W. D. Henderson

University of Texas Bulletin

No. 2330: August 8, 1923

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LEROY T. PATTON

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 geni[illegible]mc[illegible] It is the only [illegible]tor th[illegible] reem[illegible]n acknowledge and the only security that freemen desire.

Mirabeau B. Lamar

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THE GEOLOGY AND MINERAL RESOURCES OF POTTER COUNTY[1]

INTRODUCTION

LOCATION AND AREA

Potter County lies in the northwestern part of the state in that part usually known as the Panhandle. Its eastern border is 90 miles from the western border of Oklahoma, its northern 70 miles from the southern border of the Oklahoma Panhandle, and its western border 62 miles from the eastern border of New Mexico. Moore County borders it on the north, Carson County on the east, Randall County on the south and Oldham County on the west. The area of the county is 874 square miles. For the most part the county is sparsely settled, the greater part of the population being concentrated in the southern part of the county in and near the city of Amarillo. According to the census of 1920 the county had a population of 16,710, the city of Amarillo having 15,494 of this number.

The accompanying sketch map (fig. 1) shows the location and area of the county and its relation to the main physiographic divisions of the state.

NATURE AND EXTENT OF THE WORK

The field work upon which this report is based was done during the latter part of the year 1922. The writer was in the field from October 20 to January 1, 1923. During the progress of the work Dr. J. A. Udden, Director of the Bureau, spent several days in the field with the writer.

The base map used in this report is a compilation from several different sources, including blue print maps put out by several different firms and individuals; private surveys made by W. D. Twitchell for Wm. M. Bush, who kindly per-

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[1]Manuscript submitted July 15, 1923. Publication issued November, 1923.

mitted the use of this data; corrections of existing maps by Howard Trigg, County Surveyor of Potter County; and corrections made by the writer in the field. Stream courses are shown in as much detail and as accurately as possible in order to aid in the interpretation of the topography, but no attempt has been made to distinguish between permanent and intermittent streams. Relief is shown by means of hachures. Location and boundaries of land blocks are shown but sections are not indicated.

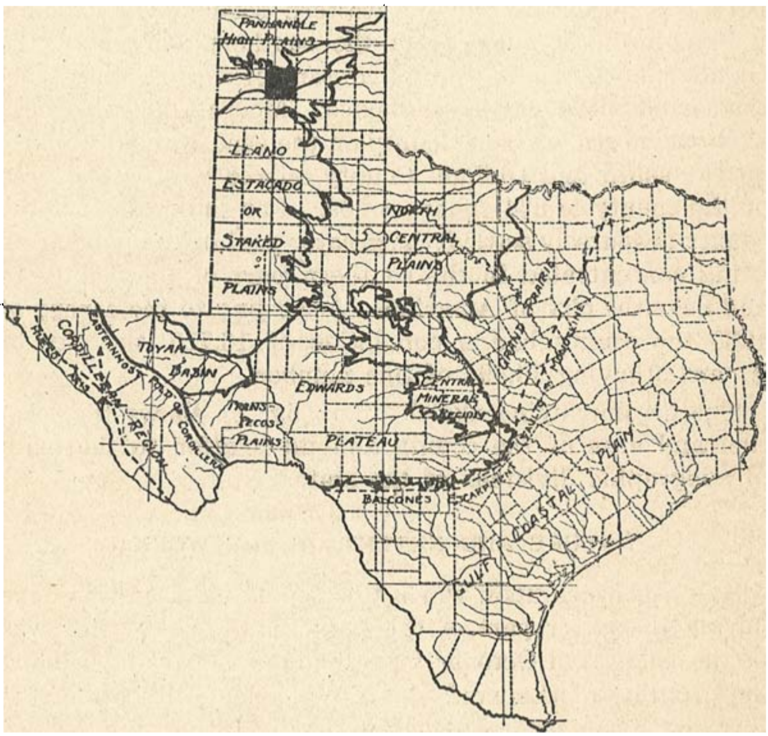

FIG. 1: Outline map of Texas showing the location and area of Potter County and its relation to the main physiographic divisions of the state. Potter County shown in black.

ACKNOWLEDGMENTS

The writer wishes to acknowledge the many courtesies extended to him by the various citizens of the county during the progress of the work. Especial acknowledgments are due to Col. W. A. Miller, Jr., O. V. Vernon, secretary of the board of city development of Amarillo, Howard Trigg, county surveyor, Col. Montgomery, and Judge C. T. Word.

Acknowledgment is also made to Dr. J. A. Udden, Director of the Bureau and to Dr. E. H. Sellards, Chief Geologist, for assistance in the organization of the work, to Dr. Udden for valuable aid and advice in the field and to Dr. Sellards for identification of the vertebrate fossils.

PREVIOUS WORK

No publication dealing exclusively with Potter County has been issued up to the present time, although several papers dealing with larger areas, of which Potter County is a part, have been published.

According to Cummins[1] the earliest geologic work in the Texas Panhandle was done by George G. Shumard, geologist of the Marcy exploring expedition of 1852. During the progress of the expedition Shumard studied the Palo Duro Canyon from the eastern escarpment of the Llano Estacado to the head of the canyon.

In 1853-54 Lieutenant A. W. Whipple, of the Corps of Topographical Engineers of the United States Army, was in charge of an exploring expedition which followed a route from Fort Smith, Arkansas, westward, near the 35th parallel, to the Pacific Coast. The object of this and other similar expeditions was to discover the most practicable route for a railroad to the Pacific Coast. One of the members of this expedition was Jules Marcou, who was the official geologist of the party. The report of this expedition was published by the War Department in 1856.[2]

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[1]Cummins, W. F., Report on the geography, topography, and geology of the Llano Estacado or Staked Plains. Third Annual Report of the Geological Survey of Texas, p. 134, 1891.

[2]Reports of the explorations and surveys to ascertain the most practicable route for a railroad from the Mississippi River to the Pacific Ocean. House of Representatives, Executive Document No. 91, 1856.

This report, which was edited by Wm. P. Blake, geologist of the office of the United States Pacific Railroad Exploration and Surveys, contains in full the notes of Lieutenant Whipple and Marcou, together with a discussion by Blake, and a geologic map compiled by him from the notes and collections of Marcou.

That this expedition passed through Potter County is certain, but it is somewhat difficult from the meager data and insufficient information contained in the notes of Whipple and Marcou to determine exactly which camps of the expedition were located in Potter County. However, the location of Camp 42 on the map prepared by Blake would be near the northeastern part of the county in the neighborhood of Alibates Creek or Turkey Creek. Concerning Camp 42, Whipple[3] states that,

"The sand hills encountered yesterday have disappeared. We are now upon the upper new red sandstone, and many remnants of 'mesas' appear, capped with dolomite. Here are good materials for masonry."

This is a remarkably accurate description of the Quartermaster formation of the northeastern part of the county.

Concerning this same location Marcou[4] states:

"At No. 42, where we rested, we found a beautiful exhibition of the dolomite of the Trias of the prairies, with red and green marls (marnes rouges) and white amorphous gypsum."

This undoubtedly refers to the Quartermaster formation and the dolomite referred to is the Alibates dolomite which here appears in the upper part of the Quartermaster. Marcou accompanies his note with a section.

There seems to be no reason, therefore, to doubt that Camp 42 was near Turkey or Alibates Creek and near or within the present limits of Potter County.

Camp 43 was most certainly in Potter County and, although its exact location is difficult to ascertain, both Lieutenant Whipple's description of the route from Camp 42 to Camp 43 and his description of the location of the camp,

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[3]Op. Cit. p. 34.

[4]Op. Cit. p. 134. Translation by Wm. P. Blake.

and Marcou's notes on the same route and description of the camp site, makes it practically certain that Camp 43 was on Bonita Creek, on what is now the L-X Ranch. As a matter of fact Marcou speaks of Camp 43 being situated on Rio Bonito, although Lieutenant Whipple speaks of it as being situated on Shady Creek. It seems probable that they both referred to the same creek by different names.

It is interesting to note that the formation described in this report as the Coetas formation and the limestone member of the formation were noticed by Marcou. His journal for September 14, is as follows:

> "September 14.—From Camp No. 42 to Camp No. 43.—We found the Rocky Mountain diluvium with white sand, and in the creek cliffs of white sandstone, a little rose colored, with whitish limestone. At Camp No. 43, at Rio Bonita, we found a great development of this sandstone; very friable; of a rose or white color, containing calcareous concretions, and some beds of white limestone. No fossils seen."

Marcou also states that eight miles from Camp 43 in the Arroyo Amarillo they found a dolomite, above and below which sandy red marls occur. He also notes the yellow marls at this place. Eight miles from Bonita Creek would bring the party to West Amarillo Creek where the Alibates dolomite again appears, being brought up by an anticline in this location. It is here that the yellow and variegated colors of the Tecovas formation would be first seen by one traveling the route of Whipple's party. While it might seem that the members of the Tecovas formation cannot properly be described as consisting of marls it is thought that these are the members that Marcou refers to in his notes since this formation in many places is quite calcareous. He speaks of them as "marnes rouges" and as "marnes irises" but on a number of occasions lapses into English and in his original notes speaks of "red sandy marls."

Lieutenant Whipple states that on September 15 they made Camp 44 on Beautiful View Creek, 20 miles from Camp 43. This was evidently on Tecovas Creek. His description of the country as well as the distance accords well with this assumption, which is confirmed by Marcou's description of the journey from Camp 43 to Camp 44.

The work of Lieutenant Whipple's party is undoubtedly the first scientific investigation made in Potter County. After this early investigation, however, no other work was done until 1890, when W. F. Cummins, as geologist of the Geological Survey of Texas, made an investigation of the Llano Estacado and spent a very brief time in Potter County. His route through Potter County was from Amarillo northwest across West Amarillo Creek to Frying Pan Ranch and thence to Tascosa. The results of his investigation of the Llano Estacado were published as a part of the Third Annual Report of the Geological Survey of Texas.[5]

During the field seasons of 1890 N. F. Drake was engaged in investigations of the Triassic of northwest Texas and made some brief studies in Potter County. It is not certain just how much of his time was devoted to Potter County but the only locality mentioned definitely in his report is on West Amarillo Creek four miles northwest of Amarillo. His report was also published as a part of the Third Annual Report of the Geological Survey of Texas.[6]

In 1891 Cummins made another trip through the Llano Estacado but did not go any further north than Palo Duro Canyon and was not, therefore, within the limits of Potter County although his report deals with formations which are exposed in this county. His report was published in the Fourth Annual Report of the Geological Survey of Texas.[7]

During the years 1899, 1900, and 1901 the American Museum of Natural History of New York sent three sucessive expeditions into the Panhandle under the leadership of J. W. Gidley. The expedition of 1899 passed through a

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[5]Cummins, W. F., Report on the geography, topography, and geology of the Llano Estacado or staked plains: Geol. Sur. Texas, Third Annual Report, pp. 129-223. 1891.

[6]Drake, N. F., Stratigraphy of the Triassic formation of northwest Texas: Geol. Sur. Texas, Third Ann. Rept. pp. 227-247. 1891.

[7]Cummins, W. F., Notes on the geology of northwest Texas: Geol. Sur. Texas, 4th Ann. Rept., pp. 179-236. 1892.

part of Potter County but Gidley states that the season's work had practically ended and that the party was merely returning to Clarendon, the base of the expedition, by the way of Canyon City, thence to Amarillo and back to Clarendon along the line of the railroad. Neither of the other two expeditions reached Potter County, but the work of these expeditions has a direct bearing upon some of the problems connected with the geology of Potter County. The results of these investigations were published as a bulletin of the American Museum of Natural History.[8]

The Twenty-first Annual Report of the United States Geological Survey contains an extensive article on the high plains of eastern New Mexico and Colorado, western Texas, Oklahoma, Kansas and Nebraska by Willard D. Johnson[9] in which he discusses the topography and geology of these plains.

His discussion of the geology, however, is confined to the Tertiary deposits.

In 1905 C. N. Gould assisted by T. B. Matthews and E. F. Schramm made a study of the geology and water resources of the western portion of the Panhandle of Texas including the counties of Sherman, Moore, Potter, Randall, Dalham, Hartley, Oldham, and Deaf Smith. The region covered contained approximately 9,360 square miles. The results of this survey were published as a water supply paper of the U. S. Geological Survey.[10]

In the introduction to this paper Gould states that a detailed study was made of each of the above mentioned counties, special attention being given to the valley of the Canadian River and to Palo Duro Canyon.

This paper is a continuation of Water Supply and Irrigation Paper No. 154 by the same author, the latter report

[8]Gidley, J. W., The fresh water Tertiary of northwestern Texas. American Museum Expeditions of 1899-1901. Am. Museum of Nat. Hist., Vol. 19, Article 26, pp. 617-635. Nov. 21, 1903.

[9]Johnson, Willard D., The high plains and their utilization: U. S. Geol. Surv., 21st. Ann. Rept. pt. 4, pp. 601-741. 1902.

[10]Gould, C. N., Geology and water resources of the western portion of the Panhandle of Texas. U. S. Geol. Sur. Water Supply and Irrigation Paper No. 191. 1907.

covering the counties of Lipscomb, Ochiltree, Hansford, Hutchinson, Roberts, Hemphill, Wheeler, Gray, Carson, Armstrong, Donley, and Collingsworth. This paper was published in 1906, the field work for the same having been done in 1903 and 1904.[11]

These two papers by Gould constitute perhaps the largest contribution to the geology of this region made up to that time.

Later J. A. Udden[11a] gave an account of the occurrence of a red potash bearing mineral, which he found in salt from the beds penetrated in a deep boring at Boden. He described many samples of cuttings from this same boring down to 2010 feet, and published the driller's log of the exploration. Before this, potash in the Texas Permian was known only from solutions in brines.

In 1915 the Bureau of Economic Geology and Technology of the University of Texas published a bulletin on the Geology and Underground Waters of the Northern Llano Estacado by C. L. Baker.[12]

The firm of geological engineers consisting of C. N. Gould, Joseph M. Perkins, Leslie C. Hanson, and Robert S. Dewey of Oklahoma City, Oklahoma, have prepared a carefully detailed structure map of the John Ray Dome and the Tuck-Trigg Dome, both of which are situated in Potter County.

At a meeting of the American Association of Petroleum Geologists in March, 1920, Gould[13] read a short paper in which he discussed the structure of the John Ray and

[11]Gould, C. N., Geology and Water Resources of the Eastern Portion of the Panhandle of Texas: U. S. Geol. Sur. Water Supply and Irrigation Paper No. 154. 1906.

[11a]Udden, J. A., Potash in the Permian of Texas, Bureau of Econ. Geol. and Technol., Univ. of Texas Bull. 17, pp. 12-17.

[12]Baker, Charles Lawrence, Geology and underground waters of the northern Llano Estacado: Bureau of Econ. Geol. and Technology, University of Texas, Bull. No. 57. 1915.

[13]Gould, C. N., Preliminary notes on the geology and structure of the Amarillo region: Bull. Am. Assoc. of Petroleum Geologists, Vol. 4, No. 3, pp. 269-275. 1920.

Tuck-Trigg domes and gave a brief resumé of the geology of the region as discussed in his previous publication on the western Panhandle region.

In discussing the work previously done in this region it should be mentioned that the credit for the discovery of the gas field of this county belongs to C. N. Gould, who first discovered the structure and located the first well.

PHYSIOGRAPHY

PHYSIOGRAPHIC RELATIONS OF THE COUNTY

Following the classification accepted by the Association of American Geographers, Potter County lies within that physiographic province known as the Great Plains, which extends from the Rocky Mountain System east to the Central Lowlands and is bordered on the southeast by the West Gulf Coastal Plain of the Atlantic Plains Province. The central part of the Great Plains province is occupied by the High Plains, which extend through the western part of Texas, Oklahoma, Kansas, and Nebraska. Potter County lies within the latter subdivision. The part of the High Plains in Texas north of the Canadian River is known as the Panhandle High Plains and that south of the river as the Llano Estacado. These parts in reality constitute one physiographic unit with the exception that they are separated from each other by the great trench of the Canadian River.

The greater portion of Potter County lies within the Canadian River trench, small portions on the south and north belonging respectively to the Llano Estacado and the Panhandle High Plains.

DRAINAGE

The Llano Estacado and the Panhandle High Plains are constructional plains being a part of the great debris apron spread out from the base of the Rocky Mountains. Topographically they are still in that stage of extreme youth in which the drainage lines have not yet been developed and in fact have only an underground drainage, the water which falls on the surface sinking into the ground until it encounters an impervious stratum and being conducted by this stratum to the scarps of the plain where it feeds the springs found in such locations.

A small part of Potter County may be said to have a drainage of this sort. The area of which this may be said to be true is confined mainly to the extreme southern and northern parts of the county. In the southern part of the county this area is confined mainly to that part of the county south of the Rock Island Railroad on the west of Amarillo, to the part south of the Santa Fe Railroad east of Amarillo, and to a strip of country three or four miles wide, which extends five or six miles north from St. Francis in the extreme eastern part of the county. In the northern part of the county there is but one area of this type, which is confined to a narrow strip one or two miles wide extending along the northern border for about 15 miles from the northwest part of the county. These areas mentioned constitute the only typical portions of the Panhandle High Plains and the Llano Estacado within the county.

The drainage of the remainder of the county is controlled by the Canadian River as the master stream. The Canadian River enters the county about seven miles from the northwest corner, flows in a general southeasterly direction for about 10 miles and then turns east, continuing in that direction until about three-fourths of the way across the county where it makes an abrupt turn to the northeast and flows in that direction for the remainder of its course through the county. The Canadian is a through-flowing river having its source in the Raton Range in northeastern New Mexico, not far from Gardner.

The principal streams tributary to the Canadian River in this county have their sources in springs at the base of the Cenozoic formations, which constitute the material of which the debris apron forming the Llano Estacado and the Panhandle High Plains was built. Some of these streams are of remarkable strength and maintain their flow almost undiminished through long seasons of drought. In all of them, however, where the sources are any distance from the mouth, the lower courses of the streams during the dry seasons of the year are nothing more than sand-choked ravines, the water in the upper courses having disappeared in the sand long before reaching the mouth at the river. The most notable exception to this condition is Bonita Creek which is fed by springs a few miles from its mouth and maintains a strong flow, at all seasons of the year, all the way to the river. The strongest springs in the county are those at the head of Tecovas Creek. It should be noted in this connection that Tecovas Creek has worked the farthest headward and developed the greatest number of drainage lines of any stream in the county.

Beginning at the extreme northeastern part of the county the stream valleys tributary to the Canadian River from the south are as follows: Turkey Creek, Alibates Creek, Coetas Creek, Chicken Creek, Bonita Creek, Pedrosa Creek, East Amarillo Creek, West Amarillo Creek, Horse Creek, Tecovas Creek, and Cerrite la Cruz Creek. Of these Coetas Creek, Bonita Creek, Tecovas Creek and West Amarillo Creek maintain their streams throughout at least a part of their courses during the entire year.

North of the Canadian River the principal stream valleys are as follows: Plum Creek, Big Canyon, Home Creek, Pitcher Creek, John Ray Creek, Lahy Creek, Sandy Creek or Little India Creek, and Big India Creek. Pitcher Creek is a short creek having its source not far from the river and maintains a fairly strong stream throughout its course at all times. John Ray Creek maintains a small stream for a mile or two from its source even during the dry season of the year. At such times the other valleys north of the river are entirely devoid of streams.

Without exception the minor streams of the county flow in a general north or south direction to the Canadian River. The result of this uniform direction of flow has been to carve the county into a large number of north and south valleys. The roads of the county follow the divides or the valleys and few roads or even trails lead from the east to the west. As a result, with the exception of the extreme southern part of the county, which is situated on the Llano Estacado, it is practically impossible to travel across the county in a direct east-west line.

RELIEF

There is a very great variety in the topographic features of the county. This variation arises from a number of different causes, chief among which are the following: (1) The great differences in elevation between the central part of the county and its northern and southern borders, due to the presence of a through-flowing stream which has entrenched itself in a high plateau. (2) Great variations in the nature of the underlying formations so that the surface formations in different localities within the county include massive resistant dolomite, massive sandstone and conglomerate, slightly consolidated sandstones, shales varying in lithologic character and in resistance, and stratified sand and gravel, some of which is partially cemented and other portions of which are wholly unconsolidated. (3) Variations in structure from domes and folds of considerable size to practically flat lying strata. The work of agents of erosion in a region in which so many diversified directional influences have been brought to bear has resulted in an almost bewildering variety of physiographic features.

The dominating topographic feature of the county is the great trench of the Canadian River. Reference to the valley of the Canadian River is usually understood to mean the somewhat narrow and steep-sided canyon through which the river flows at the present time. While this conception of the term may be considered correct in the popular usage it is not the correct one in the physiographic sense, as the real valley of the Canadian River occupies practically the whole county. From the edge of the upper rim rock on the southern part of the valley to the corresponding edge on the northern is a distance of over 25 miles, the entire distance from the northern to the southern border of the county being but a little over 30 miles.

In the southwestern part of the county the valley edge is a very distinct escarpment, formed both by the so-called "cap rock" or caliche and the massive Trujillo sandstone and conglomerate of the Triassic system. The line of the escarpment is very irregular. Streams working back headward have indented its margin leaving many promontories and lobate extensions. Along the margins there are also many isolated buttes and mesas, erosion having cut off former promontories and extensions from the escarpment. East of Amarillo this escarpment dies out and the approach to the headwaters of East Amarillo and Pedrosa creeks is by gradual and, in some places, almost imperceptible slopes. Near the headwaters of Coetas and Bonita creeks the escarpment appears again, being here formed by the Cenezoic deposits alone. North of the river a very distinct escarpment occupies a position a few miles south of the northern border and extends about two-thirds of the way across the county from the western border. East of this the distinct escarpment, for the most part, dies out.

Back from the edge of the greater valley on both sides of the county, the physiographic expression is that which is typical for the Llano Estacado and the Panhandle High Plains. The surface is flat and featureless, drainage lines are undeveloped, and broad shallow depressions locally known as "lakes," and which for a considerable portion of the year are actually occupied by shallow bodies of water, are found in considerable abundance.

From the edge of the greater valley to the bed of the river there is a considerable difference in elevation. The elevation of Bushland, in the southern part of the county a short distance from the escarpment, is 3788 feet above sea level. The elevation of the bed of the Canadian River at the bridge near the center of the county is 3004 so that the difference in elevation between the edge of the greater valley and the bottom is nearly 800 feet. Plate VIII, A shows the relation of the greater valley of the Canadian River to the topography of the county.

Below the edge of the greater valley the agents of erosion have carved the formations into many different land forms, these differences resulting from the dissimilarities in the nature and structure of the underlying materials.

In the northeastern part of the county in the eastern part of the D. & P. Block 018 and G. & M. Block 3, the geological formation at the surface is the Quartermaster formation of the Permian system. Near the top of this formation is the massive Alibates dolomite which is very resistant to weathering and erosion. In this part of the county there is also the large structural feature known as the John Ray Dome. From the river the strata rise to the north and west quite rapidly—as much as 400 feet in eight miles. The unconsolidated Tertiary deposits and most of the Quartermaster formation, down to the Alibates dolomite, have been removed by erosion; the Alibates dolomite in most places forming the surface rock. Only isolated patches of the Tecovas formation of the Triassic system are found in this region. It is thought that these were removed by erosion prior to the deposition of Tertiary sediments as these, where present, in most cases rest upon the eroded surface of the Quartermaster formation, the Tecovas occurring between the two only in rare instances in this part of the county. The type of topography resulting from the conditions outlined above is that of a dolomite capped table-land incised by numerous steep-sided canyons, varying from the narrow short canyons cutting back from the river to canyons a mile wide from rim to rim, 200 to 250 feet deep and six to eight miles long. These canyons are not ordinarily occupied by any stream and the whole table-land is a wild, thirsty, desolate region. Over the flat floor of the canyons are scattered many erosional remnants in the form of isolated buttes and small mesas and pyramid-shaped hills. These are especially numerous at the mouths of canyons where the numerous short gullies having the advantage of steep slope and short distance have carved and recarved the abutments of the canyon mouths into many fantastic and castellated forms. Plate 1, A, a photograph taken at the mouth of Alibates Creek, shows this condition very well. Plate 1, B shows one of the typical canyons of this region. The brilliant vermilion color of the Quartermaster formation gives to these canyons a peculiar beauty, combining to make the scenery of this highland region at the same time both desolate and forbidding and one of surpassing beauty.

The largest of the canyons of the region is of course the canyon of the Canadian River, which, although a mile or more wide from rim to rim and in places becoming much wider than this, is steep-sided and exhibits the same characteristics as is shown by the smaller canyons. Plate 1, C shows a view of the canyon of the Candian River.

A very peculiar feature of the canyon of the Canadian is exhibited in the relation of the canyon to the structure. The rocks of the Quartermaster formation throughout the course of the river through the county dip south from the river so that the canyon has been incised in the side of a structural slope. This relation is shown in the geologic cross section Plate VIII, B.

South of the river in the northeastern part of the county the Quartermaster formation passes underneath the surface in a short distance and its place is taken by the sands and gravels of the Cenozoic, which are for the most part unconsolidated. As a consequence the wild and desolate canyons of the highland region give place to the broader open valleys with gently sloping sides. This is especially noticeable in Bonita Creek valley, which in its pleasant open aspect, its bordering trees and grass kept green by its springs even after months of drought is in pleasant contrast to the dry, thirsty canyons of the dolomite capped table-land to the north.

Not only do the Cenozoic deposits here occupy a lower position than those on the dome north of the river but streams draining this part of the region are forced to flow against the dip of the Alibates dolomite in emptying into the river. For these reasons erosion has not removed these later deposits from this part of the region to the extent that those north of the river have been removed.

North of Coetas Creek, and especially between Alibates Creek and the river, the Cenozoic deposits have been carved into a series of small hills and ravines resulting in extensive areas of bad lands. To the east, in the neighborhood of G. & M. Block 22, the bad lands gradually pass into low lying swells of sand and gravel covered country and finally into the more level soil covered country of the plains.

Coetas and Bonita Creek valleys exhibit a somewhat different type of topography. Here the limestone which caps the soft sandstone of the Coetas formation has protected the latter from being carved into bad lands and the valleys are wide and open with somewhat broad level topped divides which, however, have been carved by many ravines and gullies giving the divide a somewhat serrated appearance in places. Plate 1, D, shows a view of the Coetas Creek-Bonita Creek divide.

East of the divide of Bonita, Chicken and Coetas Creeks there are more or less extensive areas of dune sand. Sand derived from the Coetas formation is blown up the gentle southwestward sloping valley sides and finds lodgement on the lee side of the steep northeastward facing slopes. The most extensive of these dune areas is east of the divide between Bonita and Chicken Creeks. The dune area here is half to three-fourths of a mile in width and several miles long. Dunes 30 to 40 feet high may be found. In some places the dunes are advancing across the valley of Chicken Creek and burying the valley.

West of Bonita Creek the valleys of Pedrosa and East Amarillo Creeks, where their valley walls are capped by the massive Trujillo sandstone, again assume something of the canyon-like aspect of the valleys of the Quartermaster highlands, but the generally lower elevation of this formation above the river bed results in the development of a less rugged topography than that seen north of the river.

Between Pedrosa Creek valley and East Amarillo Creek valley there is an extensive deposit of the later Cenozoic formations which have been carved into a series of bad lands similar to those north of Coetas Creek. Although the hills of these bad lands are for the most part composed of stratified sand and gravel of the later Cenozoic formations, the older underlying formations have, in some places, been cut into and constitute a part of the material of hills.

On the north side of the river in the western half of the county, extending southward from the escarpment of the cap rock near the border of the county, there is a somewhat well developed terrace several miles in width extending west to the neighborhood of the headwaters of India Creek. Whether this is a structural terrace, being a continuation westward of the structure so well known in the denuded area of the Quartermaster outcrop, or whether it is a terrace of erosion could not be determined. It is largely mantled by later Cenozoic deposits both of stratified sand and gravel and wind blown sand and over much of its extent has also a covering of loess-like soil so that little information could be gained as to its real nature. South of this terrace the underlying sand and gravel formations have been carved by erosion into many open valleys and rolling hilly country with many areas of bad lands and drifting wind blown sands. The numerous sand-choked ravines, bad land topography, and dune areas of this part of the county make investigations here very difficult. Plate II, A, shows a view taken in this part of the county.

The streams, in the majority of cases in the part of the county under discussion, enter the river valley through more or less canyon-like valleys near their mouths but this aspect is seen for only a short distance from the mouths since the Trujillo sandstone, which forms the capping of the valley walls, passes under the later deposits a short distance up stream. The valley of Big India Creek, however, is of the canyon type for the greater part of its course. It is from a hundred and seventy-five to two hundred feet in depth and three-fourths of a mile or more wide. Its walls are capped by Trujillo sandstone above which appear deposits of the Cenozoic. In many places these have been eroded away near the valley edge leaving the Trujillo sandstone as the valley capping.

The Canadian River cuts through the Alibates dolomite on the flanks of both the Tuck-Trigg and John Ray dome. In both cases the river flows through narrow steep-sided canyons. From Sec. 78, H. & T. C. R. R. Block 47, to Sec. 68 of the same block the inner valley of the river is less gorge-like, the Alibates dolomite being below the level of the river between the two domes. From Sec. 68, H. & T. C. R. R. Block 47, to the northeastern corner of the county the river flows the entire distance through a steep sided canyon cut in the Quartermaster formation. The canyon in this part of the county is not as narrow, however, as the one incised on the flank of the Tuck-Trigg dome.

West of the highway bridge across the Canadian River near the center of the county there is on the north side of the river a rather extensive flat, which has been developed on the shales of the upper part of the Quartermaster and the lower Tecovas. It attains its greatest width between the mouths of John Ray Creek and Lahy Creek, where it is a mile and a half to two miles wide. It is here terminated abruptly on the north by the cliffs capped by the Trujillo sandstone.

From the neighborhood of Section 96, H. & T. C. R. R. Blk. 47, to the western border of the county there is no immediate inner gorge such as is present where the river cuts through the Quartermaster formation and the river flows along a wide level flat several miles wide bordered by the cliffs capped by the Trujillo sandstone.

On the southern side of the Canadian River in the immediate neighborhood of the mouths of East Amarillo Creek and West Amarillo Creek in the central part of the county the upper shales and sandstones of the Quartermaster have not all been removed and they have been carved into a series of "bad lands." These bad lands extend back to the north gradually passing from the Quartermaster to the Tecovas and to the later Cenozoic, so that all of these formations are represented in this type of topography in this part of the county.

In that part of the county south of the Canadian River and between the east bluff of the valley of East Amarillo Creek and the west bluff of the valley of Tecovas Creek the

Trujillo sandstone does not outcrop north of Sec. 1, B. S. & F. Blk. J. A. D., where it outcrops in a hill east of the Ft. Worth and Denver R. R. Cenozoic deposits, however, are found in this area and so far as could be determined these rest on the eroded surface of the Tecovas. The evidence, therefore, indicates that the Trujillo sandstone had been removed by erosion prior to the deposition of these later materials. The marked difference in topography of this part of the county as contrasted with other parts is due, therefore, to a difference in geological history as well as other causes.

The valley of Tecovas Creek and the west branch of West Amarillo Creek as seen from the escarpment a few miles south of Gentry presents the aspect of an immense amphitheater. The irregular line of the escarpment of the Llano Estacado can be seen stretching out to the west with its many promitories and indentations and continued to the north as part of the escarpment of the Trujillo formation. Just west of Gentry this wall is broken through by a western tributary to West Amarillo Creek which cuts it completely in two in the neighborhood of Section 121, B. S. & F. Blk 9. This branch of West Amarillo Creek and the northeast branch of Tecovas Creek are struggling for the possession of the low divide northwest of Gentry, a struggle which will no doubt lead to the beheading of one or the other of these branches in the near future.

The floor of this amphitheater is occupied by gently rolling country, the divides and shallow valleys of the many branches of upper Tecovas Creek.

West of Tecovas Creek in the neighborhood of Boden in the southeastern part of G. & M. Blk. 8 and northeastern part of E. L. & R. R. Blk. 2 D. the Trujillo forms a distinct and prominent escarpment which, however, dies away to the southwest. This escarpment is also very prominent in the sides of the valley of Cerrite la Cruz Creek. This valley presents a topography more of the canyon type although the valley is somewhat wider in some parts than those of other valleys of this type in county, excepting of course the Canadian itself.

PHYSIOGRAPHIC RECORD

The physiographic history of Potter County is apparently that of a previously excavated valley which has been buried and subsequently resurrected by renewed erosion. This conclusion seems inescapable from the fact that the later Cenozoic deposits of stratified sand and gravel may be found in all parts of the valley from the highest rim to the lowest part of the valley and that they rest unconformably upon each and every one of the older formations exposed within the valley.

Attention has already been called to the absence of the Trujillo sandstone on the divide between East Amarillo Creek and West Amarillo Creek and the latter creek and Tecovas Creek in the neighborhood of E. L. & R. R. R., Blk. 21 W., and G. & M., Blk. 19 and the northwestern part of A. B. & M., Blk. 2. Over a considerable portion of this area the later Cenozoic deposits are found. It would seem, therefore, that the Trujillo sandstone must have been removed by erosion previous to the deposition of these deposits.

East of Bonita Creek the Trujillo sandstone disappears beneath the thick Cenozoic deposits. It is not certain that the Trujillo was removed before the deposition of these materials, but the fact that it has been removed in a portion of lower Pedrosa Creek valley would tend to favor this hypothesis.

In the valley of the Tecovas Creek the Cenozoic deposits have been entirely removed over wide areas. It is not possible, therefore, to determine just what parts of this valley are the products of the present erosion cycle and what parts of a former one.

The extreme youth of the stream valleys on the northern side of the river as compared with those on the southern side has already been noted and suggests the possibility that the present river channel is nearer the northern rim of the greater valley than that of the previous stream, thus giving these streams a greater fall in shorter distances and enabling them to cut deeper and narrower valleys. This hypothesis agrees well with the absence of the Trujillo formation for considerable distances south from the river and its presence on the bluffs bordering the river on the north side. On the other hand it should be noted that the Tuck-Trigg dome brings up the lower formations in the vicinity of the divides between East Amarillo Creek, West Amarillo Creek and Tecovas Creek thus facilitating the removal of the Trujillo sandstone by erosion.

That the present Canadian River is not flowing in the same channel as the river, which excavated the valley before the deposition of the earliest of the Cenozoic deposits, seems to be the conclusion from the extreme youth of the gorge and its relation to the structure. In the discussion of the relief it has been shown that the Canadian gorge, for a large part of its course through the county, is incised in the side of the structural slope. It is difficult to see how this could take place unless the river had started to flow upon another surface and was superimposed upon this structure.

It is not probable that the filling and reexcavation of the greater valley took place as two successive movements. The history of the later deposits has probably been that they have been deposited and reexcavated at different times as changing climatic and other conditions made the streams which were concerned, aggrading or degrading streams. The final result, however, seems to have been the complete burying of the old valley beneath the stream-laid Cenozoic deposits. When conditions again became favorable to erosion, these deposits were eroded and the old valley resurrected, but with the course of the main stream somewhat different from that of the stream which originally excavated the valley. In the course of this latter history the streams tributary to the main stream have developed a topography controlled largely by structure and the underlying geologic formations.

STRATIGRAPHIC GEOLOGY

The rocks exposed at the surface in Potter County belong to the Permian, Triassic, Tertiary and Quaternary systems, respectively. The Permian and Triassic rocks consist

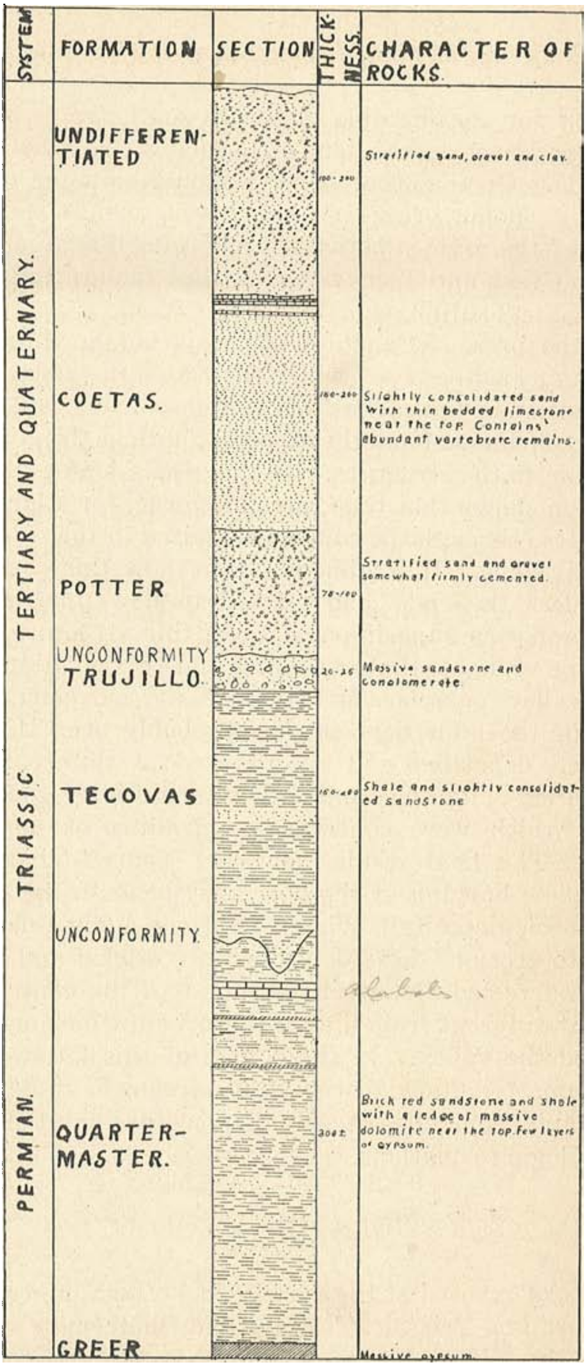

FIG. 2: Generalized columnar section of the rocks exposed in Potter County.

wholly of indurated sediments. The Quaternary sediments on the other hand consist largely of unconsolidated sands and gravels with some slightly consolidated materials near the base. Owing to the fact that Potter County lies almost wholly within the valley of the Canadian River, a greater variety of rock formations are exposed at the surface than is the case in most other Panhandle counties, making this county therefore, a valuable field for geologic study. A generalized columnar section of the rocks exposed in Potter County is given in Fig. 2.

The deep wells, drilled in exploration for oil and gas in this county, have resulted in the acquisition of valuable knowledge concerning the formations not exposed. The formations of the county will, therefore, be described under two divisions, the first consisting of the rocks not exposed and the second of the rocks exposed. The formations will be described in order of their age, beginning with the oldest.

ROCKS NOT EXPOSED

The rocks not exposed, which are known only from observations in deep borings, belong for the most part to the Permian and possibly in part to the Pennsylvanian systems.

Twenty deep wells have been drilled within the county. The deepest well is that of the White Oil Corporation well in Section 5, G. & M. Block 3, which was drilled to a depth of 4200 feet or 973 feet below sea level. The shallowest of these wells is that of the United States Geological Survey drilled near Cliffside. This well, which was drilled in a search for potash deposits, reached a depth of only 1703 feet or 1897 feet above sea level. Besides the White Oil Corporation well mentioned above, the other wells reaching depths comparable to this well are: The Amarillo Oil Company's Bivens No. 2, in Section 2, G. & M. Block 20, which reached a depth of 3724 feet or 628 feet below sea level; the Tuck-Trigg well in Section 37, G. & M. Block 5, which reached a depth of 3900 feet or 590 feet below sea level; the Miller Oil Company well in Section 59, A. B. & M. Block 2, which reached a depth of 3941 feet or 332 feet below sea level.

The majority of the other wells in the county penetrated to depths ranging from 2000 feet to about 2400 feet. With the exception of the Miller Oil Company well in Section 59, A. B. & M. Block 2, the White Oil Corporation well in Section 5, G. & M. Block 3, the Seven States Oil Company well in Section 127, A. B. & M. Block 2, the Capitol Petroleum Company well in Section 127, A. B. & M. Block 2, Carson County, near the Potter County line, the Amarillo Petroleum Company well in Section 16, A. B. & M. Block M-3, and the United States Geological Survey well in Section 21, B. S. F. Block 9, all of the wells started at or near the horizon of the Alibates dolomite which is near the top of the highest Permian formation. The wells noted above as being exceptions to this started on younger formations and penetrated a maximum of possibly 500 feet before encountering the top of the Permian.

Information regarding the rocks not exposed was obtained from two sources: (1) from logs kept by the well drillers; (2) from samples taken at various depths and submitted to the Bureau by the companies operating in the field. Samples so submitted were studied and described in the sub-surface laboratory of the Bureau and a report made to the persons submitting the samples. Records of these examinations were also entered in the Bureau files. In a separate chapter of this report there is given a log of each well drilled in the county together with descriptions of all samples obtained from that well. The most complete set of samples is that from the Amarillo Oil Company's Bivens No. 2, which includes 50 samples taken from depths from 2437 to 3724 or from 669 feet above sea level to 628 feet below.

A study of the well logs and the descriptions of the samples taken from the wells show that the strata penetrated consists largely of red beds (red shale and sandstone) salt beds, gypsum, anhydrite, dolomite and limestone, sandstone, and shale.

