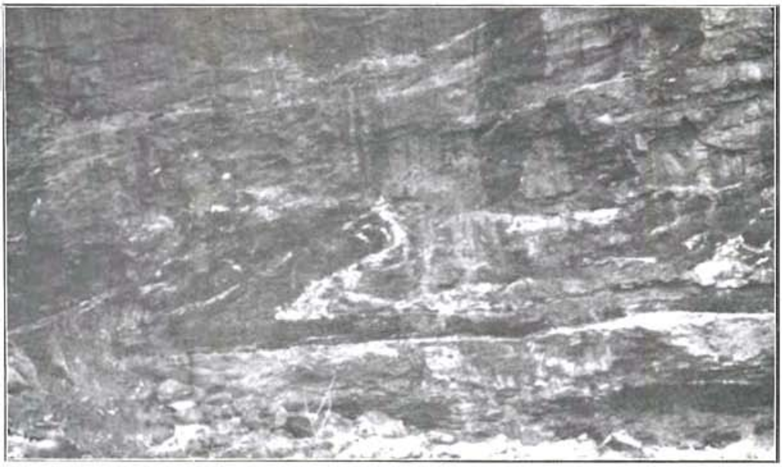
NOTE: Arrows along the fault line show direction of vertical displacement, downthrow being to east. The lines A-A and B-B indicate the position of the corresponding formations if faulted, lines C-C the same formations if folded.



A. Bluff on South Pecan Creek showing crushed zone B—C. Rocks in normal position on either side, and leached zone A—B and C—D where the rocks are light-colored. The deep red color is shown outside the leached zones. The crushed zone is also leached to a light color. Oil showing near this place.

B. A closer and more direct view of the left side of A. Note the sharp line of change in color.

A. Reversed fault in bluff on Pecan Creek, above Arlitt ranch-house.



B. Crumpled shale, slightly faulted, between undisturbed sandstone beds. Same bluff. No leaching of color has occurred in this bluff.

ment of over 10 feet. On the left side of the large fault is another in which the top bed of sandstone shown on the left side of the main fault is opposite the basal sandstone of the block next to it. This makes a total displacement of about 80 feet in this series of faults. The creek bluff is cut away on the left of the exposure and whether or not further faulting occurs there can not be determined. The direction of this fault is N 65° E. The direction of the thrust fault is S 30° E. Other quite small faults occur which are shown in the illustrations and which need not be described here. While no two are precisely alike, yet they all fall in one class.

Origin: These faults are peculiar in several respects and arouse considerable interest regarding their origin. Ordinarily they are absent over nearly all the region of Central Texas.

One of the first things to be noted here is the fact that in the case of the large fault, as well as the smaller ones, the rocks are overlaid by thick deposits of old river gravel which are practically undisturbed by these structures and, though some of the faults are open, none of them contains any of this material. In other words, these structures antedate the final development of the old valley 80 to 150 feet above the present valley of the Colorado River. The age of these gravels is unknown but it is probably either late Tertiary or Pleistocene. In any case, the age of the structure is probably as great as the later Tertiary. The faults have not been noted in the Comanchean beds but may be present.

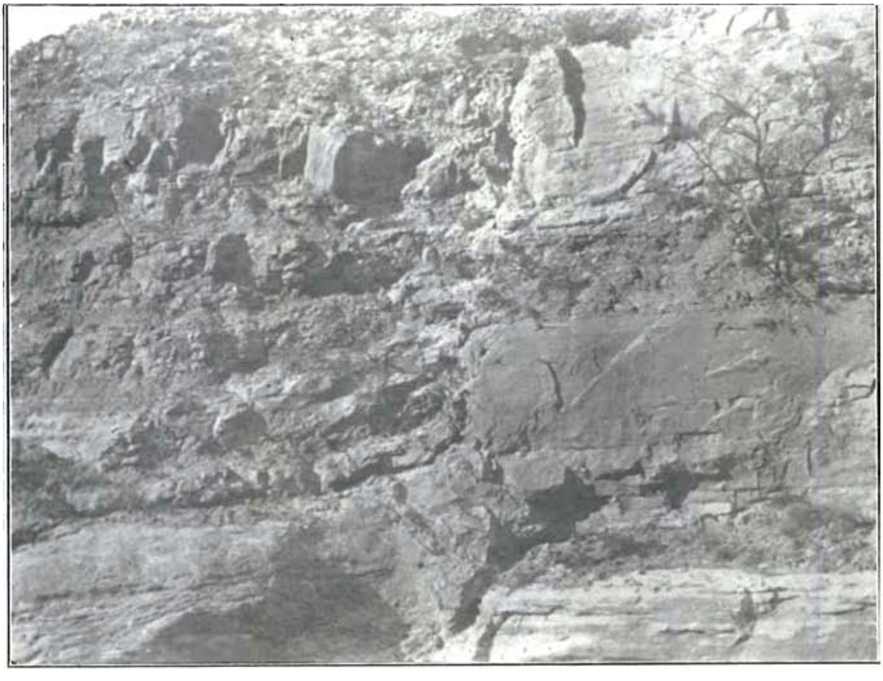
Numerous suggestions have been made regarding the possible origin of these faults, such as solution of rather deep-seated salt beds, deep-seated faulting or folding, consolidation of sediments, slumping, etc.

