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GEOLOGY AND UNDERGROUND WATERS OF THE WICHITA REGION, NORTH-CENTRAL TEXAS

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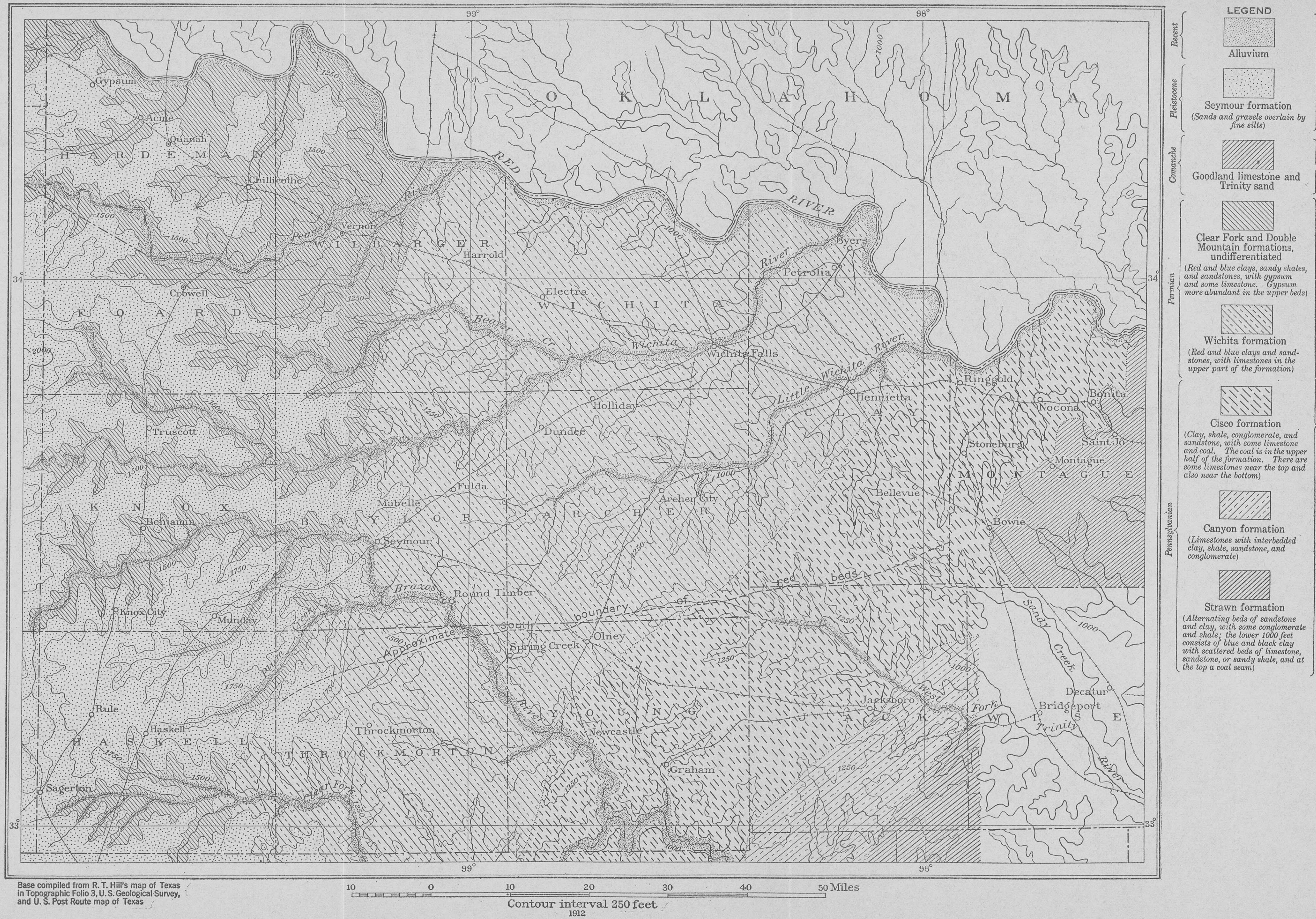

Base compiled from R. T. Hill's map of Texas in Topographic Folio 3, U. S. Geological Survey, and U. S. Post Route map of Texas

GEOLOGIC SKETCH MAP OF THE WICHITA REGION, NORTH-CENTRAL TEXAS.