The red beds seem to be mostly confined to the first 2000 feet although red beds are also reported at much greater depths than this. The salt beds seem to be mainly confined to about this depth, although exceptions occur, notably in the case of the Miller Oil Company well in Section 59, A. B. & M. Block 2, the Seven States Oil Company well in Section 127, A. B. & M. Block 2, and the Amarillo Petroleum Company well in Section 16, A. B. & M. Block M-3. The gypsum beds are also largely confined to horizons above this depth. Since red beds, gypsum and salt beds are characteristic of the Double Mountain formation of the Permian System and this formation is about 2000 feet thick[14] it seems probable that about the first 2000 feet penetrated represent the Double Mountain formation. While the data are insufficient to warrant a positive conclusion in this respect there seems to be no reason against the conclusion that the first two thousand feet, and possibly more, penetrated by those wells starting at or near the top of the highest Permian formation belong to the Permian System. Below the depth of 2000 feet the dolomite limestone ledges make up a much larger proportion of rocks although a large number of such ledges are reported above this depth.

With regard to the question as to whether all of the strata penetrated by the wells within the county belong to the Permian or not, the descriptions of samples from the Amarillo Oil Company's Bivens No. 2, in Section 2, G. & B. Block M-20, seem to offer the best evidence. Attention is called to the description of these samples and discussion of the same by Dr. Udden. It will be noted that he concludes that the samples from 2671 to 2716 and from 2740 to 2745 and from 2867 to 2872 as well as the samples below this depth indicate arkoses of the kind found in the Abo and Magdalena beds of New Mexico and that the fossils found in the samples from 3415 to 3612 are a suggestion that this interpretation is correct. Since this well starts near the top of the Permian at the horizon of the Alibates dolomite this interpretation would mean that the Pennsylvanian System is encountered at a maximum of about 2700 feet from the top of the Permian. If then the first hypothesis, namely, that

[14]Udden, J. A., Baker, C. L., Bose, Emil, Review of the Geology of Texas; University of Texas Bureau of Economic Geology and Technology, Bull. No. 44, p. 54. 1919.

the first 2000 feet represent the Double Mountain formation is retained, the Clear Fork and Wichita formations would be represented by a maximum thickness of only about 700 feet. Whether or not this is the case cannot be positively ascertained.

The main gas producing horizons occur at depths less than 2700 feet from the top of the Permian so that if the interpretations advanced above are accepted the gas producing horizons are to be assigned to the Permian. This does not necessarily mean, however, that the gas originally occurred in the rocks in this system as it may have migrated to the position which it now occupies.

The occurrence of igneous rocks in the formations under discussion calls for some attention. In seven out of the twenty wells drilled within the county igneous rocks have been reported by the drillers or found in the examination of well samples or both. In the case of two wells, Amarillo Oil Company's Bivens No. 2, in Section 2, G. & M. Block M-20 and the Amarillo Oil Company's Masterson No. 5, in Section 31, G. & M. Block M-3, the wells ended in igneous rock. In all the other cases sedimentary rocks were found below the igneous rocks. In the following table there is given a summary of the occurrence of igneous rocks in the wells of the county.

SUMMARY OF THE OCCURRENCE OF IGNEOUS ROCKS IN THE DEEP WELLS OF POTTER COUNTY

Note: (d) As reported by the driller. (s) From description of sample examined in sub-surface laboratory of the Bureau.

Name of Well.	Location.	Character of rock	Depth.
Amarillo Oil Co. Masterson No. 5	Section 31, G. & M. Block 3.	Pink lime or granite (d)	2230-2256
		Pink granite (s)	2210
		Pink granite (s)	2205-2210
		Quartz and feldspar evidently from igneous rock	2256
Amarillo Oil Co. Bivens No. 2.	Section 2, G. & M. Block 20.	Gneiss-like crystalline rock (s)	2690-2700
		Granitic material (s)	2700-2716
		Dark red, variegated gneiss-like crystalline	

Name of Well.	Location.	Character of rock	Depth.
		rock (s)	2716-2724
		Pinkish-gray schist consisting of quartz and light gray feldspar (s)	2700
		Rhyolite porphry (s)	2722
		Feldspar and quartz fragments (s)	3230-3240
		Feldspar and quartz fragments (s)	3240-3250
		Granite conglomerate (d)	3265-3280
		Granite material	3690-3692
		Quartz and feldspar evidently from granite	3694-3699
		Fragments of red granite or gneiss	3716-3724
Ranch Creek Oil Co's. Hapgood Well	Sec. 2, E. L. & R. R. R., Block B-11	Dull red granite of fine texture (s)	*
		Fine grained red granite (s)	*
		Red gneiss-like rock composed of quartz and feldspar	*
Greater Amarillo Well No. 1	Sec. 20, G. & M. Block No. 3	Porphyritic rhyolite (s)	2045-2030
Amarillo Oil Co. Bivens No. 3	Sec. 20, G. & M. Block 20	Granite (d)	2468-2501
		Granite (d)	2501-2507
		Samples containing crystalline rock but not possible to tell whether this represents crystalline rock in place or conglomerate	2500-2510
Emerald Oil Co. Masterson No. 1	Sec. 82, G. & M. Block No. 3	Granite (d)	2000-2030
		Granite (d)	2030-2050
		Granite (d)	2050-2075
		Granite (d)	2075-2131

*Exact depth not known.

Name of Well.	Location.	Character of rock	Depth.
Amarillo Oil Co. Masterson No. 3.	Sec. 102, D. & P. R.R., Block 018	Red igneous rock (d)	2752-2837
		Dark greenish-black intrusive rock (s)	2765
		Light igneous rock (d)	2837-2845
		Black igneous rock (d)	2845-2855
		Granite (s)	2962
		Dark felsite (s)	2945-2960
		Red igneous rock (d)	3030-3045
		Fine grained igneous rock	*

The relations outlined above are also shown graphically in Fig. 3.

There is some reason to believe that some of these rocks are part of a conglomerate and not igneous rocks in place. For instance, the presence of worn pebbles has been detected in a number of samples. In one of the two cases where the well ended in igneous rock worn pebbles were detected in the sample taken from that depth. In a number of samples in which igneous rocks are reported the descriptions also indicate the presence of other rocks such as would be expected if the drill had penetrated a conglomerate. The testimony of drillers that there seemed to be two kinds of rocks on opposite sides of the hole at some of the depths where igneous rock were reported seems to point to the same conclusion. The evidence, therefore, seems to indicate that in a majority of cases at least there is a strong probability that the igneous rocks encountered were parts of a conglomerate and not igneous rocks in place. On the other hand it is altogether possible that some of the igneous rocks encountered may be due to the presence of a sill or sills. The latter view has been advocated by Harrison.[1]

[1]Harrison, T. S., Porphyry at Amarillo: Bull. Am. Assos. Pet. Geologists, Vol. 7, No. 4, pp. 434-437, July-Aug., 1923

*Exact depth not known.

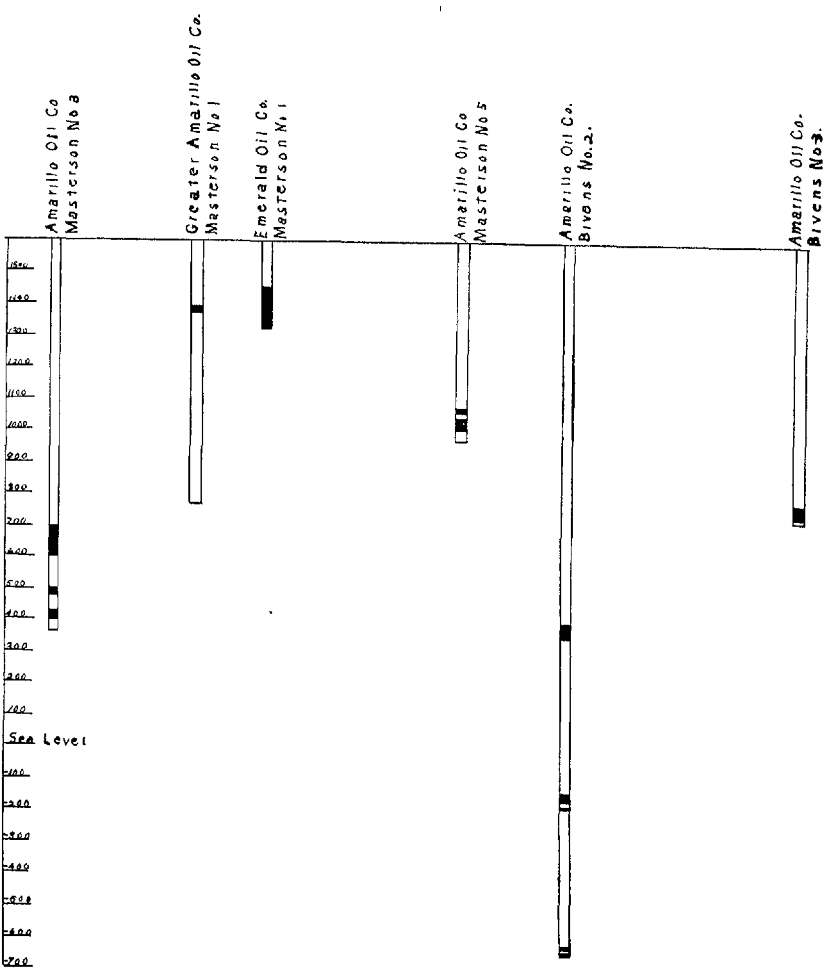

FIG. 3: Graphic representation of the occurrence of igneous rocks in the deep wells of Potter County.

ROCKS EXPOSED

PERMIAN SYSTEM

GENERAL STATEMENT

The rocks of the Permian system of Oklahoma and Texas have been given different formational names in the different states. The formations first described in Texas have been named the Wichita, Clear Fork and Double Mountain formations, respectively. In Oklahoma the Permian formations have been named the Enid, Blaine, Woodward, Greer, and Quartermaster. These names were first proposed by Gould[15] and their use extended by him to the Panhandle of Texas in publications of the United States Geological Survey. Inasmuch as these terms have been used in the literature of this region they will be used in the report on this county. Although the exact correlation of the Texas and Oklahoma formations has not yet been worked out, the Double Mountain formation is the upper part of the Permian of northern Texas and the formations exposed in Potter County may be regarded as Double Mountain, although described under the terms of Greer and Quartermaster.

GREER FORMATION

The distinctive characteristic of the Greer formation is the presence of thick beds of gypsum. The formation outcrops in only a very small portion of the northeastern part of the county, where the uppermost gypsum ledges outcrop near the level of the Canadian River.

THE QUARTERMASTER FORMATION

Definition and Distribution:—The Quartermaster formation is the highest formation of the Permian system in Oklahoma and western Texas and includes all of the shales and sandstones of that system occurring above the Greer gypsums. Typically it consists entirely of brick-red shales and soft friable red sandstones. Its thickness is reported to be from 300 to 350 feet.[16]

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[15]Gould, C. N., Geology and water resources of Oklahoma: U. S. Geol. Surv., Water Supply Paper No. 148, 1905; Geology and water resources of the eastern part of the Panhandle of Texas: U. S. Geol. Surv. Water Supply and Irrigation Paper No. 154, 1906; Geol. and water resources of the western portion of the Panhandle of Texas: U. S. Geol. Surv., Water Supply and Irrigation Paper No. 191, 1907.

[16]Gould, C. N., Geology and water resources of Oklahoma: U. S. Geol. Surv., Water Supply and Irrigation Paper No. 148, p. 22, 1905.

In Potter County the Quartermaster formation occurs in a large area in the northeastern part of the county including a large part of B. & M. Block 3, most of H. & T. C. R. R. Block 47, and Block 46. Also in the central part of the county including parts of the northern part of B. S. & F. Block JAD, B. S. & F. Block 6, western half of G. & M. Block 19, the central portion of G. & M. Block 5 with an arm extending from the northwest corner of A. B. & M. Block 2 nearly to the western border of A. B. & M. Block 2. A small area also outcrops in the vicinity of Section 9, E. L. & R. R. R. Block 11.

Character:—The Quartermaster formation in Potter County is composed of shales and sandstones with occasional gray shales and sandstones, a massive dolomite member and one gypsum lentil. The shales and sandstones are usually of a brick color but occasional gray shales and sandstones are found. The sandstones are very fine grained and grade imperceptibly into sandy shales. In many cases they are quite massive, forming layers 30 or more feet in thickness. They are often cross-bedded. The sandy shales are in many places quite hard. Many ripple-marked surfaces may be found.

The color of the Quartermaster formation is quite distinctive, being of a brick-red or vermilion color distinguishing it easily from the usual color of the younger Triassic rocks.

The most remarkable character of the Quartermaster is the great abundance of erratic local dips found within the formation. It is very difficult to distinguish between these dips and false bedding and in some cases the latter is no doubt the correct explanation. Many of the dips, however, cannot be explained on this hypothesis nor can they be attributed to true folding. Dips in all different directions and of such a complexity that they do not show any relation to structure may be found. It is to be admitted on the other hand that some of these do belong to dips which occur in connection with actual folding of the strata so that unless there is a well defined key horizon, which is usually wanting, but which fortunately is present in this county, the Quartermaster formation presents almost insurmountable difficulties in the study of structure. The Alibates dolomite, the key horizon referred to above, while making the determination of the structure over wide areas quite possible, serves to emphasize these dips as well as the true dips due to folding on account of the fact that it is a distinctive and easily identified horizon and of a character in marked contrast to the rest of the formation. The peculiar character of the formation referred to above is often masked in the body of the formation by the similarity in color and lithologic character, but the gray dolomite stands out in marked contrast to the brick-red shales and sandstones and the contrast serves to emphasize any feature of the kind described. Plate II B, shows the local and erratic dips in the Quartermaster as shown by the Alibates dolomite near the Bivens well No. 1, Section 106, H. & T. C. R. R. Block 46, in the northeastern part of the county south of the Canadian River.

This peculiarity of the Quartermaster formation was first described by Gould[17] in his discussion of the Oklahoma deposits and ascribed by him to the undermining of deep-seated rocks, probably some of the members of the Greer formation. The present writer is of the opinion that these dips are probably due to a number of different causes, among them the one mentioned by Gould, combined with true local dips due to actual folding of the strata, some false bedding, deposition of material on steeply sloping shores, etc.

The erosion of small areas, in which the features mentioned above are present, in some places results in the production of minor topographic forms, in which small areas of sandstone and shale are apparently wholly or completely surrounded by steeply dipping rocks. These features are often locally ascribed to volcanic activity or to "gas blowouts." It should be noted that this formation exhibits no evidence of igneous activity and that these features are due wholly to the cause described above.

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[17]Gould, C. N., Geology and water resources of Oklahoma: U. S. Geol. Surv., Water Supply and Irrigation Paper No. 148, p. 73, 1904.

The most important member of the Quartermaster formation in Potter County is the Alibates dolomite. This member was named by Gould [15] from Alibates Creek in the northeastern part of Potter County.

Since this member was named by Gould and described from a location within this county Gould's original description is quoted in full:

> "In the upper part of the Quartermaster formation, wherever it is exposed along the Canadian River, there occurs a very persistent ledge of dolomite. It is white, massive and more or less flinty, and exhibits definite lines of lamination which have a wavy plicated structure. This dolomite, which is designated the Alibates lentil, from Alibates Creek, where it is well exposed, is the hardest rock exposed in the region, and for that reason resists erosion and forms the cap of conspicuous bluffs and cliffs along the Canadian River and many of its tributaries. The rock is cut by a regular series of master joints and on weathering breaks into rectangular blocks which lodge on the slopes below. Usually there are two distinct dolomite ledges, the lower being eight feet and the upper two feet thick. They are separated by four feet or more of red clay, so that the combined thickness of the dolomite and interbedded clay is approximately 15 feet."

The laminae spoken of above show on a polished surface of the rocks as well as on the weathered surface but are more prominent on the latter. Examination on a polished surface show that they vary in thickness from two-tenths to three millimeters, the smaller size, however, being the more common. On the polished surface there is seen to be a variation in color as well as in width, a slight pinkish color being common. The pinkish coloring is, in some places sufficient to give the whole rock a slight pinkish tint.

Another characteristic quite common to this member in Potter County is a mottled or speckled appearance due to the presence of minute black specks. Examined in thin section under the compound microscope these specks are seen to be due to irregular deposits of black material dis-

[15]Gould, C. N., Geology and water resources of the western portion of the Panhandle of Texas: U. S. Geol. Surv., Water Supply Paper No. 191.

tributed between the grains of the rock. These deposits vary in size from minute specks 15 microns in diameter to deposits of irregular shape with a maximum length of 150 microns and a maximum width of 10 microns. The distance apart varies from 2 microns to 1.5 mm., one mm. probably being the average in the thin sections examined. Chemical analyses of specimens containing these specks show that they are due to manganese. See chemical analyses of samples of Alibates dolomite below.

CHEMICAL ANALYSES OF SAMPLES OF ALIBATES DOLOMITE. ANALYSES MADE BY THE DIVISION OF INDUSTRIAL CHEMISTRY OF THE BUREAU

Laboratory No.	C 1967	C 1968	C 1969	C 1970
Silica	1.95%	1.70%	3.76%	2.55%
Alumina	1.35	0.84	0.61	1.76
Ferric Oxide	0.54	0.46	0.46	0.54
Lime	30.40	28.34	29.64	29.66
Magnesia	20.54	20.57	20.23	20.02
Alkali oxide	1.75	1.80	1.48	1.48
Loss by ignition	43.70	45.95	43.76	44.40
Sulphur trioxide	0.32	0.80	0.16	0.23
	100.55	100.46	100.10	100.64

C 1967. Alibates dolomite from near Home Creek.
C 1968. Alibates dolomite from Sec. 65, D. & P. R. R., Block 018.
C 1969. Alibates dolomite from Sec. 33, G. & M., Block 5.
C 1970. Alibates dolomite from Sec. 8, E. L. & R. R. R., Block 11.

Some of these samples showed specks of manganese dioxide, the amount of which in one sample, was found to be as high as 1%.

E. P. SCHOCH, Head of Division.

A very distinctive characteristic of the Alibates dolomite in Potter County is the presence of abundant deposits of chert and flint within the member. In places the amount rises to a considerable proportion of the whole. Elsewhere only occassional deposits are found. Both the chert and flint break with a deep conchoidal fracture. The flint is usually banded or mottled in appearance, the banded form being more common. The banding very closely resembles the banding of the dolomite in which it is found, although it is more noticeable in the flint than in the dolomite on account of the contrast in color. The color varies from light gray to dark red, the most common form being alternating bands of light gray and dark red. These bands are much the same size as the laminæ of the dolomite and exhibit the same wavy character with the exception that this is much more easily observed in the flint than in the dolomite, the character of the former enabling the minutest variation to be seen most plainly. Much of the flint, however, is of a light gray color with only an occasional band of red, two to three millimeters in thickness.

The genesis of the flint may be ascribed to one of several different hypotheses of which the following are the most prominent: (1) It may have been formed by the direct precipitation of silicious matter by siliceous secreting organisms. (2)) It may have been formed by the replacement of the material of the dolomite by (a) soluble silica of the sea water before the dolomite emerged from the sea or (b) by circulating ground water after the emergence. (3) It may have been formed by the direct precipitation of colloidal silica contained in waters derived from the land and precipitated by the action of electrolytes contained in sea water. If it had been formed according to the first hypothesis it would be expected that some traces of these organisms would be found in thin sections of the flint. So far as the flint was examined, however, no traces of organisms were found which would seem to favor the hypotheses of replacement or direct precipitation of colloidal silica.

The member has been referred to as a dolomite. A normal dolomite consists of calcium carbonate and magnesium carbonate combined in the proportion of one gram molecular weight of calcium carbonate to one gram molecular weight of magnesium carbonate or in proportion by weight of 54.35 per cent of calcium carbonate to 45.65 per cent magnesium carbonate. Stated in the terms commonly used in chemical analysis this is equivalent to 30.4 per cent of lime and 21.7 per cent magnesia. Reference to the analyses given above show that that proportions of lime and magnesia are quite close to the above figures, so that the rock may be regarded as a fairly pure dolomite. A study of samples of the rock by means of Lemberg's solution, confirms the above conclusion. Lemberg's solution is made by boiling together crystaline hæmatoxylin and aluminium chloride. A number of different hæmatoxylin stains have very wide use in methods of histology. According to Bayer[19] the active agent of these stains is a compound of hæmatin with alumnia, which is precipitated by certain organic and inorganic salts. Dolomite is not affected by this stain but calcite is stained violet. The solution used in studying these rocks was Steidtmann's modification of the standard Lemberg solution,[20] with the exception of some slight variation in the dilution used and the addition in freshly prepared solutions of a few drops of hydrogen peroxide for the purpose of oxidizing the hæmatoxylin to hæmatin. The result of a study of the rock samples with this stain showed that the rock is a fairly pure dolomite.

A characteristic of the Alibates dolomite, which is observed in many localities, is the appearance of brecciation. The rock has the appearance of having been broken in small pieces and recemented. Thin sections made of rock from such localities, when stained with Lemberg solution, show thin lines of calcite running through the section.

The two strata of the dolomite are not always present in this county. In some cases the upper stratum has been removed by erosion and in some cases the intervening shale layer is absent and the two strata are together. The average thicknesses of the two ledges in Potter County is about the same as that given by Gould for the general average of the member i.e., about eight feet for the lower and two feet for the upper, although in some cases the lower ledge in Potter County is somewhat thicker than the average. Plate II, C shows a characteristic exposure of the Alibates dolomite in which the two ledges are present.

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[19]Uber das Farben mit Haematoxylin: Mittheilungen aus der Zoologischen Station zu Neapel 10: 170-186, 1891. Quoted by Chamberlain, C. J., in Methods in Plant Histology, University of Chicago Press, 1905.

[20]Steidtmann, Edward, Origin of dolomite as disclosed by stains and other methods. Geol. Soc. America Bull. vol. 28, No. 2, pp. 431-450. 1917.

Topographic Expression.—The topographic expression of the Quartermaster within this county varies very widely and in general is not characteristic of this formation. This difference is due to the presence of the Alibates dolomite lentil which is not usually found in this formation elsewhere. The differences in topographic expression in different parts of the county are also due to this member. In that part of the county where structural features have brought the Alibates dolomite high above the level of the master stream it has protected the underlying formations from erosion and has caused the development of deep, steep-sided canyons separated by flat-topped divides. On the other hand where the top of the Quartermaster formation is somewhere near the level of the master stream the topographic expression is that which is produced by the erosion of the soft shales and sandstones above the Alibates dolomite, which results in the formation of a jumble of many small hills and valleys. In many cases the formation is capped by the sands and gravels of the Cenozoic and the hills are the result of erosion of both kinds of material resulting in small hills of Quartermaster capped by the sand and gravel of the later formation. Much of the bad lands of the region south of the river in the neighborhood of G. & M. Blk. 20 and Blk. 5 are of this type.

Thickness.—The maximum thickness of the Quartermaster formation observed in Potter County was in the northeastern part of the county in Sec. 99, H. & T. C. R. R. Block 46, where a thickness of 265 feet was found. This thickness, however, only represents the thickness from the top of the Greer formation to the Alibates dolomite as everything above the Alibates dolomite had been removed by erosion in the location under discussion. Inasmuch as exposures may be found within the county in which from 40 to 50 feet of the red shales and sandstones of the Quartermaster overlie the Alibates dolomite, the total thickness of the formation in the county must be at least three hundred feet.

Detailed Sections.—Below are given some detailed sections of the Quartermaster formation from exposures in various parts of the county.

Section at the head of a tributary to Home Creek in Sec. 66, D. P. R. R. R., Block 018.

	Ft.	In.
Hard white to gray dolomite (Alibates dolomite) appearing on the edge of the bluff. Upper three feet very flinty	8	0
Gray shale	12	0
Red shale	2	0
Gray to red, sandy shale	1	6
Red shale	15	9
Gray, sandy shale	1	6
Brick-red shale with numerous white spots	9	0

Section one-fourth mile west of the Colorado & Gulf Highway bridge across the Canadian River on the north side of the river in Sec. 75, H. & T. C. R. R. Block 47.

	Ft.	In.
Brick-red shale	10	
Brick-red shale, strongly ripple marked	4	
Brick red shale	8	
Dolomite	3	
Brick-red shale	5	
Dolomite	10	
Brick-red shale		

Dolomite in the above section exhibits wavy lamination and contains an abundance of chert and flint. Some parts of the dolomite seem to be composed of pieces which have been broken and recemented forming a breccia.

Section at the head of John Ray Creek in Sec. 8, E. L. & R. R. Co., Block B 11.

	Ft.	In.
Alibates dolomite	10	0
Red shale	5	0
Gray shale	3	0
Red shale, mottled with gray spots and streaked with gray	5	0
Gray limestone	0	5

Section in valley of East Amarillo Creek in Sec. 32 G. & M. Block 5.

	Ft.	In.
Massive dolomite (Alibates)	4	
Red shale	10	
Massive dolomite (Alibates)	6	

Section in valley of East Amarillo Creek on east side of the creek not far above its mouth in Sec. 33, G. & M. Block 5.

	Ft.	In.
Red standstone	1	
Sandy, red shale	5	
Shaly sandstone, brick-red	4	
Red shale, partly concealed	12	
Alibates dolomite, upper stratum	4	
Red shale	10	
Alibates dolomite	5	

Section at the mouth of East Amarillo Creek in Sec. 32, G. & M., Block 5.

	Ft.	In.
Soil and gravel		
Red sandy shale	5	
Alibates dolomite (Upper stratum)	2	
Lavender shale	3	
Red shale	4	
Alibates dolomite (Lower stratum)	10	
Red shale, partly concealed	17	
Gypsum, white, massive, with wavy laminations	4	
Red shale	4	
Red massive sandstone	8	
River sand		

Section in valley of east Amarillo Creek in Sec, 205, A. B. & M., Block 2.

	Ft.	In.
Alluvium	15	
Brick-red shaly sandstone	16	

Section in valley of Tecovas Creek in north part of Sec. 12, E. L. & R. R. R. Co., Block 21 W.

	Ft.	In.
Soft, gray, unconsolidated sandstone (Tecovas formation)		
Brick-red, shaly sandstone	20	
Alibates dolomite (Upper stratum)	3	
Red shale	5	
Alibates dolomite	12	
Red sandstone	15	

Section in ravine in Sec. 40, G. & M., Block 5.

	Ft.	In.
Alibates dolomite (Upper stratum)	4	
Red shale	6	

Alibates dolomite (Lower stratum)	6
Red shale	50
Gypsum	4
Red Shale	4
Gypsum	2
Fine-grained, brick-red sandstone	32

Section in valley of East Amarillo Creek in Sec. 6, B. S. & F., Block 6.

	Ft.	In.
Shale of various colors, purple predominating (Tecovas formation)		
Brick-red shale and sandstone of the Quartermaster	24	

Section of valley of East Amarillo Creek in the S. W. ¼ of Sec. 7, B. S. & F., Block 6.

	Ft.	In.
Purple, gray, saffron and maroon shales of the Tecovas formation.		
Brick-red shale of the Quartermaster formation	20	

Section in valley of East Amarillo Creek in Sec. 7, B. S. & F., Block 6.

	Ft.	In.
Dark red shales of the Tecovas formation.		
Brick-red shales of the Quartermaster	20	

Section near the Canadian River in the northeastern part of the county in Sec. 31, G. & M., Block No. 3.

	Ft.	In.
Dolomite with numerous flint and chert fragments	10	0
Concealed	60	0
Gypsum	0	6
Red, massive sandstone	16	0
Red, sandy shale	45	0
Friable red sandstone with numerous holes which resemble borrows of worms	10	0
Concealed	42	
Brick-red sand shale and shaly sandstone	37	0

Paleontology.—No fossils were found within the Quartermaster formation in Potter County. The sandstone of this formation in places contain numerous holes which resemble worm burrows, as was noted in the last section given above, but whether these are true worm burrows or not it was not possible to determine. The formation in other localities is not usually considered as being fossiliferous although fossils have been found in it at Dozier, Texas.[21]

Correlation.—The Quartermaster formation no doubt belongs within the interval represented by the Double Mountain formation although it is altogether probable that the Double Mountain includes more than the equivalent of the Quartermaster which probably only represents the upper part of the Double Mountain formation.

Relation to Adjacent Formations.—The Quartermaster rests conformably upon the Greer formation. However, but little evidence of the relation of the two is obtainable in the county since the Greer is exposed in only a small area in the northeastern part of the county. The Quartermaster formation is overlain unconformably by the Tecovas formation. This unconformity is shown in this county principally by the varying thicknesses of the Tecovas formation and the varying thicknesses of that part of the Quartermaster above the Alibates dolomite.

TRIASSIC SYSTEM

GENERAL STATEMENT

In 1889 W. F. Cummins, who at that time was a member of the Texas geological survey, discovered certain beds overlying the Permian in the western part of Dickens County which he named Dockum beds on account of their extensive occurrence in the vicinity of Dockum, Dickens County. In a brief description of the beds he states that they consist of conglomerates, sandstone and red clay. In this report he does not assign these rocks to any particular system, merely describing them as the rocks overlying the Permian beds.[22]

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[21]Gould, C. N., Geology and Water Resources of the Eastern Portion of the Panhandle of Texas: U. S. Geol. Sur. Water Supply and Irrigation Paper No. 154. 1906.

[22]Cummins, W. F., The Permian of Texas and its overlying beds: Texas Geological Survey: First Ann. Report, pp. 189-190. 1889.

In the Second Annual Report Cummins[23] again discusses these beds which he here definitely assigns to the Triassic.

Drake, who was a member of the field party headed by Cummins in 1890, describes a belt of rocks outcropping at the basal portion of the escarpment to the Llano Estacado and sometimes very near the top in a belt six to seven miles wide in Mitchel, Borden, Dickens, Armstrong, Porter, and Oldham counties.[24] This constitutes the northward extension of the rocks discussed by Cummins in the reports mentioned above.

In his report he divides the beds into three main divisions, a lower bed of sandy clay, a central bed or beds of sandstone, conglomerate and some sandy clay and an upper bed of sandy clay and some sandstone.

Gould[25] has divided these beds in the western Panhandle regions into two formations, the Tecovas, consisting largely of shales, and an upper formation, the Trujillo, consisting of sandstones and conglomerates, these divisions, therefore, corresponding to the first two divisions of Drake, who states that the upper beds are wanting from northern Garza County to Oldham County. Drake, however, states that the upper beds are present from Oldham to the Tucumcari mountains so that Gould's classification does not exactly represent the same as that of Drake. In Drake's Section No. 11 taken three miles northwest of Amarillo his lower and central beds most certainly correspond to the Tecovas and Trujillo as classified by Gould.

Gould's classification is followed in this report.

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[23]Cummins, W. F., Geology of Northwestern Texas, Second Annual Report Geological Survey of Texas, pp. 424-431. 1891.

[24]Drake, N. F., Stratigraphy of the Triassic formation of northwest Texas: Third Annual Report of the Geological Survey of Texas, pp. 227-259. 1891.

[25]Gould, C. N., Geology and water resources of the western portion of the Panhandle of Texas: U. S. Geol. Sur. Water Supply and Irrigation Paper No. 191.

TECOVAS FORMATION

Definition and distribution.—The Tecovas formation was named by Gould[26] from the exposures on Tecovas Creek in Potter County. This formation includes all of the sediments from the top of the Quartermaster formation up to the base of the first massive sandstone. The original description states that this formation is largely composed of shales, but in Potter County it contains a fairly large proportion of slightly consolidated sandstone.

The outcrops of the Tecovas formation are largely confined to the western part of the county. Small patches of the Tecovas may be found overlying the Quartermaster in the northeastern part of this county, but in general it has been removed from this region by erosion. In the eastern half of the county it outcrops in the valley of Pedrosa Creek and in Box Canyon in the upper part of the northwest fork of Bonita Creek. In the remainder of this valley it is covered by the Coetas formation of the Cenozoic. It also outcrops in the valley of East Amarillo Creek and forms the sides of this valley in its lower portion, where the Quartermaster outcrops in the bed of the stream. It outcrops in narrow strips on both sides of the river, from the neighborhood of Section 28, G. & M. Block 5, to about one mile above the bridge across the Canadian River. From this point it appears in a progressively widening strip, varying in width from one-eighth to two or more miles between the Quartermaster, which forms the walls of the Canadian gorge, and the mortar beds of the Potter formation, and further west between the Quartermaster and the cliffs of the Trujillo formation. At about Section 91, H. & T. C. R.R. Co. Block 47, the Quartermaster formation disappears and the Tecovas occupies the strip two or more miles wide between the river and the bluffs of the Trujillo. It outcrops also in the valley of Pitcher Creek, John Ray Creek, Lahy Creek and Little India Creek. The outcrops in the valley of these creeks, however, extend but a short distance north of where these creeks debouch upon the level

[26]Gould, C. N., Op. Cit.

shelf south of the cliffs of the Potter and Trujillo formations, which, as indicated above, are from one-eighth of a mile to two or more miles north of the river. North of this the older formations are largely covered by the deposits of sand and gravel of the Cenozoic. The formation outcrops in the valley of Big India Creek, and as that valley is followed to the north, the strata are seen to rise in that direction bringing up more and more of this formation, until it comes to occupy both the sides and bottom of the valley. North of Section 55, D. & P. R. R. Co. Block 018, the older formations are buried beneath the Cenozoic deposits.

In the western part of the county south of the Canadian River, the Tecovas formation outcrops in a number of large areas. South of Section 29, G. & M. Block 19, the formation occupies the valley of West Amarillo Creek to Section 10, B. S. & F. Block 6, where it occupies both the sides and bottom of the valley. The various branches of West Amarillo Creek have worked back headward exposing the Tecovas formation in a broad valley, from two to four miles wide, as far south as Sections 17, 19, 43, 60 and 11, B. S. & S. Block 9, two miles from the southern border of the county. North of Gentry, in Section 188, B. S. & F. Block 9, a western branch of West Amarillo Creek has headed back to near the headwaters of the northeast branch of Tecovas Creek and has exposed a strip of Tecovas formation two or more miles wide, connecting the outcrops of the West Amarillo Creek valley with those of Tecovas Creek valley. Between the mouths of West Amarillo Creek and Tecovas Creek there is a broad rolling divide, dissected to some degree by two small tributaries to the Canadian River. For about a mile and a half south of the Canadian River this divide is occupied by the Quartermaster formation. South of this the Tecovas occupies a strip across the divide, varying in width from three to five miles, bounded on the south by the outcrops of the Cenozoic, which occupy the divide from here to the valley of the western branch of West Amarillo Creek mentioned above.

Tecovas Creek has numerous tributaries, which, heading back into the younger formations, have carved out a somewhat fan-shaped valley in which the Tecovas formation is exposed in a wide area, varying from five to ten miles. The lower part of Tecovas Creek valley is occupied by the Quartermaster formation, but the sides of the broad shallow valley are, for the most part, occupied by the Tecovas, which, on the west joins with the exposures at the wide open mouth of the valley of Ceritte la Cruz Creek and is continued along the south bank of the river to the western border of the county. The valleys of the Cerritte la Cruz and its branches are occupied by the Tecovas formation. Roughly estimated the Tecovas formation occupies from one-fourth to one-third the area of the county. Its areal extent is greater than any other formation within the county with the exception of the undifferentiated Cenozoic deposits, which, however, probably do not represent a single formation.

Character.—The Tecovas formation of Potter County consists of various colored shales and soft gray unconsolidated sandstone. Gould has divided the Tecovas formation into two parts which he describes as a lower formation consisting of variegated shales and upper of maroon-colored shales. The writer is of the opinion that this generalization is not applicable to Potter County as observation shows that any of these may occur at any part of the formation.

A considerable part of the formation consists of a soft gray unconsolidated sandstone, of very fine grain, and characterized by peculiar concretions, which in many places have weathered to fantastic shapes. The concretions vary in sizes from minute spherical bodies, a few millimeters in diameter, to concretions nearly an inch in diameter and six to eight inches long. This sandstone varies greatly in thickness, reaching a maximum thickness in an exposure between the mouths of Bonita Creek and Pedrosa Creek of from 35 to 40 feet. While the character of this sandstone is quite uniform it should not be understood that it is a single stratum extending throughout the formation. It is rather a series of lenses scattered throughout the formation, occurring at different heights in the geological column and of irregular geographical distribution. Sand of the same color and texture is in many places found alternating with shale layers, its gray color contrasting vividly with the brighter colors of the shale and making the minutest layer stand out distinctly. On the other hand, exposures of the sandstone may be seen in which the sandstone is cut with minute layers of the different colored shales.

Layers of this soft slightly consolidated sandstone may be seen to pass laterally into shale formations, in some cases in very short distances, serving to emphasize the lens-like character of these deposits. Since a search is being made in this region for sands suitable for the manufacture of glass, and these sands are being considered as a possible source, it is important to note this character and the necessity of careful exploration by test holes in order to determine the extent of any deposit should be emphasized. Plate II, D shows a typical exposure of a ledge of this sandstone.

Mechanical analyses of samples of these sands were made by Mr. Parkinson, of the Division of Engineering, in connection with tests made to determine the suitability of these sands for glass sands. Below is given Mr. Parkinson's results:

Screen-sieve analyses of sand from the Tecovas formation from near Boden:

	Grams	Per cent.
Retained on 100-mesh sieve	4.00	2.7
Retained on 200-mesh sieve	122.50	81.7
By analysis*	22.50	15.00
By washing*	5.00	3.3
Total	150.00	100.00

Screen-sieve analyses of sand from the Tecovas formation from Section 188 B. S. & F., Block 9:

	Grams	Per cent.
Retained on 80-mesh sieve	.50	.2
Retained on 100-mesh sieve	2.00	.8
Retained on 200-mesh sieve	147.00	58.8
By analysis*	98.50	39.4

*See note on page 54.

	Grams	Per cent.
By washing*	4.50	1.8
Total	250.00	100.00

Screen-sieve analyses of sand from the Tecovas formation from the N. W. ¼ Sec. 23, B. S. & F., Block 9

	Grams	Per cent.
Retained on 50-mesh sieve	.50	.2
Retained on 60-mesh sieve	.75	.6
Retained on 80-mesh sieve	1.50	.6
Retained on 100-mesh sieve	4.00	1.6
Retained on 200-mesh sieve	133.00	53.2
By analysis*	82.00	32.8
By washing*	35.00	14.0
Total	250.00	100.00

Screen-sieve analyses of sand from the Tecovas formation from Sec. 8, G. & M., Block M 19.

	Grams	Per cent.
Retained on 40-mesh sieve	.50	.3
Retained on 50-mesh sieve	.75	.5
Retained on 60-mesh sieve	1.00	.7
Retained on 80-mesh sieve	1.50	1.0
Retained on 100-mesh sieve	3.25	2.2
Retained on 200-mesh sieve	98.50	65.7
By analysis*	47.00	31.3
By washing*	4.50	3.0
Total	150.00	100.00

Screen-sieve analyses of sand from the Tecovas formation from Section 22, B. S. & F., Block 9.

	Grams	Per cent.
Retained on 10-mesh sieve	2.50	1.0
Retained on 20-mesh sieve	5.00	2.0
Retained on 30-mesh sieve	6.00	2.4
Retained on 40-mesh sieve	6.50	2.6
Retained on 50-mesh sieve	7.00	2.8
Retained on 60-mesh sieve	7.25	2.9
Retained on 80-mesh sieve	8.00	3.2
Retained on 100-mesh sieve	9.00	3.6
Retained on 200-mesh sieve	136.50	54.6
By analysis*	79.50	31.8
By washing*	34.00	13.6
Total	250.00	100.00

*See note on page 54.

Screen-sieve analyses of sand from the Tecovas formation from the S. W. ¼ of Sec. 22, B. S. & F., Block 9.

	Grams	Per cent.
Retained on 40-mesh sieve	.50	.2
Retained on 50-mesh sieve	.75	.3
Retained on 60-mesh sieve	1.00	.4
Retained on 80-mesh sieve	1.25	.5
Retained on 100-mesh sieve	2.50	1.0
Retained on 200-mesh sieve	105.50	42.2
By analysis	74.50	29.8
By washing	70.00	28.0
Total	250.00	100.00

Remarks.—The amounts under "By Analysis" and "By Washing" were obtained thus:

The material which passed through the 200-mesh sieve was thoroughly stirred up with water, the mixture allowed to remain at rest for 15 seconds, and the water then decanted carefully. The material which had settled was then dried and weighed: This is the amount reported under "By Analysis." The portion which remained suspended in the water is given under "By Washing."

Respectfully submitted,

T. A. PARKINSON,

Assistant Testing Engineer.

The suitability of these sands for the manufacture of glass is discussed under Economic Geology.

The shales of the Tecovas are largely maroon and saffron-yellow. Some of the shale appears to be of a lavender color. That the lavender color is not a true color of the shale will be seen whenever an exposure of this kind is closely examined. It is not possible to collect a sample of lavender shale. An exposure which appears to have this color will invariably be found to have one of the darker red color when examined beneath the weathered surface. This color is therefore, evidently due to weathering which produces a thin film of this color on the outer surface or so affects the physical nature of the outer film that the reflected light gives the sensation of lavender.

Although saffron-colored shales perhaps do not make up as large a proportion of the formation as the maroon and dark red shales, they are, nevertheless, important members in exposures. These saffron-colored shales may be found in any part of the geological column and it is not thought that any generalization can be made as to their occurrence in Potter County, at least, although it is no doubt true that they are more abundant at some horizons than at others.

The most prominent member of the Tecovas formation is a dark red or maroon shale. This occurs both as small, minute laminae and in deposits reaching considerable thickness consisting of nothing except the maroon shale.

Very many of the deposits of the Tecovas are seen to consist of alternating bands of the materials described above. In many places the laminae are only a few millimetres in thickness and alternate in almost bewildering confusion.