Solution: The most apparent explanation at first thought would be the solution of rather deep-seated salt or gypsum beds. This might well produce structures similar to the ones seen. However, it becomes necessary to assume the removal of beds as thick as, or thicker than, the largest structures seen, or 80 to 100 feet or more thick. This presupposes the presence of thick salt or gypsum beds (not an incongruous assumption in these red beds) which were removed, producing collapse structures. Most of the structures are small, and well separated from each other, and the beds in the intervening areas are very even and undisturbed. Further, it is necessary to assume the complete removal of the bed at the time of origin of the structures or else structures would have been forming for a long time afterward, the movements of which would probably have involved the overlying conglomerate. This is not the case, however. The disturbances are far too slight and too distant, as a rule, to be attributed to this cause. In such cases the beds should be quite broken and haphazard in their appearance as a whole. On the contrary, the beds are very even and undisturbed except here and there.

Consolidation of sediments: The settling of the beds might under some circumstances produce similar results, but to account for larger faults in that manner presupposes too large an amount of differential settling. Likewise the phenomenon is too local, since it should at least be distributed over the whole terrace, if not over the whole region where the same succession of beds is involved.

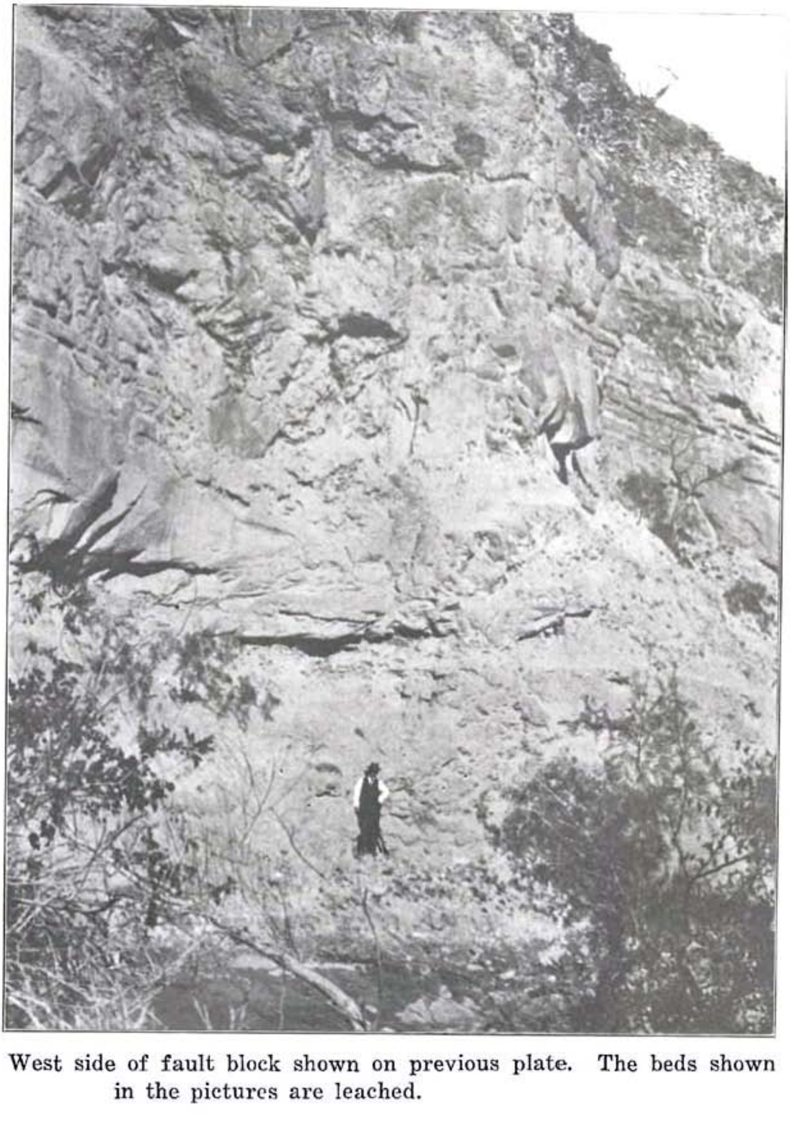
Slumping: The beds of the formation here considered show negligible evidence of slumping along the creek and river bluffs where it would likely be noticeable. They are sandstone and sandy shales which do not slump readily.