GEOLOGY AND UNDERGROUND WATERS OF THE WICHITA REGION, NORTH-CENTRAL TEXAS.

By C. H. Gordon.

INTRODUCTION.

Location and area.—The region considered in this report is a part of north-central Texas. Red River forms its northern boundary, and it comprises Montague, Clay, Wichita, Wilbarger, Hardeman, Foard, Knox, Baylor, Archer, Jack, Young, Throckmorton, and Haskell counties. Its area is approximately 11,139 square miles, and its population, according to the census of 1910, is 158,046, an increase of 78,215 over the population in 1900.

The United States Geological Survey has prepared atlas sheets covering Montague County and the tier of counties bordering the Wichita region on the south (Palo Pinto, Stephens, Shackelford, and Jones), but for the remaining portion no accurate base maps are available. Plate I is based chiefly on Hill's map of Texas.

Purpose of the investigation.—This region depends for its water supplies almost wholly on surface waters, which are insufficient, so that the problem of finding underground sources of potable water in sufficient quantities is of great importance. The field investigations were directed to the determination of the geologic conditions with a view to locating water-bearing formations that might be available sources of water. The region is one of interest to geologists because of the stratigraphic problems occurring within its boundaries. On these problems numerous papers have been published, in which wide differences of opinion are expressed concerning the stratigraphic relations of the beds. The explanation of the discordant views concerning the stratigraphy of the region is found (1) in the diverse character of the formations and the lack of satisfactory exposures, which render the tracing of formations and their correlation even at points not far distant from each other difficult or impossible; (2) in the lack of detailed investigation and of accurate maps; and (3) in the lack of knowledge in regard to the life and relations of the American Permian.

Field work and acknowledgments.—Portions of the field seasons of each of the years 1906 and 1907 were devoted to investigations for this report. During the first season the work was done by the writer alone. During the second season he was assisted by Messrs. Leon F. Russ, of the University of Texas, and Frank Brock, of the University of Kansas, to whose efficient services he is much indebted. The necessity for rapid work in a region so difficult of study makes the adequate treatment of the stratigraphic problem impossible, but it is believed that the results of the investigation constitute an important if small contribution to the solution of the problem connected with the much-discussed "Red Beds" of Texas.

LITERATURE.

Much of the literature relating to this region is widely scattered, and no attempt is made to present here a complete bibliography of it. The effort has been made, however, to compile a list of the writings of chief importance on the problems involved in the preparation of this report. For a more exhaustive record of the publications relating to the geology of Texas the reader is referred to the excellent bibliographies of Hill [1] and Simonds.[2]

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[2] Simonds, F. W., A record of the geology of Texas for the decade ending Dec. 31, 1896. Trans. Texas Acad. Sci., vol. 3, 1899, pp. 17–296.

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PHYSIOGRAPHY.

The surface of the region constitutes in the main a gently eastward-sloping plain dissected by well-marked systems of drainage. It has an elevation of about 1,000 feet above sea level at the east and about 1,600 feet at the west, showing an average eastward slope of about 5.5 feet to the mile. The valleys are relatively wide and are bounded by abrupt escarpments within which the rivers flow in broad, shallow channels. During stages of high water the channels may be filled from side to side, but in dry seasons the streams may shrink to the dimensions of brooks and may wind about through the sands of the wide flood plain.