Chemical analyses of the different phases of shales of this formation were made by the Division of Industrial Chemistry of the Bureau. The results of these analyses are given below:

Chemical analysis of a sample of the saffron colored phase of the Tecovas shale from Section 3, E. L. & R. R. Co., Block 21 W.

Silica	48.20
Alumina	13.45
Ferric oxide	6.10
Lime	7.90
Magnesia	4.92
Alkali oxide	4.85
Loss by ignition	14.55
Sulphur trioxide	0.27
	100.24

Chemical analysis of a sample of the maroon colored phase of the Tecovas shale from the pit of the Panhandle Brick and Tile Company, Section 48, B. S. & F., Block 9.

Silica	55.00
Alumina	19.10
Ferric oxide	6.29
Lime	3.18
Magnesia	3.24
Sodium oxide	3.18
Loss on ignition	10.00
	99.99

In Section 8, G. & M. Block 8, about two miles northwest of Boden a small deposit of lignite was found in an exposure at the bottom of one of the numerous ravines of the bad lands of this location. The exposure was about 15 feet thick and consisted of various colored shales, saffron-yellow predominating, with occasional layers of dark carbonaceous matter, usually thin but in places amounting to two or three inches thick. The whole was overlain by soft, friable fine-grained sandstone. The lignite deposit was from four to six inches thick, having the woody structure well preserved. The deposit was very close to the base of the Tecovas, for the Quartermaster which is here brought up by a slight local fold outcrops a short distance down the ravine.

The formation as a whole is characterized by minor unconformities occurring within the formation itself. An excellent example of this characteristic is found on the west branch of West Amarillo Creek at the juncture with the main stream in Section 51, B.S.&F. Block 9. Here 12 feet of the fine-grained soft sandstone is cut diagonally across and the interval is replaced by alternating layers of dark maroon shale and fine grained gray sand. (See Plate II, E.)

Near the base of the formation in West Amarillo Creek, near Section 11, B. S. & F. Block 6, there is found a somewhat conglomeratic sandstone. This passes laterally into the gray sandstone found extensively in the Tecovas. At a second exposure this conglomeratic phase is seen overlying three feet of the saffron-colored shale. In this exposure it grades upward into the fine-grained sandstone.

Also in Section 8 and 7, G. & M. Block 8, near the base of the formation there occurs a deposit of conglomerate. The larger pieces in these conglomerates consist mainly of irregular pieces of limestone and dolomite. They seldom exceed two inches in diameter and are in most cases much smaller. On the polished surfaces some of them exhibit concretionary structures, while others do not exhibit this characteristic.

While these deposits are of interest in throwing light upon the history of the formation they are not of sufficient extent to serve as horizon markers and the boundary between the

Quartermaster and the Tecovas can more easily be distinguished by other means.

Although the Trujillo sandstones above the Tecovas formation contain an abundance of mica the sands and shales of the Tecovas do not contain such amounts. It is no doubt true that in many places the mica content will be sufficient to aid in distinguishing the Tecovas from the Quartermaster, but this characteristic is by no means a reliable guide. The colors of the two formations, however, are generally very distinct, the brick-red of the Quartermaster and the maroon and other colors of the Tecovas being easily distinguished from each other. Some of the shales of the Tecovas in situations where they are known to be in the body of the formation, having distinctive Tecovas both above and below, show the brick-red color characteristic of the Quartermaster so that color alone is not always a reliable guide. The lithological character of the two formations differ considerably, however, the shales of the Quartermaster being in general more sandy and having more of the characteristic of shaly sandstone than those of the Tecovas. Field experience with the two formations enables the stratigrapher to distinguish the two more easily than a discussion of the formations would seem to indicate. All characteristics used to distinguish these two formations, however, should be used with care and caution.

In general the Tecovas formation seems to exhibit the characteristics of deposits laid down in moderately still water with, however, shifting currents of sufficient strength to cause occasional erosion in previously laid deposits, and a shifting of conditions of deposition sufficient to account for the alternation in the lithologic character of the deposit.

Thickness.—The total thickness of the Tecovas formation in this county is somewhat difficult to obtain, owing to the fact that the top and bottom of the formation is usually not exposed in closely connected localities, but the average thickness in this county seems to be about 200 feet. The thickness, of course, varies in different localities on account of the unconformity between the Quartermaster and the Tecovas.

Detailed Sections.—The following sections taken at different places in the county serve to illustrate the character of the formation. On account of the tendency of the formation to weather to long gentle slopes with few exposures, it is not possible to get a complete section of the whole formation at any one locality.

Section in the valley of West Amarillo Creek, Section 48, B. S. & F., Block 9.

	Ft.	In.
Alluvium		
Dark red shale	6	0
Soft, very slightly consolidated sandstone with alternating layers of dark red shale. Layers of shale about 6 inches apart and ½ to 1 inch thick	15	0

Section near the Canadian River, central part of the county in Section 76, H. & T. C. R. R., Block 47.

	Ft.	In.
Gray sandstone with many nodular concretions on the surface. Silicified log one foot in diameter found in the sandstone	5	0
Maroon, light gray and lavender shale partly concealed, grading into sulphur-yellow shale at the top	13	0
Concealed	5	0
Massive dolomite (Quartermaster formation)	15	0

Section in valley of Pedrosa Creek, Section 16 A. B. & M., Block 3.

	Ft.	In.
Soft gray sandstone	25	0
Maroon shale	5	0

Section in ravine opening into valley of Pedrosa Creek, Section 16, A. B. & M., Block 3.

	Ft.	In.
Saffron-yellow shale, partly concealed	12	0
Red and gray shale	6	0
Concealed	15	0
Alternating dark and gray shales	15	0
Light colored gray sandstone	5	0
Dark red shale	5	0

Section in valley of Pedrosa Creek in Section 13, A. B. & M., Block 3.

	Ft.	In.
Gray conglomeratic sandstone (Trujillo formation).		

	Ft.	In.
Gray to light red shale grading into saffron-yellow at the top	10	0
Concealed	60	0
Soft gray sandstone	2	0

Section on bluff, west side of West Amarillo Creek, Section 55, B. S. & F., Block 9.

	Ft.	In.
Massive sandstone (Trujillo formation)		
Light gray shale	2	0
Dark maroon shale	10	0

Section taken on bluff, west side of West Amarillo Creek, in N. W. ¼ Section 55, B. S. & F., Block 9.

Concealed	5	0
Massive dolomite (Quartermaster formation)	15	0

Section in valley of Pedrosa Creek, Sec. 16, A. B. & M., Block 3.

	Ft.	In.
Soft gray sandstone	25	0
Maroon shale	5	0

Section in ravine opening into valley of Pedrosa Creek, Sec. 16, A. B. & M., Block 3.

	Ft.	In.
Saffron-yellow shale, partly concealed	12	0
Red and gray shale	6	0
Concealed	15	0
Alternating dark and gray shales	15	0
Light colored gray sandstone	5	0
Dark red shale	5	0

Section in valley of Pedrosa Creek in Sec. 13, A. B. & M., Block 3.
Gray conglomeratic sandstone (Trujillo formation)

	Ft.	In.
Gray to light red shale grading into saffron-yellow at the top	10	0
Concealed	60	0
Soft gray sandstone	2	0

Section of bluff, west side of West Amarillo Creek, Section 55, B. S. & F., Block 9.
Massive sandstone (Trujillo formation)

	Ft.	In.
Light gray shale	2	0
Dark maroon shale	10	0

Section in ravine, N. W. ¼ Sec. 55, B. S. & F. Block No. 9

	Ft.	In.
Mostly concealed up to the base of the Trujillo formation	111	
Very dark maroon shale	2	
Light red shale	3	
Light gray shale	2	
Soft fine-grained sandstone at the bottom of the ravine.		

Section in valley of Tecovas Creek in the north part of Sec. 12, E. L. & R. R.R. Block No. 21 W.

	Ft.	In.
Saffron colored shale	10	
Dark maroon shale	5	
Saffron shale	2	
Bluish-green shale	2	
Bulish-green shale	2	
Soft gray sandstone	8	
Brick-red shaly sandstone (Quartermaster formation).		

Section in valley of Tecovas Creek, north part of Sec. 12, E. L. R.R. Block No. 21 W.

	Ft.	In.
Saffron-yellow shale	5	
Blue shale, with layers of maroon and saffron-yellow	15	
Soft gray sandstone	10	
Brick-red shale (Quartermaster formation).		

Section at bottom of hill about three miles northwest of Gentry in center of Sec. 121, B. S. & F. Block No. 9. Top of section 70 feet below the Trujillo formation

	Ft.	In.
Soft white sandstone	3	
Saffron shale	2	
Dark maroon shale	15	

Section in valley of Tecovas Creek, Sec. 188, B. S. & F. Block No. 9

	Ft.	In.
Slightly consolidated sandstone, light pink in weathered exposure, gray with bands of dark red in unweathered exposure	12	
Sandy shale of various colors, maroon, lavender, gray, magenta, etc. in alternating bands, varying in thickness from a fraction of an inch to 6 inches	10	

Section in valley of east branch of West Amarillo Creek approximately Sec. 15, B. S. & F. Block No. 9

	Ft.	In.
Dark red shale	----	3
Fine, white, slightly consolidated sandstone	15	
Saffron-yellow shale with alternating dark maroon bands	15	

Section in valley of West Amarillo Creek, Sec. 18, B. S. & F. Block 9

	Ft.	In.
Alternating bands of red shale and gray sandy shale	12	
Red shaly sandstone resembling Quartermaster	15	
Saffron-yellow shales which grade horizontally into dark red shales	15	

Section on east side of West Amarillo Creek, about seven miles from the mouth, in S. W. ¼ of Sec. 7, B. S. & F. Block No. 6

	Ft.	In.
Soil	1	
Dark maroon shale	15	
Saffron shale	30	
Purple shale	1	
Purple shale	1	
Gray shale	3	
Bluish shale	3	
Brick-red shale (Quartermaster)	20	

Section in ravine opening into Bonita Creek in Sec. 51, B. S. & F. Block No. 1

	Ft.	In.
Conglomerate (Trujillo formation):		
Gray sandy shale	4	
Fine-grained massive sandstone	7	
Dark red shale	25	

Section in ravine opening into Bonita Creek in Sec. 58, B. S. & F. Block No. 1

	Ft.	In.
Sandy shale, gray to red	10	
Dark red shale	15-29	
Saffron shale	40	
Fine-grained shaly sandstone	0	6
Dark red shale	20	

Section on John Ray Creek, northern part of Sec. 85, H. & T. C. R.R. Co. Block No. 47

	Ft.	In.
Dark yellow shale	8	

	Ft.	In.
Dark maroon shale	20	
Saffron colored shale	11	

Section near the Canadian River in Sec. 30, G. & M. Block No. 5

	Ft.	In.
Stratified sand and gravel (Potter formation):		
Fine-grained, gray, soft sandstone	50-60	

Section on Big India Creek in Sec. 30, D. & P. R.R. Block No. 018

	Ft.	In.
Sand and gravel (Tertiary):		
Red to gray sandy shale	10	
Red and gray shale	2	
Gray sandy shale	2	
Dark red shale	6	
Maroon and gray shale	15	
Dark red shale	5	
Gray sandy shale and dark red shale	5	
Coarse conglomerate passing into gray shale above	1	6

Section taken in valley of west branch of West Amarillo Creek in Sec. 48, B. S. & F. Block No. 9

	Ft.	In.
Sand gravel and soil:		
Gray sandy shale	5	
Light red shale	5	
Dark maroon shale with varying bands of gray sand	35	
Red shale	5	

Section in valley of West Amarillo Creek, Sec. 10, B. S. & F. Block 6.

	Ft.	In.
Sand and gravel (Tertiary):		
Dark maroon, lavender and yellow shale	10	
Marly shale with some flinty limestone	2	
Gray and lavender shale, gray occurring both as spots and streaks	8	
Light gray sandstone		8
Dark red shale with white spots and streaks with nodules of chert and flint at the base	4	
Brick red shale (Quartermaster)	20	

Section on west side of Amarillo Creek in Sec. 46, B. S. & F. Block 9

	Ft.	In.
Soil	1	
Yellow to brown shale cut by vertical veins of gypsite		6

Gray shale	6
Alternating bands of red and gray shale	2
Dark red nodular shale	2

Paleontology.—The first fossils reported from the Triassic of Texas are those which were found by W. F. Cummins[27] in the beds in Dickens County which he designated by the name of Dockum. He states that in the conglomerate are many silicified trunks of trees. In the red clay above the conglomerate he found the fossil remains of large reptiles. In the upper sandstone he reports many casts of *Unio,* which he provisionally named *Unio dockumensis.* It appears from this report, therefore, that the fossils found were from the Trujillo formation rather than from the Tecovas. In his report in the Second Annual Report of the Texas Geological Survey, Cummins[28] again refers to *Unio dockumensis,* which he states is found in the conglomerate. Drake,[29] who made a much more detailed report of the Triassic, reports *Unios* from the sandstones and conglomerates and from red sandy clay above the conglomerate. It does not appear, therefore, that any of the *Unios* were found in the equivalent of the Tecovas formation, but it seems rather that they came from the equivalent of the Trujillo. From a study of the reports of Cummins and Drake it seems that this is probably true of the vertebrate fossils also.

Unios submitted by E. T. Dumble, director of the Survey, under whom the work mentioned above was done, were described by C. T. Simpson.[30] The species are as follows: *Unio subplanatus,* new species; *Unio dumblei,*

[27]Cummins, W. F., The Permian of Texas and its overlying beds: Texas Geol. Surv. First Ann. Report, pp. 189-190, 1889.

[28]Cummins, W. F., Geology of Northwest Texas: Second Annual Report Geological Survey of Texas, p. 426, 1891.

[29]Drake, N. F., Stratigraphy of the Triassic formations of northwest Texas: Third Ann. Rept. of the Geological Survey of Texas, pp. 227-259, 1891.

[30]Simpson, C. T., Description of four new Triassic Unios from the Staked Plains of Texas. U. S. Nat. Museum Proc., Vol. 28, pp. 381-385,1896.

new species; *Unio graciliratus,* new species; and *Unio dockumensis,* Cummins.

The vertebrate fossils were identified and described by E. D. Cope,[31] who states that the fossils bear a general resemblance to those found elsewhere in the Triassic.

No true fossils were found in the Tecovas shale in this county but a large number of casts resembling casts of roots, or of burrows of worms were found in the maroon-colored shales. They were found in especial abundance in one stratum about six feet thick, in the pit of the Panhandle Brick and Tile Company, in Section 48, B. S. & F. Block 9. They are also found in the saffron colored shale. In the locality first mentioned they may be found in closely packed masses, very much resembling a tangle of roots. They vary in size from a diameter of one to ten millimeters, the average diameter being about five millimeters. The longest pieces observed were from six to ten centimeters. They break up very easily in taking out the pieces of shale or in separating them from the shale so that the length of the specimens found is no evidence of their original length. A very characteristic feature in all cases is rather faint sculpturing, which can be seen both on the surface of the casts and the interior of the moulds, after the casts have been removed. These consist of minute raised areas, roughly parallel to each other and to the axis of the cylinder, although in some cases they are found to vary from this arrangement. These areas do not form continuous lines but the parts of each line are slightly separated from each other at intervals, varying from one to two millimeters, depending upon the size of the specimen, the larger cylinders having the coarser markings. The areas are from two to three times as long as wide. A number of the casts show branching. In some cases those which appear to be branching are found upon careful dissection not to be branching but merely two clyinders closely approaching each other or a case in which one cylinder has been crushed down over another. However, certain ones are found which appear

[31]Cope, E. D., Report on Paleontology of the Vertebrate: Third Annual Report of the Geological Survey of Texas, pp. 257-259.

to be true branching forms. Other cases are found, also in which one form has penetrated another at right angles. In all of their characteristics they seem to most closely resemble casts of plant roots but also bear some resemblance to the tubes of *Serpula*. The interpretation of certain forms could be more easily explained by the latter hypothesis. In any case, however, the state of preservation is probably not good enough to warrant an attempt at positive identification.

Plate III, A and Plate III, B show some of the forms in place in blocks of the shale and Plate III, C shows a number of these forms which have been dissected out of the matrix.

This characteristic of this formation was first observed in the deposits of the Tecovas at Post, Texas, by Dr. J. A. Udden,[32] who directed the writer's attention to them in the formation in this county.

Fossilized wood is found in the Tecovas formation as well as in the Trujillo formation. In the Tecovas formation the silicified wood is always found in the sandy phase of the formation. The lignite, which has already been mentioned was found in shaly parts of the formation.

Relation to adjacent formations.—The Tecovas formation rests unconformably upon the eroded surface of the Quartermaster formation. This unconformity should show itself in the varying thickness of the Tecovas shales and would undoubtedly do so if these were capable of exact measurement in many places. However, it does show very plainly in the varying thickness of Quartermaster found between the Alibates dolomite and the Tecovas shale. This thickness varies from five to forty feet. It seems rather remarkable, however, that in only one instance was the Tecovas shale found resting directly on the Alibates dolomite. Even in this case it was not absolutely determined that the Triassic shales rested directly upon the Alibates dolomite as there was a concealed interval of about five feet. See section near the Canadian River, central part of this county, in Section 76, H. & T. C. R. R., Block 47. It is admitted that it is possible that there are more cases than the one

[32]Personal communication.

cited but in the course of an investigation such as the one undertaken here it would be expected that more such instances would be found, since the soft and easily eroded shales and sandstones of the Quartermaster should be easily cut down to the more resistant Alibates dolomite. It seems to be indicated, therefore, that the region had been brought near to at least a local base level during the post-Quartermaster erosion period. Otherwise, more and wider areas of the Quartermaster would have been denuded down to the Alibates dolomite and the Triassic shales would have in more instances been found resting directly upon the Alibates dolomite itself.

TRUJILLO FORMATION

Definition and Distribution.—The sandstones and conglomerates of the upper part of the Triassic formation in the Panhandle have been named by Gould[33] the Trujillo formation from the exposures in Trujillo Creek valley in Oldham County. In its typical development the Trujillo formation consists of three to five ledges of sandstones with interbedded shales. The more prominent and constant of these have been designated the lower, middle and upper sandstones, respectively. The present writer is of the opinion that there is in Potter County only one prominent sandstone horizon. Either the other ledges have been removed by post-Trujillo erosion or there has been a consolidation of two ledges. There is some evidence in favor of each hypothesis. In the valley of West Amarillo Creek, Section 58, B. S. & F. Block 9, near the juncture of two branches of the stream there are two sandstone layers each of about five feet in thickness, which are separated by a concealed interval of fifteen feet. However, one-eighth mile to the east across the valley an exposure at the same level does not indicate two horizons but only one. This exposure shows a ledge about 20 feet thick consisting of sandstone and conglomerate and

[33]Gould,C. N., Geology and water resources of the western part of the Panhandleof Texas:.U. S. Geol. Surv. Water Supply and Irrigation Paper 191, 1907, p. 26.

some sandy shale. There are several other instances of this kind on West Amarillo Creek which might be interpreted as representing more than one horizon but if carefully examined with regard to their relation to the other exposures do not seem to conclusively indicate that this is the case, but that rather there is only one horizon in reality represented here. In the valley of Big India Creek in the extreme western part of the county on the north side of the Canadian River, near Section 35, D. & P. R. R. Block 018, there is exposed in a cliff in the side of the valley 96 feet of sandstone and conglomerate. About one mile north of this location this sandstone seems to be represented by two layers, each about eight feet thick. The interval between the two, so far as exposures showed, is occupied by shales. These facts seem to indicate the existence locally of two sandstone ledges, which have been merged into one at the exposure first mentioned. South of this exposure on Big India Creek only one ledge seems to be present.

With the exceptions noted above, the Trujillo formation in Potter County is represented by only one ledge of sandstone and conglomerate varying in general from 10 to 20 feet thick. That this is the same ledge in all cases and not exposures of different layers of the Trujillo seen at different places is shown from the following: In all cases the ledge is found to directly overlie the Tecovas formation and is either found at locations where sufficient amount of the Tecovas formation is exposed so as to make its identification and the position of the sandstone with respect to it beyond doubt or the ledge can be traced directly to a location where the conditions are as outlined above. In some places as on East Amarillo Creek and parts of Tecovas Creek valley the ledge may be directly traced to locations where the Quartermaster, Tecovas and Trujillo are all exposed and the relations of the three positively determined. In this report, therefore, the Trujillo formation will be discussed as a single ledge of sandstone and conglomerate directly overlying the Tecovas shale. The question whether this is the lower sandstone of Gould, the other sandstones having been removed by erosion, or whether two sandstone ledges have been merged into one is left open. The sandstone horizon discussed here, however, belongs to the Trujillo formation and is the only part of that formation exposed within the limits of the county.

The Trujillo formation in Potter County is mostly exposed along the edge of the bluffs bordering the valleys. It is covered above by younger deposits of the Cenozoic, which, although they have been removed to a considerable extent from some of the divides, nevertheless, persist as a thin veneer, in practically all cases. In the southern part of the county the Trujillo is covered by the thick deposits of the later formation and appears below the "cap" or "rim rock" or the so-called caliche of the rim of the greater valley of the Canadian. The formation therefore appears as a narrow rim of exposures on the sides of the valleys.

In the northeastern part of the county in the vicinity of the highlands of the Quartermaster formation erosion has removed all Trujillo although outcrops of it may be found on the west branch of Plum Creek across the line a few miles in Moore County. No outcrops are found south of the river east of Bonita Creek, except in the extreme southern part of the valley of this creek near its head in Box Canyon. Either the Trujillo has been removed here by erosion previous to the deposition of the sands and gravels of the later deposits, or it is buried beneath them. That it has been removed over part of this area is evident from the fact that these deposits are in places found resting upon the eroded surface of the Quartermaster formation. The formation, however, is seen to have strong dips to the north and east in the neighborhood of Bonita Creek and it may be that it is preserved in a syncline to the east and north of this valley. It has been removed by pre-Potter erosion between the mouth of Bonita Creek and Pedrosa Creek where the mortar beds of the latter formation overlie the beveled edges of both the Quartermaster and Tecovas formations. It has also been removed from a large proportion of the lower part of Pedrosa Creek valley where it appears only in two small remnants apparently preserved in a local synclinal fold. It caps the bluffs immediately above the

Canadian River from the east border of Section 30 to the center of Section 31, G. & M. Block 5, on the south side of the river between the mouths of Pedrosa and East Amarillo creeks and on the corresponding part of the north side of the river from the east border of Section 71 to the east border of Section 75, H. & T. C. R. R. Block 47. Between the last named outcrop on the north side of the river and the mouth of John Ray Creek in the neighborhood of Section 85, H. & T. C. R. R. Block 47, outcrops of this formation are concealed beneath the later formation. There is some evidence that this is due to a syncline between these two points, the rocks near the latter location in Section 86 of the same block showing a strong dip to the northeast. North of the last named location on John Ray Creek the Trujillo is buried beneath the stratified sands and gravels of the later formations. A small exposure of it is found in Section 80, G. M. Block 3, in John Ray Creek Valley, but it is everywhere else buried or else has been removed by erosion before the deposition of the stratified deposits of the Cenozoic. West of John Ray Creek in Section 86 the formation caps the bluffs which overlook the river valley at a distance of one and one-half to two miles from the river and continues along the river to the western border of the county. It also extends up the valleys of the Sandy, Lahy, Corrall, Little India and Big India creeks, but, with the exception of the latter, the extent of the outcrop is not great, being buried under the later sediments a short distance north of the line of bluffs before mentioned. Three outcrops, however, are found on Corrall Creek a considerable distance to the north. All of these are found near the headquarters of the Miles Bivens ranch, Section 21, E. L. & R. R. R. Block 11. One of these outcrops occurs one-fifth of a mile directly north of the ranch headquarters, the second about the same distance to the northeast and the third a few hundred yards to the south of the headquarters. At the first locality about 10 feet are exposed but it is not known whether this represents the total thickness, as the bottom of the ledge cannot be seen. At the second exposure the bottom can be seen and the deposit is about eight feet thick. In the third exposure 20 feet of sandstone and conglomerate can be seen. In the valley of Big India Creek the formation is found capping the bluffs of the valley north to about Section 30 of the D. & P. R. R., where the rise of the rocks to the north has brought the Tecovas formation to the surface and the Trujillo disappears. A short distance north of this the latter formation is buried beneath the later sediments. On the southwest branch of Bonita Creek, in the northeast corner of B. S. & F. Block 1, at the head of the branch the formation outcrops along the sides of a somewhat rectangular-shaped amphitheatre locally known as Box Canyon. A strong northward dip, however, carries it to the level of the valley bottom a short distance below the mouth of the canyon and it does not again appear in the Bonita Creek valley. This is the only part of Bonita Creek valley where this formation appears, except in the neighborhood of Section 8, A. B. & M. Block 3. Just north of this location a small tributary valley opens into the valley of Bonita Creek and the Trujillo formation appears as a ledge along the southern valley wall. The Trujillo formation exposed along this valley wall disappears beneath the Cenozoic sands and gravels near the main valley.

As mentioned above the formation has been removed from the lower part of Pedrosa Creek with the exception of the remnants in Section 29, G. &. M., Block 5. South of Section 13, A. B. & M. Block 3, however, it forms a continuous line of outcrops along the sides of the valley to the north border of Section 18, B. S. & F., Block 1, where the valley merges into the level plain and the formation passes beneath the latter desposits and the soil.

It occupies the east side of the valley of East Amarillo Creek from Section 18, A. B. & M., Block M 3, to Section 130, A. B. & M., Block 2, where this valley also merges into the level plain. North of Section 18, A. B. & M., Block M. 3, it is either absent or concealed. It is thought that the latter is the case.

The formation does not outcrop along the west side of East Amarillo Creek nor anywhere along West Amarillo Creek, north of the south part of Sections 15 and 54, B. S.

& F. Block 9, with the exception of the outlier on the south side of the northwest branch of West Amarillo Creek in Section 1, B. S. & F., Block JAD, and Section 120, B. S. & F., Block 9. There is, therefore, an area of approximately nearly two hundred square miles in the west-central part of the county from which the formation has evidently been removed by erosion, which took place before the deposition of the Cenozoic materials, since some of the latter materials are still in place over parts of this area.

South of Sections 15 and 54, B. S. & F., Block 9, in the valley of West Amarillo Creek, the formation outcrops around the side of an amphitheatre-shaped valley formed by the working back headward of the many tributaries of West Amarillo Creek. The sides of this amphitheatre being indented by many minor tributary valleys, especially on the western side, the border is very irregular. From the western corner of this amphitheatre the exposures extend west toward Gentry with, however, a very considerable curve to the south between these two points. At Gentry the cliffs formed by the Trujillo, turn abruptly south and the thickening of the later Cenozoic deposits in a short distance cause the Trujillo to occupy a middle position on the cliffs, the caliche or cap rock forming the top of the cliffs. The line of cliffs forming the wall of the great amphitheatre of the upper Tecovas Creek valley extends south from Gentry four or five miles and then turns west, this southern border also having many indentations due to the valleys cut into its border by streams working back headward. The Trujillo outcrops along this border below the cap and some places at or near the base of the cliff. West of Section 183, B. S. & F., Block 9, however, the formation is either absent or concealed. On the western side of the main Tecovas Creek valley it forms a prominent outcrop at the top of the valley wall from Section 11, G. & M., Block 8 to Section 2, E. L. & R. R., Block 2D. South of this the outcrops are obscure and largely concealed but the formation apparently extends in a fairly direct southwest line to the border of the county. It forms prominent outcrops along the sides of the valley of the Cerrite de La Cruz Creek and its tributaries in the extreme western part of the county.

Character.—As stated in the discussion of the definition and distribution of the Trujillo formation, it is the opinion of the writer that this formation within the county is represented by only one general horizon. This consists of from 10 to 25 feet of massive sandstone and conglomerate. The character of the formation is quite variable and changes considerably in short distances. The sandstone as a rule is gray to buff, rather firmly cemented and somewhat coarse-grained, although exposures can be found in which the sand is quite fine-grained. The sandstone is cross-bedded in some places but this characteristic is seen most frequently in the conglomeratic phases of the formation, the sandstone being more often of the massive variety. Small quartz pebbles, varying in size from buck-shot to the size of a pea, but seldom larger, are of frequent occurrence in the sandstone and conglomerate layers. The proportion of these silicious pebbles in the sandstone phase of the formation varies greatly. In some exposures only a few scattered pebbles may be found, in others the proportion is sufficiently large that the rock might almost be classed as a conglomerate. As a rule, however, the quartz pebbles make up only a small percentage of the rock. This is also true with regard to the conglomeratic phase, the particles of the latter being made up largely of limestone fragments.

The sandstone in many exposures contains an abundance of fragments of mica. It is also characterized by the presence of many small pieces of bone.

A very common characteristic of the sandstone, which is seen best on the unweathered surface, is the presence of numerous minute particles of limestone from one to four millimeters in diameter. This characteristic is brought out very vividly by polishing the surface and staining the polished slab in Lemberg's solution. This solution stains calsium carbonate a deep violet but leaves the sand grains unaffected. This brings out the two kinds of material in sharp contrast. Surfaces treated in this manner show a somewhat regular pattern of areas of calcium carbonate more or less circular in outline, surrounded by sand grains as if particles of calcareous mud had been rolled over a sandy bottom accumulating sand grains on the periphery. All variations from this condition to that in which the sand grains occupy the greater part of the polished surface may be found. In all cases, both staining and tests with acids, show that the cementing material is largely calcium carbonate.

On the weathered surface the calcium carbonate dissolves more readily than the sand grains and the weathered surface, therefore, has more the appearance of a pure sandstone than the unweathered.

In addition to the massive sandstone phase described above, the Trujillo formation in Potter County has several layers of typical conglomerate. The conglomerate varies from a condition not greatly different from some of the phases of the sandstone described above, to a very coarse conglomerate with pieces of limestone and other sedimentary rocks, as much as five to ten centimeters in diameter. On weathering many of the more easily attacked pieces are removed and their casts are left in the more highly indurated matrix. Many of the pieces in this type are evidently somewhat flattened. This is a very common characteristic of this phase of the formation. In many cases however, the pebbles of the conglomerate are more rounded. A very common phase of the conglomerate consists of somewhat uniform particles usually not over four to five millimeters in diameter. In all cases the fragments which make up the conglomerate are mostly limestone. A few silicious pebbles may be found but the proportion of these is very small.

The conglomerate is found both above and below the prominent sandstone ledge or as partings in between the layers, although perhaps it occurs most frequently at the bottom of the formation. The conglomeratic phase of the formation is strongly cross-bedded in many places.

Topographic Expression.—The Trujillo formation, in contrast with the Tecovas, tends to form prominent escarpments. It is quite resistant to erosion and where present along the sides of the minor valleys protects the softer underlying sediments from erosion tending to form steep-sided canyons, the most notable example of which is seen on Pedrosa Creek. Its escarpment-making qualities are not so noticeable in situations where it is covered by the thick deposits of the Cenozoic, and where the so-called caliche or cap rock forms the rim of the valleys, as is the case in the upper portions of the valley of Tecovas Creek.

Thickness.—The whole formation is seldom found to be over 25 feet thick within the limits of Potter County, although exceptions to this may occur, the most notable exception being in the valley of Big India Creek, where a section was found which is 78 feet thick. In many exposures the thickness is less than 20 feet.

The following detailed sections serve to illustrate the general character of the formation:

Section at head of ravine east side of West Amarillo Creek in Sec. 13, B. S. & F. Block 9.

	Ft.	In.
Coarse gray sandstone with marked cross bedding	3	0
Sandstone, gray coarse and thin-bedded	4	0
Massive, gray sandstone	4	0
Coarse gray thin-bedded sandstone	2	0
Massive gray conglomerate	3	0

Section taken about one-half mile north of the head of Corral Creek in Sec. 10, D. & P. R. R., Block 018.

	Ft.
Massive gray conglomeratic sandstone containing an abundance of white quartz. Vertical layers of calcite run through some of the blocks	10

Section near the head of Tecovas Creek in Sec. 184, B. S. & F., Block 9

	Ft.
Fine-grained soft gray sandstone	3
Soft gray sandstone	5
Massive sandstone	2 to 3

Section on bluff on the west side of West Amarillo Creek in Sec. 55, B. S. & F., Block 9.

	Ft.
Massive sandstone	1

Conglomerate, a large number of limestone fragments	4
Sandy shale	1
Massive, fine-grained, micaceous sandstone	5

Section taken in valley of Cerrite La Cruz in Sec. 88, G. & M., Block 5.

Soft gray massive sandstone with layer of cross-bedded sandstone at the top. Sandstone quite micaceous in places	25

Section near the head of the southwest branch of West Amarillo Creek in Sec. 79, B. S. & F., Block 9.

	Ft.
Massive sandstone	20
Gray sandy shale	10
Shaly sandstone, thin-bedded	2

Section in valley of Pedrosa Creek in Sec. 4, A. C. H. & B., Block 4.

	Ft.
Massive sandstone with layers of conglomerate containing fragments of limestone	10

Section about 3 miles north of Soncy, in Sec. 58, B. S. & F., Block 9.

	Ft.
Cross-bedded sandstone, conglomeratic at the base	6
Massive sandstone, somewhat conglomeratic	10
Gray conglomerate	2

Section on Little India Creek in Sec. 39, D. & P. R. R., Block 018.

	Ft.
Massive sandstone, very fine-grained, and somewhat soft, containing many fine concretions about 2 to 3 mm. in diameter. Passes laterally into harder and more characteristic Trujillo sandstone. Also passes laterally from the massive to the conglomeratic character	20
Conglomerate containing limestone pebbles	2

Section at the head of Corral Creek in Sec. 21, E. L. & R. R. R. Co., Block 11.

	Ft.
Massive sandstone containing some siliceous pebbles varying from about 2 to 5 mm. in diameter and containing a few layers of limestone conglomerate. In the latter layers some bone fragments were found	20

Section on Big India Creek in Sec. 26, E. L. & R. R. R. Co., Block 11.

	Ft.
Limestone and clay conglomerate	3
Fine-grained buff sandstone	50
Conglomerate consisting mostly of limestone and shale pebbles	3
Fine-grained, massive, micaceous sandstone with few mud lumps	22

Section west of Boden in Sec. 8, G. & M., Block 8.

	Ft.
Massive sandstone with few conglomerate layers	8
Typical limestone and shale conglomerate	2
Fine-grained sandstone	1

Section of John Ray Creek in the south part of Sec. 80, D. & P. R. R. Co., Block 018.

	Ft.
Massive sandstone with few conglomerate layers, no siliceous pebbles larger than 5mm.	10

Paleontology.—This formation contains a considerable amount of silicified wood. The greater amount of silicified wood found in this county, however, is found in situations where it has been weathered out either from this formation or from the Tecovas and where both formations have been largely removed, as is the case with the large deposits of fossil wood found near the headquarters of the L. X. ranch on Bonita Creek, and it is not possible to ascertain definitely which formation such deposits came from originally as both formations contain such silicified wood. Logs as much as two and three feet in diameter may be found although the majority of the deposits are composed of much smaller pieces than this.

This formation also contains many fragments of bones. These fragments are quite scattered and no pieces capable of identification were found. Most of the pieces are not more than a centimeter or two in length and are found nearly altogether in the conglomeratic phases of the formation.

Relation to Adjacent Formations.—The Trujillo formation. rests conformably on the Tecovas with the possible exception of such local unconformities as have been described as occurring in the Tecovas formation itself.

The sandstone and conglomerate horizon described above is the highest portion of the Triassic represented in this county, with the exception of a few localities where a few feet of red shale occur above this horizon. In general, however, the sands and gravels of the Cenozoic rest directly upon a ledge of sandstone and conglomerate.

TERTIARY AND QUATERNARY SYSTEMS

GENERAL STATEMENT

Occupying the highest part of the geologic column in the Panhandle are the sands and gravels of the Cenozoic. These are for the most part unconsolidated or only partially consolidated deposits of coarsely stratified sand and gravel. They have been ably discussed by a number of geologists who agree that they are the remnant of a great debris apron spread out at the base of the Rocky mountains. The view of the older geologists that these deposits are lacustrine does not now seem to find general acceptance. Johnson,[34] whose views probably express the generally accepted theories of the origin of these deposits makes the following statement.

> "The present writer has described the whole of the great plain of which the High Plains plateaus are but fragments as, in its original condition, an aggradation plain on a vast scale, built to a smooth but sloping surface by the subdividing, shifting, and alternately increasing and failing streams of a dry climate; the initiation of that building is attributed to change of climate from relative humidity to dryness, not to interference with stream grade merely, by deformation; and its present erosion, together with the several recorded inter-epochs of erosion, grouped together in the Pleistocene, is attributed to climatic shiftings back toward humidity. The complex structure, finally—an uneven net-work of gravel courses and elongated beds of sand penetrating a mass of silt and sand streaked clay—is described as the normal product of desert-stream work under con-

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[34] Johnson, Willard H., The high plains and their utilization; U. S. Geol. Sur. 21st Annual Report. pt. 4 pp. p. 654 & 655.

stant desert conditions. The coarse material is not regarded as the product of necessarily strong running streams, and the fine material of sluggish streams, in alternating epochs, either of humid or dry climate or high and low inclination of slope, but as the simultaneous product of branching streams of the desert habit, here running in a channel and there spreading thinly."

Gould[35] in discussing the opinion quoted above states that the only point of variance which other geologists may have from the opinion of Johnson is whether the source of the indiscriminate, uneven, lenticular deposition of the material by the streams should be sought in climatic changes or in diastrophic changes. He expresses it as his opinion that both of these causes may have been operative. The present writer is inclined to favor the hypothesis advanced by Johnson.

PLIOCENE OR PRE-PLIOCENE (?) SERIES

POTTER FORMATION

Definition and Distribution.—The name Potter formation is proposed for a group of sediments characteristically developed along the Canadian River, near the central part of the county, and which bear a definite relation to the sediments to which the name Coetas formation is given. The term, Potter formation, is applied to those beds of coarsely stratified and partly consolidated sand and gravel which can be shown to occupy a stratigraphic position, just below the Coetas formation, or which show a definite relation to beds which do occupy such a position. These beds have been classed by other writers as "mortar beds" on account of their resemblance to the artificial product, as they are somewhat firmly cemented by calcium carbonate. It should be noted, however, that it is not proposed to class all "mortar beds" under the term Potter formation but only

[35]Gould, C. N., Geology and water resources of the western portion of the Panhandle of Texas. U. S. Geol. Sur. Water Supply and Irrigation Paper No. 191, p. 34.

those beds which are shown to have a definite relation to the overlying beds as stated above.

A part of the outcrops, which are here grouped under the name Potter, are so classified only tentatively as the writer does not believe that the evidence for such classifications in the case of some of the beds is conclusive. These include the deposits on the north side of the Canadian River from Sections 78 to 85, H. & T. C. R. R. Co., Block 47. With regard to the deposits in the neighborhood of Bonita Creek it is thought that the evidence is quite conclusive. Mortar bed deposits occurring in other parts of the county, where no relation to the Coetas formation can be demonstrated, are classed with Cenozoic of undetermined age. While the evidence seems to point to the fact that all of the "mortar beds" within the county are basal and, therefore, belong to the Potter formation, it is not disputed on the other hand that the "mortar beds" might occur at other points than basal, especially if Johnson's hypothesis that the cementation represents the position of a former ground water level, and that the position of such beds in different places in the deposits represent fluctuations of the ground water level, is accepted.[36] Deposits which present merely the character of "mortar beds" are not regarded, therefore, as being members of this formation unless other evidence is found.

Deposits classified as Potter occur along the Canadian River on the east side of G. & M. Block 20, from Section 14 to Section 2; along the north side of G. & M. Block 5, from Section 24 to Section 29; along the south part of Sections 69 and 70, H. & T. C. R. R. Co. Block 47, and from Section 78 to Section 85 of Block 47 of the H. & T. C. R. R. Co.

Character.—The formation, as defined above, consists of coarsely stratified sand and gravel, the whole somewhat firmly cemented by calcium carbonate. The color of the formation is slightly darker than that of the overlying beds, being of a reddish cast, the overlying beds being gray to buff. The formation is characterized by the presence of a large number of water-worn fossils mainly of the

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[36]Johnson, Willard D., Op. Cit.

genus *Gryphaea*. These fossils are not found in the upper beds of the Cenozoic of this county.

The gravel of these deposits varies in size from pieces several inches in diameter to a fraction of an inch. About 80 per cent of these pebbles consist of quartz and quartzite, the remaining part containing a few sedimentary and some igneous rocks.

The formation is strongly cross-bedded in many localities. The assortment of the material is very poor but lines of stratification can in most places be readily distinquished.

Topographic Expression.—On account of its resistance to erosion the Potter is cliff-forming. Along the sides of valleys it has a tendency to stand up in steep vertical cliffs. It does not erode to "bad lands" as easily as some of the other formations and the location of this formation is made somewhat noticeable in the character of the topography for this reason.

Paleontology.—No fossils were found in this formation with the exception of the water-worn fossils mentioned above, which have been weathered out of earlier formations and which do not belong to this formation.

Relation to Adjacent Formations.—The Potter lies unconformably upon rocks of both the Permian and Triassic systems. It underlies the sediments of the Coetas formation, which, on account of the vertebrate fossils found in it, is classed as Pliocene. The Potter, therefore, is either Pliocene or pre-Pliocene in age.