Deep-seated movements: This agency could produce any of the results shown here in two ways: First, by dislocations which extend to the surface from deeply buried structure; second, by folding or slight movements of deeper structures without rupture but producing rupture in the suface beds. This latter would seem highly improbable unless the character of the surface strata is considered. These clayey sandstones and sandy shales are so friable that movements causing slight local tension or compression or flexure of the beds might result in just such structures as are seen. Furthermore, these faults and crushed zones are associated with gentle folds upon a large structural terrace, and the possibility of their origin from deeper-seated causes can not be thoroughly comprehended without taking



Large fault on Pecan Creek. None of the beds checks across the fault. Another fault on the left not shown. All are faulted in the same direction.

East side of a fault zone above the Arlitt ranch-house on Pecan Creek. The west side of the fault zone, broken and crushed, is shown in the next plate.



West side of fault block shown on previous plate. The beds shown in the pictures are leached.

this terrace and all its peculiarities and relationships into account.

General Considerations: The terrace itself is broad, extending from near Robert Lee to Wilson Mountain, or beyond; a distance of about 12 miles in an air line. The surface indications of its western limit are stronger than of its eastern edge. So far as observed, faulted structures are confined to the eastern half of the structure, and are strongest near the center of the terrace. This localization of these peculiar structures has some considerable interest if the broader relations of the terrace itself are taken into account. For instance, a similar terrace having a known length of some fifteen to twenty miles at Sheffield, Texas, is described by Liddle in another bulletin.[16] The Sheffield terrace extends almost directly toward the Coke County terrace (N 40°–60° E) is as wide, and, like the Coke County terrace, has its chief local minor structural features on the southeastern side. In addition to this the Sheffield terrace is almost in line with the general axis of the Marathon structure as a whole, and is nearly in line with a very steep fold of the mountain type in Pennsylvanian sediments of the Marathon region. This Marathon fold disappears under the nearly level Comanchean sediments east of Marathon. The Marathon structure has been described by Udden,[17] and further discussed by Liddle in the paper above referred to. In view of these facts, it is by no means impossible that the Coke County terrace is a part of a general structure extending from the Marathon region to Coke County. This structure may persist the whole distance either with local arches and intermediate saddles or without them.

The details upon which this conclusion is based, aside from the general surface similarities already mentioned, are to be had in the comparison of three wells: the Southwestern Petroleum Syndicate Cain No. 1, located about four miles west of San Angelo; the Texas Elkhorn Oil Syn-

[16]Liddle, R. A., Univ. Texas Bull. 1847, pp. 9-16. 1920.

[17]Udden, J. A., Univ. Texas Bull. 1753, pp. 56-57. 1918.

dicate Richardson No. 1 in the southeast corner of Sterling County; and the Robert Lee Oil Company Stroud No. 1, near Robert Lee. We are indebted to Mr. H. H. Jones for samples and valuable data regarding these San Angelo and Sterling County wells. The data are as follows:

The elevation of the Texas Elkhorn Oil Syndicate Richardson No. 1 well is 2200 feet, and it is located near the southeast corner of Sterling County. The Southwestern Petroleum Syndicate's Cain No. 1 well has an elevation of 1890 feet, leaving the Richardson well 310 feet higher than the Cain well. The graphic logs are given on Plate 17. The distance of the Richardson well from the Cain well is approximately 22 miles in an air line and is in the direction of the dip. Over western Runnels, eastern Coke, and probably eastern Tom Green counties, the dip is approximately 50 feet per mile to the northwest.