Extending through Shackelford, Throckmorton, and Baylor counties, from Albany north to the vicinity of Harrold, is a series of rock terraces along which the surface descends in a succession of escarpments 150 to 250 feet in height. These scarps mark the outcropping edges of limestone strata which constitute a prominent feature of the Wichita formation toward the south. Scattered over the plain surface in the western part of the area are many eminences rising from 100 to 200 feet above the general level; they are remnants of an older plain surface, the main portion of which lies to the west of the area.

Owing to the change in the character of the formations in the terrace belt in their northward extensions, the contrast in relief that is notable in the western and eastern portions of the region becomes less well defined in the northern portion and appears only in the increase of gradient in the surface level, as shown, for example, in the profile of the Fort Worth & Denver City Railway.

The plain lying to the east of the terrace belt is moderately dissected by the streams and their tributaries, but the relief on the whole is not so marked as in the higher surfaces on the west; in general the stream valleys are wider and shallower and the interstream areas more worn and rounded. Instead, therefore, of level interstream areas trenched by narrow and deep channels, as in the western part of the region, the eastern part has an irregular rolling surface of moderate relief. The explanation of these physiographic features is to be found in the effects of erosion as determined in large part apparently by the character of the rocks.

CLIMATE.

The region lies at the border of the semiarid portion of the United States. The mean annual rainfall ranges between 32 inches in the eastern and 23 inches in the western part of the region. The mean annual temperature is 64° F. in the eastern part and 60° F. in the western part.

The line of 20 inches of annual rainfall, which is the approximate limit of agriculture without irrigation, follows closely the foot of the Llano Estacado, about 60 miles west of the region here discussed. The average annual rainfall in the Wichita region is 29 inches. In the eastern half of the region the average is nearly 31 inches; in the western half it is about 26.5 inches. The westernmost tier of counties, Hardeman, Foard, Knox, and Haskell, have an average of 25 inches. The maximum precipitation occurs in the easternmost counties, Montague having 35 inches, Clay 32 inches, and Jack 33 inches. The records show in general a regular decrease in rainfall from the east toward the west, but Wichita County departs from the rule in having an average fall of only 25 inches, which is less than that of any of its adjoining counties—Wilbarger and Baylor on the west having 28 inches each, Archer on the south 30 inches, and Clay on the east 32 inches. The rainfall in this portion of the State comes mainly from the Gulf of Mexico and descends most abundantly in the winter.

SURFACE WATERS.

The drainage of the region is toward the east and southeast, in the direction of the general slope. The northern half is drained by tributaries of Red River, chief of which are Wichita, Little Wichita, and Pease rivers. The southwestern portion is drained by the Brazos through its two main tributaries—Salt and Clear forks—and the southeastern portion is drained by the West Fork of Trinity River. Only the large streams have permanent supplies of water, and in dry weather even these dwindle to mere brooks.

The unindurated character of the formations over considerable portions of the district favors rapid erosion during times of freshet and the larger streams are choked by the abundance of material supplied to them by their tributaries. They partake, therefore, of the nature of overloaded streams. Except in times of freshet the bottoms of the wide channels are covered with sand bars, and much of the water sinks below the surface. Owing to the treacherous character of these beds of sand, the fording of the streams often becomes a matter of considerable difficulty and even of danger.

Interesting examples of the physiographic development of valleys are presented in the streams of the region, especially by the Brazos and its tributaries, Salt and Clear forks. Tarr [1] has called attention to the superimposed character of the drainage of the region and to the differences in the work accomplished by the Brazos and the Colorado. He remarks that the Brazos, owing to the accidental selection of a region of softer rocks, has had the advantage in the struggle for drainage territory and has been enabled "to push the divide close up to the Colorado in territory which under more favorable circumstances should belong to the latter stream." The general course of the Brazos and its tributaries has been selected without reference to the structural character of the beds upon which it flows; nevertheless, the effect of variations in the hardness of the rocks is clearly registered in the differences in the work accomplished by the streams in the different parts of their courses. Both the Clear Fork, from the point