PLIOCENE SERIES

COETAS FORMATION

Definition and Distribution.—The name, Coetas formation, is given to indicate certain slightly consolidated sands and flaggy limestones which by their fossil content are known to be Pliocene in age. The name is from Coetas Creek in the eastern part of the county where the formation is well exposed. The formation is exposed in an irregular area south of the Canadian River between Coetas Creek and Bonita Creek. It is exposed throughout the greater portion of the southeastern part of G. & M. Block 20, the northeastern part of B. S. & F. Block 1, nearly all of B. & B. Block 2, all of A. C. H. & B. Block 3, with the exception of a sand dune area in the center of the block, the northern part of A. B. & M. Block M3, and parts of Sections 25 to 28, G. & M. Block 5.

As has been previously mentioned (p. 11) Marcou, in his journal of the Whipple expedition of 1853, has a brief note, concerning the exposures in the neighborhood of Bonita Creek, which quite accurately describes some of the typical features of this formation. Marcou did not, of course, describe these deposits as a separate formation, nor did he notice the vertebrate fossils, which is not remarkable, since he had not time to take more than passing notice of the exposures.

Character.—The Coetas formation consists for the most part of slightly consolidated sand together with a flaggy, somewhat sandy, limestone near the top of the formation.

The sand of this formation is uniform in texture and does not show much evidence of stratification. It is, in most exposures, of a yellow to buff color, although the color varies somewhat. The formation is quite calcareous and contains many tubular calcareous concretions. In some places the sand is quite firmly cemented by calcareous material. In none of the exposures examined does this formation show any of the stratified deposits of gravel which are characteristic of the other Cenozoic deposits of the county. Plate IV, A shows a typical exposure of the Coetas.

A conspicuous characteristic of the Coetas formation is the presence of flaggy, somewhat sandy, limestone, which occurs near the top of the formation. This limestone shows variations from thinly laminated strata, with laminæ one millimeter in thickness, to strata having layers several centimeters in thickness. In many places it occurs as thin flags separated by stratified shale and sand, the flags being from six to twelve inches apart and as many as fifteen in number. In other places these flags are close together, forming a rather solid stratum. In general this stratum is not over two feet thick but in approximately Section 1, G. & M. Block 20, between Chicken Creek and Bonita Creek, there is an exposure of limestone of the above character 20 feet thick. This is the maximum thickness of the member observed in this formation. This may represent either an unusual development of the member in this particular locality or it may indicate that this is the original thickness and that erosion has removed a considerable portion of the limestone. Plate IV, B shows an exposure of the Coetas formation in which a considerable thickness of the limestone member is shown.

In places this limestone shows distinct ripple marks which indicate its shallow water origin. In the majority of the exposures the limestone is white in color although in some cases a slightly pinkish tinge is noticed.

In some exposures the limestone is seen to contain a considerable amount of fine-grained sand and at best it should probably be classed as a rather impure limestone. In the neighborhood of Section 3, B. & B. Block 2, the limestone has a flinty character.

The limestone member is exposed most extensively along the divide between Chicken Creek and Coetas Creek. Plate I, D shows the distribution of this member along the divide mentioned. It also occurs in isolated outcrops between Bonita Creek and Chicken Creek, as in the neighborhood of Section 3, B. & B. Block 2.

Topographic Expression.—Were it not for the limestone member the Coetas formation would be very easily eroded. The presence of this member, however, causes the formation to outcrop in broad sloping divides. Erosion has cut these by numerous ravines, leaving many isolated flat-topped hills with accordant slopes. See Plate I, D. Where the limestone has been removed by erosion the formation weathers very easily and much of the material is eroded by the wind. On the east side of Chicken Creek, extending from the neighborhood of Section 24, S. K. & K. Block 1, there is an extensive dune area composed of sand blown from the Coetas formation, which is exposed just west of this area. Dunes of this area are from 40 to 50 feet in height and the area is from one-fourth to one-half mile broad. At one point, about three miles from the mouth of Chicken Creek, the dunes are advancing across the valley of the creek and are burying it. Dunes are also forming to a more limited extent along Coetas Creek.

Thickness.—No exposure could be found which would give a complete section of the formation from top to bottom. Exposures may be found at different localities in which from 50 to 75 feet of the material may be seen. From the top of the formation on the Bonita Creek divide to the bottom of the valley is 230 feet. Since the formation is exposed at different places from the top of the divide to the bottom of the valley it seems probable that the total thickness of the formation is about 200 feet.

Paleontology. — The most distinctive characteristic of the Coetas formation is the great abundance of bones found in the deposit. These occur as scattered fragments in most places but whole bones are frequently found. The majority of these have been so poorly preserved, however, that it is impossible to get them out without destroying them. These bones occur both in the sand of the formation and in the limestone at the top. The remains are very abundant, hardly an outcrop being found which does not contain some fragments. A number of teeth were found, some of which are sufficiently preserved to admit of identification. Several teeth have been identified by Dr. E. H. Sellards, of this bureau, as those of *Hipparion* sp.? The age of this formation is, therefore, regarded as Pliocene. In the material weathered out from the limestone which caps the bluff on the west side of Coetas Creek, in Section 10, G. & M. Block 20, two lower teeth of an unidentified species of horse were found. In different parts of the Coetas formation many fragments of teeth and also several astragali and one large leg bone were found which were in a fair state of preservation.

In Section 10, A. B. & M. Block M3, there are two erosional remnants about 20 or 25 feet high and 25 or 35 yards in diameter, the material of which consists of slightly consolidated yellow or buff colored sand resembling in every way the material of which the Coetas formation is composed. An abundance of fragments of bones was found in the material composing these remnants. A partially preserved left upper jaw, containing six teeth as well as several individual teeth, were taken out at this place. The teeth were identified by Dr. Sellards as those of *Equus* sp.? On account of the presence of the *Equus* teeth in this deposit it might seem somewhat doubtful whether the deposits at this place should be classed as belonging to the Coetas formation. The deposits are in the bottom of a small valley tributary to Bonita Creek valley from the west. The presence of *Equus* teeth in these deposits then might be explained by the hypothesis that these erosional remnants are either the remains of a later terrace in the bottom of a valley, which was excavated in the Coetas formation, or that they are wind blown deposits in a similar situation. However, the lithologic character of the material of these remnants and their relation to the main body of the Coetas formation is such that were it not for the occurrence of the *Equus* teeth in this deposit and the occurrence of *Hipparion* teeth in the Coetas there would be no hesitation in classifying the former as a part of the Coetas formation. Plate V, C shows a view of these erosional remnants.

In the material of these erosional remnants there were also found large quantities of fossils, which have been identified by Dr. J. A. Udden as endocarps of drupes of *Celtis*. The characteristically wrinkled surface and pattern found on the surface of the endocarps of this genus are perfectly preserved in these fossils. They occur in aggregates which are somewhat cylindrical in form and three or four inches in diameter and up to a foot in length. Plate VI shows a photograph of one of these aggregates. These occur imbedded in the sand, of which the two remnants are composed and the majority of them were found from eight to ten feet above the base of the easternmost of these two small hills, which is shown at the right of the photograph, Plate V, C.

The peculiar shape of these aggregates suggest that they might be the result of fossilization of endocarps stored in the burrows of animals. It seems possible, therefore, that these might have been introduced here after the deposits were laid down and that they are not contemporary with the *Equus* remains. The deposits at this place, like the Coetas formation in general, contain a considerable amount of calcium carbonate and it would seem that conditions for fossilization under such circumstances would be favorable.

Correlation.—Upon the basis of paleontological evidence the Coetas formation would be correlated with Blanco beds, which have been determined as Pliocene in age.[37]

Relation to Adjacent Formations.—The Coetas formation is seen to overlie the Potter formation in several places, notably on the west side of Coetas Creek, on the Coetas Creek-Chicken Creek divide and the divide between Chicken Creek and Bonita Creek. It is not known whether the Potter formation underlies all of the Coetas formation or whether the latter formation merely overlies the Potter along the northern border of the former. As shown by the limestone member, the Coetas formation has a strong dip to the south and west, amounting to as much in some cases as five to ten degrees—a dip which apparently carries the formation to the level of Bonita Creek in the neighborhood of Section 1, A. B. & M. Block 3. In this particular location formations, which are a part of the undifferentiated Cenozoic formation, are also found at the level of the valley so that the Coetas formation apparently passes under these in this location. The dip of this formation is in the opposite direction to that of the Trujillo formation of the Triassic system, south of Bonita Creek, and corresponds somewhat to the dip of the Permian rocks farther north. This raises the question whether the Coetas formation was not tilted at the time the deformation of the older rocks took place. It is not thought that the evidence

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[37]Gidley, J. W., The Fresh-Water Tertiary of Northwestern Texas. American Museum Expeditions of 1899-1901. American Museum of Natural History, Vol. XIX, Article XXVI, p. 624. 1903.

is sufficient for a conclusion in this respect, but it is sufficient to raise the question.

The limestone member of the formation when traced south along the divide of Chicken Creek and Coetas Creek valleys to the neighborhood of Section 23, G. & M. Block M20, is seen to pass under 85 feet of material which more closely resembles the Cenozoic deposits of the higher parts of the county, and which are evidently the latest deposits. The broken land or "breaks" end here and level uplands extend south from this neighborhood. The later deposits under which the Coetas passes, consist of pink calcareous sand or partly formed caliche with abundant gravel on the top. Marly cap rock is found 50 feet from the top of the hill to the south. The actual passage of the Coetas formation under the above described later formation is not seen, as the two are separated by a concealed area 100 yards in width, but the dip of the formation takes it under this concealed area, and so far as can be determined, under the younger formations.

That the Coetas formation is an older formation than those just mentioned above, is also attested by the fact that a thin veneer of the gravels of the later formation is found in places on the top of the Coetas formation, although none is found in the formation itself.

There seems to be no doubt, therefore, in considering the combination of evidences, that the Coetas formation represents a deposit younger than the Potter formation and older than the stratified sands and gravels and caliche to the south and east of it.

UNDIFFERENTIATED CENOZOIC

General Statement.—The nature of the larger part of the Cenozoic deposits of the Llano Estacado and the Panhandle High Plains is such that it is impossible on lithologic or stratigraphic grounds, to separate them into different formations. This statement is equally true with regard to these deposits in Potter County. As has been shown in the discussion of the Coetas formation, the latter formation evidently passes under the beds of the stratified sand and gravel, which constitute the later deposits. It might seem therefore, that the former should be classed as younger in age and regarded as a post Pliocene or later Pliocene. While this is no doubt true with regard to the immediate deposits concerned, the writer is of the opinion that the evidence is insufficient to warrant this classification of other deposits, except those which are shown to be directly related to the Coetas deposits.

Gould[38] in discussing this question with respect to the eastern portion of the Panhandle says:

> "It is the experience of the writer, after ten seasons spent in studying these deposits in Kansas, Oklahoma, Texas, and New Mexico, that it is practically impossible to separate either the Tertiary or Pleistocene deposits of the plains into mappable formations. From the bottom of the Loup Fork to the top of the Equus beds the general character of the rocks changes so constantly and with such extreme irregularity that they cannot for the most part be identified in the field. Sections made at about twelve points in eastern Colorado, western Kansas, western Oklahoma, and in the Panhandle of Texas show such a marked similarity of structure that without the evidence of fossils it is impossible to determine whether the rocks belong to the Miocene, the Pliocene, or the Equus beds."

Definition and Distribution.—All Cenozoic deposits whose age cannot be determined by the evidence of fossils or by immediate relation to deposits, in which the age is so determined, are referred to the class under discussion.

These formations outcrop over a considerable area of the county and occupy a greater areal extent than any single formation which has been discussed. They occupy all of the southeastern one-fourth of the county, with the exception of the valleys of the East Amarillo, Pedrosa and part of Bonita creeks, all of the eastern part of the county to near the river, with the exception of the areas occupied by the Potter and Coetas formations, and all of the western

[38]Gould, C. N., The geology and water resources of the eastern portion of the Panhandle of Texas: U. S. Geol. Surv. Water Supply and Irrigation Paper No. 154, p. 27.

part of the county north of the outcrop of the Trujillo, on the north side of the river, with the exception of a few isolated patches. In the southwestern part of the county these formations occupy a strip varying in width, from two to eight miles, bounded on the north by the escarpment overlooking the headwaters of the Tecovas and West Amarillo Creeks. The deposits also occupy the inter-stream divides in the southern half of the county, reaching as far north as the river between Pedrosa and Bonita creeks and between East Amarillo and Pedrosa creeks and nearly to the river between East and West Amarillo creeks. A large irregular area occupies the divide between West Amarillo and Tecovas creeks and another between Tecovas and Cerritte la Cruz creeks. Minor areas are found between the forks of West Amarillo Creek and between those of Tecovas Creek.

Character.—The deposits consist for the most part of stratified sand and gravels and clays, the first two being the most prominent. In situations where the deposits have been weathered and eroded, as in the case of many of the inter-stream divides, it is not possible always to correctly distinguish between deposits in situ and deposits which have resulted from wash from the original beds. The gravels vary in size from pieces several inches in diameter to those no larger than can be classed as gravel, although pieces about one-third of an inch in diameter are probably the most numerous. The pebbles are largely composed of quartzite, the latter predominating and making up about 60 or 70 per cent of that part of the deposit. Plate V, A and B, shows typical exposures in these deposits.

The sand is usually a light yellow or buff color contrasting with the darker color of the Potter formation. The deposits also contrast with the Potter formation on account of the absence of water-worn Gryphaeas, etc. in the latter. The thickness of the deposits vary from a thin veneer to 200 feet but in the majority of exposures less than 100 feet is found. The larger figures are derived mainly from the data of water well drillers.

A very prominent feature of the deposits under discussion is the so-called "caliche" or "cap rock" of the formation. This is a limestone rock usually not over four or five feet thick but in some places reaching a thickness of 10 feet or more and also in some places being represented by two or more separate beds. The cap rock is very variable, but the character encountered most frequently is that of a soft white chalky limestone. In many places it contains many concretions and some exposures show a complete gradation between the concretions, which occur very abundantly in the sand and gravel of the formation, and the solid "cap rock." The rock very often exhibits a hard outer crust. The outer surface of the rock also frequently has a somewhat pitted surface.

The origin of this rock has been ascribed to secondary deposition of calcium carbonate by ground water drawn toward the surface by capillarity.[39] Udden[39a] is of the opinion that the accumulation of a loess-like soil, such as exists in the Panhandle, has been a factor in the precipitation of calcium carbonate below the surface from water moving upward under capillary attraction, as such a deposit would furnish a superficial layer of very porous material making possible evaporation at a considerable depth below the surface. He is also of the opinion that the existence of more than one layer of rock may be due to changes in topography caused by a continuous accumulation of loess thus shifting the ground water level and causing precipitation at different depths.

While this rock is popularly known as the "cap rock" and found in most cases near the top of the formation, it does occur in other parts of the formation, even in some cases lying immediately on the Tecovas formation. In cases of this kind, however, all of the younger deposits have been removed by erosion so that the rock still occurs near the surface.

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[39]Baker, Charles Lawrence, Geology and underground waters of the northern Llano Estacado. Bur. Econ. Geol. & Tech. Univ. of Texas Bull. 57, p. 31. 1915.

[39a]Udden, J. A., The "rim rock" of the high plains. Bull. Am. Assn. Petr. Geol., Vol. VII, No. 1, Jan-Feb., 1923, pp. 72-74.

Topographic Expression.—Along the rim of the greater valley of the Canadian River the cap rock or caliche preserves the formations from erosion and a distinct escarpment is formed, the extent and nature of which has been discussed in the description of the "caliche" or cap rock. Plate V, D shows some outliers of this escarpment in the southern part of the county.

Back of the rim the surface is that of an almost featureless plain and typical of the Llano Estacado and the Panhandle High Plains. Very prominent features of the latter type of topography are the so-called "lakes" or sinks, broad shallow depressions which, during the wet season of the year, are occupied by shallow bodies of water. From rim to rim these depressions average from a half to three-quarters of a mile in diameter. They are sometimes elongated but are more often circular in shape. The difference in elevation between the center and the extreme outer rim is usually not over 30 or 40 feet, and in many cases less than this. There is nearly always present an inner basin of a diameter of one-third or less of that of the depression proper. This inner basin has a depth of usually less than ten feet. From this inner basin the ground slopes very gradually to the outer rim. There are little more than a dozen prominent sinks within the limits of the county, although they are a very common feature of the topography of the rest of the Panhandle. These are nearly all confined to the southeastern corner of the county.

Johnson[40] has given an elaborate discussion of the questoin of the origin of these basins and concludes that they are due to "ground settlement, rather than to some process either of original construction or subsequent erosion." He believes that these depressions are due to compacting within the formation itself and to caving in the underlying floor beneath the Tertiary and Quaternary deposits.

Within the greater valley of the Canadian River the cap rock usually does not appear except as occasional outcrops, which, it is believed, are secondary depositions made in the

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[40]Johnson, Willard H., The high plains and their utilization: U. S. Geol. Sur. 21st Ann. Rep't. pt. 4 p. 701 et seq. 1901.

same manner as those of the main outcrops but subsequent to the re-excavation of the valley and, therefore, subsequent to the deposition of the main "cap rock." The deposits within the main valley, therefore, not having the protection of the overlying cap rock, are easily eroded and give rise to small rounded, irregular hills and numerous gullies of the "bad land" type of topography. The extent and nature of this type of topography has already been discussed under the subject of Physiography.

Back from the river, where the erosion is not so vigorous, the topography of these deposits grade from the bad land type to rough broken land of rolling hills of sand and gravel and sand choked, dry valleys. The latter type of topography is typical of a large part of the northern portion of the county which lies west of the outcrop of the Permian rocks.

The formations under discussion frequently give rise to dune topography. The dune areas, as a rule, are not so sharply and distinctly set off from the formations as is the case with those which are derived from the Coetas formation, so that dune areas and weathered and broken down original deposits grade into each other almost insensibly.

Another deposit to which no definite classification is assigned is a fine-grained, very hard rock varying from a highly siliceous limestone to almost pure chert. This deposit is found exposed on the bluff four miles east of the railroad in Section 13, B. S. & F. Block No. 9. It has a maximum thickness of about four feet. It contains a few quartz pebbles some of which are as much as an inch in diameter. It occurs directly above the outcrop of the Trujillo at this place and apparently rests unconformably upon the latter.

ALLUVIUM

The alluvium of the Canadian River is almost wholly composed of sand. The alluvium of the smaller streams, especially those whose courses are through the thick Tertiary and Quarternary deposits is largely of the same character. Many of the creeks of this kind are known as "sand creeks" because during a larger part of the year they contain no stream and their beds are filled with thick deposits of sand. Streams which flow wholly on other formations, such as the Tecovas, have less deposits of sand and more deposits of finer alluvium derived from the shales of the formations over which they flow.

STRUCTURAL GEOLOGY

The structure of a part of the county has been discussed by Gould[41] in connection with the structure of the region in general. Mention has already been made of the structural map of the Amarillo gas field prepared by Gould and others. (See p. 14.)

Gould states that the structures in which gas has been found in the Amarillo region belong to a system of some ten to twelve domes along the Canadian River from Plemons, Hutchinson County, to the west line of the Panhandle. He describes these as large oval, more or less symmetrical domes, with an uplift of 200 to 500 feet and a major axis of from six to twenty-five miles. He describes the John Ray Dome, which lies in the northeast part of Potter County, as a broad symmetrical structure 15 to 20 miles long and 8 to 10 miles wide a lift or upfold of 500 feet.

A second of the series of domes mentioned by Gould in the paper cited is the Tuck-Trigg Dome which he describes as being situated about 10 miles south of the John Ray Dome and about 200 feet lower than the John Ray Dome. These structures were also briefly mentioned by Gould in Water Supply Paper 191 published in 1905.

The John Ray Dome is the most conspicuous structural feature of the county. The canyon of the Canadian River cuts through the side of the dome so that the dip of the rocks can be plainly seen. (See Plate V, E.)

The Alibates dolomite has been thoroughly exposed by erosion over a considerable portion of the structure and furnishes an easily identifiable reference horizon so that accurate and detailed structure mapping is possible. The same statement holds true with regard to the Tuck-Trigg Dome. The excellent work done by Gould and his colaborators by mapping on this horizon render unnecessary

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[41]Gould, C. N., Geology and Structure of the Amarillo region, Bull. of American Association of Petroleum Geologists, Vol. 4, No. 3, pp. 269-275. 1920.

any further work of this kind and those who are interested are referred to the work of these gentlemen.[42]

The John Ray Dome occupies the eastern part of D. & P. R. R., Block 018, G. & M., Block 3, eastern portion of H. & T. C. R. R., Blocks 47 and 46. The Tuck-Trigg Dome lies mainly in the east-central part of G. & M. Block 5. In Fig. 6 is shown a structural map of the John Ray Dome made by contouring on the highest gas horizon in the field.

The origin of these and similar structures have been attributed by Powers[43] as possibly due to condensation of sediments around and over buried hills.

In a discussion of the oil and gas possibilities of the Texas Panhandle Pratt[44] express agreement with this hypothesis.

The Triassic rocks in the southern half of the county show in general a dip to the north and east which is somewhat the reciprocal of the dip shown by the rocks of the Permian system on the north. This dip averages about 30 feet to the mile up to the neighborhood of Bonita Creek where the dip increases to as much as five to ten degrees. The dip of the Permian rocks north of this location is also very steep, similar dips being recorded on the Alibates dolomite. It will be seen from the cross section Plate VIII, B that the dips here are so great as to indicate the possibility of a fault in this location. However, the relations of the formations and the dips are sufficient to account for the observed conditions and it is not thought that there is any positive evidence of faulting in the conditions here.

From the Canadian River the Triassic formations apparently rise to the north as is seen from exposures in northern Corrall Creek and in Big India Creek, although the Triassic rocks at the river have in general local dips away from the river causing the formation of northward-dipping cuestas away from the river valley.

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[42]On the map accompanying this report the hundred-foot contours of Gould's map are reproduced and are shown in green.

[43]Powers, Sidney. Reflected buried hills and their importance in petroleum geology: Econ. Geol. Vo. 17, No. 4. June-July, 1922.

[44]Pratt, Wallace E. Oil and gas in the Texas Panhandle. Bull. Am. Assoc. Petroleum Geologists. Vol. 17, No. 3, pp. 237-250. May-June, 1923.

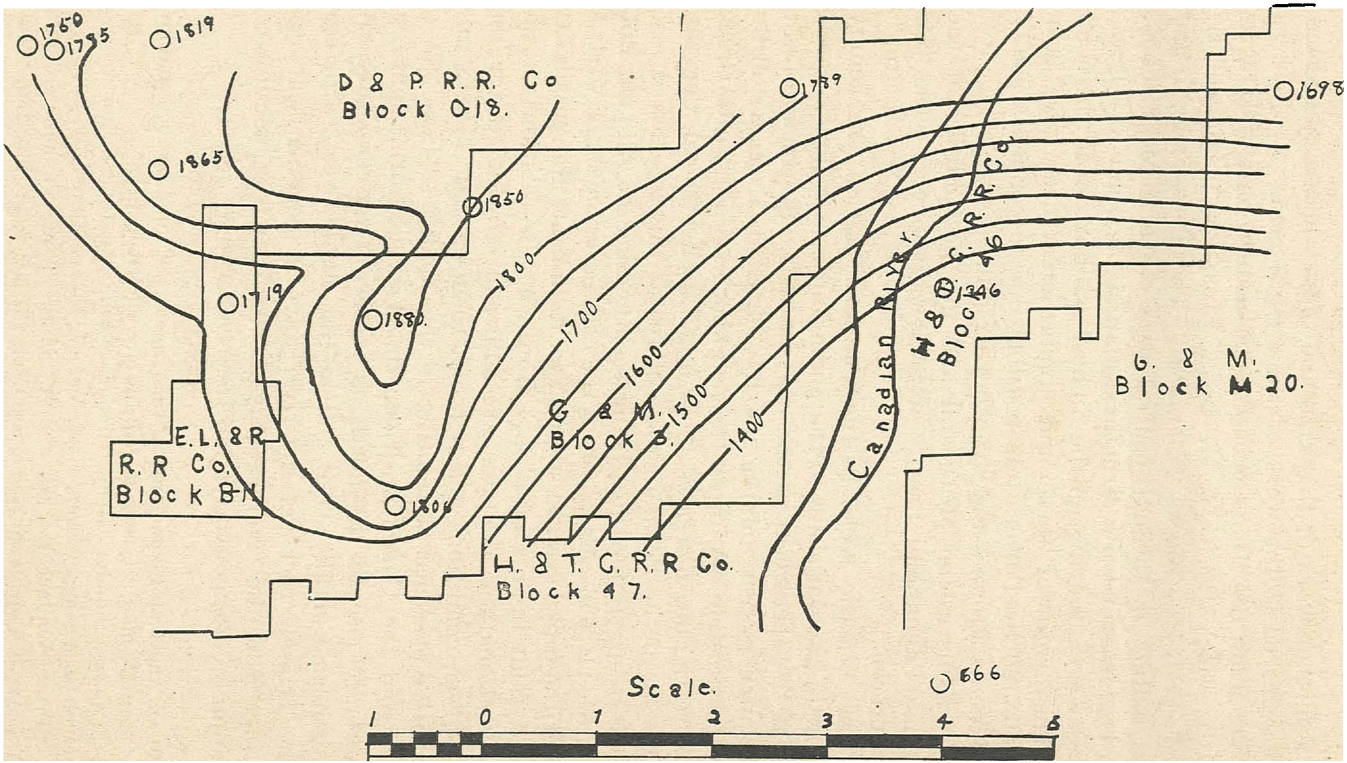

FIG. 4: Structural map of the John Ray Dome made by contouring on the highest gas horizon.

In Big India Creek the Triassic rocks are seen to have many local folds showing four or five minor folds, in as many miles, having dips of from two to five degrees. The northward rise of the Triassic formations is sufficient to bring up the Tecovas formation as the formation of both the bottom and walls of the valley north of Section 30, D. & Q. R. R., Block 018.

There is apparently a syncline between the mouths of John Ray and Home Creek. This has already been discussed under Stratigraphic Geology. (See p. 71.)

The contours shown on the map accompanying this report, which are drawn on the top of the Trujillo formation, are based, for the most part, on elevations obtained by corrected barometric readings. Owing to the scarcity of bench marks, and the distance which it was necessary to traverse between bench marks and outcrops in many cases, the results must be considered as only approximate and any conclusions based upon them should be carefully checked by accurate plane-table surveys. It is thought, however, that they serve to indicate in a general way the structure of that part of the county, which on account of the absence of a good horizon marker, such as the Alibates dolomite, has not received the attention that the more easily mappable portions of the county have been given.

In Section 86, H. & T. C. R. R., Block 47, the Triassic formations appear to have been cut by a fault trending east and west, with downthrow to the south. After careful study of the conditions here the writer is of the opinion that the conditions shown are not due to an ordinary fault but merely indicate slumping of the formations, either a slump of a large portion of the cliff down the face or slumping due to caving in of the underlying Permian formation, a condition which is common in the latter formation. The condition seems to be entirely local and not traceable any considerable distance in either direction. A condition somewhat similar to that described above is seen in Box Canyon in the neighborhood of Section 58, A. B. & M., Block 1.

One-half mile west of John Ray Creek, Section 86, H. & T. C. R. R., Block 47, is seen a small local fault with a throw of about eight feet, downthrow to the west and fault plane about vertical. (Plate II, D shows a view of this fault.) Another small fault is seen in the valley of Pedrosa Creek in Section 13, A. B. & M., Block 3. The throw here is of only a few feet.

ECONOMIC GEOLOGY

OIL AND GAS

The oil and gas development of Potter County began with the drilling of the Masterson Well No. 1 in Section 65, Block 018, D. & P. R. R. Co. This well was brought in as a gas well September 1, 1918, and was completed in December, 1918. This was the discovery well of the Panhandle as well as of the Potter County field. Its capacity upon completion was estimated at from eight to ten million cubic feet of gas daily. The drilling of this well was followed rapidly by the drilling of other wells. In 1922 there were twelve producing wells within the limits of Potter County, with a total estimated capacity of 25 million cubic feet of gas per day. In addition to wells located within the boundaries of the county, there are twelve producing wells in the part of the field which is outside of the county.

In the discussion of "Rock Not Exposed" it was shown that the gas-bearing horizons are probably situated in the Permian system and that the gas may have migrated into the structures in which it is now found.

In practically all of the producing wells the gas occurs at more than one horizon. In the Amarillo Oil Co.'s Masterson No. 3 for example, seven different horizons are reported. The gas horizons are close together in some cases and far apart in others, the maximum distance of separation being that of two horizons in the Amarillo Oil Co.'s Masterson No. 5, where two horizons are separated by an interval of 555 feet.

With the exception of one well situated on the Tuck-Trigg Dome, all of the producing wells in Potter County up to the time of the publication of this report, have been drilled on the John Ray Dome, in the northeastern part of the county.

Several wells have been drilled in other parts of the county but none of them resulted in producing wells.

A showing of oil has been reported in the logs of some of the wells but so far no oil has been produced within the county, although oil is being produced in parts of the field which do not lie within the limits of the county.

Pipe lines have been laid from the gas field to the city of Amarillo and the gas is being used for domestic and manufacturing purposes. The city of Amarillo uses from four and a half to five million cubic feet of gas daily for domestic purposes. The United Zinc Smelter Company is at present constructing a plant which it is expected will use five million cubic feet of gas daily. The Panhandle Brick and Tile Company also use the gas in their furnaces in the manufacture of brick.

HELIUM

The United States Bureau of Mines has conducted an investigation to determine the helium content of the gas from this field but so far no public announcement of the results of their work has been made.

NATURAL-GAS GASOLINE

The Cannon Gasoline Company of Amarillo has recently completed and has in operation a plant for the extraction of gasoline from natural gas of the Amarillo field. The plant at the present time is treating 20 million cubic feet of gas per day. The method used in this extraction is the one known as the absorption process.

Concerning the Natural-Gas Gasoline industry as a whole, the U. S. Mineral Resources for 1918, makes the following statement which is quoted here for the reason that it is sometimes thought that this extraction lowers the value of the natural gas for domestic and other purposes:

> "In increasing the supply of motor fuel, natural-gas gasoline is a direct means of conservation in that its extraction does not destroy the gas in which it is contained.

Experiment has demonstrated that the extraction of gasoline from natural gas does not reduce appreciably the value of the gas for heat, power, and light, but that it is a benefit, for it removes not only the water but also the gasoline, which causes leakage by disintegrating the rubber gaskets in the pipes."

With the increased use of the natural gas from the Potter County field, the Natural-Gas Gasoline industry will no doubt assume larger proportions.

POTASH

Sea water contains a number of different salts of varying solubility. When such a solution is evaporated the salts are deposited in the order of their solubility, the less soluble ones coming down first. The element, potassium, forms but few insoluble salts. As a consequence, the salts of potassium are among the last to be precipitated when a solution of sea water is evaporated. The most soluble salts found in sea water are the chlorides and sulphates of potassium and magnesium and the chlorides of calcium.

The conditions surrounding the precipitation of the salts from sea water on evaporation from sea water are somewhat complex both from the standpoint of the chemical and geological factors involved. The solubility of a salt is influenced by the presence of another salt in the solution and by the temperature. Furthermore, the geological conditions necessary for the precipitation of various salts from sea water require a nice adjustment of a number of different factors, and in general it may be said that the adjustments become increasingly complex as the conditions necessary for the precipitation of the more soluble salts are reached. It is to be expected, therefore, that the deposits of the more soluble salts found in sea water should be relatively rare, as is the case.

The largest potash deposits definitely known at the present time are those in Germany and France. The German deposits were discovered in 1843 and up to the period of the World War had been the principal source of the world's supply of these salts since 1860. The principal raw materials from which the commercial supply of potash is derived from these deposits are carnallite ($KCl. MgCl_2. 6H_2O$), kainite ($KCl. MgSO_4. 3H_2O$), and hartsalz, a mixture of sylvine (KCl), kieserite ($MgSO_4. H_2O$) and rock salt ($NaCl$).

In 1904 extensive deposits of potash were discovered in Alsace. These contain principally the mineral sylvite.[45]

Minor deposits of potash in different parts of the world have yielded small amounts of potassium salts and some salts have been derived from natural brines, ashes of sea weeds, cement dust, treatment of the mineral alunite ($K_2SO_4. Al_2(SO_4)_3. 4\ Al(OH)_3$), and by treatment of silicate rocks. In 1920, in the United States, there were produced by the various processes outlined above 48,077 short tons of potash (K_2O) or the equivalent of 19 per cent of the average annual consumption of the country for the years immediately preceding the World War. There were imported into the United States in 1920, 224,792 short tons of potash (K_2O). Of this amount 197,795 short tons were imported largely for use as a fertilizer.[46]

Potassium is a characteristic constitutent of plants and the compounds of this element are necessarily present in all fertile soils. Unless supplied in the form of fertilizers the soils will rapidly become exhausted. An adequate supply of these salts for fertilizers is, therefore, an imperative necessity for agriculture. The problem of securing an adequate domestic supply of potassium salts is, therefore, of vital importance to the nation and any possible domestic source of supply should be most carefully investigated.

At present the most promising field for exploration for potash deposits seems to be that of the great salt beds which underlie central Kansas, western Oklahoma, northern and western Texas, and eastern New Mexico. Although this is the greatest known salt field in the world it does not necessarily follow that it, therefore, contains

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[45]Gale, Hoyt S., Potash deposits of Alsace: U. S. Geol. Sur. Bull. 715-B. 1920.

[46]Nourse, M. R., Potash in 1920. U. S. Geol. Sur. Mineral Resources, 1920. Part 2, pp. 99-110.

large deposits of potash. Potash deposits are associated with deposits of common salt but it does not necessarily follow that where salt deposits occur that potash deposits will be found also. Attention has already been called to to fact that the conditions necessary for the precipitation of the most soluble constitutents of sea water call for such a nice adjustment of a number of factors that the conditions are seldom fulfilled, and that there are, therefore, many deposits of gypsum and sodium chloride, etc., which do not have associated with them any deposits of salts of potassium. On the other hand it is also obvious that where extensive beds of sodium chloride have been laid down that it is likely that somewhere within that area conditions for the precipitation of potassium salts might have been met.

Positive evidence of the presence of potash minerals in the salt beds of Texas is not wanting, however, although the exact extent of such deposits has not yet been determined. It is worthy of note in this connection that the discovery of potash in borings in Potter County were among the first discoveries of potash in the great salt field under discussion.

The first discovery of potash in the salt beds of west Texas was made in 1912 by Dr. J. A. Udden, Director of the Bureau, who was at that time Geologist of the Bureau. The discovery was made from an examination of samples from a boring at Spur in Dickens County. In 1915 in examining samples from a well drilled on Sec. 4, E. L. & R. R. R. Co., Block 21 W, in the western part of Potter County he found potash minerals containing as high as 9.23 per cent of potash (K_2O) in the soluble portion from the depth of 875-925 feet below the mouth of the well or from 2389-2239 feet above sea level. Potash was also found by Dr. Udden in samples from the boring on the Miller ranch in Randall County. These discoveries and the question of the possibility of finding workable deposits of potash minerals in the Texas Permian were made the subject of two bulletins by the Bureau.[47]

In 1916 the U. S. Geological Survey undertook a deep drilling in Sec. 21, B. S. & F., Block 29, near Cliffside in Potter County in order to make a test of the beds there for potash minerals. In the report of the results of this boring it is stated that no potash of special significance was found although a great quantity of crystaline rock salt was penetrated.[48]

With regard to this particular boring, however, the following statement is made in the report cited above:

> "The negative results obtained from this one well should not be a discouragement to drillers looking for potash elsewhere in this general region or deeper in this same vicinity, as it is entirely possible that potash bearing zones may be struck at any time in association with thick salt deposits in the United States and may prove a valuable asset when found."

Subsequently the United States Geological Survey and the Bureau of Economic Geology and Technology entered into a cooperative agreement to obtain all the information, regarding the occurrence of potash, that it was possible to obtain from wells being drilled for oil in the western part of the state. As a result of this work potash was found in five new places in the Llano Estacado. A discussion of these discoveries is given in an article by Dr. J. A. Udden,[49] director of the Bureau of Economic Geology and Technology and in an article by David White,[50]

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[47]Udden, J. A., The deep boring at Spur: Univ. of Texas Bull. 363. 1914.

Udden, J. A., Potash in the Texas Permian: Univ. of Texas Bull. 17. 1914.

[48]Gale, Hoyt S. and Hicks, W. B., Potash: U. S. Geol. Sur. Mineral Resources, 1917, Part 2. Non-metals. 00. 427-428.

[49]Udden, J. A., On the Discovery of Potash in West Texas: Chemical and Metallurgical Engineering. Vol. 25, No. 26, pp. 1179-1180. Dec. 28, 1921.

[50]White, David, Potash Reserves in West Texas: Mining and Metallurgy. April, 1922.

chief geologist of the United States Geological Survey, and in press bulletins issued by each of these organizations.

It is the expressed conviction of both organizations that the possibility of discovering workable beds of potash in the Texas Permian is sufficient to warrant explorations by means of careful drilling and examination of drill cores.

With regard to the possibilities of potash in Potter County, some additional information may be obtained by a study of the well logs of wells drilled for oil and gas. It It has been noted before that although the presence of thick beds of ordinary salt are not positive indications of the occurrence of potash minerals, it is in such locations that potash deposits are most likely to be found. Below is given in tabulated form the number and aggregate thickness of beds of salt encountered in the drilling of oil wells in Potter County.

In the examination of samples from Haines Masterson Well No. 2, in Section 10, D. & P. R. R. Block 018, traces of potash were found in samples from depths 1225-1230, 1295-1305, 1305-1330. See description of samples from this well on page 148.

The foregoing data are sufficient to show that Potter County lies within the region of the thick beds of salt of the Permian system, which places it within the area in which potash deposits may possibly be found.

In summarizing, it may be said that there are in West Texas extensive beds of thick sodium chloride deposits; that the conditions under which these deposits were laid down were such as to make it likely that potassium salts also have been precipitated somewhere in this area; that such salts have been found at widely separated points within the limits of this area, but that no definite information is at present available with regard to the thickness and areal extent of such deposits. With regard to Potter County it may be said; that the county lies within the limits of the thick salt beds referred to; that potash varying in amount from .027 to 9.23 per cent of the soluble portion has been found in wells in the county; but that the one test well drilled especially for the purpose of exploration for potash,

Name and location of well.	No. beds of salt	Total thickness in feet	Remarks:
Amarillo Oil Co. Masterson No. 1, Sec. 65, Block 018 D. & P. R. Co.	1	35	
Amarillo Oil Co. Masterson No. 3, Sec. 102, D. & P. P. R. R., Block 018	0	0	
Amarillo Oil Co. Masterson No. 2, Sec. 70, D. & P. R. R., Block 018	0	0	
Amarillo Oil Co. Masterson No. 4, Sec. 108, D. & P. R. R., Block 018	0	0	
Amarillo Oil Co. Masterson No. 5, Sec. 31, G. & M., Block 3	6	180	Two strata reported by driller as shale and salt.
Emerald Oil Co. Masterson No. 1, Sec. 82, G. & M., Block 3	0	0	
White Oil Corporation. Masterson No. 1, Sec. 5, G. & M. Block 3	3	265	
Greater Amarillo Oil Co. Masterson No. 1, Sec. 20, G. & M., Block 3	3	564	Two strata reported as salt and red rock.
Haines Little Pool Masterson No. 1. Sec. 14, G. & M., Block 3	6	322	One bed reported as salt and gypsum.
Ranch Creek Oil Co. Masterson No. 1, Sec. 2, E. L. & R. R. R. Co., Block B-11	5	312	Driller reports 700-730 as "salt water." This not included in number of

Name and location of well.	No. beds of salt	Total thickness in feet	Remarks:
Amarillo Oil Co. Bivens No. 1, Sec. 106, H. & T. C. R. R., Block 46	3	416	One stratum reported by driller as salt and red rock. Another as salt, gyp and slate.
Amarillo Oil Co. Bivens No. 2, Sec. 2, G. & M., Block M-20	7	715	Two strata reported as red rock and salt.
Amarillo Oil Co. Bivens No. 3, Sec. 15, G. & M., Block M-20	1	20	Reported as salt and gyp.
Amarillo Petroleum Co. Jacobs No. 1, Sec. 16, A. B. & M., Block 2	10	205	One stratum reported as rock salt and lime.
Miller Oil & Refining Co. Tanner No. 1, Sec. 59, A. B. & M., Block 2	19	619	Eight strata reported as shale and salt. Three as lime and salt.
Haines Oil Co. Tuck-Trigg No. 1, Sec. 37, G. & M., Block 21-W	10	324	
U. S. Geol. Sur. Well, Sec. 21, B. S. & F., Block 9.	9	358	Two strata reported as salt and anhydrite. One as salt with intercalated red clay.
Amarillo Petroleum & Gas Co. Boden Well, Sec. 4, E. L. & R. R. Co., Block 21-W	10	314	

did not yield any results. Whether or not there are any workable beds of potash within the county cannot at present be positively stated.

GLASS SAND

On account of the abundance of fuel from the gas fields of the county, the location of deposits of sand suitable for the making of glass is desirable. For this reason careful search was made for suitable deposits of this sort. The most promising deposits seemed to be the slightly consolidated sandstone of the Tecovas formation, which have been described under that formation. As has been stated under the discussion of the Tecovas formation, these slightly consolidated sands occur as lens-like bodies in the formation and show very great variations in thickness from place to place. For this reason careful prospecting should precede any attempted development of these deposits for glass sand purposes. Considerable thickness at one exposure does not necessarily mean that there is a large deposit of this sand at that locality. Careful exploration by means of test holes should precede development in any locality in order that the exact amount of the deposit may be ascertained in advance.