If this condition continues from the Cain well to the Richardson well the same formations should be about 1100 feet lower in actual elevation than in the Cain well, or 1410 feet deeper in the well. As a matter of fact, the lower part of the log shows an actual elevation 463 feet higher in the Richardson well than in the Cain well. This conclusion is based upon three sets of data.

First, the top of the known Bend formation as determined by the samples, was –2040[18] feet in the Cain well, and –1575 feet in the Richardson well, leaving the top of this formation 465 feet lower in the Cain well than in the Richardson well.

Second, the top of the formation determined by the drillers and some geologists to be the Smithwick shale, in the two wells was: Cain well, –1431 feet; Richardson well, –985 feet, a difference of 446 feet in favor of the Richardson well.

Third, the top of a black limestone of considerable thickness recognized as identical in the two wells by the driller, was –2030 feet in the Cain well and –1550 feet in the Rich-

[18]The symbol "–" signifies below sea-level datum.

ardson well, leaving a difference of elevation of 480 feet in favor of the Richardson well.

Averaging the difference in elevation of the three horizons in the two wells gives 463 feet. The greatest variation of the levels of the horizons is at one extreme 17 feet higher and at the other 19 feet lower than the average. This is practically within the limit of error of determination by usual drilling, on one hand, and is certainly within the limits of variation in thickness of a set of formations 600 feet thick in a distance of 22 miles.

Thus we are forced to concede that the basal part of the sections in these wells demonstrates an actual structure showing an elevation of 463 feet in the level of these beds in the southeast corner of Sterling County, when the continuation of the dip should show an actual depression of 1100 feet for them in this locality. The position of the Richardson well would fall in the Coke County terrace, if continued, and the San Angelo well would not. This should be regarded as strong evidence of the continuation of the large sub-surface structure shown in Coke County at least as far as the south line of Sterling County.

Regarding the correlation of the deeper rocks of Coke County, and the apparent changes which the formations undergo to the westward and southwestward from the Runnels County region, the interpretation of the drill logs is necessary in order to reach any positive conclusions.

The Westbrook well near Tennyson started in the Choza formation of the Clear Fork stage, The base of the Clear Fork and the top of the Wichita Stage appear to have been reached at 750 feet. The base of the Wichita is probably somewhere between 2375 and 2420 feet. Samples are not available and this point can not be determined with any degree of certainty. According to this record, the Vale formation has a thickness of 153 feet, while the estimated thickness of the formation in Runnels County was 154 feet.

The Choza formation in which the well started shows a thickness of 597 feet including the Bullwagon dolomite. The well began below the top of the formation as exposed on the Colorado River. The thickness in Runnels County and eastern Coke County is estimated at 626 feet.[19]

The thickness of the Clear Fork will be seen to check out almost exactly with the Runnels County section.

The base of the Wichita in the Cain well is proably about 3000 feet below the surface. This can not be positively stated until the *Fusulinae* of the central Texas region are known. It certainly should be between 2800 and 3000 feet; probably much nearer the latter than the former figure. If this is the case, the whole of the Strawn and Canyon is wanting here, and, if the driller's diagnosis of the top of the Smithwick shales is a correct one, at 3321 feet, the Cisco is reduced in thickness from 800 feet on the Colorado River in Coleman County to about 321 feet in the Cain well, or at the very most, 525 feet.

In comparing the upper parts of the Cain and Westbrook wells, it is difficult to fix definite limits for the Wichita-Clear Fork and the Clear Fork-Double Mountain stages in the Cain well.

From the nature of the sediments it would seem that the base of the San Angelo beds and top of the Clear Fork beds was at 447 feet, at the bottom of the sandstone members. Comparison of the logs shows that the Clear Fork has apparently thickened at the expense of the Wichita beds, whether by replacement of the upper limestones by shales, or otherwise, can not be said. The top of the Clear Fork is consequently at 447 feet below the surface, and its base —upon purely lithological grounds—seems to be at 1390 feet. This gives it a thickness of 948 feet, showing a slight thickening to the southward, in the Cain well.

If 3000 feet be considered the base of the Wichita, the formation has a thickness of 1610 feet, or 80 feet less than on the Colorado River, all but a little over 200 feet of which is limestone. It should be noted that there are two sand-

[19]The statement on page 49 that the "thickness of the whole formation is 870 feet," should read "thickness of the Clear Fork Stage is 870 (or 880) feet on the Colorado River." Univ. Texas Bull. 1816. 1919.

stones near the top of the Wichita. The Cisco below the Wichita is largely shales with limestone streaks. The coal streak may be near the base of the Cisco in the Cain, Westbrook well, if the underlying beds belong to the Smithwick. The identification of these shales from logs of tests far separated, and from samples frequently leaves much to be desired. A sample of the limestone at 3862 feet was studied by Waite who pronounced it to be Marble Falls limestone.