[1] Tarr, R. S., Superimposition of the drainage in central Texas: Am. Jour. Sci., 3d ser., vol. 40, 1890, pp. 359–362.

where it enters Shackelford County to its junction with the main stream, and the Brazos itself, to and beyond the point where it leaves the region, flow with serpentine courses in comparatively narrow valleys with more or less prominent rock escarpments. In this portion of its course the Brazos has been working upon a series of rocks in which hard limestones are conspicuous. On the other hand, the Salt Fork flows throughout most of its course upon softer beds in which it has excavated a valley much wider than that of the Clear Fork or that of the main stream below the junction. The serpentine course so characteristic of the Clear Fork and of portions of the Brazos is not a feature of the Salt Fork. West of Seymour the stream flows in a valley 2 to 4 miles in width which has been excavated to a depth of 50 to 60 feet below the general plain level. An important stage in its physiographic history is recorded in the remnants of a terrace which occurs about 25 feet above the present flood plain. At Seymour the river crosses a belt of limestone and for several miles is confined within a rock-walled valley not exceeding a mile in width. After passing this obstruction the valley again widens to 4 or 5 miles. The 25-foot terrace probably finds its explanation in the obstruction at Seymour, but their relation has yet to be determined.

DEEP WATERS.

Occurrence.—The water which permeates the rocks has its source in the rainfall. It does not come wholly nor, it may be, mainly from the local precipitation, but may be derived from some far-distant region where the rocks come to the surface and form catchment areas for the rain. This is especially the case where deep-lying rocks are overlain by impervious strata which effectually prevent the water falling locally from finding its way into the strata below. Shallow wells derive their supplies from the rainfall of the immediate locality or from closely adjacent regions.

The upper surface of the ground water, called the water table, conforms in a general way to the surface of the ground, being higher under elevated areas than under valleys. The depth to the water level is, however, generally greater under the hills than under the valleys. Where the streams have cut their valleys to the level of the water table, springs and seeps abound along the valley sides. The fact that the water obtained from shallow wells comes from the surface suggests the dangers involved in their use, especially where they are most liable to contamination, as in towns and cities. Many people suppose that any contaminating elements absorbed at the surface by the water will be soon removed in its course through the ground, but this is not invariably the case. Some deleterious substances go into solution and can not then be removed by filtration, and certain injurious microbes sometimes present along with harmless ones in the soil waters may find their way for long distances underground. The waters obtained from deeper sources are rarely subject to surface contamination.

Relation to rock structure.—The distribution of underground waters depends on the character and the arrangement or geologic structure of the rocks. A knowledge of the geology of the region is therefore necessary in order to understand the underground water conditions. Rocks which have had their origin as sediments at the bottom of some body of water are arranged in a succession of layers, varying according to the character and abundance of the materials supplied and the conditions under which they were deposited. Normally the different strata would lie in regular succession, the oldest being at the bottom and the youngest at the top. The strata were not laid down in a perfectly horizontal position and, moreover, in most places they have been somewhat tilted since they were deposited. In view of this inclination of the beds and of the fact that erosion has modified the surface of the land, each stratum is likely to make its appearance at the surface somewhere, under conditions determined by the character and thickness of the rock bed, the dip of the strata, and the surface relief. A rock sheet, therefore, consists of two related parts, the outcrop, or exposed portion, and the embed, or portion which is concealed. As a rule the embed is by far the larger part of the stratum. In a water-bearing stratum the outcrop is its main catchment area and the embed constitutes the storage reservoir.

The capacity of rocks for absorbing water varies greatly. Rocks of open texture, like sands, sandstones, and gravels, imbibe water freely. Rocks of close texture may be nearly or quite impervious. Thus slate, marble, and granite imbibe very little water unless they are fractured. Limestones may become water bearing through the development of spaces and channels by solution. The conditions which determine the availability of deep-lying water are (1) the presence of a water-bearing stratum capped by an impervious stratum whereby the water is prevented from being dissipated into the adjoining beds; (2) a sufficient outcrop or catchment area in a region of sufficient rainfall to furnish a water supply; (3) an inclination of the water-bearing bed not so great as to carry it too quickly beyond the reach of the drill; (4) the absence of openings which will permit the escape of the water at a level below the well; (5) such relation between the elevation of the outcrop and that of the top of the well that hydrostatic pressure will bring the water to the surface or so near to it as to be economically available by pumping.