Sands of the Tecovas formation are exposed in the valleys of Tecovas Creek, West Amarillo Creek, East Amarillo Creek, Pedrosa Creek and along the Canadian River, between the mouths of Bonita and Pedrosa creeks, and north of the Canadian River along the northern part of the west one-half of H. & T. C. R. R. Block 47. It should be noted, however, that the outcrops are not continuous throughout the locations named and that the areal extent of the sandstone members under discussion is probably not large, although there may be a possibility of locating deposits of sufficient extent for commercial purposes.

Representative samples from the deposits under discussion were collected by the writer and submitted to the Division of Industrial Chemistry for analysis, to determine their suitability for the manufacture of glass. Below is given the report of Dr. E. P. Schoch, head of the Division of Industrial Chemistry.

"The seven samples of sand from Potter County, submitted by you to this laboratory to be tested for their fitness for glass making, were analyzed by Mr. J. E. Stullken after this manner of procedure:

"Silica was determined by fusing 1 gm. of the sand with sodium carbonate, by the usual procedure.

"For the determination of alumina, ferric oxide, calcium and magnesia, 20 gms. of sand were treated with sulphuric and hydrofluoric acids three times and each time evaporated to dryness. The residue was treated three times with hydrochloric acid and finally diluted and the soluble portion filtered off and examined for alumina, ferric oxide, lime and magnesia in the usual way. The insoluble residue was dried, ignited and fused with sodium carbonate and treated in the usual way for additional lime.

"Tests for phosphates were made on 10 gm. portions of sand, treating repeatedly with nitric acid and filtering. To the filtrate ammonium molybdate was added to precipitate the phosphoric acid.

"For sulphates 10 gm. portions of sand were repeatedly treated with hydrochloric acid, evaporated to dryness, taken up with dilute hydrochloric acid and filtered. The filtrate was tested in the usual way with barium chloride solution. No sulphates were found in any of the samples.

"**Sources of Samples:**

"A" From Tecovas formation near headquarters, Hall Ranch, West Amarillo Creek, Potter County. N. W. ¼ Sec. 23, B. S. & F., Block 9.

"B" J. Hall Ranch, West Amarillo Creek, Potter County, S. W. ¼ of Sec. 22, B. S. & F., Block 9.

"C" J. Hall Ranch, West Amarillo Creek, Potter County, Sec. 22, B. S. & F., Block 9.

"D" Word Ranch, Sec. 8, G. & M., Block M. 19.

"E" Tecovas formation, 1 mile west of Boden on ranch of Judge Word.

"F" Tecovas formation on Tecovas Creek, approximately Sec. 188, B. S. & F., Block 9.

"G" Undifferentiated Cenozoic, Potter County. Taken on Colorado and Gulf Highway, N. of Canadian River near the river.

Appearance of Samples: These are all of very fine grain except "G" which is somewhat coarser (see Sieve Analyses).

"A" pinkish-gray.

"B" grayish-white.
"C" nearly white.
"D" pinkish-white.
"E" a little brighter than "D."
"F" light yellow.
"G" pinkish-gray.

Analyses:

Lab. No.	Mark	Ignition Loss	Silica	Ferric Oxide	Alumina	Lime	Magnesia	Phos-phates
C1879	"A"	1.79	93.20	0.53	2.29	0.11	0.01	none
C1880	"B"	3.30	87.70	1.16	3.33	none	none	little
C1881	"C"	2.00	91.85	.61	4.65	.19	.16	none
C1882	"D"	....	99.00	.46	....	....	....	none
C1883	"E"	....	98.50	.77	.08	....	....	none
C1884	"F"	.90	94.41	.66	2.35	none	none	trace
C1885	"G"	2.35	82.50	1.32	5.97	1.11	trace	little

Remarks on composition of these samples: "The only two that can be considered as glass sand are 'D' and 'E,' and these are fit only for window glass.

"As far as the iron oxide is concerned, the rest might be used for bottle glass, but the high per cent of alumina renders them unfit for glass."

Note: Sample "G" of the above is not from the formation under discussion but from the sands of the Cenozoic deposits, but the analysis was included with the analyses of the other sands.

The foregoing shows the need of careful investigations of any of these deposits from the standpoint of chemical analysis, as well as areal extent of the deposits, before any development of them is attempted.

MOULDING SAND

As indicated in the report of the analysis of sands for glass sand the Division of Industrial Chemistry also reported upon the suitability of these sands for foundry purposes. Below is given the report of Mr. Potter, chemist of the Division of Industrial Chemistry:

"With reference to the suitability of the samples of sand submitted by Dr. Udden for foundry purposes, I wish to say that the samples marked A, B, and E, are too fine grained for this purpose.

"Sample C is very fine grained and has fair bonding power. This sand could possibly be used for light castings.

"Sample D is very fine grained and has a low to fair bonding power. This sand could possibly be used for light work in brass, but its use would be very limited.

"Sample F is fine grained and has fair bonding power. This sand could probably be used for light castings in gray iron and brass.

"Sample G is the only sand that really has much promise as a molding sand, and it has the disadvantage of a rather low bonding power. It is medium grained, however, and could be used for medium castings."

Sample "G," which Mr. Potter reports as having the most promise as a moulding sand, is a representative sample of the sand of the Cenozoic deposits of the county, which have a very considerable areal extent and thickness within the county.

BRICK AND TILE

Representative samples of the Tecovas shale were collected and submitted to the Division of Industrial Chemistry to be tested for their suitability for the manufacture of brick and tile. The following report was rendered:

REPORT ON SAMPLES TECOVAS SHALE
By E. P. SCHOCH

The samples of Tecovas Shale from the pit of Panhandle Brick and Tile Co., Section 55, Block No. 9, Potter County, have been examined by Mr. A. D. Potter according to the specifications of the American Ceramic Society, and he reports the following:

The raw clay was made up into test pieces by both the stiff mud and dry press process and were tested according to specifications. The linear drying shrinkage of the stiff mud test pieces amounted to 12%. This excessive shrinkage caused the pieces to crack and they were not fired. The plasticity of this sample was medium, and it required 23.7% of water for working. Test pieces were also made by the stiff mud process containing 5, 10, and 15% of grog, respectively. Of these samples, the ones containing 5 and 10% grog, showed fair drying qualities. The samples containing 15% grog, showed good drying qualities. These samples were fired at a uniform temperature of about 950°C. The samples containing 5 and 10% grog developed some cracks during the firing; the samples containing 15% grog came out sound.

The dry press test pieces made from raw clay were fired, but it was found that all pieces were cracked badly at 950°C., and the entire set was removed from the furnace at this temparture.

In conclusion I should say that on the basis of these tests, this clay could be used in the manufacture of red burning brick and tile by the stiff mud process, providing 15—20% of grog, or dead material, is added to the raw clay.

The shales of which these samples are representative are quite extensively exposed in the county. Many of these exposures have little overburden and are in locations which are fairly easily accessible. The gas fields offer an abundant supply of fuel so that it would seem that conditions are favorable for the manufacture of brick and tile. The Panhandle Brick and Tile Company has a plant near Cliffside which has been in operation since June 1, 1922. At the time the plant was visited by the writer there were in operation one permanent and three temporary kilns giving an output of 10,000 bricks per day. The product is a building brick.

ROAD MATERIALS

The county has abundant deposits of gravel which is excellent material either for macadam purposes or for the purpose of making a bed for the use of other materials, such as asphalt. The county at present has 35 miles of paved highway. In the construction of these highways local gravel was used for the gravel macadam base of these pavements. The gravel for these projects was obtained largely from two gravel pits, one situated on the Hall Ranch, near Cliffside, and another three miles south of the bridge across East Amarillo Creek, on the Colorado and Gulf Highway.

The gravel deposits are wide-spread throughout the county. The nature and distribution of the Cenozoic deposits, in which they are contained, has already been discussed. (See under Potter formation and undifferentiated

Cenozoic deposits.) The wide variation in the nature of these formations makes it impossible to designate any particular location as being particularly valuable for its gravel deposits but wherever these formations exist throughout the county good deposits of gravel may be looked for. The situation in Potter County is much better than in many other counties of the Panhandle in respect to the availability of these deposits. Over a large part of the area of this county erosion has removed the cap rock or "caliche" from these deposits, thus rendering them more available than they would otherwise be. It is true, of course, that the formation of another caliche deposit, as discussed on page 89, in some places will cause some trouble but the deposits in this county are ordinarily as available as any gravel deposits. Where mixed with sand to the extent of 60 to 75 per cent, engineers in charge of highway construction report that it does not pay to screen the gravel out.

While it is not practicable to indicate areas which may be of value because of their gravel deposits, on account of the very variable nature of the deposits in which the gravel is contained, there are, nevertheless, certain areas which are more favorable than others. The "bad lands" south of the Canadian River, in the eastern part of the county, contain many gravel deposits which are evidently easily available and which do not seem to contain too great a proportion of sand. The same is true with regard to the "bad lands" between the mouths of East and West Amarillo creeks. North of the river many of the exposures exhibit too large a proportion of sand but careful prospecting will reveal many deposits which are satisfactory in respect to the proportion of sand and gravel and which would require but little work of excavation. The so-called mortar beds of the Potter formation nearly everywhere contain a proportion of gravel large enough to make them available for the purposes in question and, although they are somewhat firmly cemented, the induration is not sufficient to greatly injure them for the purposes under discussion.

The Alibates dolomite is a rock which would make a very good material for crushed stone to use in road making and is extensively exposed without any overburden so that it could be easily quarried.

SOIL

The soils of Potter County have been classed by the United States Department of Agriculture into Amarillo silty clay loam and Amarillo sandy loams and loam (undifferentiated).[51]

A considerable portion of the county, in the neighborhood of the river and the larger tributary streams, is classed as "rough, broken land" and no classification of the soils is made.

The extent of the Amarillo silty clay loam, as mapped in the report cited above, is practically identical with that part of the county which occupies the high lands back of the cap rock. The undifferentiated Amarillo sandy loams and loams occupy the interstream divides and the rolling land immediately below the escarpment.

The Amarillo sandy loams are thought to have been derived from the sandy deposits of Tertiary and Quaternary age. They are described as brown or reddish-brown, medium to fine sandy loam. The Amarillo loam is described as a dark brown loam varying to heavy sandy loam. It has also been derived from the weathering of the Tertiary and Quaternary deposits. In the report cited it is stated that in the Canadian River Valley, portions of this type may have been formed by the weathering of the Jura-Trias and Permian rocks where the younger material is removed by erosion. It is the opinion of the writer that this mode of origin in Potter County probably accounts for a larger proportion of the soils of the county than the report would indicate. This seems to be particularly the case in the western part of the county in the valley of the Tecovas and its tributaries.

The following quotation taken from the Bureau of Soils

[51]A reconnoisance soil survey of the Panhandle region of Texas: U. S. Department of Agriculture, Bureau of Soils. 1910.

report indicates the character of the Amarillo sandy loam with regard to its value for agricultural purposes.

"The type is fairly productive and adapted to a large number of crops. Being of open structure and sandy texture, the surface soil absorbs practically all of the rainfall, while the heavier subsoil retains a good supply of moisture. Its drought-resistant qualities are remarkable and a valuable feature in a region of light rainfall. This inherent quality is greatly increased in effectiveness by good tillage. On the other hand, where the white underlying material comes too close to the surface, say within a foot, crops are liable to suffer during dry weather."

With regard to the Amarillo silty clay loam the same report contains the following statement:

"* * * The soil is very productive and if the rainfall is sufficient large yields of many different crops are secured. In dry seasons the yields as a usual thing are scant, although some farmers make fair yields even in seasons of very light rainfall."

WELL RECORDS

In this chapter are given the logs of deep wells drilled within the county for oil and gas or in search of potash minerals, descriptions of samples taken from these wells, and logs of water wells drilled within the county. The description of samples follows immediately after the log of the well from which the samples were taken. The examinations and descriptions of all of the samples were made in the sub-surface laboratory of the Bureau and all descriptions were verified by Dr. J. A. Udden.

DEEP WELL RECORDS INCLUDING DESCRIPTIONS OF SAMPLES

Log of the Amarillo Oil Co.'s Masterson No. 1, in Section 65, D. & P. R. R. Co., Block 018. Elevation of the well site, 3485′. Completed December 9, 1918.

	Depth in Feet. From	To.	Thickness.
Cellar 8x10x10. Dolomite			
Red rock	10	100	90
Water sand	100	108	8

Red rock	108	345	237
Water sand (200 bbls. gypsum)	345	355	10
Brown shale	355	365	10
Quicksand	365	405	40
Brown shale (carrying salt)	405	745	340
Rock salt	745	780	35
Brown shale	780	800	20
Quicksand and salt water	800	860	60
Blue shale	1000	1040	40
Shell	1040	1041	1
Coarse dry sand	1041	1047	6
Brown shale	1047	1300	253
Hard rock	1300	1350	50
Heavy sand	1315	1335	20
Brown shale	1335	1370	35
Brown shale with streaks of blue	1405	1675	270
Blue shale	1675	1700	25
Gas sand	1700	1717	17
Brown shale	1800	1812	12
Gray lime	1812	1892	80
Brown shale (more gas)	1897	1904	7
Hard shell	1904	1905	1
Blue shale	1905	2000	95
Good show of heavy oil	2000	2010	10
Blue shale	2010	2100	90
Conglomerate	2100	2125	25
Brown shale	2125	2155	30
Blue shale	2155	2250	95
Shell	2250	2253	3
Brown shell and gas	2253	2269	16
Hard rock	2269	2273	4
Brown shale	2273	2330	57
Calcareous rock	2330	2359	29
Blue shale	2359	2395	36

Log of the Amarillo Oil Co.'s Masterson No. 2, in Section 70, G. & M., Block 2. Elevation of the well site, 3505′. Completed September 19, 1919.

	Depth in Feet. From	To.	Thick-ness.
Soil	0	10	10
Clay	10	40	30
Sand	40	120	80
Red rock and water	120	130	10
Sand	130	350	220
Red rock	350	360	10

Chalky flint	360	475	115
Red rock	475	490	15
Blue shale	490	535	45
Gypsum	535	555	20
Blue shale	555	565	10
Gypsum	565	580	15
Red rock	580	585	5
Gypsum	585	635	50
Brown shale	635	640	5
Sand and water	640	740	100
Lime, shell	740	780	40
Blue shale	780	800	20
Quicksand	800	820	20
Red rock	820	830	10
Red rock	870	940	70
Gypsum	940	950	10
Red rock	950	1000	50
Gypsum	1000	1080	80
Gypsum	1000	1080	80
Red rock	1080	1085	5
Gypsum	1085	1135	50
Gypsum	1135	1140	5
Gypsum	1140	1150	10
Red rock	1150	1190	40
Gypsum	1190	1235	45
Red rock	1235	1245	10
Gypsum	1245	1260	15
Red rock	1260	1265	5
Gypsum	1265	1275	10
Red rock	1275	1300	25
Gypsum	1300	1355	55
Red sand, quick	1355	1360	5
Red rock	1360	1385	25
Sand, brown	1385	1430	45
Red rock	1430	1435	5
Brown sand	1435	1500	65
Red rock	1500	1510	10
Lime	1510	1530	20
Red rock	1530	1540	10
Brown sand	1540	1555	15
Brown shale	1555	1575	20
Lime	1575	1585	10
Brown shale	1585	1635	50
Lime	1635	1645	10
Brown shale	1645	1675	30
Lime	1675	1700	25

Brown shale	1700	1755	55
Lime, gas sand, ¼ million cubic feet gas	1755	1760	5
Red rock	1760	1785	25
Gas sand, 2 million cubic feet gas	1785	1795	10
Red rock	1795	1800	5
Red rock, more gas	1800	1803	3
Red rock	1803	1840	37
Red rock	1840	1885	45
Red rock, gas, 4¼ million cubic feet	1885	1890	5
Red rock	1890	1910	20
Gas	1910	1915	5
Red rock	1915	1950	35
Gas sand, good showing of oil	1950	1960	10
Limestone	1960	2025	165

Well completed September 19, 1919. Capacity, 4,900,000 ft. gas.

Log of Amarillo Oil Co.'s Masterson No. 3. Located on Section 102, Block 0-18, D. & P. R. R. Co. Surv., Potter County, Texas, Map No. 12, Co-ordinate 0-10. Supdded in June 12, 1919, completed to 2195 ft., September 23, 1919.....Resumed work to deepen June 30, 1922, completed January, 1923.

	Depth in feet. From	To.	Thickness.
Soil	0	7	7
Lime	7	12	5
Red rock	12	115	103
Sand	115	120	5
Red rock	120	140	20
Quicksand	140	147	7
Red rock	147	200	53
Sand	200	205	5
Red rock	205	259	54
Quicksand and water	259	274	15
Red rock	274	329	55
Blue shale	329	334	5
Sand	334	359	25
Blue shale	359	364	5
Sand flint	364	374	10
Gypsum with white water	374	404	30
Gypsum	404	414	10
Blue shale	414	419	5
Gray flint	419	424	5
Red rock	434	439	5
White gypsum	439	449	10
Flinty lime	449	479	30

Blue shale	479	494	15
White gypsum	494	539	35
Blue shale	539	549	10
Gypsum	549	594	45
Dark shale	594	604	10
Gypsum and water	604	625	21
Shale	625	645	20
Blue shale	645	659	15
Lime flint	659	669	10
Quicksand and water	669	684	15
Blue shale	684	694	10
Blue shale	694	704	10
Quicksand	704	714	10
Red rock	714	729	15
Gray flint	729	734	5
Red rock	734	1125	391
Red rock	1125	1325	200
Salt rock	1325	1415	90
Lime salt	1415	1585	170
Blue shale	1585	1624	39
Broken gas sand ½ million cubic feet	1624	1629	5
Blue shale	1629	1654	25
Gas sand and blue shale	1654	1661	7
Blue shale	1661	1686	25
Gas sand	1686	1688	2
Shale, 4¾ million cubic feet gas	1688	1710	22
Shale, more gas	1710	1712	2
Shell, (prob. lime)	1712	1714	2
Shale	1714	1716	2
Shell	1716	1718	2
Red rock	1718	1807	89
Gas, 2 mi. cu. ft. with oil show	1807	1812	5
Red rock	1812	1945	133
Blue shale	1945	1960	15
White lime	1960	2145	185
Red rock	2145	2180	35
Red sand with 2 million cubic feet gas	2180	2195	15
Red sand, 8¼″ set at 2220′	2195	2348	153
Gas sand, gas 11 million	2348	2365	17
Blue slate	2365	2375	10
Lime	2375	2430	55
Blue shale	2430	2435	5
Black lime	2435	2460	25
Lime	2460	2495	35
Blue shale	2495	2525	30
Blue shale	2525	2535	60

Gas sand	2585	2590	5
Blue shale	2590	2692	102
Blue shale	2692	2738	46
Pink lime	2738	2752	14
Red igneous rock 6⅝″ set 2752′	2752	2837	85
Light igneous rock	2837	2845	8
Black igneous rock	2845	2855	10
Sand, caving	2855	2885	30
Sand, caving, black	2885	2925	40
Red sand	2925	2972	47
Red sand, hard gas	2972	3030	58
Red igneous rock	3030	3045	15
Red sand, hard	3045	3082	37

Completed at 3082′, total gas, 18,500,000.
Casing pulled.

Description of Samples

	Depth in feet.
A piece of dark greenish-black intrusive igneous rock which breaks easily. In thin section were noted interlocking laths of plagioclase feldspar in a ground mass of ferro-magnesian minerals. Probably a diabase. D. N. S. and T. L. B.*	2765
Sample consists of cuttings of about three-fourths compact, dark, flint-like siliceous (metamorphic?) rock and about one-fourth red granite	2914-2926
Sample consists of finely ground up red granite	2925-2950
Sample consists of a single fragment of felsite. The rock is cut by joints along some of which there is a thin layer of reddish oxidized material	2945 2960
Very well ground up material consisting principally of orthoclase and quartz, evidently from a fine-grained granite	2962
Sample consists of about one-half dozen pieces measuring from one-half to eight inches in diameter. Most of the samples are evidently crystalline. Some of the fragments show joints which in one fragment is filled with calcareous material. In another fragment were noted concretion-like spheroidal segregations. Several other fragments are noted in two specimens, some straight and some irregular. The largest specimen shows what appears to be true laminations. All the samples consist of black siliceous material. They appear to be metamorphic	Exact depth of last samples not known.

*In the following these initials refer to the persons who have described the samples, viz.: T. L. Bailey, H. T. Kniker, J. A. Udden, D. N. Shoaf, E. B. Stiles.

Log of the Amarillo Oil Co.'s Masterson No. 4, in Section 108, D. & P. R. R., Block 018. Elevation of well site 3505'. Completed Nov. 29, 1919.

	Depth in feet. From	To	Thick-ness
Soil	0	38	38
Red rock	38	44	6
Lime	44	48	4
Gray shale	48	58	10
Red rock	58	145	87
Gypsum	145	150	5
Red rock	150	155	5
Gypsum	155	160	5
Red rock	160	270	110
Water sand	280	285	5
Red rock	285	310	25
Gypsum	310	324	14
Red rock	324	370	46
Red rock and gypsum	370	380'	10
Red rock and gypsum	380	395	15
Red rock	395	410	15
Gypsum	410	416	6
Gravel, water	416	420	4
Gypsum	420	435	15
Gravel, water	435	445	10
Red rock	445	460	15
Gypsum	460	485	25
Red rock	485	490	5
Gypsum	490	510	20
Red rock	510	520	10
Gypsum	520	545	25
Red rock	545	550	5
Gypsum	550	580	30
Red rock	580	585	5
Gypsum	585	605	20
Red rock	605	610	5
Gypsum	610	657	47
Brown shale	657	692	35
Quicksand, water	692	715	23
Gumbo	715	725	10
Red rock	725	735	10
Quicksand, water, set 12" pipe	735	780	45
Red rock	780	786	6
Blue gypsum	786	805	19
Red rock	805	940	135
Gypsum	940	960	20

Red rock	960	1020	60
Gypsum	1020	1046	26
Red rock	1046	1095	49
Gypsum	1095	1140	45
Red rock	1140	1150	10
Gypsum	1150	1170	20
Red rock	1170	1185	15
Gypsum	1185	1205	20
Red rock	1205	1215	10
Gypsum	1215	1235	20
Red rock	1235	1240	5
Gypsum	1240	1250	10
Red rock	1250	1290	40
Gypsum	1290	1310	20
Sand	1310	1360	50
Red rock	1360	1370	10
Sand	1370	1420	50
Red rock	1420	1425	5
Brown rock	1425	1479	54
Red rock	1479	1490	11
Lime	1490	1615	125
Blue shale	1615	1640	25
Gas sand, 500,000 cu. ft. gas	1640	1645	5
Blue shale	1645	1660	15
Gas sand	1660	1665	5
Gas sand, 107,000,000 cu. ft. gas	1665	1670	5

Log of the Amarillo Oil Co.'s Masterson No. 5, in Section 31, G. & M., Block 3. Elevation of well site 3279′. Completed June 24, 1920.

	Depth in Feet. From	To	Thickness
Soil	0	10	10
Lime	10	25	15
Red rock	25	280	255
Red rock	290	745	455
Quicksand	745	900	155
Red rock	900	1075	175
Slate, red	1075	1140	65
Salt rock	1140	1175	35
Lime, hard	1175	1190	15
Sand, hard	1190	1256	66
Red rock	1256	1300	44
Salt rock	1300	1345	45
Slate, brown	1345	1355	10
Lime, hard	1355	1370	15

Blue shale	1370	1380	10
Salt	1380	1385	5
Shale, brown	1385	1405	20
Blue shale	1405	1410	5
Salt rock, lime	1410	1430	20
Red rock	1430	1450	20
Brown shale and salt.	1450	1470	20
Shale and salt	1470	1500	30
Shale and salt	1500	1545	45
Lime, hard	1545	1560	15
Blue shale	1560	1590	30
Red rock, 1,150,000 cu. ft. gas	1590	1610	20
Red rock	1610	1680	70
Lime	1680	1687	7
Red rock	1687	1775	88
Lime	1775	1835	60
Lime shells and red rock.	1835	1890	55
Lime, hard	1890	2130	240
Red rock and lime.	2130	2140	10
Sand and lime	2140	2160	20
Blue shale, 5,100,000 cu. ft. gas	2160	2165	5
Lime	2165	2185	20
Hard lime	2185	2205	20
Blue shale	2205	2208	3
Lime, 22	2208	2230	22
Pink lime or granite	2230	2256	26

Well completed and shut in at 2285′.
Total gas, 6,250,000 cu. ft.

Description of Samples

	Depth in feet
Red granite at	2205-2225
Pink granite and some fragments of dark gray dolomite and cherty limestone. All contain pyrite. The granite shows fresh surfaces and probably represents rock in place. The largest feldspar crystals are about 2 mm. in diameter, but most of them are slightly smaller. The quartz particles do not differ from the feldspar crystals in size	2210

Pink granite, and a few fragments of light gray fine-grained limestone, and darker gray siliceous rock. All fragments contain pyrite. In this section the limestone is seen to contain fine sand and crystalline vein-like branching areas which are widened at some places. Limestone is probably from higher up in the boring. The granite appears fresh and probably represents rock in place. The largest feldspar and quartz crystals measure 1⅜ bb. across but 1½ mm. is a more common size of the crystals. Some measuring less than ½ mm. in diameter are not uncommon 2205-2210

Sample consists of a mixture of fragments of dolomite, and white, gray and clear quartz, much pink feldspar, pyrite, evidently mainly from an igneous rock 2256

Log of the Amarillo Oil Co.'s Biven's No. 1, in Section 106, H. & T. C. R. R., Block 46. Elevation of well site 2926′.

	Depth in Feet. From	To	Thick-ness
Sand	0	60	60
Red rock	60	115	55
Gypsum	115	118	3
Red rock	118	125	7
Gypsum	125	160	35
Red rock	160	180	20
Gypsum	180	210	30
Red rock	210	215	5
Gypsum	215	365	150
Blue shale	365	370	5
Gypsum	370	385	15
Blue shale	385	395	10
Red rock, water	395	400	5
Gypsum	400	415	15
Blue shale	435	438	3
Quicksand	438	484	49
Blue shale	484	490	6
Gypsum	490	495	5
Red rock	495	555	60
Quicksand	555	575	20
Red rock	575	580	5
Gypsum	580	588	8
Quicksand	582	608	26
Red rock	608	692	84
Salt and red rock	692	940	248
Sand	940	1000	60
Red rock	1000	1070	70
Gypsum, slate	1070	1145	75
Salt	1145	1183	38
Lime	1183	1200	17
Salt, gypsum, slate	1200	1330	130
Gypsum	1330	1337	7
Red rock	1370	1375	5

Red rock, shale	1375	1580	5
½ million cu. ft. gas, showing oil.			
Lime, hard	1580	1605	25
Red rock	1605	1635	30
Blue, hard	1635	1880	245
Sand, top gas	1880	1895	15
Sand, big pay, ½ million cu. ft. gas	1895	1902	7
Shale, blue	1902	1907	5
Sand	1907	1919	12
Sand, gas	1919	1920	1
5.1 M. ft. gas.			
Sand, gas, 7½ million cu. ft. gas	1920	1937	17
Sand, gas, 10 million cu. ft. gas	1937	1942	5
Sand, big pay, 20 million cu. ft. gas	1942	1945	3
Completed at 1945′, Feb. 27, 1920.			

Description of Sample

	Depth in Feet
Gray dolomite, with some anhydrite. In thin section the dolomite is seen to be very fine-grained and to have oolitic texture, which is somewhat obscured by secondary changes. Fumes of sulphur and bituminous fumes with deposition of small drop of oil on sides of tube were noted on heating in closed tube. Representing part of Double Mountain of the Permian.	1890′

Log of the Amarillo Oil Co.'s Bivens No. 2, in Section 2, G. & M., Block M 20. Elevation of well site 3096′.

	Depth in Feet. From	To	Thickness
Red sand	0	45	45
Gravel and water	45	50	5
Red rock	50	290	240
Gypsum	290	300	10
Red rock	300	400	100
Gypsum	400	410	10
Red rock	410	415	5
Gypsum	415	430	15
Blue salt	430	445	15
Quicksand	445	455	10
Gypsum	455	460	5
Lime	460	475	15
Gypsum	475	560	85
Blue slate	560	575	15
White gypsum	575	630	55
Blue shale	630	640	10

Brown shale	640	665	25
Water sand	665	690	25
Brown lime	690	695	5
Brown shale	695	720	25
Quicksand	720	738	18
Dark slate	738	765	27
Blue slate	765	790	25
Salt	790	800	10
Red rock and salt	800	850	50
Rock salt	850	915	65
Red rock	915	940	25
Red rock and salt	940	965	25
Red rock, salt	965	1350	385
Hard lime	1350	1365	15
Sand	1365	1430	65
Red rock	1430	1520	90
Salt	1520	1630	110
Gypsum	1630	1645	15
Lime	1645	1665	20
Blue shale, salt	1665	1675	10
Salt	1675	1730	55
Red rock and shells	1730	1760	30
Red rock	1760	1790	30
Lime	1790	1805	15
Red rock and lime shells	1852	1995	143
Red rock	1995	2030	35
Lime	2030	2060	30
Red rock and lime shells	2060	2075	15
Lime	2075	2130	55
Blue slate	2130	2155	25
Lime	2155	2195	40
Blue slate	2195	2200	5
Lime	2200	2230	30
Blue slate	2230	2240	10
Lime	2240	2430	190
Sand, gas	2430	2440	10
Lime, gas	2440	2450	10
Sand, gas	2450	2465	15
Lime, gas, total 1½ million	2465	2520	55
Sand, gas	2520	2525	5
Lime, gas	2525	2540	15
Sand, gas	2540	2600	60
Light sand, water	2600	2690	90
Red sand	2690	2760	70
Lime sand, granite, decomposed.	2760	2780	20
Conglomerate	2780	2835	55
Sand	2835	2845	10

Dark slate, water	2845	2865	20
Lime	2865	3000	135
Sand	3000	3085	85
Lime	3085	3090	5
Black slate	3090	3100	10
Red sand	3100	3110	10
Black slate	3110	3115	5
Sand	3115	3135	20
Hard sand	3135	3175	40
Lime	3175	3200	25
Hard lime	3200	3215	15
Hard sand	3215	3265	50
Conglomerate, granite	3265	3280	15
Hard sand	3280	3290	10
Lime	3290	3300	10
Hard lime	3300	3305	5
Sharp sand	3305	3335	30
Lime	3335	3340	5
Hard lime	3340	3425	85
Black shale	3425	3430	5
Lime	3430	3455	25
Sand	3455	3500	45
Lime	3500	3550	50
Hard lime	3550	3570	20
Lime	3570	3590	20
Black shale	3590	3600	10
Hard lime	3600	3620	20
Blue sticky shale	3620	3630	10
Lime, gray	3630	3645	15
Gray lime	3635	3643	8
Shale	3643	3650	8
Sand	3650	3660	10
Conglomerate	3660	3680	20
Lime	3690	3720	30

Description of Samples

	Depth in Feet
Very light gray dolomite, which in thin section is seen to be rather finely crystalline in texture, has a slightly mottled appearance, and shows anhydrite. Several areas vaguely suggestive of organic forms were noted. When heated in closed tube faint bituminous fumes and very faint ammonia fumes were noted. Permian. H. T. K.	2437
Mostly gray dolomite with some dark gray dolomite. In thin section anhydrite occurs in small pockets	2440-2445
Gray porous dolomite containing irregular pockets of anhydrite as shown in thin section. Average size of crystals measure about one-fifteenth mm.	2465-2475

Like the sample at 2502-2508 ... 2474
Like the sample from 2437 feet ... 2480-2495
Like the sample from 2437 feet ... 2496-2602
Light gray dolomite slightly porous. Average size of crystals about one-fifteenth mm. Some anhydrite present. 2502-2506
Light yellowish-gray porous dolomite. Anhydrite is present but not abundant. In thin section the average size of the dolomite crystals was seen to be about .1mm ... 2514-2520
Very light gray and white dolomitic chert. Some anhydrite, white chert, a few crystals of quartz about one-fourth mm. in size, and a few grains of quarz were noted. A thin section shows obscure traces of sponge spicules, fine granular particles and some bituminous material in the cherty matrix ... 2528-2536
Light gray dolomite. Size of dolomite crystals vary from .1 mm. to one-fifth mm. Rock is somewhat porous and contains irregular areas of anhydrite. No fossils noted ... 2544-2552
Very light gray and white dolomitic chert and some white chert and anhydrite. In this section the dolomitic chert shows fine veins which, in most cases, form a network. One fragment of chert, when seen in section, was noted to have a number of minute irregularly shaped concentrically layered bodies of chert. In washed material several fragments were noted which contained aggregations of quartz crystals surrounded by chert. Upon heating in closed tube, bituminous fumes were liberated 2552-2560
Grayish-white dolomite of fine texture. In thin section most of the fragments are finely crystalline and uniform in texture with some scattered small stains believed to bitumen. This type of dolomite contains no anhydrite. Two other fragments show the presence of siliceous material and contain the casts of sponge spicules. Indistinct traces of organic bodies were also noted. Some fragments of flint noted ... 2560-2568
Light gray dolomite. In thin section the rock is seen to be slightly porous and to have replacements by anhydrite and flint or chert. Traces of sponge spicules noted ... 2568-2580
Like the sample from 2560-2568 feet ... 2580-2590
Very light gray, finely crystalline dolomite and dolomitic chert, and white chert. This rock contains some anhydrite and minute crystals of pyrite. Traces of organic fragments noted. Faint bituminous fumes and very faint ammonia fumes were liberated when sample was heated in closed tube ... 2600-2610
White and bluish-gray dolomite. In thin section the dolomite is seen to contain some anhydrite. Streaks of yellow are seen in the anhydrite. These are believed to be

bitumen. One fragment was seen to contain spherical remnants of unaltered limestone.....2610-2620

White dolomite of medium texture. In thin sections this dolomite is seen to contain unaltered round bodies of limestone. Streaks of anhydrite were noted.....2620-2630

Like the sample from 2620-2630 feet.....2638-2646

Very light gray, almost white, dolomite containing anhydrite and a few scattered crystals of pyrite. In thin section the dolomite is seen to be of medium coarse crystalline texture. When heated in closed tube, faint ammonia fumes were obtained.....2640-2650

The sample consists mostly of a white dolomite with some dark fragments of trachyte rock and vein quartz. The dolomite shows concretionary lumpy texture and fairly uniform crystalline texture. It has much anhydrite evidently occurring as replacements in the original rock .2662-2671

A rock consisting of siliceous dark gray microscopically laminated material and light gray dolomitic material, both appearing together in quite small fragments. Under the microscope, the dark part of the rock is seen to be very finely laminated and contains in places crystals of dolomite and anhydrite. The lamination is seen to be deformed by the growth of crystals and in places it is apparently deformed by pressure. It is also cut by exceedingly fine veins, mostly curving irregularly and runing across the lamination. In the dolomitic, light gray part of the rock, traces of organic remains are common .2671-2680

Sample consists of dark and light gray dolomite, some anhydrite and some grains of quartz, red feldspar and quartzite. Dark gray igneous rock also present 2680-2693

Red variegated gneiss-like crystalline rock consisting mostly of red feldspar and quartz. Some light gray, fairly coarsely crystalline dolomite containing anhydrite is present. In several fragments of dolomite, feldspar crystals were noted. In thin section several fragments of crystalline rock show an irregularly banded structure. In one of these fragments, two quartz crystals were noted, in another one there are several large rectangular crystals, probably of dolomite.....2690-2700

Sample consists almost wholly of granitic material. Several small worn pebbles were noted. Sample contains very little calcareous material. Some fragments of dark red indurated argillaceous rock was noted.....2700-2716

Dark red variegated gneiss-like crystalline rock consisting mostly of quartz, most of which is red in color. A few black specks and some feldspar and some dolomite crystals were noted in the rock. In thin section one fragment shows banded structure, the bands making their way between large, rectangular crystals. Another in which can be seen narrow, elongated areas of darker granular material and apparently elongated crystals of quartz(?), all extending in the same direction 2716-2724

Pinkish-gray dolomite containing anhydrite. Some red arkose or gneiss-like crystalline rock is present. In thin section the dolomite is seen to be coarsely crystalline. One fragment shows a round (one mm. in diameter) area. Other fragments show areas of anhydrite which evidently represent replaced organic fragments 2724-2732

Sample contains a mixture of shale, dolomite, pieces of blue shale and some pieces of granite or gneiss. Washed material shows a large amount of white dolomite and pieces of blue shale. Fragments of pink feldspar also observed. In thin section the limestone is seen to be almost entirely crystalline........ 2732-2740

Rock such as found at 2716-2724 feet, but with pure red feldspar and bluish-gray crystalline rock containing some pyrite. One feldspar fragment was seen to be intergrown with two irregular crystals of calcite. In thin section one gneiss fragment is seen to have a banded structure and to contain a number of rounded quartz grains. In section the bluish-gray rock shows a chert-like texture and contains considerable granular material. One fragment has several round areas of fine-grained material ... 2740-2745

Light pinkish-gray schist consisting of gray quartz, very light red feldspar and considerable pyrite. Minute irregular laminations seen in this section........ 2700

Sample consists of a piece of igneous rock, 2x2x3 inches, in which the matrix is a mixture of small crystals of quartz and feldspar much altered. In this matrix are phenocrysts of pink orthoclase and microcline feldspar which are also altered. Probably a rhyolite porphyry D. N. S........ 2770

Finely ground pink gneiss-like crystalline rock consisting of pink feldspar and clear quartz. Some coarsely crystalline dolomite is present 2868-2870

Pinkish dolomite marble with some anhydrite; and pink feldspar crystals and quartz crystals probably from above. A thin section shows the dolomite to be coarsely crystalline and to have considerable granular material within the crystals 2870-2880

Sample is very finely ground and consists of crystals of clear quartz and pink feldspar, fragments of gray fairly coarsely crystalline dolomite, and very light gray, fine-grained limestone 2910-2920

Feldspar and quartz in aggregations of crystals and in separate crystals, light gray, fairly coarsely crystalline dolomite and bluish-gray, coarsely crystalline dolomite and bluish-gray schist 3190-3200

Like sample from 3190-3200 feet 3206-3218

Sample ground fine. It consists of mostly angular quartz grains, but also some rounded grains of quartz. There is considerable crystalline calcite present in the sample. Some larger fragments of rock present in the sample can be described as a very poorly sorted sandstone cemented with lime. When heated in closed tube, bituminous fumes were noted.......... 3218-3230

Gray and light-gray limestone, pinkish feldspar, probably from above, rounded and slightly etched sand, some of which is composed of gray, red and black chert; and some crystalline quartz. A number of fragments of crinoid joints and a brachiopod spine were noted. Strong bituminous fumes were obtained when sample was heated in closed tube.......... 3230-3240

Dark gray shale, red feldspar, pinkish and white quartz, gray limestone, and some pyrite. In thin section one bryozoan (?) fragment was noted in which there are a dozen round (about one-fourth mm. in size) and oblong openings surrounded by a network of walls. In washed material several fragments of crinoid joints were noted. When heated in closed tube, bituminous fumes and ammonia fumes were liberated 3240-3250

Gray and some light gray limestone containing a small amount of pyrite. In thin section the rock is seen to be mostly fine-grained with some larger crystalline areas. Many undeterminable organic fragments were noted. Several fragments of crinoid joints and two brachiopod (?) spines were seen. When heated in closed tube, strong ammonia fumes and bituminous fumes were liberated 3415

Sample consists of light gray limestone, gray and dark-gray shale. In closed tube gives bituminous odor and fumes of ammonia. Limestone is partly crystalline and partly organic-fragmental. In this section this rock is seen to be granular in texture and to contain various minute fossil fragments, one believed to be an ostracod shell. In the washed material, one smooth spherical foraminfer (?) was found, also sponge spicules and a spine of a Productus. A small quartz crystal was seen imbedded in one fragment of limestone. The light gray shale resembles kaolin in texture.......... 3586-3593

Sample consists largely of bluish-gray shale. In washed sample about a dozen pieces of limestone, 2 mm. in diameter, were observed, and a large number of smaller diameter. Two of the larger pieces of limestone were seen to be incrusted with minute cubes of pyrite. Fusulina and Rhombopora lepidodendroides found in the washed material. Also Endothyra and tube of Ammodiscus. In thin section the limestone is seen to be organic fragmental and with minute oolitic texture. It contains minute scattered spaces filled with calcite..3593-3665

Light gray and gray limestone containing some pyrite. A few lignitized vegetable fibers and coaly shreds were noted. In thin section, the limestone is seen to be very fine-grained with many minute and occasionally larger crystalline areas. Some distinct organic fragments and bituminous impregnations are present 3607-3812

Sample consists of pieces of limestone and dark gray shale. Number of pieces of oolitic limestone seen in washed material. Also some crystals of pyrite. Some pieces of kaolin-like shale noted..3615-3620

Sample consists almost wholly of greenish-gray shale. A few small fragments of white limestone found in the washed material. A little iron pyrites occur with the shale fragments. Rhombopora and Fusulina found in the washed material. Few fragments of oolitic limestone, the spherules being scattered 3625-3630

Very small sample consisting mainly of small fragments of quartz and feldspar 3648-3651

Very small sample consisting mainly of various colored grains of quartz. Grains of feldspar present..............3675-3680

Sample consist of about two-thirds limestone and dark shale and one-third granitic material. One flint pebble, 4 mm. in diameter, was noted. Several small worn pebbles broken by the drill were noted. Sample evidently a conglomerate of partly igneous and partly sedimentary material 3690-3692

Finely ground material of which a fairly high percentage is calcareous. The remainder consists of quartz and red feldspar evidently from granite..3694-3699

Sample consist of fragments of red granite or gneiss. Many fragments resemble a fine-textured felsite containing occasional small scattered crystals of red feldspar. A number of slightly worn pebbles were noted. Many of these were also fractured by the drill.................3716-3724

Note: My interpretation of the Bivens Well No. 2 is that the samples from 2670-2715 feet and from 2740-2745 feet, and from 2867-2872 feet, as well as some samples below this which are described as consisting mainly of of feldspar and schist, represent arkose conglomerates that are interbedded among sedimentaries. Arkoses of this kind are known in the Abo and in the Magdalena in New Mexico. The fossils noted in the samples from 3415-3615 are a suggestion that this interpretation is correct and that these sediments perhaps may be correlated with the Magdalena.—J.A.U.