In the Richardson well there are 80 feet of sandstone and conglomerate at the top, apparently belonging to the San Angelo formation. However, it is not impossible that much of the basal San Angelo formation is here represented by shales and occasional thin limestones.

If we conclude that only the 80 feet belong to the San Angelo formation, then it follows that the Clear Fork has thickened to 1345 feet, the base being at 1425 feet is much more probable that the base is as high as 1170 feet. The top of the Wichita in this well seems to be at the depth of 1425 feet, and its base may be regarded tentatively as at 2852 feet, though it may be below that point. This gives a thickness of 1427 feet for the Wichita, a continued thinning over the Cain well, of 83 feet, or 163 feet over the surface section in Runnels and Coleman counties.

A marked increase in the number of sandstones in the upper and lower Wichita is of interest, there being four here as compared with two in the upper Wichita of the Cain well. These four sandstones have an aggregate thickness of 158 feet. In the lower part there are three sands with an aggregate thickness of 36 feet, while nearly the whole limestone of the Wichita beds is reported as sandy. The base of the Cisco may be 3185 feet, or a thickness of 333 feet. Whether or not the beds below this all belong to the Smithwick shales or to the Cisco is uncertain. The known Bend occurs at 3735 feet and continues to the bottom of the well. Several oil horizons seem to have been struck in the lower part of the well.

The limestones of the Wichita Stage show a marked increase in thickness in the Sterling County well, compared with the Cain well and the shales are thinner and more calcareous, according to the driller, H. H. Jones, who had charge of the drilling of the Cain well and the deeper part of the Richardson well.

One striking feature of the Richardson well is its sandy nature, according to the log. This may indicate extensive sandstones farther southwest, but hardly speaks well for shales there, since it would seem that there was sufficient current present at the time of deposition to sort out the finer material and carry it away. We have seen no samples of this sandy limestone.

While the shales decrease in the lower part of this well they increase very markedly in the upper part, and some of the limestones thin out or become thinner than in the Cain well. In the Stroud well the base of the San Angelo beds is found at 560 feet. The top of the Merkel dolomite, here an anhydrite, is probably at 650 feet below the surface. The heavy limestone which sets in at a depth of 1202 may be the top of the Wichita, or the top may begin with the limestone at 1680 feet. Judging by the Westbrook well, 1680 feet may be considered as approximately the top of the Wichita. This gives the Bullwagon dolomite here a thickness of 217 feet, and the Vale formation thickens from 153 feet in the Westbrook well to 261 feet in the Stroud well, which is a material thickening of the lower Clear Fork beds.

Beginning the Wichita at 1680 feet, its base may be considered roughly at 2986 feet. It may be somewhat above or below this point. This would leave the thickness of the Wichita stage at 1306 feet, a thinning of more than 380 feet over the surface section in Coleman and Runnels counties. This thinning is accompanied by a disappearance of nearly all the shales, and an introduction of sandstone beds in the lower part. The well probably ends near the base of the Cisco. The Cisco will probably be as thin here as in the Cain and Richardson wells.

In view of these circumstances it seems reasonable to interpret the Coke County faults in the light of their position upon this larger structure. As is shown in the section along the Colorado River, the structure beneath the Double Mountain series of rocks appears to be very much greater than that revealed in the surface strata. Whether this structure is due more to faulting or to folding is unknown. As has been stated, the character of the sediments involved in the faults and crushed zones is such that in case of slight disturbance by either folding or faulting, just such structures would likely be formed as actually occur. For this reason the assumption of faulting is unnecessary. However, the oil filling the sandstones of fossil delta channels built in the margin of a sea of highly concentrated waters can but doubtfully be regarded as indigenous and would indicate that there has been sufficient faulting of underlying beds to permit its escape into surface rocks.