Samples of igneous material from depths 3690-3692 and from 3716-3724 were submitted to Harold W. Tomlinson for examination. His report is as follows:

"The sections show the samples to have the composition of acid igneous rocks of the granite group with felsitic texture or sparsely porphyritic with phenocrysts of orthoclase. Phenocrysts are irregular and often rounded as though corroded. The base is mostly felsitic in texture but in some pieces shows a marked flow structure.

Sample 3690-3692 has very few phenocrysts and a good deal of residual quartz. One piece shows a patch of calcite replacing a portion of the base. Several of these pieces appear to have been vitrified by heat, perhaps from the drilling.

Sample 3716-3724 is more nearly a porphry though phenocrysts still but few in number. One piece of this sample has adhering to it a few crystals of anhydrite which must have been derived adjacent saline beds.

I would classify both samples as felsitic porphries. While phenocrysts are more (slightly) abundant in the two lower sample there is really no difference between the two samples. The formation is intrusive. The texture suggests a dike. It is probably connected with and may be the basal complex."

Log of the Amarillo Oil Co.'s Bivens No. 3, in Section 15, G. & M., Block 20. Elevation of well site, 3235′. Completed December 2, 1922.

	Depth in Feet. From	To.	Thickness.
White and red clay	0	35	35
Red rock and gypsum shells, little water at 225′	35	225	190
Red sand	225	230	5
Red rock, casing set 18′ below floor	230	280	50
Red sand, water from 280-291′	280	291	11
Gypsum	291	295	4

Red rock	295	310	15
Red sand, big flow of water	310	320	10
Sand and gypsum	320	334	14
Gypsum, reamed for 20″ casing 340-345′	334	341	7
Sand and water	341	360	19
Gypsum and red rock, casing set 14′ below floor. Set at 362′	360	385	25
Red rock	385	395	10
Gypsum	395	405	10
Gypsum shells and red rock	405	420	15
Gypsum	420	455	35
Gypsum and some red rock	455	520	65
Gypsum, mostly, little red rock	520	595	75
Gypsum shells and shale	595	620	25
Blue shale	620	625	5
Gypsum shells and brown shale	625	665	40
Brown shale	665	675	10
Sand and water	675	685	10
Lime shell	685	695	10
Blue shale, wet hole, water standing 500′	695	705	10
No record	705	717	12
Quicksand	717	725	8
Sand	725	731	6
Blue shale	731	740	9
Gypsum, 15″ set at 742′	740	744	4
Red rock	744	770	26
Red rock, quicksand, heaved up 200′ in hole, shut down to run 12½″	770	802	32
Quicksand	802	815	13
Red rock	815	820	5
Quicksand	820	830	10
Red rock	830	837	7
Quicksand	837	847	10
Red rock	847	986	139
Gypsum	986	1000	14
Red rock, 12½″ set at 988′	1000	1020	20
Gypsum and red rock	1020	1100	80
Red rock	1100	1125	25
Sand and gypsum	1125	1180	55
Red rock	1180	1315	135
Red rock and gypsum	1315	1355	40
Gypsum and lime	1355	1400	45
Gypsum and red rock	1400	1485	85
Salt and gypsum	1485	1505	25
Hard lime	1505	1520	15
Blue shale	1520	1540	20

Brown shale	1540	1545	5
Blue slate	1545	1555	10
Gas sand, about 1½ million cu. ft. gas	1555	1557	2
Brown shale	1557	1755	198
Lime and shells	1755	1765	10
Lime, 10″ set at 1947′	1765	2020	55
Gray lime, little more gas at 2045′	2020	2090	70
Dark gray lime	2090	2100	10
Broken lime, little gas sand, more gas	2100	2105	5
Gray lime, dark	2105	2135	30
Gray lime	2135	2145	10
Broken lime, more gas	2145	2150	5
Gray lime	2150	2155	5
Sandy lime, more gas	2155	2160	5
Gas sand, 6 million cu. ft. gas.	2160	2162	2
Gray lime	2162	2169	7
Broken gray lime	2169	2181	12
Broken lime	2181	2190	9
White lime	2190	2372	182
Pyrite of iron, or granite	2372	2435	63
Red, broken granite	2435	2468	33
Blue granite with shale, 8¼″ set at 2501′	2468	2501	33
Blue granite, very hard	2501	2507	6
White lime	2509	2525	16

Completed at 2525′, volume of gas gauged through 10″, 10,981,000 cu. ft.

Description of Samples

Depth in Feet

Sample consists of small pieces of cream colored, slightly calcareous sandstone. Washed material is mostly white and gray quartz sand. Driller's note: "Gas sand" ... 2160-2162

Sample consists of three kinds of rock. One is a greenish-gray dolomite having white streaks and containing small sub-angular pebbles of dark gray chert and pink chert. In the washed material a little anhydrite was noted and a very little quartz, feldspar and pyrite. This is evdently a contact breccia. The other two rocks at this depth are dark crystalline rocks, one is like that described from 2500′, a trachyte. The other is also a trachyte but lighter in color, more altered, and the flow structure is more apparent. D. N. S. ... 2300

Sample consists of crumbly fragments of a dark red clayey arkose in which angular pieces of quartz and feldspar are loosely held together by a deep brown clay. D. N. S. 2435

A piece of greenish-gray clay containing imbedded angu-

lar fragments which measure from fine sand up to 4 mm. in diameter. These angular fragments are pieces of rhyolite in which the matrix has been silicified and the feldspar phenocrysts have been partly altered........ ...	2475
Two different types of rock are represented by these two samples. One of these is a trachyte and the other type is that of a crush breccia of sedimentary rock produced by an intrusion.. The crush breccia is represented by two samples. One consists of greenish-gray, indurated clay containing dolomite, fragments of gray quartz, altered feldspar and a little pyrite. The other breccia sample was a greenish-gray, indurated dolomite having streaks of pink and white dolomite. The other sample at this depth is a dark crystalline rock probably a trachyte, in which the minerals are much altered and flow structure is quite apparent in thin section. It consists of a dark matrix containing pink crystals, some magnetite, biotite altering to magnetite, chlorite, etc. D. N. S...	2500
Driller's Note: "Two different samples seem to occur together in the hole about 100 feet from time hard material is encountered until gnoe through. Driller reports that one appears on one side and other on other side."	
Sample consists of a piece of greenish-gray indurated dolomite having pink and white streaks. Imbedded in the dolomite was a dark gray chert pebble having disseminated particles of what appears to be marcasite. In thin section the dolomite is seen to contain much anhydrite, some calcite and probably some brucite. D. N. S...... .	2510
Note: It is not possible to say from these samples whether the crystalline rock represents parts of a conglomerate or igneous rock in place. J. A. U.	
A mixture of fragments of limestone, dolomite, gray shale, minute calcite crystals, a little biotite and much pink feldspar which is probably of the same nature as that in the sample from 2475′, derived from rhyolite..... D. N. S.	Exact depth uncertain

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Log of the Amarillo Petroleum Co.'s Bivens No. 1, in Section 16, A. B. & M., Block M.3. Elevation of well site, 3177′.

	Depth in feet. From	To.	Thickness.
Surface and red clay	0	60	60
Pink shale	60	90	30
Water sand	90	105	15
Water sand	105	120	15
Red bed	120	125	5

Red rock	129	160	31
White pebbly sand, large flow water	160	170	10
Red rock and shells	170	212	42
Red lime	212	220	8
Red rock with hard shell	220	240	20
Gypsum and shell	240	260	20
Gypsum and hard shell	260	280	20
Red sand	280	295	15
Red rock and very sticky	295	310	15
Gypsum with streak of adobe	310	320	10
Gypsum	320	350	30
Red rock, soft and gluey	350	380	30
Gypsum and shells	380	400	20
Water sand	400	432	32
Rock (put in 12½″ pipe, 442′)	432	442	10
Water sand (put in more 12½″ red rock)	442	456	14
Red sand	456	465	9
Red gumbo	465	480	15
White gypsum and red rock	480	495	15
Gypsum, water sand at 500′	495	500	5
Water sand, quicksand	500	535	35
Bottom of quicksand at 533′, 12½″ casing, 630′.			
Red bed	535	595	60
Quicksand	595	620	25
Gypsum	620	630	10
Sandy shell	630	635	5
Red bed	635	645	10
Limestone	645	660	15
Gypsum	660	670	10
Limestone	670	690	20
Blue shale	690	695	5
Limestone	695	705	10
Rock salt, salt water and lime, 720′.	705	720	15
Blue shale	720	730	10
Flint	730	775	45
Red shale	775	780	5
Sand	780	790	10
Lime	790	810	20
Rock salt	810	830	20
White sand	830	850	20
Brown shale	850	870	20
Gray sand	870	890	20
Lime	890	905	15
Blue shale	905	915	10
Limestone, 10″ casing at 930′	915	930	15

Lime, 10″ casing at 930′	930	937	7
Blue shale	937	950	13
Rock slate, salt	950	980	30
Limestone	980	1000	20
Blue shale	1000	1006	6
Limestone	1006	1030	24
Rock salt	1030	1060	30
Limestone	1060	1080	20
Brown shale	1080	1100	20
Limestone	1100	1150	50
Rock salt	1150	1170	20
Limstone	1170	1180	10
Rock salt	1180	1195	15
Limestone	1195	1245	50
Brown shale	1245	1280	35
Blue mud	1280	1290	10
Brown shale	1290	1310	20
Red-brawn shale	1290	1310	20
Dark brown shale	1410	1450	40
Blue mud	1450	1455	5
Red sandy shale	1455	1470	15
Red adobe	1470	1475	5
Sand, red-brown shale	1475	1515	40
Red sand	1515	1525	10
Red shale	1525	1555	30
No record	1555	1590	35
Red sandy shale	1590	1600	10
Red-brown shale	1600	1655	55
Red adobe	1655	1670	15
Red sand shale	1670	1720	50
Red adobe	1720	1740	20
Red sandy shale	1740	1850	110
Red sandy shale	1850	2000	150
No record	2000	2020	20
Brown shale	2020	2070	50
Brown shale	2070	2175	105
Red-brown shale, sandy	2175	2240	65
Red sandy shale	2240	2250	10
Red sand, rainbow colors	2250	2255	5
Red sandy shale	2255	2275	20
Brown shale	2275	2290	15
Red sandy shale	2290	2350	60
Brown shale	2350	2400	50
Red sandy shale	2400	2420	20
Rock salt	2420	2440	20
Brown shale	2440	2495	55

Rock salt	2495	2515	20
Brown shale	2515	2535	20
Limestone, black	2535	2550	15
Limestone, gray	2550	2575	25
Rock salt	2575	2590	15
Brown shale, sandy	2590	2600	10
Rock salt and lime	2600	2680	80
Sandy brown shale	2680	2730	50
Black lime	2730	2742	12
Gray sand with black lime	2742	2760	18
Black lime shells and gray sand	2760	2790	30
Red brown shale caving	2790	2835	45
Red rock	2835	2910	75
Red gumbo	2910	2935	25
Red rock	2935	3010	75

Log of Amarillo Petroleum & Gas Co.'s well near Boden, in Section 4, E. L. & R. R. Co., Block 21 W. Elevation of well site 3267'*

	Depth in feet. From	To.	Thickness.
Soil	0	12	12
White clay	12	22	10
White sand mixed with charcoal	22	32	10
Blue clay	32	46	14
White sand mixed with charcoal, light flow of fresh water	46	50	4
Red clay	50	95	45
Gray rock	95	105	10
Red clay	105	115	10
Yellow rock	115	125	10
Red clay	125	165	40
Red sand with white shelly rock	165	190	25
Red clay	190	325	35
Red water sand (salt water, heavy flow, rose about 100 feet)	325	340	15
Red clay	340	350	10
Red water sand (salt water)	350	390	40
White rock	390	400	10
Red sand	400	465	65
Red sand	465	565	100
Red clay	565	615	50
Blue clay	615	633	18
Red shelly rock and salt	633	640	7
Salt	640	645	5
Red sand	645	650	5
Salt	650	665	15

*The log and descriptions of samples from this well are taken from University of Texas Bulletin No. 17, "Potash in the Texas Permian," by J. A. Udden.

Hard white rock	665	695	30
Blue clay	695	698	3
Dark red clay	698	701	3
Salt	701	710	9
Hard white rock	710	720	10
Salt	720	730	10
Brown sand	730	745	15
Hard gray rock	745	765	20
Hard white rock	765	770	5
Hard gray rock	770	775	5
Salt	775	785	10
Hard white rock	785	795	10
Yellow rock	795	800	5
Salt	800	810	10
Hard gray rock	810	850	40
Hard brown clay	850	855	5
Hard white rock	855	875	20
Salt	875	925	50
Blue clay	925	930	5
Salt	930	950	20
Hard gray rock	950	955	5
Blue rock	955	975	20
Hard white rock	975	1005	30
Salt	1005	1230	225
Blue rock	1230	1290	60
Salt	1290	1460	170
Blue rock	1460	1475	15
Blue shale	1475	1485	10
Red sandy clay	1485	1680	195
Red sand rock	1680	1690	10
Hard brown rock	1690	1720	30
Red sandy clay, with occasionally thin strata of salt	1720	2010	290
Bubbles of gas noted	1900	2000	100

Description of Samples

	Depth in Feet
Brownish-yellow sandy adobe	0- 12
Gray siliceous clay of fine texture. Does not effervesce in acid	12- 22
Gray fine sand and some brownish-red sandy shale. With this is a considerable quantity of lignitic wood, like that found in the Triassic beds	22- 32
Gray clay, giving no reaction to acid. It contains fine siliceous sand	32- 46
Gray sand, grains mostly from 1/16 to ½ mm. in diameter,	

of clear quartz, the larger sizes well rounded. Some red cherty fragments. Much lignite, showing woody structure	46- 50
Red fine silt, slightly calcareous, containing red sand with grains mostly less than ¼ mm. in diameter	50- 95
Gray dolomite of very fine texture, with a few fragments of white and pink gypsum. One fragment of sandy and gypsiferous dolomite had many small pale green grains, seen in thin section	95- 105
White gypsum, coarsely crystalline, and some red sandy clay	105- 115
Gypsum, white and pink in color	115- 125
Red clay, somewhat open in texture	125- 165
Brownish-red silty clay and gypsum. The red silt has light greenish secks or blotches. Clusters of cubic pyrite noted	165- 190
Sandy dark red silt. Minute flakes of mica noted	190- 325
Red sand, with grains mostly from 1/16 to ¼ mm. in diameter	325- 340
Red sandy and clayey silt, with some gypsum	340- 350
Red sand of fine texture	350- 390
White gypsum and some gray dolomite. Pyrite present and some salt. Potash, strong trace	390- 400
Red sand, moderately fine in texture. Coarser grains rounded	400- 465
Red sand, containing some silt	465- 565
Light red silt, showing some greenish-gray blotches	565- 615
Mostly gray dolomite of fine texture. The crystals are clear cut in outline and quite uniform in size. The sample contains some red silt, some white anhydrite and a few flakes of selenite. Potash, trace	615- 633
A mixture of gray dolomite of fine texture, white anhydrite, red argillaceous sandy rock and gypsum. Potash, trace	633- 640
Salt in original crystalline fragments, and red sand and silt. Some gypsum and anhydrite. Potash, trace	640- 645
Red sand with some fragments of green shale of very fine texture	645- 650
Rock salt, red sand and some lumps of dark red shale	650- 665
Pure white anhydrite	665- 695
Gray, marly shale or clay. Heated in a closed tube, it gives very strong fumes of sulphur and a deposit of sulphur on the inside of the tube. The material contains no pyrite. With low heat in an open casserole, pungent sulphur fumes are given off. It is believed the sample contains some free sulphur very finely divided	695- 698

Dark brownish-red, sandy and silty clay	698- 701
Much salt, and some red sandy silt. There are some chips of a silty gray shale, which is slightly micaceous. Gypsum noted. Potash, trace	701- 710
White and gray anhydrite of compact texture. Some red silty material	710- 720
Mostly pieces of clear salt. Potash, trace	720- 730
Salt, with some red silt and some blue silt. The sample contains several fragments of red rock composed of a mixture of salt and silt. Potash, trace	730- 745
White anhydrite of moderately fine texture	745- 765
White anhydrite	765- 770
Grayish-white anhydrite with some brownish-gray silt	770- 775
White anhydrite, with a few fragments of red silt. Potash, trace	775- 785
White anhydrite	785- 790
Yellowish-white anhydrite	790- 800
White and yellowish anhydrite of moderately coarse texture. Potash, trace	800- 810
Gray anhydrite, mostly of compact texture	810- 850
Brownish-red silt and white and variegated anhydrite, with scattered fragments of dolomite	850- 855
Bright white anhydrite	855- 875
Clear salt, with a few fragments of salmon-colored salt. The salmon-colored salt was picked out and analyzed and found to contain approximately 9.23 per cent potash (K_2O), equivalent to 14.81 per cent potassium chloride. These fragments may be a mixture of potash-bearing minerals, with some common salt. The colorless salt contains 0.66 per cent potash (K_2O). Another sample of drillings from this depth, received later, consisted of chocolate-colored clay, in which were seen surfaces covered with quartz crystals, in an incrusted plate; anhydrite containing small bodies of salt, rock salt with clouds of red silt, and a matrix of gray anhydrite, showing moulds of cubic crystals of salt a half-inch in diameter. In one of these moulds a salt-crystal remained undissolved	875- 925
Mostly gray anhydrite, with some fragments of gray and red silt. Potash, trace	925- 930
Salt in fairly clear fragments. Potash, trace	930- 950
Gray anhydrite	950- 955
Dark, soft shaly rock giving strong fumes of sulphur when heated. With this is some anhydrite. No pyrite noted. Potash, trace	955- 975

White compact anhydrite, with some fragments of red and gray silt 975-1005
Pure salt. Trace of potash........ 1005-1230
Mostly gray, slightly impure anhydrite. In thin section one fragment shows the dark impurities distributed in a matrix, which incloses kernels of clear anhydrite of long, straight crystals forming a network. One fragment showed thin laminae 1230-1290
Halite, anhydrite, red clay and silt and greenish-gray shale. The salt adheres to anhydrite in one piece, and to red silt in another lump. One piece of anhydrite has empty moulds of cubic form, evidently left by dissolved halite. Some of the red silt has blue blotches. When washed it is seen to contain small crystals of quartz. The anhydrite is fine in texture and gray in color. The greenish shale yields strong fumes of sulphur. Potash, trace 1290-1460
Gray anhydrite of fine compact texture. The gray color is apparently due to slight argillaceous impurity, which is present in streaks and blotches in some fragments .1460-1475
Gray, earthy, porous anhydrite of fine and uniform texture. It contains a small ingredient of silt and sand, and in this a few crystals of quartz were noted 1475-1485
Red sandy silt mingled with some anhydrite and containing a few clear pieces of halite. Octahedral pyrite noted. The sand contains small clear crystals of quartz. Most of the anhydrite is white and granular. Some is pinkish or gray and compact, some has a flaky character, and the flakes are composed of acicular crystals promiscuously oriented. Potash, trace 1485-1680
Red sand and silt with grains mostly from 1/16 to ⅛ mm. in diameter. In the coarsest sand, crystals of quartz were noted 1680-1690
Pure salt, mingled with some red silt. Trace of potash........ 1690-1720
Red silt, sand, and salt. The salt is in clear bodies in the sand. The red silty sand contains mica and also many small crystals of quartz. Potash, 0.14 per cent........ 1720-2010
One sample contains a lump of gray, very fine-grained anhydrite with an irregular 0.2-inch thick plate of red silt. One side of this lump shows cubic cavities, apparently places once occupied by salt crystals, plates 0.1 to 0.3-inch in thickness, of pure halite. Quartz crystals with two opposite pyramids and other more irregular quartz crystals occur among the larger sand grains. Marked: "All salt found in this formation"........ Depth not stated

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

Log of the Capitol Petroleum Company's Purvine No. 1, in Section 11, A. B. & M., Block T. B. & F. (Carson County). Elevation of well site, 3563′.

	Depth in feet. From	To.	Thickness.
Surface	9	140	140
Quicksand	140	706	566
Red rock	706	806	100
Quicksand	806	1470	664
Limestone	1470	1515	35
Slate	1515	1525	10
Sand	1525	1560	35
Shale	1560	1630	70
Limestone	1630	1685	55
Red rock	1685	1710	25
Limestone	1710	1720	10
Red rock	1720	1885	165
Limestone	1885	1985	100
Limestone and shale	1985	2010	25
Limestone	2010	2015	5
Limestone and shale	2015	2025	10
Shale	2025	2074	49
White sand	2074	2110	36
Red sand	2110	2245	135
Limestone	2245	2590	345
Red shale	2590	2695	105
Gray shale, top dolomite 2750′	2695	2760	65
Broken limestone	Depth not stated		
Hard limestone		2900	
Black shale	2900	2910	10
Hard lime	2910	3010	100

Log of the Emerald Oil Co.'s Masterson No. 1, in Section 82, G. & M., Block No. 3. Elevation of well site 3452′.

	Depth in feet. From	To.	Thickness.
Red rock	0	10	10

Lime, hard	10	46	36
Red rock	45	70	25
Lime shell	70	75	5
Red rock	75	155	80
Lime	155	160	5
Red rock	160	165	5
Lime	165	170	5
Red rock	170	255	85
Hard lime	255	280	25
Red rock	280	320	40
Lime	320	330	10
Red rock	330	340	10
Hard lime	340	405	65
Quicksand	405	415	10
Hard lime	415	485	70
Red rock	485	490	5
White lime with hard streaks	490	685	195
Blue slate	685	695	10
Quicksand	695	735	40
Red rock	735	740	5
White slate	740	750	10
Red rock	750	785	35
Quicksand, water	785	815	30
Lime	815	820	5
Red rock	820	825	5
Gypsum and lime	835	840	15
Red rock	840	850	10
Salt	850	870	20
Red rock	870	950	80
Lime	950	980	30
Red rock	980	1080	100
Salt	1080	1135	45
Hard lime	1135	1215	80
Sharp sand and salt	1215	1240	25
Hard sand	1240	1260	20
Lime	1260	1270	10
Shale	1270	1280	10
Red rock	1280	1305	25
Lime and shells	1305	1315	10
Red rock	1315	1340	25
Hard lime	1340	1490	50
Blue slate	1490	1510	20
Hard blue lime	1510	1580	70
Black and blue shale	1580	1600	20
Red rock	1600	1602	2
Sand, gas	1602	1606	4
Pink shale	1606	1626	20

Lime and shells	1626	1631	5
Sand, 1¾ million cu. ft. gas	1631	1636	5
Broken sand, gas	1636	1651	15
Red rock	1651	1671	20
Sandy lime	1671	1681	10
Red rock	1681	1686	5
Sand, ¼ million cu. ft. gas	1686	1705	25
Red rock	1705	1730	25
Sand and shale	1730	1735	5
Red rock	1735	1745	10
Lime and shells	1745	1750	5
Shells	1750	1755	5
Red rock	1755	1775	20
Sand, ½ million cu. ft. gas	1775	1800	25
Sandy lime	1800	1830	30
Red rock	1830	1845	15
Hard lime	1845	1860	15
Brown shale	1860	1875	15
Lime	1875	1895	20
Brown shale	1895	1905	10
Hard lime	1905	1990	85
Sand and gravel	1990	1995	5
Hard lime	1995	2000	5
Red rock, red granite	2000	2030	30
Red sand, red granite	2030	2050	20
Sand, red granite	2050	2075	25
Red sand, hard granite	2075	2131	56

Shut in for gas well Sept., 15, 1920.

Description of Samples

	Depth in Feet
Red, partly crystalline gneiss, showing some clastic elements. With this are some fragments of dark greenish schist (?)	2000
Like sample at 2000 ft.	2065
The sample consists of red and greenish-gray shale. In the washed material some anhydrite was noted. Calcareous concretions, a little quartz sand and pyrite were also present	1607
The sample consists of red and dark greenish-gray shale. In the washed material some anhydrite was noted. A few small calcareous concretions and a little fine quartz sand was also present	1630
The sample consists of reddish-brown and green shale and a little light gray indurated shale. In the washed material many fragments of a fine sandstone were noted. White	

anhydrite, calcareous concretions and a little quartz sand were also present	1680-1685
The sample consists of reddish-brown, dark greenish-gray shale and light greenish-gray, silty shale. In the washed material some white anhydrite was noted. A few small calcareous concretions and a very little quartz sand were also present	1690-1695
The sample consists of reddish-brown, dark gray shale, and some light greenish-gray, indurated shale. In the washed material many fragments of fine sandstone were noted. Some white anhydrite and a little fine quartz sand was also present	1705-1710
The sample consists of reddish-brown and greenish-gray shale. In the washed material much white anhydrite and a little quartz sand were noted	1710-1720
The sample consists of reddish-brown shale with some light greenish-gray, silty shale. In the washed material many fragments of fine sandstone were noted. A little anhydrite was also present	1730-1735
Just Above Third Gas Sand. The sample consists of greenish-gray, sandy dolomite. A little fine quartz sand was noted in the washed material. In this section a great many grains of fine sand could be seen in the limestone. The limestone has been partly replaced by anhydrite which was more transparent than the dolomite, giving the section a mottled appearance	1735
The sample consists of very dark brown, dark-gray shales and some light gray, silty shale. Some of the dark gray shale was seen included in the brown shale. In the washed material fragments of fine sandstone and anhydrite were noted	1756
The sample consists of dark reddish-brown and greenish-gray shale. In the washed material some white anhydrite and a very little quartz sand was noted	1745-1760
The sample consists of dark reddish-brown, pinkish and greenish-gray shale, which is variegated. In the washed material some fragments of fine sandstone and anhydrite were noted	1760-1765
The sample consists of reddish-brown and greenish-gray shales. In the washed materials some fragments of fine sandstone and anhydrite were noted	1765-1770
Red, partly crystalline gneiss, showing some clastic elements. With this are some fragments of dark greenish schist (?)	2000
Like sample at 2000 ft.	2065

Log of the Greater Amarillo Oil Co.'s Masterson No. 1, in Section 20, G. & M., Block No. 36. Elevation of well site 3423′.

	Depth in feet. From	To.	Thick-ness.
Surface	0	15	15
Lime	15	35	20
Red clay, one-half bailer of water	35	240	205
Clay	240	250	10
Water sand, three bailers water per hour	250	260	10
Lime	260	270	10
Red clay	270	340	70
Water sand	340	348	8
Clay	348	355	7
Quicksand	355	365	10
Clay	365	395	30
Gypsum	395	470	75
Red bed, nine barrels water per hour, two barrels later, two barrels per hour, two hours later exhausted	470	475	5
Gypsum	475	495	20
Red bed	495	500	5
Gypsum	500	510	10
Brown shale	510	515	5
Gypsum	515	555	50
Clay	555	560	5
Gypsum	560	575	15
Blue shale	575	580	5
Brown shale	580	595	15
Water sand, salt water filled to 300 foot level	595	600	5
Lime	600	630	30
Blue shale, caved badly	630	645	15
Quicksand	645	677	32
Clay	677	685	8
Lime	685	695	10
Red rock, cave	695	696	1
Salt and red rock	696	710	14
Red rock	710	745	35
Salt and red rock	745	1195	450
Sand, sharp	1195	1235	40
Red rock	1235	1390	155
Lime	1390	1397	7
Gypsum	1397	1420	23
Salt, white	1420	1510	90
Lime, bottom 15 feet very hard	1510	1550	40
Blue shale	1550	1563	13
Gas sand, estimated 4,000,000 cu. ft.	1563	1580	17

Red rock	1580	1610	30
Gas sand, total gas now estimated to be 40,000,000 cu. ft.	1610	1625	15
Red rock	1625	1637	12
Gas sand, additional flow, not estimated	1637	1650	13
Red rock	1650	1680	30
Blue shale, more gas	1680	1685	5
Red rock	1685	1700	15
Gas sand, more flow of gas	1700	1712	12
Red shale	1712	1718	6
Blue shale	1718	1768	50
White slate	1768	1775	7
Blue shale	1775	1785	10
Lime	1785	1792	7
Red rock	1792	1797	5
Sandy shale	1797	1820	23
White lime	1820	1860	40
Sand, showing oil and gas	1860	1870	10
White lime	1870	1920	50
Gas sand, additional gas estimated at 30,000,000 cu. ft.	1920	1935	15
Sharp sand	1935	2145	210
Gas sand	2145	2185	40
Lime, hard	2185	2190	5
Gas sand	2190	2225	35
Lime, gray	2225	2320	95
Blue shale	2320	2328	8
White lime	2328	2390	62
Black lime, hard	2390	2415	25
Gray lime	2415	2430	15
Gas sand, estimated 60,000,000 cu. ft.	2430	2450	20
Gray lime	2450	2510	60
Brown lime	2510	2550	40
Gray lime	2550	2580	30
Quicksand	2580	2595	15

Description of Sample

	Depth in Feet
A dark gray siliceous and, at least in part, crystalline rock. The bulk of the rock is feldsitic material, which as a matrix contains crystals of quartz and red feldspar. In thin section parallel wavy fibers characterize the felsitic matrix. These bend around the crystals. A thin quartz vein was also noted. Perhaps the rock may be a porphyritic rhyolite. J. A. U.	2045-2050

Log of the Haines Little Pool Well in Section 14, G. & M., Block No. 3. Elevation of the well site, 3411′.

	Depth in feet. From	To.	Thick-ness.
Grass turf	0	2	2
Dry sand and gravel	2	14	12
Dolomite rock and gravel	14	36	22
Water sand	36	40	4
Lime and rock	40	80	40
Sand and gypsum	80	110	30
Red beds and rock	110	165	55
Sand and red rock	165	248	83
Rock and gypsum	248	336	88
River sand and water	336	342	6
Set 15½″ casing at 342′.			
Red beds	342	400	58
Gypsum	400	430	30
Light shale	430	438	8
Blue shale	438	465	27
Gray, blue shale and hard rock	465	480	15
Gray rock and gypsum	480	495	15
White gypsum	495	540	45
Red beds	540	565	25
Red rock	565	585	20
Brown shale	585	610	25
Light gypsum	610	630	20
Gray shale	630	645	15
White gypsum	645	665	20
Brown shale and little water sand	665	680	15
Dark shale and gumbo	680	700	20
Blue shale	700	718	18
Water and heaving quicksand, set 12½″ casing at 762′ 10″	718	760	42
Blue shale and rock	760	835	75
Rock salt	835	920	85
Red rock	920	1070	150
Red beds, set 10″ casing at 1138′ on account of cave in redbeds. Water leak in 12½″	1070	1138	68
Salt and gypsum	1138	1250	112
Rock salt	1250	1285	35
Shale and sand	1285	1320	35
Red rock	1320	1375	55
Red rock	1375	1390	15
Loose sand	1390	1400	10
Rock salt	1400	1415	15
Red rock	1415	1455	40

Sandy brown shale, hard	1455	1475	20
Blue shale	1475	1480	5
Rock salt	1480	1520	40
Rock salt	1520	1545	25
Lime	1545	1575	30
Blue shale, little gas showing	1575	1605	30
Red rock, more gas 500,000 cu. ft.	1605	1630	25
Red rock	1630	1670	40
Red shale	1670	1680	10
Red rock	1680	1705	25
Brown shale and red rock	1705	1725	20
Sandy blue shale	1725	1740	15
Blue shale	1740	1770	30
Very hard lime, set 8¼″ casing at 1858′, 9″	1770	1780	10
Red rock	1780	1787	7
Lime, little more gas	1787	1810	23
Lime, showing of 3,000,000 cu. ft. gas	1810	1950	140
Lime	1950	1980	30
Lime, sandy showing of gas with oil	1980	1995	15
Gas sand and lime	1995	2010	15
Gas sand	2010	2028	18

Shut down, making more gas, 21,000,000 cu. ft.

Description of Samples from Haines Masterson No. 2, in Section 10, D. & P. R. R., Block 0-18.

	Depth in Feet
Mostly fine-grained red sand. Some pieces of anhydrite. Some pieces of anhydrite and a few pieces of gray shale noted	880
About one-half of the sample consists of rock salt. Some salt fragments are white. Some are streaked red. The other one-half of the sample consists of brick-red silt. One-half of the sample was submitted to Dr. E. P. Schoch of the Division of Industrial Chemistry with a request for a determination of the per cent of potassium in the soluble portion. The report showed the presence of 0.038 per cent of potassium	1225-1230
Redbed silt. Some pieces of bluish-gray shale, rock salt and anhydrite. Rock salt fairly abundant. One-half sample submitted to Dr. E. P. Schoch of the Division of Industrial Chemistry with a request for a determination of the per cent of potassium in the soluble portion. The reports showed the presences of 0.058 per cent of potassium	1225-1232
White and light gray anhydrite	1295-1305
Mostly fine-grained red sand. A few pieces of red shale	

and a few pieces of blue shale noted. Small amount of salt noted. One-half sample submitted to Dr. E. P. Schoch of the Division of Industrial Chemistry with a request for a determination of the per cent of potassium in the soluble portion. Report showed 0.027 per cent of potassium 1305-1330

Fine-grained red sand. Few pieces of red shale and gray shale noted. Few pieces of anhydrite. Some sand grains and other fragments were seen to be salt incrusted but no pieces of rock salt observed 1335-1365

Red silty clay, containing some fine sand. The clay gives no reaction for lime. With this clay occurs some anhydrite which is reddish-gray. The anhydrite fragments have the appearance of coming from thin layers occurring in the clay 1365

Log of the Miller Oil Co.'s Tanner No. 1, in Section 59, A. B. & M., Block 2. Elevation of well site, 3609′.

	Depth in feet. From	To.	Thickness.
Black and red clay	0	180	180
Clay and chalky stone	180	220	40
Water sand and gravel	220	300	80
Red shale	300	480	180
Red clay	480	500	20
Red clay and shale	500	550	50
Red clay, shale and gypsum	550	600	50
Red clay, shale, gypsum rock and gyp	600	1050	450
Gypsum rock, shale and salt	1050	1095	45
Gypsum rock, gravel and shale	1095	1143	48
Rock salt	1143	1160	17
Clay and shale	1160	1200	40
Clay, shale and gypsum rock	1200	1240	40
Shale, slate and anthracite	1240	1276	36
Shale and clay	1276	1310	34
Shale, clay and lime	1310	1375	65
White lime	1375	1400	25
White lime and shale	1400	1430	30
Blue shale	1430	1460	30
Blue and red shale and salt	1460	1480	20
White lime	1480	1490	10
Salt	1490	1510	20
Gray lime and salt	1510	1530	20
White lime and salt	1530	1565	35
Gray lime	1565	1600	35
Rock salt	1600	1670	70

Rock salt and shale	1670	1820	150
Blue shale	1820	1825	5
Gray lime	1825	1830	5
Brown lime	1830	1845	15
Black lime	1845	1880	35
Blue shale	1880	1900	20
Gray lime and salt	1900	1925	25
White lime	1925	1940	15
Brown shale and salt	1940	1980	40
Salt	1980	2025	45
Salt and lime	2025	2035	10
Brown shale	2035	2045	10
Blue shale	2045	2070	25
Brown shale	2070	2080	10
Shale and salt	2080	2120	40
Red beds	2120	2280	160
Red and blue shale	2280	2310	30
Broken lime	2310	2325	15
Hard lime	2325	2335	10
Shale and salt	2335	2350	15
Broken lime	2350	2390	40
Shale	2390	2395	5
White lime	2395	2400	5
Shale and red beds	2400	2435	35
Shale	2435	2445	10
Shale and red beds	2445	2500	55
Broken lime and shale	2500	2550	50
Red beds	2550	2565	15
Broken lime and slate	2565	2575	10
Red beds and rock	2575	2600	25
Broken lime, shale and red rock	2600	2650	50
Red beds and red rock	2650	2670	20
White lime	2670	2682	12
Blue shale and lime	2682	2700	18
Gray lime and shale	2700	2720	20
Gray lime, shale and salt	2720	2735	15
Blue and brown shale	2735	2755	30
Gray lime and shale	2755	2765	10
Gray lime, shale and gypsum	2765	2790	25
Gray lime and shale	2790	2815	25
Salt	2815	2825	10
Gray lime	2825	2840	15
Gray lime and shale	2840	2855	15
Gray lime	2855	2860	5
Gray lime and sand	2860	2870	10
Gray shale and gypsum	2870	2885	15

Blue and red shale	2885	2895	10
Red beds	2895	2920	25
Red beds and blue shale	2920	2988	68
Blue shale and salt	2988	3005	17
Blue shale and salt	3005	3010	5
Blue shale	3010	3030	20
Brown shale	3030	3055	25
Black shale	3055	3080	25
Salt	3080	3092	12
Black shale and gypsum	3092	3130	38
Gray shale and salt	3130	3160	30
Salt	3160	3180	20
Salt and shale	3180	3210	30
Salt	3210	3245	35
Gray lime	3245	3290	45
Broken lime and shale	3290	3300	10
Salt	3300	3310	10
Blue shale and salt	3310	3325	15
Blue lime	3325	3340	15
Gray lime and shale	3340	3360	20
Black shale and slate	3360	3380	20
White lime	3380	3395	15
Shale and gray lime	3395	3420	25
Blue shale	3420	3430	10
White lime	3430	3470	40
White lime and shale	3470	3480	10
Black shale and slate	3480	3500	20
Blue shale	3500	3506	6
Blue shale and lime	3506	3536	30
Blue shale and slate	3536	3548	12
Blue and red shale	3548	3555	7
Red shale	3555	3600	45
Red and blue shale	3600	3635	35
Red and blue shale and gray lime	3635	3682	47
Red and blue shale	3682	3688	6
Red and blue shale and blue lime	3688	3696	8
Blue shale	3696	3701	5
Blue shale and lime	3701	3712	11
Hard lime	3712	3718	6
Hard lime and shale	3718	3723	5
Hard lime	3723	3726	3
Lime and blue shale	3726	3755	29
Blue lime and shale	3755	3795	40
Red shale and lime	3795	3860	65
Red and blue shale	3860	3880	20
Red lime	3880	3890	10

Red shale	3890	3895	5
Red shale and lime	3895	3917	22
Blue and red shale	3917	3926	9
Blue and red shale and lime	3926	3941	15
Bottom of hole	3941		

Abandoned, dry hole.

Description of Samples

	Depth in Feet
Red, fine-grained, loosely-cemented sandstone, banded with layers of white sandstone. The sand is calcareous and contains some shaly material. The larger grains are considerably worn. About 80% of the sand grains range from ¼ to ⅛ mm. in size. Weak fumes of ammonia noted	230- 240
Mostly red shale, slightly calcareous, containing some gypsum and anhydrite. Some fine sand present. Fumes of sulphur noted	311
Red shale, containing some selentite and gypsum and a small amount of anhydrite. Rounded grains of sand noted	660- 670
Like sample from 660-670, with an increased amount of gypsum and sand grains. Fumes of ammonia present	730- 740
Red shale containing some fibrous gypsum. A few sand grains present. Weak fumes of ammonia noted	740- 750
Red shale, containing a small amount of gypsum and anhydrite. A few sand grains present. Weak fumes of ammonia noted	750- 760
Red shale and gypsum. Some fine sand present. Fumes of ammonia noted	755
Like the sample from 755′. Weak fumes of ammonia noted	760- 770
Like sample from 755′. Weak fumes of ammonia noted	770- 780
Like sample from 755′. Weak fumes of ammonia noted	780- 790
Like sample from 755′. Contains some calcareous fragments	800- 818
Red clay with some etched crystals of anhydrite and some gypsum. A few calcareous fragments present. Weak fumes of ammonia noted	818- 830
Red clay with some gypsum and a considerable amount of fine sand. Fumes of ammonia noted	830
Red shale, gypsum, and a considerable amount of very fine sand. Some light gray calcareous fragments present. Weak fumes of ammonia noted	835
Like sample from 835′	830- 840
Red shale, some gray shale, and gypsum. Some fine sand	

and fragments of calcareous material present. Weak ammonia fumes noted	840- 850
Like sample from 840-860′. No fumes noted	850- 860
Red sandy clay, containing a small amount of calcareous material. Ammonia fumes noted	860- 870
A light red, fine, silty sandstone and some gypsum. Some calcareous material present. About 70% of sand grains are from ⅛ to 1/16 mm. in size, and all are below ¼ mm. in size. Ammonia fumes noted	870- 873
Red sandy clay and gypsum. Weak fumes of ammonia noted	873- 883
Like sample from 873-883′. Contains a few fragments of calcareous material	878
Red shale and some gray shale. Sample contains a small amount of impure calcareous material and gypsum. No fumes noted	877- 880
Red sandy clay and gypsum	883- 893
Red shale, gypsum, and anhydrite. A small amount of sand grains present. Fumes of ammonia noted	893- 900
Like sample from 893-900′, containing white calcareous fragments. Fumes of ammonia noted	900
Red, sandy, calcareous clay containing some gypsum and anhydrite. Fumes of ammonia noted	900- 970
Red shale and gypsum. A few fragments of white calcareous material and hard black shale. Weak fumes of ammonia noted	900- 910
Like sample from 900-910′. No black shale observed. Weak fumes of ammonia noted	910- 920
Like sample from 910-920. No fumes were noted	925- 935
Red and brown shale, anhydrite and gypsum and a considerable amount of calcareous material. Fumes of ammonia noted	945- 948
Red shale, spotted with gray, gypsum and some anhydrite. One fragment of the shale has a soapy appearance. A few fragments of calcareous material present. Weak fumes of ammounia noted	980
Red and brown shale, with some gypsum and anhydrite. A few fragments of calcareous material. Weak ammonia fumes noted	1135
Like sample from 1135	1140-1145
Like sample from 1135. No fumes present	1145-1150
Red and brown shale, gypsum and anhydrite. One fragment of light gray calcareous material present	1150-1155
Red and gray shale, anhydrite and gypsum. Weak fumes of ammonia	1155-1160
Red and gray shale, anhydrite and gypsum. A few large	

fragments of light gray calcareous material present. Weak fumes of ammonia 1160-1170

Red shale and some gray shale. Shale has slick soapy appearance. Anhydrite and gypsum present. Weak fumes of ammonia noted 1170-1180

Red and brown shale and gypsum and anhydrite. A few fragments of calcareous material present....................1180-1190

Like sample from 1180-1190. Fumes of ammonia noted....1190-1200

Red and brown shale, gypsum and anhydrite. Some fragments of calcareous material present. Weak fumes of ammonia noted 1210-1220

Red and brown shale, somewhat sandy with anhydrite and gypsum. Weak fumes of ammonia noted....................1226

Red shale, somewhat sandy, anhydrite and gypsum, and a few fragments of calcareous material. Fumes of ammonia noted 1230-1240

Like sample from 1230-1240. Weak fumes of ammonia noted 1240-1250

Red and gray shale, gypsum and anhydrite. A few fragments of gray calcareous material....................1250-1280

Red sandy shale, gypsum and anhydrite. Fumes of ammonia noted 1265

Red and gray shale, gypsum and anhydrite. Also fragments of gray calcareous material noted. Fumes of ammonia noted 1300

Red sandy silt and clay with bluish-gray small round blotches, and containing a few very small flakes of mica. Some porous white gypsum, partly in small perfect crystals of selenite. Some fibrous white gypsum. Above and at 1325

Log of the Ranch Creek Oil Co.'s Masterson No. 1, in Section 2, E. L. & R. Co., Block B-11. Elevation of the well site, 3434'.

	Depth in feet. From	To.	Thickness.
Surface	0	2	2
Dolomite	2	29	27
Red sand rock	29	110	81
Dry sand	110	120	10
Red rock	120	140	20
Water sand	140	145	5
Red rock	145	180	35
Water sand (gypsum)	180	205	25

Red rock	205	260	55
Water sand	260	280	20
Set 15″ casing at 395′.			
Red rock	280	340	60
Water sand	340	350	10
Red rock	350	380	30
Water sand (hole full water)	380	400	20
Red bed	400	425	25
Gypsum	425	430	5
Light shale	430	435	5
Blue shale	435	440	5
Brown shale	440	465	25
Hard rock, blue	465	480	15
Gray rock	480	490	10
Gypsum	490	540	50
Red rock	540	545	5
Gypsum	545	565	20
Red rock	565	575	10
Gypsum	575	585	10
Brown shale	585	610	25
Gypsum	610	630	20
Gray shale	630	645	15
Gypsum	645	685	40
Brown shale	685	700	15
Salt water	700	730	30
Blue shale	730	740	10
Dark shale	740	750	10
Quicksand	750	785	35
Set 12½″ casing at 785′.			
Blue shale	785	795	10
Red rock	795	885	90
Salt	885	920	35
Red rock	920	1345	425
Gray lime	1345	1350	5
Dry sand	1350	1370	20
Rock salt	1370	1382	12
Dry sand	1382	1386	4
Brown shale	1386	1505	119
Salt	1505	1550	45
Brown shale	1550	1565	15
Blue shale	1565	1570	5
Hard gypsum	1570	1590	20
Salt	1590	1670	80
Blue shale	1670	1715	45

Gas sand	1715	1740	25
Hard shell	1740	1745	5
Gas sand	1745	1760	15
Rock salt and shells	1760	1900	140
Pocket of gas.			
Blue shale	1900	1940	40
Hard lime	1940	2200	260
Brown shale	2200	2310	110
Shale	2310	2340	30
Sand, showing oil	2340	2343	3

Description of Samples

	Depth in Feet
Sample consists of a fragment about one-half inch in diameter of dull red granite of fine texture, containing a few grains of magnetite. E. B. S.	*
Sample consists of three fragments, one about one-fourth inch, one one-half inch, and one three-fourths inch in diameter. Each one of them is from a red, apparently unweathered, gneiss-like rock, in which quartz and orthoclase feldspar make up the bulk of the rock, but in which no mica can be seen. The specimens show an indistinctly layered texture	*
Two pieces of rather fine-grained red granite about 8 mm. in size. H. T. K.	*

Log of the Seven States Oil Co.,s olbrook No. 1, in Section 127, A. B. & M., Block 2. Elevation of well site, 3582′.

	Depth in feet. From	To.	Thickness.
Soil	0	15	15
Red sand	15	40	25
Blue slate	40	65	25
Red rock	65	105	40
Lime	105	115	10
Red rock	115	145	30
Gypsum	145	150	5
Red rock	150	190	40
Lime	190	205	15
Red rock	205	220	15
Red sand	220	225	5
Red rock	225	320	95
Blue shale	320	335	15
Gypsum	335	350	15
Red rock	350	410	60

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*Exact depth not known.

Lime	410	415	5
Red rock	415	490	75
Red sand, water	490	500	10
Lime	500	505	5
Red rock	505	520	15
Gypsum	520	555	25
Red rock	555	570	15
Gypsum	570	585	15
Red rock	585	620	35
Gypsum	620	680	60
Red rock	680	735	55
Red sand	735	745	10
Gypsum	745	750	5
Gravel	750	760	10
Red rock	760	840	80
Red sand, water	840	860	20
Gypsum	860	870	10
Red sand, water	870	895	25
Red rock	895	950	55
Gas sand	950	955	5
Red rock	955	990	35
Brown sand	990	1030	40
Rock salt	1030	1045	15
Brown sand	1045	1100	55
Rock salt	1100	1110	10
White lime	1110	1160	50
Rock salt	1160	1175	15
White lime	1175	1210	35
Rock salt	1210	1240	30
Blue sandy lime	1240	1250	10
White lime	1250	1300	50
Rock salt	1300	1320	20
White lime	1320	1400	80
Gypsum	1400	1420	20
Brown lime	1420	1450	30
Rock salt	1450	1575	125
Gray lime	1575	1610	35
Rock salt	1610	1630	20
Black lime	1630	1640	10
White lime	1640	1645	5
Brown lime	1645	1720	75
Gray lime	1720	1750	30
Blue shale	1750	1768	18
Salt and shale	1768	1805	37
Lavender sand	1805	1815	10
Rock salt	1815	1905	90

Gray sand	1905	1915	10
Black lime	1915	1930	15
Blue shale	1930	1945	15
Red rock	1945	2020	75
Rock salt	2020	2030	10
Red rock	2030	2130	100
Water sand	2130	2135	5
Red rock	2135	2380	245
Black sand, ½ million cu. ft. gas	2380	2385	5
Red rock	2385	2555	170
Brown and gray lime	2555	2570	15
Brown shale	2570	2585	15
Lime and salt	2585	2770	185
Brown sand	2770	2795	15
Red rock	2795	2800	5
Brown shale	2800	2835	35
Brown shale and red rock	2835	2880	45
Blue and gray lime	2880	2905	25
Brown sand	2905	2930	25
Salt	2930	2980	50
Blue lime	2980	3010	30
Lime and salt	3010	3145	135
Black slate	3145	3150	5
Gray lime	3150	3210	60
Rock salt	3210	3225	15
Gray lime	3225	3280	55
Gray shale	3280	3300	20
Gray lime	3300	3345	45
Blue shale	3345	3350	5
Black lime	3350	3355	5
Blue shale	3355	3365	10
Black lime	3365	3370	5
Blue shale	3370	3380	10
Rock salt	3380	3395	15
Black lime	3395	3425	30
Blue slate	3425	3445	20
Black lime	3445	3465	20
Blue slate	3465	3480	15
Black lime	3480	3495	15
Red rock, cave	3495	3530	35

Log of the Tuck-Trigg well in Section 37, G. & M., Block 5. Elevation of well site, 3310′.

	Depth in feet. From	To.	Thickness.
Soil	0	8	8
Dolomite, white, hard	8	13	5

Red beds, medium	13	17	4
Dolomite, white, hard	17	25	8
Sandy shale, red, soft	25	29	4
Red beds, soft	29	65	36
Lime, gypsum, white, hard	65	68	3
Red beds	68	72	4
Gypsum, white	72	74	2
Red beds	74	78	4
Gypsum, white	78	81	3
Red beds	81	89	8
Gypsum, white	89	91	2
Red beds	91	96	5
Gypsum, white	96	100	4
Red beds	100	140	40
Sandy lime, white	140	146	6
Red beds	146	175	29
Show of water, ½ bbl. per hour. Cave.			
Gypsum, white	175	180	5
Red beds	180	195	15
Gypsum, white	195	200	5
Red beds	200	278	78
Gravel (3½ bbls. water per hour)	278	286	8
Shale, red to blue	286	320	34
Lime and gypsum, white	320	340	20
Red beds	340	345	5
Gravel, hole full of water	345	352	7
Red beds	352	404	52
Quicksand, alkali water	404	410	6
Red beds	410	414	4
Quicksand, alkali water	414	420	6
Gypsum, white	420	424	4
White sand	424	430	6
Shale, red	430	460	30
Red and blue shale	460	495	35
Gypsum	495	509	14
Blue shale	509	512	3
Lime, white, hard	512	535	23
Shale, blue	535	538	3
Shale, brown	538	547	9
Sand, red, nitrogen gas	547	552	5
Lime, white, hard	552	578	26
Chalk, white	578	580	2
Gypsum, brown	580	595	15
Lime, white, hard.	595	630	35
Red beds	630	635	5
Gypsum, white	635	640	5

Lime, pink, hard	640	650	10
Red rock	650	655	5
Salt, white	655	660	5
Lime, brown	660	665	5
Flinty lime, white, hard	665	685	20
Salt, white	685	710	25
Shale, brown	710	715	5
Lime, pink	715	725	10
Salt, white	725	740	15
Lime, white	740	765	25
Shale, blue	765	770	5
Lime, blue	770	775	5
Lime, white	775	795	20
Blue shale	795	800	5
Lime	800	805	5
Salt and shale, dark brown	805	830	25
Gypsum, white	830	845	15
Salt, gypsum and red bed	845	920	75
Salt and shale, brown	920	1020	100
Lime, brown	1020	1028	8
White lime	1028	1038	10
Gray lime	1038	1068	30
Blue shale	1068	1070	2
Blue lime	1070	1078	8
Blue shale	1078	1090	12
White salt	1090	1135	45
Coarse sand, red, dry	1135	1158	23
Salt, white	1158	1225	67
Lime	1225	1235	10
Shale, white	1235	1255	20
Blue shale	1255	1265	10
Salt, white	1265	1275	10
Red rock, dry	1275	1340	65
Sand, dry	1340	1355	15
Red rock	1355	1372	17
Gypsum	1372	1376	4
Sandy shale, red	1376	1708	332
Brown lime	1708	1718	10
Red shale	1718	1798	80
Sandy lime, water in ten days	1798	1820	22
Sandy shale, brown	1820	1840	20
Lime, pink, and blue	1840	1860	20
Sandy shale, red	1860	1880	20
Brown lime	1880	1885	5
Red shale	1885	1900	15
White salt	1900	1915	15
Red shale	1915	1932	17

Lime, pink, blue and gray	1932	1939	7
White salt	1939	1950	11
Lime	1950	1960	10
Red rock	1960	1985	25
Sandy lime, showing of gas	1985	1989	4
Red rock	1989	2005	16
White lime	2005	2020	15
Red sand	2020	2050	30
Sandy shale, dark brown	2050	2100	50
Sand, blue and brown	2100	2104	4
Brown shale	2104	2125	21
Red shale	2125	2145	20
Brown shale	2145	2160	15
Sandy shale, dark brown	2160	2185	25
Sand, blue and brown	2185	2195	10
Lime	2195	2220	15
White salt	2220	2265	45
Blue and brown shale	2265	2300	35
Blue shale	2300	2315	15
White salt	2315	2325	10
White lime	2325	2337	12
Blue shale	2337	2347	10
White salt	2347	2370	23
Blue slate	2370	2380	10
Brown salt	2380	2460	80
Shale, blue, showing oil	2460	2480	20
Brown shale	2480	2490	10
Blue lime	2490	2496	6
Blue, sandy lime	2496	2515	19
Black slate	2515	2530	15
Blue shale	2530	2540	10
Red shale	2540	2550	10
Gas pay at 2500, 2560, 2590, 2600 feet.			
Gas sand and red shale	2550	2640	90
Red shale	2640	2650	10
Lime	2650	2655	5
Red rock	2655	2685	30
Lime	2685	2695	10
Red rock	2695	2710	15
Sandy lime	2710	2718	8
Red rock	2718	2745	27
Lime	2745	2750	5
Red rock	2750	2760	10
Brown lime	2760	2790	30
Red rock	2790	2795	5
Lime	2795	2805	10

Red rock	2805	2815	10
Broken lime, red breaks	2815	2865	50
Blue shale	2865	2870	5
Brown lime	2870	2875	5
Black shale	2875	2890	15
Lime with blue shale, breaks	2890	2985	95
Blue shale with lime shells	2985	3035	50
Lime, white	3035	3045	10
White shale	3045	3055	10
Blue shale	3055	3064	9
Solid lime	3064	3575	511
Lime	3575	3660	85
Water sand	3660	3685	25
Lime	3685	3880	195
Black lime	3880	3920	40

Description of Samples

	Depth in Feet
Brown granular and dolomitic limestone with some clear anhydrite. No fossils were seen	3600
Very finely-ground yellowish dolomite. Some anhydrite and some slightly rounded and etched sand grains are present. Permian. H. T. K.	3625-2630
The sample consists of very finely ground, light brown dolomite. In the washed material a little anhydrite was noted	3625-3630
Almost white dolomitic limestone stained brown by rust. Some anhydrite present. No fossils were seen	3630-3637
Almost white dolomitic limestone like 3630-3637′	3637-3647
The sample consists of very finely ground light brown dolomite. In the washed material a little white anhydrite was noted	3647-3653
Gray limestone and clear anhydrite. Sample is very finely ground and stained by iron rust. No fossils were seen	3680-3684
The sample consists of finely ground up white dolomite and red and greenish-gray, indurated shales. In the washed material some white anhydrite and a little gypsum were noted	3688-3691
The sample consists of finely ground up white dolomite. In the washed material some white anhydrite and a few fragments of red and greenish-gray shale were noted	3700-3705
Light yellow dolomite and some quartz grains showing crystalline faces. Some anhydrite is present. A thin section shows the dolomite to be mostly rather coarsely crystalline. One fragment has a fine-grained texture	3705-3714
Light gray dolomite limestone and clear anhydrite. No fossils were seen	3705-3714

The sample consists of finely ground up white dolomite. In the washed material some white anhydrite and several small quartz crystals were noted........................3714-3718
Like sample from 3705-3714 feet........................3715-3718
The sample consists of finely ground up white anhydrite. In the washed material some anhydrite and gypsum were noted. A few fragments of red and gray shale were also present........................3718-3722
Like sample from 3718-3722 feet........................3740-3745
Like sample from 3718-3722 feet........................3745-3750
The sample consists of very finely ground up light brown dolomite. In the washed material some white anhydrite was noted........................3750-3755
Like sample from 3705-3714 feet........................3755-3760
The sample consists of finely ground up white dolomite. In the washed material some white anhydrite was noted. A few fragments of red and greenish-gray shale were also present........................3755-3760
Light gray, almost white, dolomitic limestone and clear anhydrite. No fossils were seen........................3760-3765
Like sample from 3755-3760 feet........................3765-3770
Like sample from 3755-3760 feet........................3770-3780
White dolomitic limestone with some anhydrite. No fossils were seen. Sample ground very fine........................3778-3785
Like sample from 3755-3760 feet........................3790-3795
Like sample from 3755-3760 feet........................3795-3800
White dolomitic limestone like 3778-3785 feet........................3800
Like sample from 3778-3785 feet........................3805-3810
Like sample from 3755-3760 feet........................3810-3815
Light gray dolomitic limestone containing some clear anhydrite and a few fragments of maroon colored and dark gray shale. No fossils were seen........................3815-3820
Like sample from 3755-3760 feet........................3820-3825
Like sample from 3755-3760 feet........................3825-3830
Light gray dolomitic limestone with some anhydrite. No fossils were seen........................3840-3845
The sample consists of very finely ground, very light gray dolomite. In the washed material some white anhydrite and a few fragments of red and greenish-gray shale were noted........................3845-3852
Gray dolomitic limestone with some clear anhydrite. No fossils were seen. In closed tube faint sulphur odor was noted........................3852-3857
Very light gray dolomitic limestone with some anhydrite. No fossils were noted........................3857-3865
Gray dolomitic limestone with some anhydrite. In one fragment an indication of a replaced sponge spicule was

noted. No other fossils were seen. In closed tube bituminous fumes were given off	3865-3870
Gray dolomite limestone with some anhydrite. In one fragment an indication of a replaced sponge spicule was noted. No other fossils were seen. In closed tube bituminous fumes were given off	3865-3870
Dark gray dolomitic limestone which is in part siliceous. In thin section the limestone is seen to be finely crystalline with considerable granular inclusion within the crystals. In the siliceous fragments the granular material of the limestone is retained in the brownish matrix. In some fragments bituminous stains are seen. No fossils noted. In closed tube bituminous fumes and strong fumes of ammonia were noted	3870-3880
Dark gray dolomitic limestone like that from 3870-3880. Some white cylindrical spines suggesting casts of sponge spicules were seen in washed material. In closed tube ammonia fumes were noted	3880-3884
Gray medium coarse crystalline dolomite and a small amount of white flint and anhydrite	3885-3890
Dark gray dolomite and a few fragments of anhydrite. In thin section the dolomite is seen to be finely crystalline in texture. When heated in closed tube, faint bituminous fumes were liberated. The texture and general appearance of this rock reminds one of the Word formation of the Glass Mountain section. J. A. U.	3900-3905
Light yellow, fine grained dolomite and some anhydrite. Still Permian. H. T. K.	3995-3998

Log of the White Oil Corporation's Masterson No. 1, in Section 5, G. & M. Block No. 3. Elevation of well site 3227′.

	Depth in feet. From	To.	Thickness.
Shale	0	1370	1370
Gypsum	1370	1380	10
Sand	1380	1411	31
Lime shell	1411	1417	6
Lime	1417	1430	13
Shale	1430	1435	5
Water sand	1435	1440	5
Lime	1440	1450	10
Water sand	1450	1455	5
Lime	1455	1460	5
Shale	1460	1470	10
Gypsum	1470	1475	5

Red Rock	1475	1480	5
Rock salt	1480	1510	30
Red shale	1510	1595	85
Lime	1595	1600	5
Red shale	1600	1625	25
Red sand	1625	1645	20
Lime shell	1645	1650	5
Red sand	1650	1660	10
Red shale	1660	1670	10
Salt	1670	1700	30
Lime	1700	1710	10
Red shale	1710	1720	10
Sand	1720	1750	30
Red sand, caving	1750	1780	30
Sand and red shale	1780	2230	450
Gypsum	2230	2280	50
Sand	2280	2310	50
Red rock	2310	2510	200
Salt	2510	2605	95
Lime	2605	2655	50
Salt	2655	2755	100
Blue shale	2755	2776	2
Red shale	2776	2796	20
Lime	2796	2806	10
Red Rock	2806	2814	8
Brown lime	2814	2822	8
Red rock	2822	3009	177
Red sandy shale, showing of gas at 3055′	3009	3090	81
Red rock	3090	3115	25
Brown sandy lime	3115	3120	5
Red Rock	3120	3122	2
Hard gray lime	3122	3225	103
Red rock	3225	3285	60
Gray lime	3285	3305	20
White sand, showing little oil	3305	3320	15
Sandy lime	3320	3444	124
Sand, oil show	3444	3449	5
Gray lime	3449	3470	21
Lime, very small gas show	3470	3485	15
Gray lime	3485	3572	87
Sand, little oil	3572	3584	12
Lime	3584	3595	11
Hard lime	3595	3667	72
Lime and sand	3667	3700	33
Sandy lime, salty	3700	3745	45

3 Bailers water per hour at 3720′

Gray sandy lime	3745	3802	57
Gray sandy lime	3802	3885	83
White lime	3885	3910	25
Brown lime	3910	3915	5
Black lime	3915	3920	5
Brown lime	3920	3930	10
Coarse black lime	3930	3945	15
Black shale and lime, trace of oil	3945	3948	3
Black shale, caving, trace of oil	3948	3960	12
Hard sand, 10% lime	3960	3968	8
White lime	3968	3972	4
Gray lime	3972	3998	26
Hard gray lime	3998	4007	9
Gray lime	4007	4165	158
Reddish-brown sand	4165	4200	35
Dry and abandoned at	4200		

First Shot: 420 quarts from 3310′ to 3447′—no response.
Second shot: 200 quarts from 3310′ to 3447′—no response.
After shot there was no show of oil or gas.
Formation from 4165′—4200′ may carry granite fragments.
Casing pulled and hole plugged.

Description of samples

Depth in Feet

The sample consists of red clay. In the washed material fragments of fine sandstone, a little white anhydrite and a very little quartz sand were noted 2822-2980

Brownish-red clay, reddish dolomite, rounded, etched sand, anhydrite, some quartz crystals, and a few fragments of limestone. Permian. H. T. K. 2828

The sample consists of reddish-brown and greenish-gray shale. In the washed material numerous small calcareous concretions and some white anhydrite were noted .. 3115-3118

The sample consists of red, purple and greenish-gray shales. In the washed material same white anhydrite was noted. Small calcareous concretions, a very litte fine quartz sand and pyrite were also present........ 3275-3280

Maroon-red fine textured shale and bluish-gray shale, both of which are dolomitic. With the shale is considerable crystalline anhydrite 3320-3326

Maroon-red and gray shale like that from 3320-3326′, and some gray fine-grained thin bedded (1 mm. thick layers) dolomite. Anhydrite present 3355-3365

Blue and red non-calcareous indurated clay, gray dolomite, some anhydrite, and a few grains of subangular sand.

In thin section the red clay is seen to contain some fine sand and inclusions of gray clay. In this section the dolomite shows oolitic texture, the oolitic spherules being all shapes from round (one-third mm. in size) to very narrow and elongated and having a finely granular texture. Some of the oolitic spherules have an outer lighter layer and a darker center, others have a light center surrounded by a dark and a light layer. Many of the oolitic spherules seem to have been flattened by pressure. The oolites are separated from each other by coarser granular material. One dolomite fragment has a finely mottled texture. When heated in closed tube, faint ammonia fumes were liberated.. 3360

Gray dolomite which contains much anhydrite. In thin section the anhydrite is seen to occupy circular areas of various sizes resembling oolitc spherules, and irregular elongated areas more or less branching and connected. The quantity of anhydrite varies in different fragments but anhydrite seems to be present in all. One fragment which was digested in warm hydrochloric acid left the anhydrite in a skeletal arrangement. Several of the circular bodies of anhydrite have a central area of dolomite and same show concentric rings. In closed tube enough bitumen to have a deposit in tube was given off..3370-3380

Light gray dolomite containing much anhydrite, and some gray shale. In thin section the dolomite is seen to be very fine grained and to contain minute clear crystalline bodies and areas of anhydrite........................ 3390

Dark bluish-gray dolomitic shale, brown dolomite, gray anhydrite and some maroon-red shale. In thin section the shale is seen to contain minute quartz grains. The anhydrite is seen to be crystalline in thin section. In closed tube ammonia and bituminous fumes were given off 3390-3400

Light gray dolomite containing anhydrite, and some dark gray shale. In thin section the dolomite is seen to have oolitic texture, the oolites being composed of finer grained material than the matrix and are mostly irregular in shape, being mostly oblong. Some of the oolites are replaced partly or wholly by anhydrite and several are surrounded by a distinct ring. The dolomite in this sample differs from that found at 3360′, in being coarser grained. The oolites are smaller and are more distant. When heated in closed tube, faint ammonia fumes and faint bituminous fumes were liberated........................ 3396

The sample consists of dark greenish-gray and light greenish-gray shales and some anhydrite. In the washed material some small calcareous concretions and a little fine quartz sand were noted 3400-3406

The sample consists of light gray dolomite, dark gray shale and a little red shale. In the washed material some white anhydrite and a little pyrite were noted. In thin section the dolomite was seen to be finely granular and to contain indistinct traces of fossils. There are irregular areas of anhydrite which have partly replaced the dolomite 3408-3412

Brownish-gray granular dolomite containing included areas of anhydrite. In thin section the dolomite shows oval and irregular areas of anhydrite. Some of the areas have a small lump of granular dolomite in the center and suggest replaced organic remains. Areas of darker color and of finer texture within the dolomite itself also bear out this suggestion. Some areas which are darkened by very fine black specks are seen in the dolomite and bordering some areas of the anhydrite. In closed tube bitumen sufficient to make a deposit in tube and sustain slight flame was given off 3410-3420

Gray fine-grained dolomite and dark bluish dolomitic shale. In thin section the dolomite shows areas of anhydrite in uniform fine-grained groundmass. The shale contains considerable fine quartz sand or silt. Bituminous fumes sustained slight flame and form slight deposit of oil in closed tube, ammonia fumes also present 3433-3440

Brown very finely crystalline dolomite containing much anhydrite in irregular areas. Some dark gray dolomitic shale present. In closed tube ammonia and bituminous fumes were given off 3451

The sample consists of greenish-gray shale and a few pieces of red shale. In the washed material many fragments of gray dolomite were noted. White anhydrite and pyrite were also present 3458

The sample consists of light gray dolomite and dark gray shale. The dolomite splits into thin plates. In the washed material a little white anhydrite was noted. In thin section the dolomite was seen to be finely granular and to contain thin irregular bodies and wavy lines of dark gray material. Areas of anhydrite which have partly replaced the dolomite were noted. Some rugged dark streaks occur throughout the dolomite 3458-3463

Gray fine-textured dolomite with scattering fine quartz grains. Brown dolomite like that described at 3451′; and some black and some maroon-red shale. In closed tube a slight deposit of bitumen was formed in tube. In thin section the rock shows many indistinct round spherules possibly originally real oolitic granules.......... . 3468

The sample consists of light gray dolomite and dark gray shale. In the washed material a little white anhydrite and a few fragments of red shale were noted. 3471

The sample consists of gray dolomite and a few fragments of red shale. In the washed material a little white anhydrite was noted 3480-3503

Gray dolomite and black non-calcareous shale. In thin section the dolomite is seen to be oolitic in texture. The oolitic spherules range in size from slightly less than one-fourth mm. to three-eighth mm. in diameter. Several of the spherules have been filled by anhydrite. Others show indistinct concentric rings or layers in the crystalline dolomite. The larger part of the spherules however are distinguished by their fine texture and darker color. The rock breaks in thin flakes. One fragment seen in section shows discontinuous and roughly parallel layers of dark material. The black shale contains some fine sand and silt. In closed tube bituminous and ammonia fumes were given off. 3486

Gray dolomite and some red shale which splits into square pegs. In thin section the dolomite is seen to be oolitic. Most of the oolitic spherules are found to measure between one-fourth and three-eighths mm. in diameter, others are elongated and measure one-half mm. in length by one-eighth in width. Some of the spherules are filled by anhydrite and some of the matrix of the rock is replaced by anhydrite. The oolitic spherules are distinctly finer in texture and darker in color than the surrounding matrix and generally show one or more distinct rings around the circumference. This dolomite resembles very closely the rock described from 2609-24′ in the Spur Well, Dickens County, in Univ. of Tex. Bull. 363, Plate 8 A-B. In closed tube ammonia and bituminous fumes were given off. E. B. S....................... 3496

Gray and white anhydrite, gray dolomitic shale and red shale. In closed tube bituminous fumes and fumes of ammonia were given off 3507

The sample consists of gray dolomite, white anhydrite and a few fragments of red shale. In thin section the dolomite was seen to be granular and to be blotchy in appearance. Some areas of clear anhydrite were noted which had partly replaced the dolomite. 3508

Dark gray dolomite, reddish-brown shale and some gray shale. In thin section the dolomite is seen to be oolitic.

The oolitic spherules are from three-eights to one-half mm. in diameter. Some of the spherules vary from their oval outline in order to conform to the shape of adjoining bodies. The spherules are for the most part darker than the matrix and of finer texture. They show concentric banding or rings suggesting growth by accretion. Anhydrite has partially replaced the matrix in some fragments and an occasional spherule shows partial replacement by hydrite. In closed tube ammonia and bituminous fumes were given off.................................. 3526

The sample consists largely of gray dolomite with a little red shale. The dolomite splits into thin plates. In the washed material a little white anhydrite was noted. In thin section the dolomite was seen to be finely granular and to contain small blotches of darker materials. Some small areas of anhydrite which have partly replaced the dolomite were noted. The grouping of the darker areas suggests organic material.................................. 3532

Gray dolomite and gray fine-grained dolomitic shale. In thin section of the dolomite is seen to be of uneven texture partly granular and partly clear crystalline. The outlines of two organic bodies were seen in section. Other outlines less distinct but probably of the same origin are also seen. The gray shale is fine textured with an occasional clear grain imbedded. Some red shale present. In closed tube ammonia and bitumen were given off 3540

Gray dolomite and dark bluish-gray dolomitic shale. In thin section the dolomite is seen to have a blotched, uneven texture. Areas of irregular outline, of crystalline material are surrounded by a granular ground mass which contains darker areas, that may be traces of organic remains. Some anhydrite and some red shale present. The rock breaks in thin flakes. In closed tube ammonia fumes and fumes of bitumen were given off.... 3560

Gray dolomite with a small amount of red and bluish-gray shale. In thin section of the dolomite organic outlines are seen in a rock which consists largely of secondary anhydrite. In some fragments the anhydrite constitutes almost the entire rock only a few small areas of the granular dolomite texture remaining. In closed tube ammonia and bituminous fumes were given off 3574

The sample consists of dark-gray dolomite and a little red shale. In the washed material some white anhydrite was seen to be included in the dolomite. A little pyrite was also present. On heating the dolomite in a closed tube a strong odor of bitumen was noted............ 3585

Gray dolomite. In thin section the dolomite is seen to be largely replaced by anhydrite. Faint outlines of organic bodies are seen in some fragments. In closed tube ammonia and bituminous fumes were given off	3593
Light gray dolomite. In thin section anhydrite is seen to have replaced relatively large areas of the dolomite. Ill-defined outlines probably of organic bodies are seen in several fragments. In closed tube very faint ammonia fumes were given off	3606
The sample consists of gray dolomite which splits into thin plates. In thin section the dolomite is seen to be crystalline and to contain areas of anhydrite	3615
Gray and slightly brownish dolomite. In thin section the dolomite is seen to contain less secondary anhydrite than has been present in samples next above, and is somewhat coarser crystalline in texture. No organic outlines were seen in section. A small amount of red shale is present in this sample. In closed tube faint bituminous fumes were given off	3639
Slightly dark gray dolomite. In thin section the dolomite is seen to vary in texture from fine crystalline to crystalline, with areas of darker finer texture which are probably traces of organic fragments. A very few fragments show very small areas of anhydrite. In closed tube very faint bituminous fumes were given off	3653
Gray crystalline dolomite with some anhydrite and a small amount of red shale. No thin section was made of this sample. In closed tube faint bituminous fumes were given off	3675
Slightly brownish-gray, non-laminated dolomite. In thin section an even crystalline texture with occasional areas of granular, darker material are seen. Some fragments show small areas of anhydrite. In closed tube faint bituminous fumes were given off	3697
Light gray, almost white, fine crystalline dolomite containing secondary anhydrite areas. No thin section was made of this sample. A few fragments of red shale present. In closed tube very faint bituminous fumes were noted	3705
Very light gray, crystalline dolomite containing some secondary anhydrite. Small porosities were seen in several small fragments. Some red shale and several fragments of green shale were seen in washed material. No section was made on account of fineness of material. In closed tube very faint bituminous fumes were noted	3715
Light gray dolomite. In thin section of a number of very small fragments, secondary anhydrite is seen to have	

replaced more than fifty per cent of the original granular dolomite. The remaining dolomite is mostly in small grains about one-eighth mm. in diameter and not clearly defined, surrounded by anhydrite. Some red and a small amount of bluish-gray shale present	3725
Very light gray fine grained dolomite and anhydrite. The sample is ground unusually fine, all fragments being less than one-fourth mm. in size. Still Permian	3725
Like sample from 3725′	3735
Slightly brownish light gray dolomite like that from 3735′. Some faintly bluish-white flint is present in this sample. Some red shale also present	3740
Yellow, dolomitic limestone, anhydrite, and a few fragments of gray chert, and red and blue clay. The sample is ground unusually fine and has a yellow flour-like appearance. Probably Permian. E. B. S.	3745
The sample consists of greenish-gray shale, reddish-brown shale and many fragments of anhydrite. A large piece of very fine-grained anhydrite was present. In the washed material many fragments of dolomite were noted. Some pyrite was also present. The sample contains one large fragment of bluish-gray dolomite of fine texture. This shows some small traversings of slightly lighter color than the mass	3745

Log of the United States Geological Survey well in Section 21, B. S. & F., Block No. 9. Elevation of well site 3400′.*

	Depth in feet. From	To.	Thickness.
Soil and clay, surface deposits	0	15	15
Tevocas shale (Triassic):			
Clay, variegated, white, and bright yellow	15	100	85
Quartermaster formation (Permian):			
Clay, mostly red, with some nodules of lime	100	180	80
Dolomite; compact strata, separated by a stratum of red clay	180	195	15
Shales, brick-red, sandy, with several strata of gypsum in lower part	195	260	65
Sandstone, brick-red, and red shale in alternating strata	260	330	70
Gypsum and red sandy clay	330	360	30
Sandstone and shale, predominating			

*Log taken from U. S. Geol. Survey Mineral Resources 1917, p. 427.

brick-red color	360	478	118
Greer formation (Permian):			
Limestone, siliceous	478	488	10
Limestone, dolomitic and anhydrite	488	510	22
Clay, red, sandy, mottled with gray, containing some gypsum	510	560	50
Beds as yet undifferentiated stratigraphically:			
Sandstone	560	582	22
Limestone and anhydrite	582	588	6
Clay, red, sandy	588	661	73
Anhydrite	661	665	4
Clay, dark brown and red, sandy beds and Salt	665	743	78
Salt	743	759	16
Anhydrite, limestone, clay and some salt	759	779	20
Salt	779	819	40
Anhydrite	819	835	16
Anhydrite and limestone in thick beds, with some clay	835	972	137
Salt and anhydrite	972	996	24
Salt	996	1029	33
Silt and anhydrite	1029	1037	8
Salt	1037	1058	21
Anhydrite and limestone, with thin beds blue clay	1058	1116	58
Salt with red clay intercalated strata	1116	1215	99
Salt	1215	1313	98
Limestone and some anhydrite between blue clay beds	1313	1392	79
Salt	1392	1440	48
Limestone, anhydrite, intercalated sandstone, clay and salt	1440	1570	130
Clay, red, with intercalated beds of anhydrite and limestone	1570	1703	133

SHALLOW WELL RECORDS

1. A. T. & S. F. Ry. Co. well No. 1 at St. Francis in Section 4, A. B. & M., Block 2. Log furnished by the company:

Black soil 2 feet; white marl 5 feet; light-colored clay and sand 43 feet; red clay and sand, caves, 100 feet; light-colored clay and sand 25 feet; brown clay and sand 35 feet; sand and dry gravel, caves bad, 43 feet; red clay 35 feet; red water-bearing sand 21 feet; red clay 5 feet.

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2. A. T. & S. F. Ry. Co. well No. 2 at St. Francis in Section 4, A. B. & M., Block 2. Log furnished by the company:

Black soil 2 feet; white marl 5 feet; light-colored clay and sand 43 feet; red clay and sand, caves, 100 feet; light-colored clay and sand 25 feet; brown clay and sand 35 feet; sand and dry gravel, caves bad, 43 feet; red clay 35 feet; red clay 5 feet.

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3. A. T. & S. F. Ry. Co. well No. 3 at St. Francis in Section 4, A. B. & M., Block 2. Log furnished by the company:

Black soil 2 feet; white marl 5 feet; light-colored clay and sand 43 feet; red clay and sand, caves, 100 feet; light-colored clay and sand 25 feet; brown clay and sand 35 feet; sand and dry gravel, caves bad, 43 feet; red clay 35 feet; red clay 6 feet.

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4. A. T. & S. F. Ry. Co. well No. 4 at St. Francis in Section 4, A. B. & M., Block 2. Log furnished by the company:

Black soil 2 feet; white marl 5 feet; light-colored clay and sand 43 feet; red clay and sand, caves, 100 feet; light-colored clay and sand 25 feet; brown clay and sand 35 feet; sand and dry gravel, caves bad, 43 feet; red clay 35 feet; red clay 6 feet.

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5. City Light and Water Company well at the Country Club. Log furnished by the company.

Soil 1 foot; reddish clay 10 feet; gray putty clay 30 feet; red clay 20 feet; gray rock 4 feet; gray pack sand 80 feet; brown sand-rock 15 feet; brown sandy clay 4 feet; shelly, brown sand-rock, streaked 34 feet; reddish sandy shale 3 feet.

6. Log of well drilled in Section 103, A. B. & M., Block 2. Driller: Joe Connor, Amarillo, Texas. Log given from memory by the driller.

Soil 3 feet; clay 50 feet; cap rock 8 feet; sand 150 feet; red clay 180 feet.

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7. Log of well drilled in Section 103, A. B. & M., Block 2. Driller: Joe Connor, Amarillo, Texas. Log given from memory by the driller:

Soil 2 feet; clay 50 feet; cap rock 8 feet; sand 160 feet; red sandstone.

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8. Log of well drilled in Section 103, A. B. & M., Block 2. Driller: Joe Connor, Amarillo, Texas. Log given from memory by the driller:

Soil 2 feet; clay 50 feet; cap rock 8 feet; sand 160 feet; red sandstone.

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9. Log of well drilled in Section 103, A. B. & M., Block 2. Driller: Joe Connor, Amarillo, Texas. Log given from memory by the driller:

Soil 5 feet; clay 55 feet; cap rock 10; sand 110 feet; white sand rock 20 feet.

10. Log of well drilled in Section 135, A. B. & M., Block 2. Driller: Joe Connor, Amarillo, Texas. Log given from memory by the driller:

Soil 5 feet; clay 40 feet; cap rock 10 feet; rock sandstone 135 feet; hard rock 1 foot; gravel 1 foot; clay 25 feet.

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11. Log of well drilled in Section 158, A. B. & M., Block 2. Driller: Joe Connor, Amarillo, Texas. Log given from memory by the driller:

Soil 5 feet; clay 30 feet; cap rock 8 feet; sand 195 feet; very hard rock 5 feet; no record 20 feet.

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12. Log of well drilled in Section 48, B. S. & F., Block 9. Driller: Joe Connor, Amarillo, Texas. Log given from memory by the driller:

Sand 130 feet.

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13. Log of well dilled in Section 4, J. H. Gibson, Block Z-6 Driller: Joe Connor, Amarillo, Texas. Log given from memory by the driller.

Sand 50 feet.

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14. Log of well drilled in Section 3, G. & M., Block M-19. Driller: Joe Connor, Amarillo, Texas. Log given from memory by the driller.

Clay 50 feet; clay and sand rock 120 feet.

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15. Log of well drilled in Section 1, G. & M., Block M-19. Driller: Joe Connor, Amarillo, Texas. Log given from memory by the driller.

Soil 17 feet; clay 330 feet; sand rock 70 feet.

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16. Log of well drilled in Section 60, B. S. & F., Block 9. Driller: Joe Connor, Amarillo, Texas. Log given from memory by the driller.

Soil 5 feet; no record 50 feet; cap rock 8 feet; sand 125 feet.

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17. Log of well drilled in Section 111, B. S. & F., Block 9. Driller: Joe Connor, Amarillo, Texas. Log given from memory by the driller.

Soil 5 feet; clay 30 feet; cap rock 8 feet; sand 150 feet.

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18. Log of well drilled in Section 44, A. B. & M., Block 2. Driller: Joe Connor, Amarillo, Texas. Log given from memory by the driller.

Soil 8 feet; no record 45 feet; cap rock, hard, 10 feet; sand 90 feet; dry sand 60 feet; mortar beds 35 feet; sand 75 feet; white rock 10 feet.

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19. Log of well drilled in Section 63, A. B. & M., Block 2. Driller: Joe Connor, Amarillo, Texas. Log given from memory by the driller.

Cap rock 10 feet; sand 230 feet; completed in sandstone.

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20. Log of well drilled in Section 50, A. B. & M., Block 2. Driller: Joe Connor, Amarillo, Texas. Log given from memory by the driller.