OIL AND GAS POSSIBILITIES

Coke County is unique in Central Texas in having good showings of oil in surface sandstones. Some of these sandstones were the sands of delta channels on the margin of a shallow Permian sea. The presence of salt seeps and of gypsum and anhydrite replacing dolomites, as shown by drill cuttings, indicates that the waters of this shallow sea were very concentrated. It is quite doubtful if oil accumulations would occur under such circumstances on account of the scarcity of marine life in such waters. Indications of fossil remains in these sediments are very rare. Moreover, it is yet to be demonstrated that commercial oil accumulations have been found which were indigenous to this type of red beds sediments. Several oil fields have been found beneath or in the red beds. Ohern[20] cites a list of such cases, and a few more have since come to light.

So far as we are aware, all of the known oil in commercial quantities in the red beds is either in a region of known faults, or overlies highly-inclined bituminous beds

[20]Ohern, D. W., A Contribution to the Stratigraphy of the Red Beds. Bull. Amer. Assn. Petr. Geol., II, p. 114. 1918.

beneath an unconformity between the Permian and Pennsylvanian rocks from which the oil might have migrated, as is the case in the western Oklahoma fields around the Wichita and Arbuckle Mountains. Regions near the margin of the red beds and remote from gypsum and salt deposits are excepted.

If these premises be true, it is unlikely that the Coke County oil showings originated in the beds in which they are found, unless they may possibly have been formed in relatively small lagoons of fresher water.

If the oil did not originate in the beds where it now exists it could only reach its present position in one of two ways: First, by lateral migration; and second, by vertical migration.

It is difficult to see how the oil could be formed in this horizon at any other point any better than where it is found. Such concentrated waters are too barren of life to warrant this conclusion. It could be argued that it may have come a long distance from outside of an embayment where the waters were less concentrated. No such sea is known within reasonable distance. The land lay to the east of this region. Almost certainly, the Mount Margaret conglomerate is very near the debouchure of a river of considerable size, since the coarse conglomerate occupies an area 30 miles across. This condition clearly precludes a westward migration. Since the oil showings are about equally profuse in both the San Angelo and the lower Greer formations, separated by considerable thickness of rock, it might have originated in either, but, if anything, the Greer is a less likely source of it than the San Angelo formation. These beds wherever found are characterized by their very extensive gypsum and salt deposits.

The only other possible source that occurs to us is a deep-seated one. It may have been formed in rocks far below the surface and have reached its present position by rising through faults. If we turn our attention to the structure of the rocks of this region a few things are visible which throw some light on the problem. One of these is that, as far known, the oil is found on or near the east side of the terrace in positions coincident with the faulted surface beds of their eastward extension. Another point to be considered is that in the Locke No. 1 well at Robert Lee the driller reported all the rocks encountered as being in normal position and condition. The same driller reported all hard rocks encountered in the Stroud No. 1 well as broken up and not in normal position for a depth of nearly a thousand feet. If this is true, there is some additional evidence of faulting in the rock below the Double Mountain beds. Such a condition could account for the presence of the oil as it is found at the surface. So far as has been determined the larger faults in the surface beds, and for that matter the more pronounced structures as seen at the surface, are in the Pecan Creek region, where oil showings occur. They also occur near Robert Lee.

In the light of available data it seems most reasonable at present to ascribe the origin of the surface oils in Coke County to deep-seated beds.

An inspection of the section along the Colorado River shows the east side of a sub-surface structure, and indicates that much of the top of the buried structure was removed by erosion before the San Angelo and Greer beds were deposited, and further indicates that some 500 or more feet of the structure may have been carried away, bringing any possible oil-bearing bed that much closer to the surface. In this connection, the Texas Elkhorn Oil Syndicate's Richardson No. 1 test in southeast Sterling County is of especial interest since it throws light upon the subject, as has already been pointed out. The difference in elevation of the heavy limestone penetrated in the Stroud No. 1 test and the Locke well, where it was not drilled into, is about 150 feet. Whether this is due to folding or faulting cannot be said, and both possibilities are indicated on the accompanying chart. The driller's report of conditions encountered in the Stroud well would favor the hypothesis that the beds are faulted. Both faulting and folding may have occurred.

Structures not on the Terrace: The structures in the eastern half or third of Coke County are low gentle folds and noses closely related to similar structures described from Runnels County. These have not been worked out in detail, but are suitable structures for oil accumulation should proper sub-surface conditions exist for producing oil. The region has not been sufficiently exploited to determine the point. Four wells have been drilled or are drilling in this part of Coke County but none is of sufficient depth at this writing to form a true test of the presence or absence of these conditions.