Clay 35 feet; cap rock 10 feet; sand and rock 170 feet; red clay, red sand and rock 40 feet; white sand-rock 15 feet.

21. Log of well drilled in Section 25, A. B. & M., Block 2. Driller: Joe Connor, Amarillo, Texas. Log given from memory by the driller.

Soil 4 feet; clay 30 feet; cap rock 8 feet; sand 195 feet.

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22. Log of well drilled in Section 24, A. B. & M., Block 22. Driller: Joe Connor, Amarillo, Texas. Log given from memory by the driller:

Soil 5 feet; clay 38 feet; cap rock 10 feet; sand, with little rock, 170 feet; red rock and clay 20 feet.

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23. Log of well drilled in Section 23, A. B. & M., Block 23. Driller: Joe Connor, Amarillo, Texas. Log given from memory by the driller.

Soil 5 feet; clay 35 feet; cap rock 8 feet; red clay 25 feet.

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24. Log of well drilled in Section 44, A. B. & M., Block 2. Driller: Joe Connor, Amarillo, Texas. Log given from memory by the driller:

Soil 5 feet; clay 40 feet; cap rock 5 feet; no record of 25 feet; red clay 5 feet; sand rock 140 feet.

WELLS WITHIN THE CITY LIMITS OF AMARILLO

25. City Light and Water Company well at 506 Arthur Street. Log furnished by the company:

Gumbo 30 feet; yellow clay 60 feet; hard sand 27 feet; clay 2 feet; hard sand 41 feet; yellow clay 30 feet; sand 20 feet; clay 12 feet; sand 34 feet.

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26. City Light and Water Company well at 507 Arthur Street. Log furnished by the company:

Red gumbo 30 feet; yellow gumbo 70 feet; hard sand 50 feet; sandstone 85 feet; rock 10 feet; sand 10 feet; yellow clay 8 feet; sand 3 feet; clay 25 feet; sand 3 feet; clay 3 feet; water 53 feet.

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27. City Light and Water Company well at 303 Houston Street. Log furnished by the company:

Top soil 9 feet; chalky clay 9 feet; brown clay, very tough, 31 feet; sandy brown clay 60 feet; brown packed sand 25 feet; boulders on lime formation 7 feet; brownish shale rock 20 feet; brown packed sand 53 feet; loose fine red sand, containing pans, 30 feet; red clay 5 feet.

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28. City Light and Water Company well No. 15. Log furnished by the company:

Top soil 5 feet; brown clay 145 feet; hard pan, "boulder rock," 6 feet; brown sandy formation 79 feet; coarse gravel, first water

237 feet, 2 feet; hard bluish rock, "lime," 4 feet; brown sand rock 20 feet; red clay 11 feet; conglomerate of red shale, streaked with white sand, 3 feet; brown sand rock 19 feet; red clay 13 feet; water 89 feet.

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29. City Light and Water Company well at 1509 Jefferson Street. Log furnished by the company:

Soil 3 feet; brown clay 135 feet; hard pan, boulders, 8 feet; packed sand formation 67 feet; brown water sand 25 feet; coarse sand gravel 2 feet; sand rock formation, streaked with limestone, 48 feet; gray shale 1 foot; red shale 2 feet; gray shale or clay 1 foot; white sand rock 5 feet; yellow shale 5 feet; red clay 2 feet.

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30. City Light and Water Company well at 305 Polk Street. Log furnished by the company:

Soil and subsoil 5 feet; brown clay 140 feet; red shale 5 feet; brown sand shale 10 feet; red shale, streaked with brown and white sand, 30 feet; yellow clay, with gravel and red sand, fine, 10 feet; red clay 7 feet; water 80 feet.

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31. City Light and Water Company well at 607 Adams Street. Log furnished by the company:

Top soil 6 feet; chalky clay 60 feet; packed sand 44 feet; boulders 10 feet; loose dry yellow sand 20 feet; brown clay 20 feet; brown sand, streaked with red clay, 30 feet; brown, gray and red clay 30 feet; brown sand, containing clay and gravel, 15 feet; yellow clay, containing hard streaks of rock, 48 feet; red clay, very soft, 7 feet.

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32. City Light and Water Company well at 402 North Grant Street. Log furnished by the company:

Top soil 5 feet; chalky clay 55 feet; brown sandy clay 20 feet; brown, tough clay 25 feet; brown sandy formation 30 feet; hard pan, apparently cement or lime, 5 feet; brown sand shale 20 feet; brown packed sand 45 feet; yellowish shale 20 feet; yellow sand gravel 22 feet; hard brown sand rock 14 feet; red shale or clay 1 foot.

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33. City Light and Water Company well at 317 South Madison Street. Log furnished by the company:

Top soil 2 feet; light brown clay 45 feet; brown packed sand 28 feet; yellowish clay 15 feet; brown packed sand or rock 95 feet; boulders 5 feet; brown sand 15 feet; red sandy clay 25 feet; loose brown sand 19 feet; gravel 1 foot; red clay, streaked with fine sand, 14 feet; tough red clay 17 feet.

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34. City Light and Water Company well. Log furnished by the company:

Top soil 4 feet; different colored clays 245 feet; fine brown sand, streaked with red clay, 16 feet; brown water sand 25 feet; brown and white sand 15 feet; sand gravel 1 foot; yellow clay 2 feet; red clay 1 foot.

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35. City Light and Water Company well at 400 North Arthur Street. Log furnished by the company:

Top soil 5 feet; chalky clay 20 feet; brown clay 75 feet; red clay 80 feet; brown packed sand and rock 65 feet; porous sand rock with brown sand 6 feet; red shale 9 feet; brown sand 28 feet; white sand 2 feet; coarse yellow sand 3 feet; white gravel (all colors), 8 feet; red clay 2 feet.

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36. City Light and Water Company well at 700 North Johnson Street. Log furnished by the company:

Top soil 6 feet; reddish clay 75 feet; dry, brown sand 49 feet; boulders 5 feet; brown clay 2 feet; gray, sandy shale 18 feet; cap rock and lime 5 feet; gray shale 20 feet; brown sand 30 feet; fine red sand 20 feet; red, sandy clay 15 feet; brown sand 25 feet; brown sand and gravel 15 feet; brown sandy clay 11 feet; red clay 4 feet.

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37. City Light and Water Company well No. 24. Log furnished by the company.

Chocolate loam 3 feet; chocolate clay 20 feet; red sandy clay 60 feet; brown sandy clay 97 feet; boulders, lime 5 feet; brown sand, containing small boulders, 70 feet; first water at 255 feet; thin shell rock, streaked with fine brown sand, 40 feet; gray shale 1 foot, water gravel 8 feet; yellow sandy clay 6 feet.

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38. City Light and Water Company well No. 25. Log furnished by the company:

Clay 125 feet, no boulders at 125 feet; gray sandy clay 30 feet; sand, streaked with hard pan one-half to one inch thick, 40 feet; yellow clay 5 feet; clay, with sand streaks up to 8 inches thick, 20 feet.

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39. City Light and Water Company well at 506 North Garfield Street. Log furnished by the company.

Loam 2 feet; reddish clay 100 feet; gray sandy clay 143 feet; red sandy clay 10 feet; brown sand containing thin hard strata 40 feet; gravel 6 feet.

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40. City Light and Water Company well at North Second and Bynum streets. Log furnished by the company:

Top soil 5 feet; chalky clay 20 feet; red clay 85 feet; light sandy clay or shale 130 feet; red muddy fine sand, first water noted, 5 feet; brown sand 20 feet; hard pan (gravel) 4 feet; yellow clay 1 foot; yellow sand 12 feet; lavender, white clay 1 foot.

41. City Light and Water Company well at North Fifth and William streets.

Soil 3 feet; bluish sandy clay, containing small boulders, 80 feet; brown sand rock 42 feet; gray clay 90 feet; brown, sandy clay 45 feet; fine red water sand, streaked with shelly rock, 22 feet; brown sandy clay 7 feet; gas sand 8 feet; gravel 41 feet; yellow sandy clay 11 feet; yellow sticky clay 314 feet.

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42. City Light and Water Company well at 607 North Houston Street. Log furnished by the company:

Top soil 3 feet; reddish clay 47 feet; red clay, containing small boulders, 60 feet; gray, sandy shale 170 feet; red sticky clay 20 feet; red sand rocks 5 feet; red shelly sand rock 10 feet; red sand, streaked with gravel, 25 feet; coarse gravel and clay 5 feet; white sand shale 5 feet; lavender clay 3 feet.

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43. A. T. & S. F. Ry. Co. well No. 9. Log furnished by the company:

Soil 5 feet; clay 60 feet; sand 73 feet; gray sand 122 feet; water bearing sand 30 feet; clay 19 feet.

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44. A. T. & S. F. Ry. Co. well No. 10. Log furnished by the company:

Soil 5 feet; clay 60 feet; sand 73 feet; gray sand 105 feet; white sand 47 feet; red clay 19 feet.

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45. A. T. & S. F. Ry. Co. well No. 11. Log furnished by the company:

Soil 3 feet; clay 62 feet; sand 73 feet; gray sand 100 feet; white sand, water bearing, 44 feet; red clay 33 feet.

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46. A. T. & S. F. Ry. Co. well No. 14. Log furnished by the company:

Red clay 10 feet; light-colored clay 10 feet; yellow clay 10 feet; dark-colored clay, with reddish tint, 10 feet; red clay 70 feet; yellow clay 5 feet; sandy clay 10 feet; red sandy clay 15 feet; red clay and some gravel 25 feet; yellow clay 25 feet; light red, sandy clay 45 feet; yellow sandy clay, first water struck at 250 feet, 25 feet; bright-red clay 10 feet; red clay and sand, water-bearing 15 feet; sand and clay mixed, no water, 15 feet; red clay 7 feet.

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47. A. T. & S. F. Ry. Co. well No. 15. Log furnished by the company:

Red clay 6 feet; light-colored clay 10 feet; yellow clay 10 feet; dark colored clay 10 feet; red clay 70 feet; yellow clay 5 feet; sandy clay 10 feet; red sandy clay 15 feet; red clay, some gravel, 25 feet; yellow clay 25 feet; light-colored sandy clay 45 feet; yellow, sandy clay 25 feet; red clay 5 feet; red clay, with some water, 5 feet; red clay with gravel and more water 15 feet; red clay 4 feet; water sand and very coarse gravel 11 feet; red clay 20 feet; red and yellow clay 21 feet.

48. A. T. & S. F. Ry. Co. well No. 16. Log furnished by the company:

Sandy clay 98 feet; gray sand 117 feet; sand and clay (brown) 11 feet; sand and clay 10 feet; red clay and sand, struck water at 278 feet, rose to 260 feet, normal water level 261 feet 6 inches, 28 feet; red clay, some pebble gravel 18 feet; red sand, cave badly, 8 feet; coarse water gravel (shot well at 294 feet 8 inches, sticks 80 per cent, 9 feet; red sandy clay (caves easily), 19 feet; yellow clay (caved some), 44 feet; red packed sand, shallow streaks of rock (5 inches to 1 foot thick red shale), 110 feet 6 inches.

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49. A. T. & S. F. Ry. Co. well No. 17. Log furnished by the company:

Ground line 2 feet; sandy clay, red, 168 feet; white colored clay 22 feet; red clay, some sand, cavy, 36 feet; rotten red sand rock, hard drilling, 17 feet; red clay, struck some water at 270 feet, 25 feet; medium coarse water sand 6 feet; rotten sand rock, hard drilling, 10 feet; white water sand, medium coarse, good water flow, 7 feet; light colored clay, cavy, 3 feet; red clay, dry, hard to drill and mix, 43 feet; yellow clay, cavy, 19 feet; hard red sand rock, cut bit out of gauge fast, 8 feet; red sticky clay, hard to mix, 4 feet; soft rock, struck salt water at 474 feet (rose to 360 feet), 2 feet.

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50. A. T. & S. F. Ry. Co. well No. 19. Log furnished by the company:

Cinders, ashes 18 feet; yellow clay 62 feet; yellow clay, very hard, 10 feet; gray sandstone, hard, 15 feet; gray sandstone, coarse, 20 feet; light sandy clay 45 feet; gray sandstone, hard, 25 feet; light sandy clay 30 feet; red sandy clay 20 feet; red sand with some clay 45 feet; 21 feet 7 inches of 10 inches perforated, 9-16-inch holes, 4-inch centers, water at 290 feet; red sand, with some gravel, 15 feet; light red clay 24 feet.

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51. A. T. & S. F. Ry. Co. well No. 20. Log furnished by the company:

Soil 3 feet; yellow clay 77 feet; light sandy clay 50 feet; sticky yellow clay 40 feet; light sandy clay 60 feet; yellow sandy clay 28 feett; red clay, water level at 265 feet, 7 feet; red sand, struck water at 280 feet, 35 feet; gravel 5 feet; red clay 18 feet.

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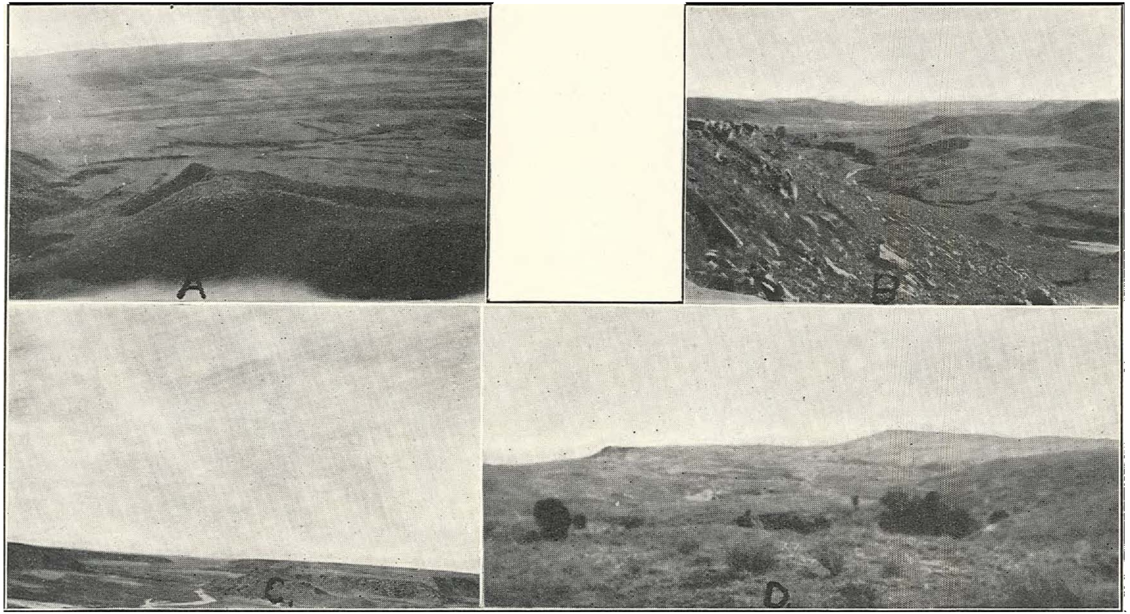
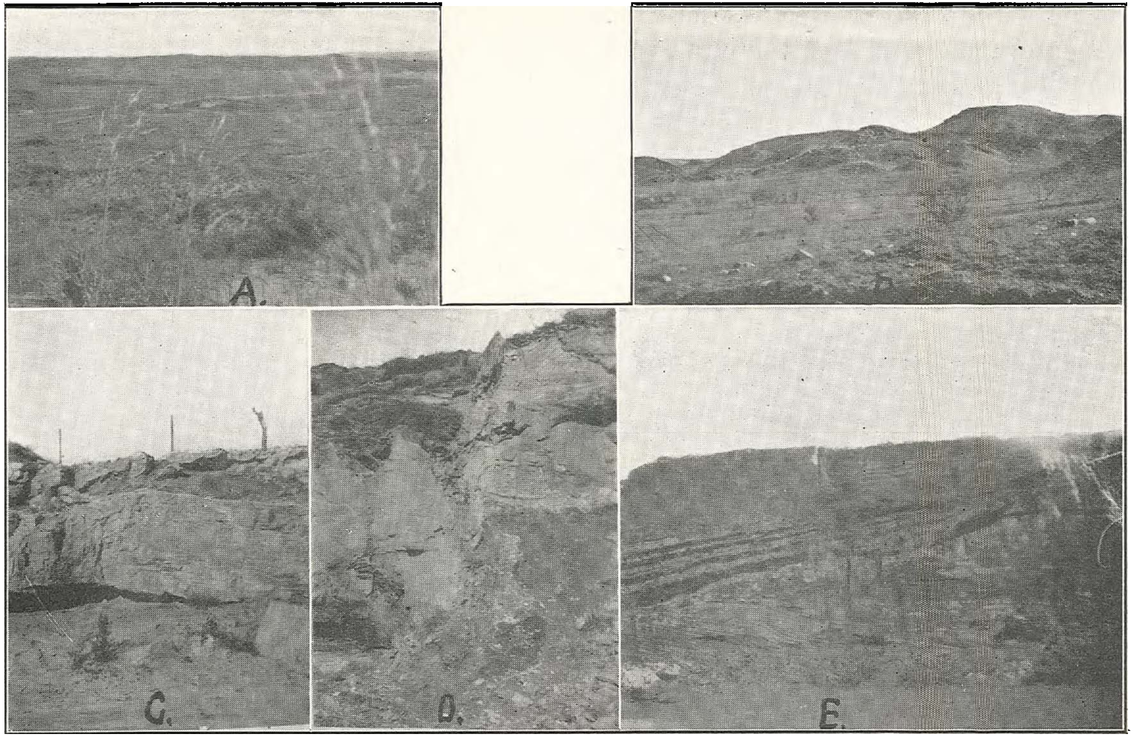
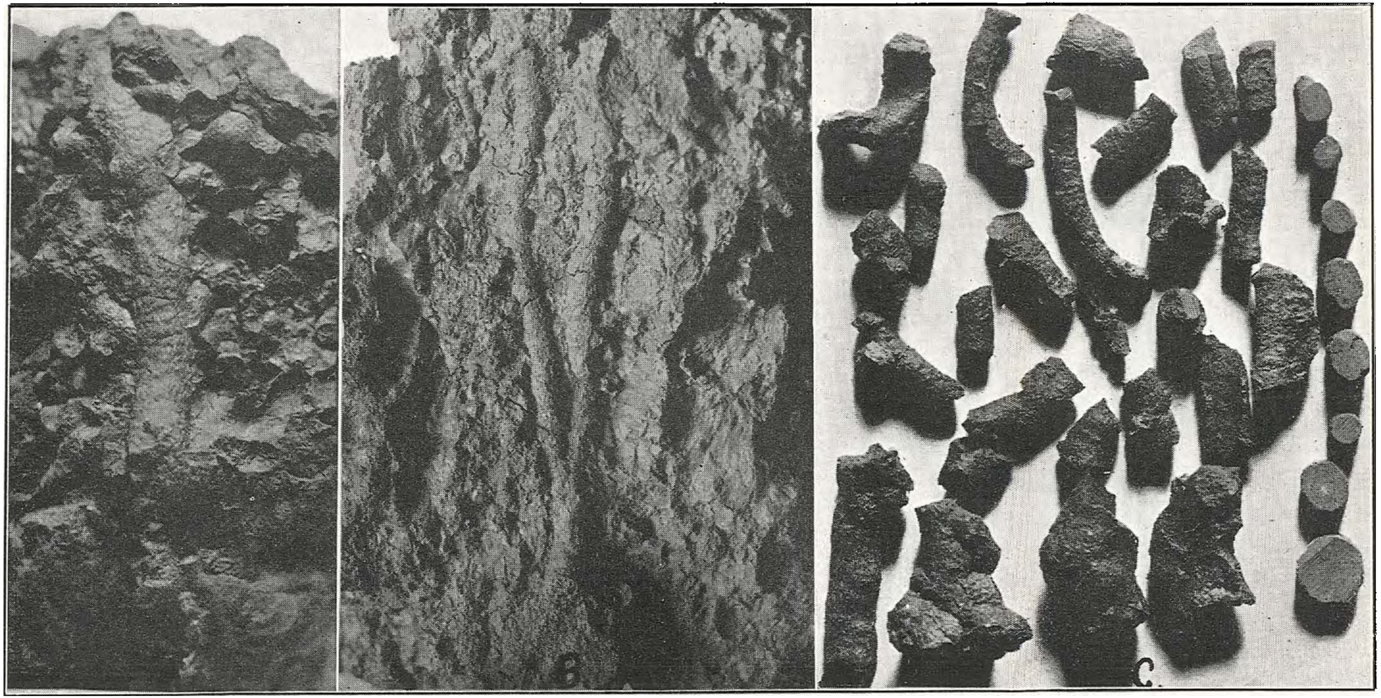


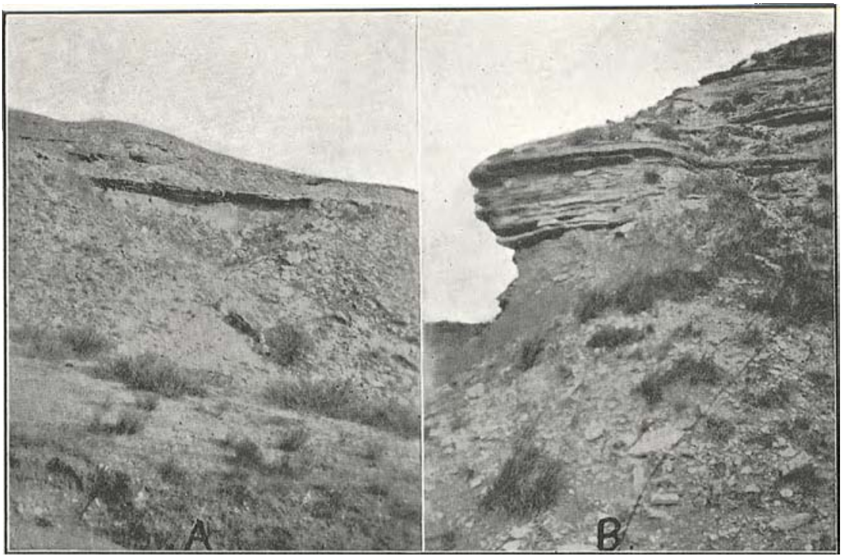
A. View taken at the mouth of Alibates Creek looking southward up the creek valley.
B. View of the canyon of Plum Creek.
C. View of the Canadian River taken from the mouth of Chicken Creek.
D. View of the divide between Coetas Creek and Chicken Creek.



A. Topography of the sand covered country immediately north of the Canadian River.
B. View showing local and erratic dips in the Quartermaster formation.
C. Exposure of the Alibates dolomite showing the two ledges. View taken from near Pitcher Creek.
D. Exposure of Tecovas formation near John Ray Creek showing ledge of soft unconsolidated sandstone which occurs in the formation. The ledge is here cut by a small fault.
E. Exposure of Tecovas formation in the valley of West Amarillo Creek showing a local unconformity within the formaiton.

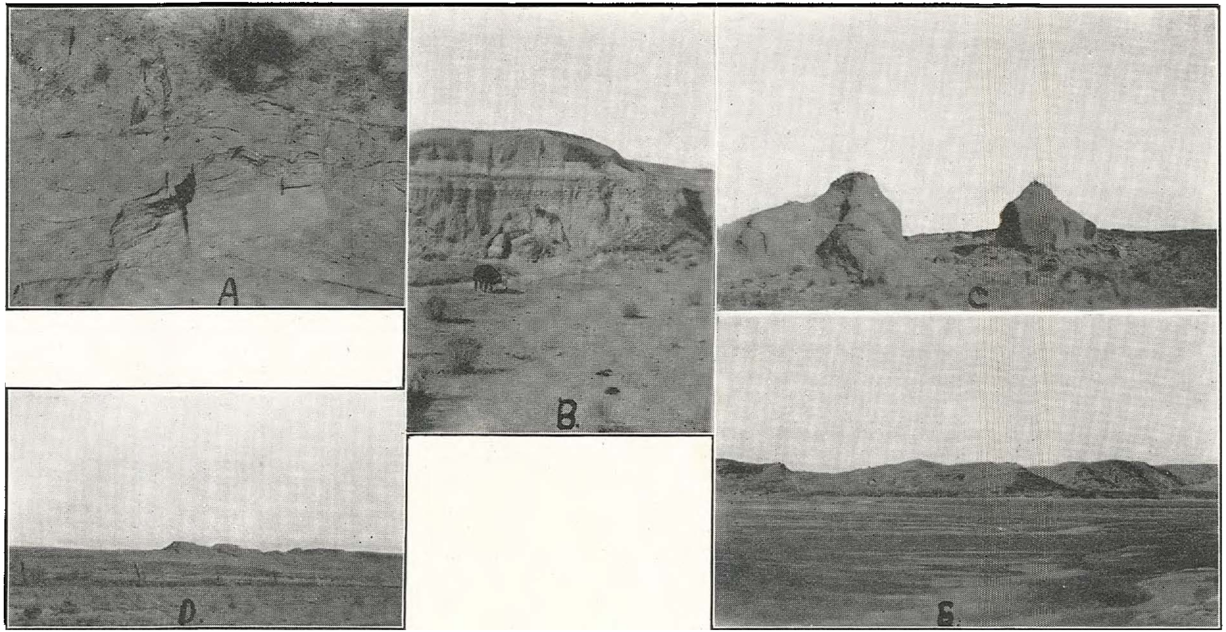


A. Block of Tecovas shale showing casts found in the shale.
B. Block of Tecovas shale showing one of the branching forms of the casts.
C. Casts found in the Tecovas shale dissected out of the matrix.

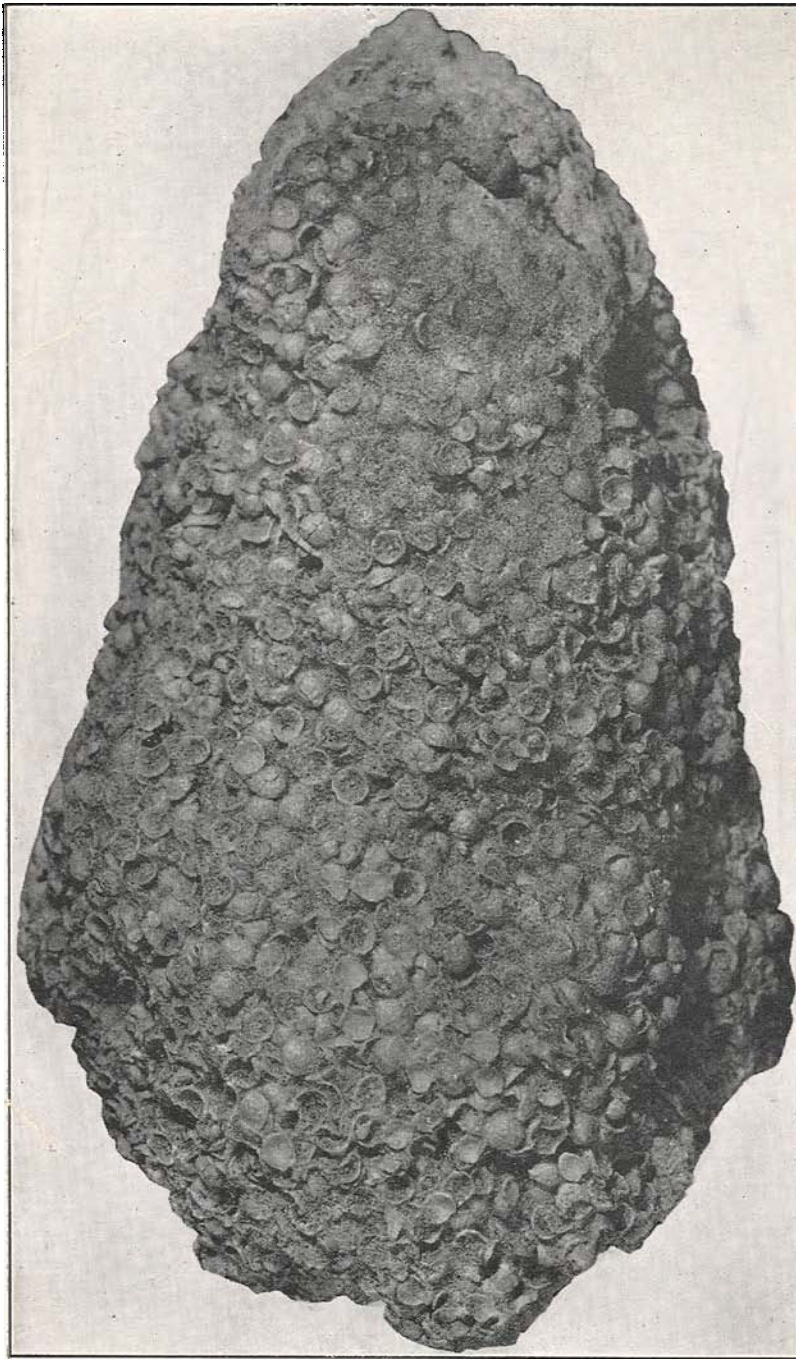


A. An exposure in the Coetas formation showing the slightly consolidated sandstone and thin bedded limestone of the formation. One of the localities at which vertebrate fossils were found.

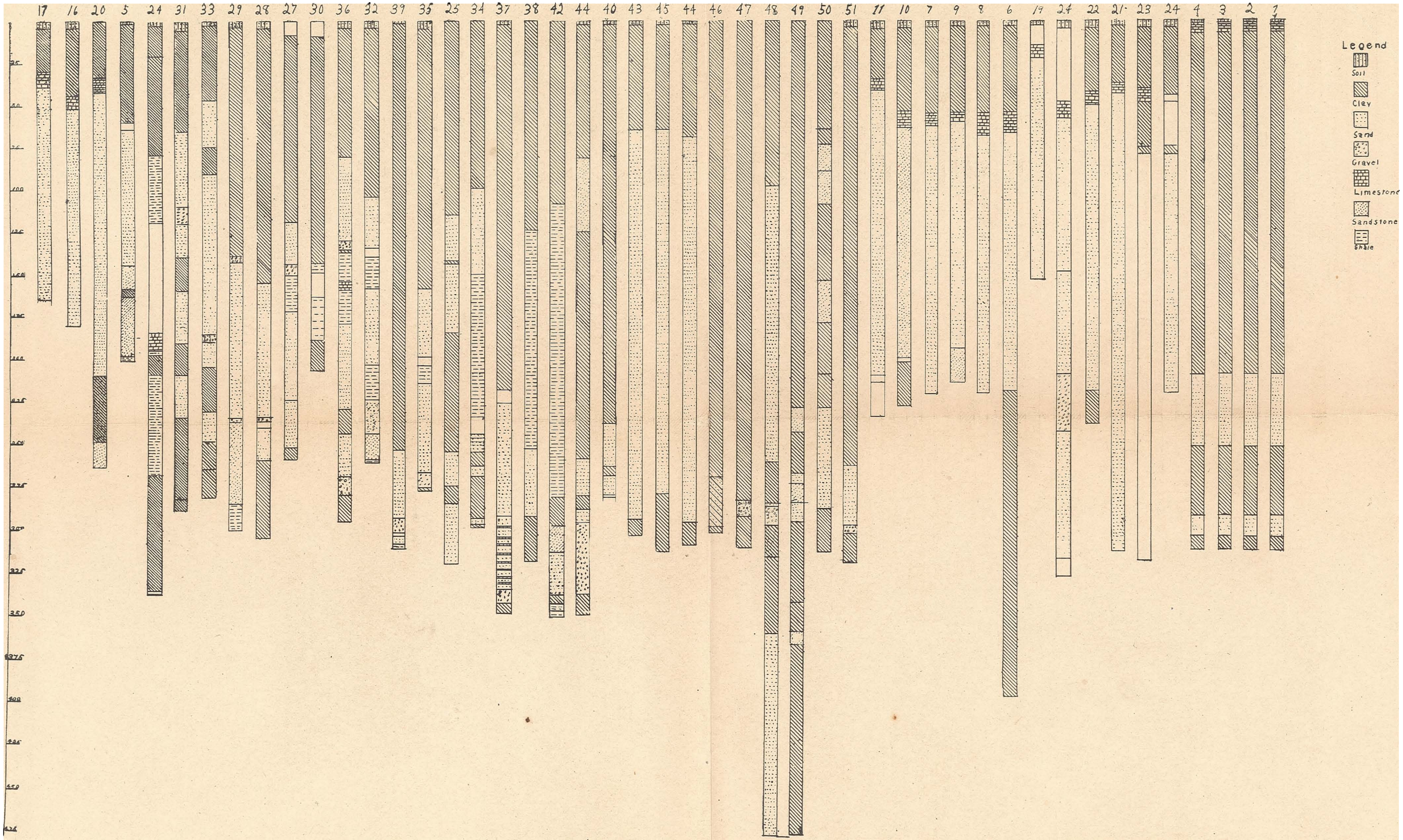
B. An exposure of the Coetas formation showing the thin bedded limestone of the formation.



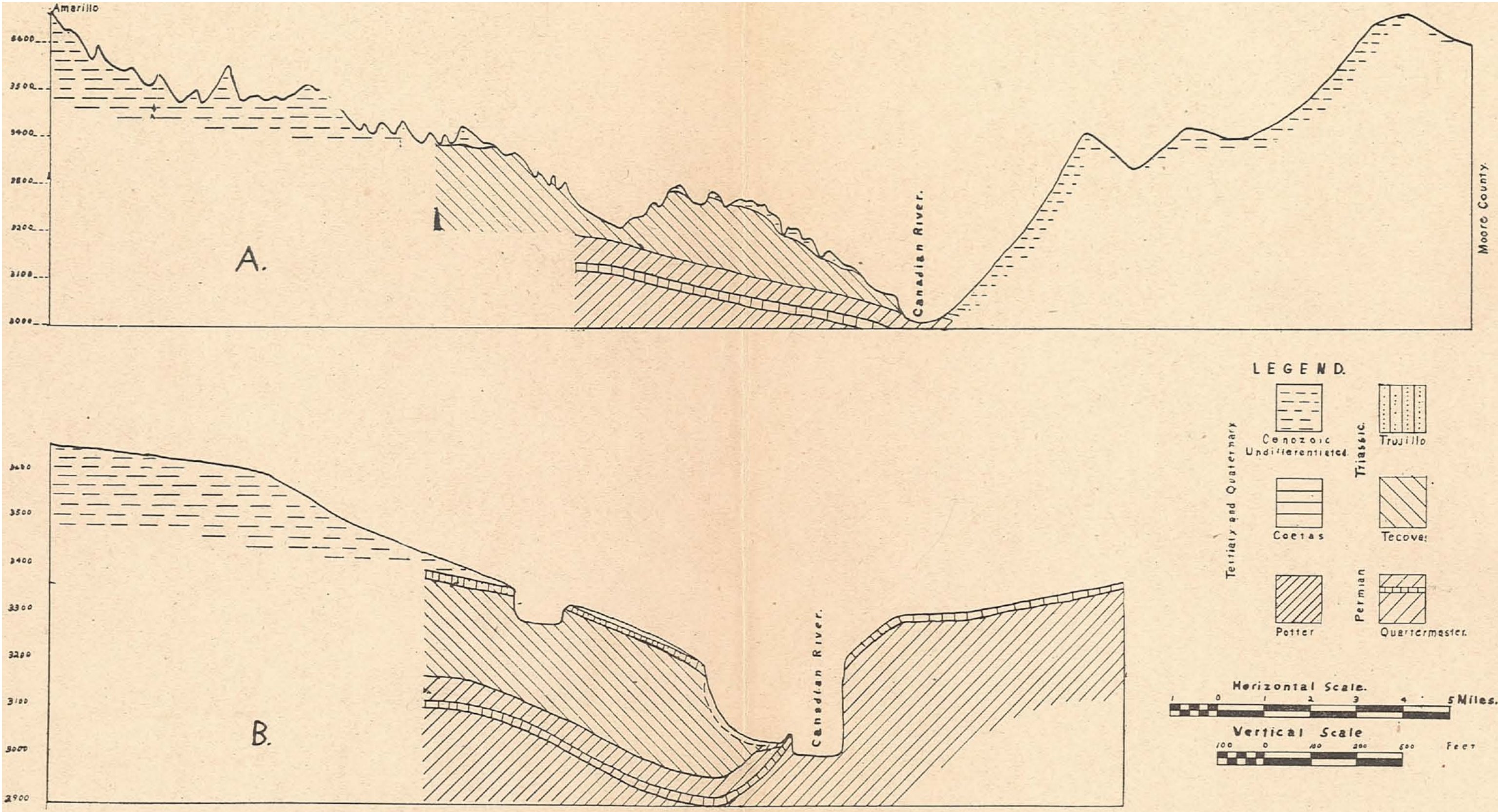
A. An exposure of the undifferentiated Cenozoic deposits a short distance north of the Canadian River in the central part of the county.
B. An exposure of the undifferentiated Cenozoic. View taken in the valley of Corral Creek about three miles from the mouth.
C. Erosional remnants in the valley of Bonita Creek in which vertebrate fossile were found.
D. Outline of the cap rock escarpment in the southern part of the county.
E. View taken on the south side of the Canadian River showing the steeply dipping rocks of the John Ray dome.



Aggregate of fossil endocraps of drupes of Celtis found in the erosional remnant shown in Plate V. C.



Graphic representation of logs of water wells drilled south of the escarpment of the Llano Estacado in the southern part of the county.



A. Topographic and geologic cross section from Amarillo north along the Colorado and Gulf Highway to Moore County. The surface elevations are siprit level elevations furnished by Nagel, Witt and Rollins Engineering Company and corrected aneroid barometer readings made by the author. All elevations from Amarillo to the Canadian River are spirit level elevations.

B. Topographic and geologic cross section taken along line AA′ of the map.

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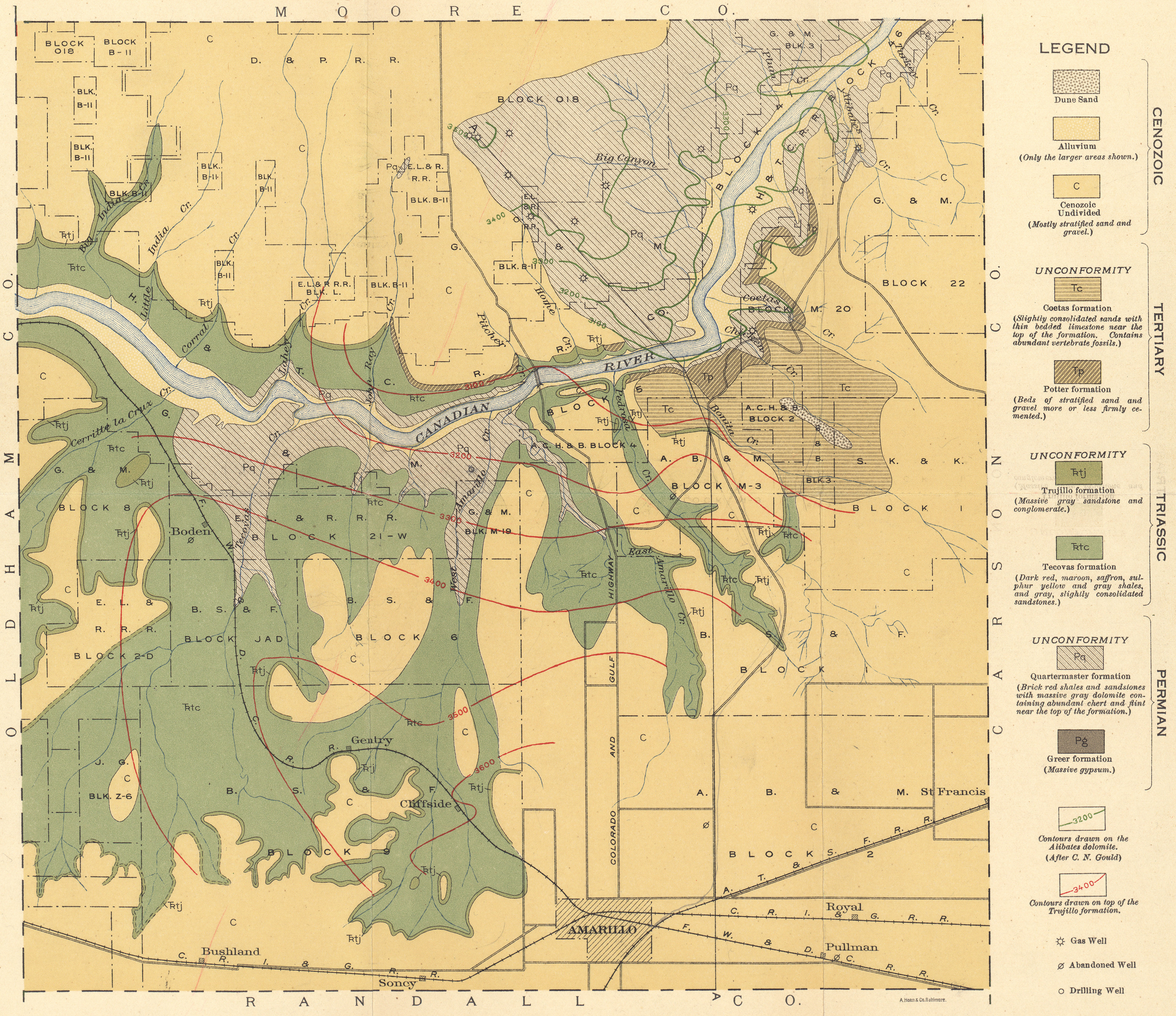

GEOLOGIC MAP OF POTTER COUNTY, TEXAS

BY LEROY T. PATTON

Scale
1 0 1 2 3 Miles