In the eastern part of Coke County occur other folds formed by gently dips which are quite similar to those occurring in Runnels County and the region east and northeast. They are rarely conspicuous. Some of the structures of Runnels County were described in the bulletin on Runnels County.[21]

The Westbrook test at Tennyson apparently entered the Arroyo formation at 690 feet and the base of the Lueders at 1174 feet. According to these figures, if the formations maintain their thickness westward, the top of the Cisco in the neighborhood of Tennyson should be reached at about 2350 feet, and the base of the Canyon at about 3300 feet. Just how much of the Canyon may be present is a question, since in some places in this western region there appears to be nothing between the Cisco and the Bend. Whatever tests are made here should be carried through the Bend to the Ellenburger and samples and logs of all the beds penetrated carefully kept and studied.

The main difficulty likely to be encountered in this part of the county is the lack of extensive sandstone or other porous beds to serve as reservoirs for the oil. However, some sandstones were encountered in the Stroud well and more may be encountered if the well should be drilled deeper. Very little sandy material was encountered in the Westbrook well, down to a depth of 3000 feet, as will be noted in the log.

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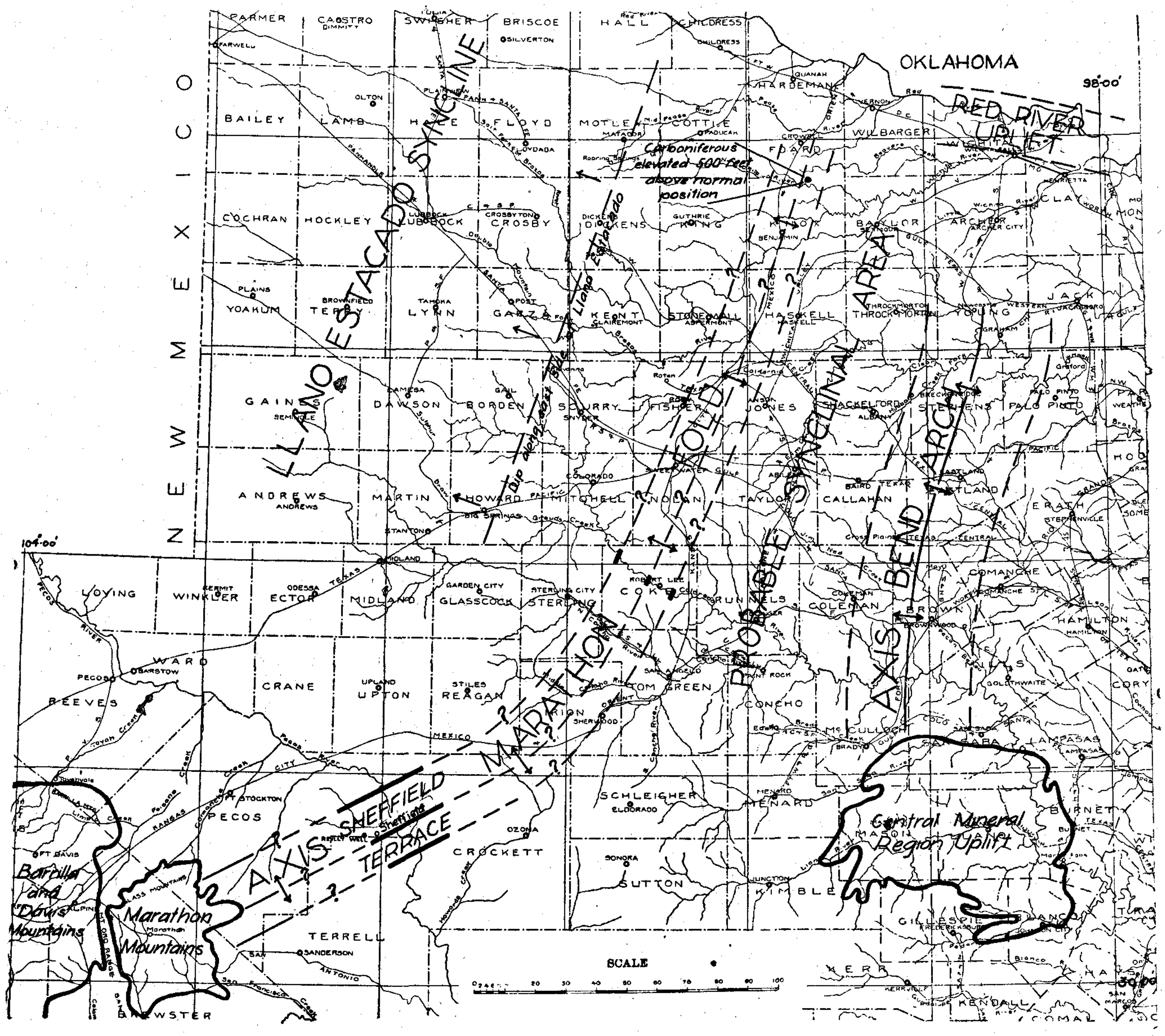
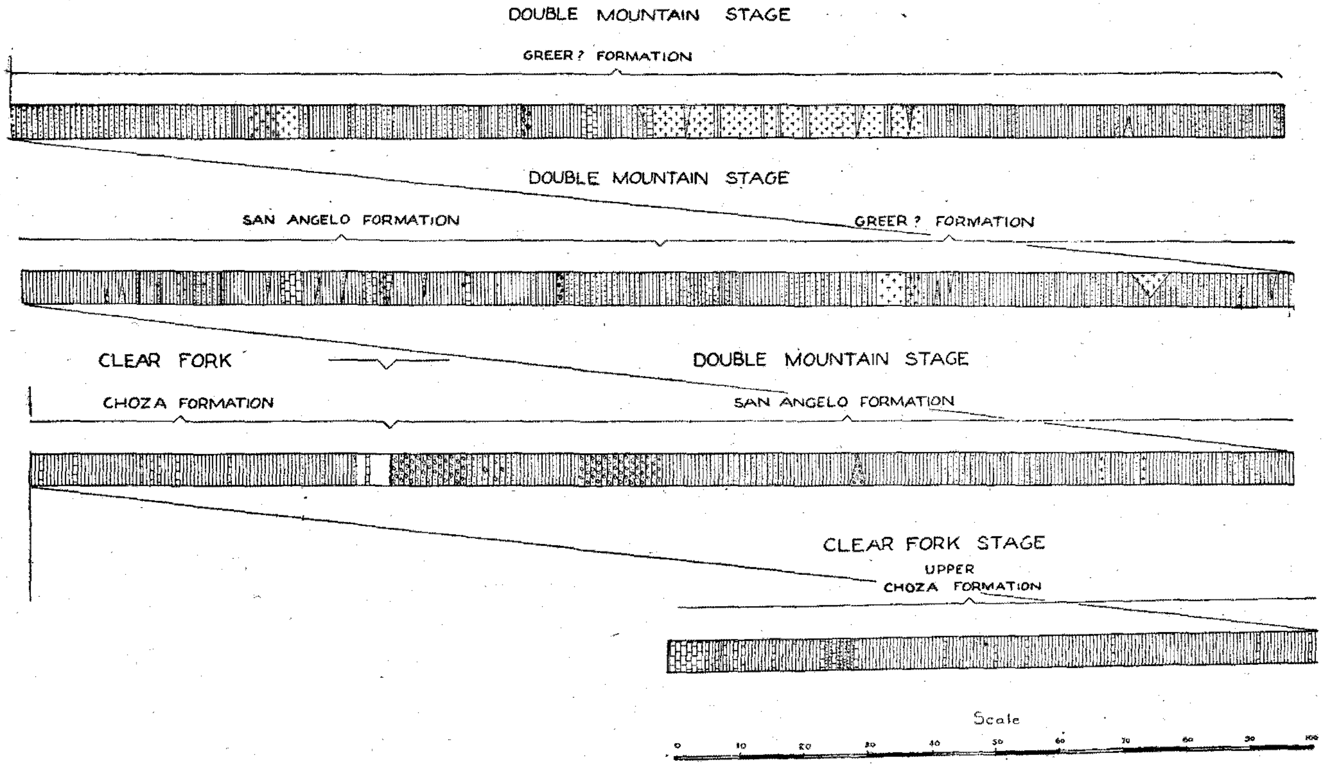
[21]Univ. Texas Bull. 1816, pp. 55-59. 1919.

A. Bluff on South Pecan Creek showing the effect of solution of gypsum beds from between clay and soft sandstone beds. The sandstone below the gypsum zone is in normal condition.

B. Oil showing in highly cross-bedded sandstone in the bed of Mountain Creek just east of Robert Lee.



Map showing hypothetical extension of Marathon Fold. Explanation on map.



Vertical section of surface exposures of the rocks of the Colorado River section in Coke County.

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