Quality of underground waters.—All underground waters are mineralized to a greater or less extent. The composition of the waters is determined by the character of the rocks through which they pass and the kind and proportion of mineral ingredients which they take into solution. Moreover the quantity of mineral matter taken into solution is likely to be greater in proportion to the distance from the point of entry. Hence water from shallow wells in the catchment area of formations which contain much soluble mineral matter may be fairly good, while that from the same formations under cover may be too highly charged with deleterious mineral matter to be used.

To yield abundant and satisfactory supplies of water the water-bearing stratum should be sufficiently porous to permit the free movement of the water and should contain only a small proportion of readily soluble mineral compounds which render the water bad for use. The most abundant of such substances in this area are the carbonates and sulphates of calcium, magnesium, and sodium and the chloride of sodium, or common salt. The prevailing type of water from the Permian beds is highly charged with sulphates, carbonates, calcium, magnesium, and sodium, and the water of the Carboniferous rocks is for the most part strongly impregnated with salt. The mineral ingredients of rocks are not uniformly distributed, and hence wells at different places in the same formation may yield water very unlike in quality. For example, at Graham and Jacksboro wells in close proximity to each other yield water that is wholly unlike in quality. (See analyses Nos. 2 and 3, p. 77.)

Fluctuating wells.—According to G. A. Stafford, of Belcherville, who has put down a number of wells in Montague County, water in many wells in the county whose depth is from 60 to 120 feet is lowered when the wind blows from the north. On the other hand, it is said that the water in some shallow wells is lower when the wind is from the south. The probable explanation is that the ground-water level is affected by changes in barometric pressure. With decrease in barometric pressure the water will rise, and with increase in pressure it will descend. Such wells are often called "weather wells," from the fact that they indicate the change in weather which is also indicated by the change in barometric pressure. With this phenomenon is sometimes associated a clouding or boiling of the water. This also is probably due to change in barometric pressure, which affects the water surface over a large area and causes a movement whereby the water gathers up the fine clayey material in the sandrock and thus becomes cloudy. In some wells there is a daily fluctuation, the rising and falling accompanying the daily change in pressure, or it may be the changes of temperature. The fine material in the water of this region contains a considerable percentage of iron oxide, and cloudy water taken from a well requires a considerable time to settle. This appearance is sometimes taken as an indication of oil, and some persons even assert that the water smells of oil. Although it is not improbable that oil exists in small quantities in the rocks of this region, it is the opinion of the writer that the supposed indications of oil are due to the presence of the iron, a very small quantity of which is sufficient to give the appearance described. In favor of this conclusion is the statement of Mr. Stafford that the water, after standing for some time, tends to clear at the top by settling, whereas if oil were present it would remain at the top.

GEOLOGIC FORMATIONS AND THEIR WATER-BEARING CAPACITY.

GENERAL RELATIONS.

All the rocks of this region are of sedimentary origin, except possibly a deposit at Red Bluff, near Vernon, which is said to be volcanic ash.[1] Except in the Cretaceous area in the eastern part of Montague County the basement rocks are all of Carboniferous age (Pennsylvanian or Permian). They consist of limestones, clays, shales, sandstones, and conglomerates. The shales and sandstones in many places are soft and yield readily to erosive agencies. The limestones are harder and more resistant and appear in outcropping ledges and rock terraces, which in some localities constitute notable features of the topography.

The Carboniferous strata have a general west-northwest dip of about 25 to 30 feet to the mile, though locally they are horizontal or dip in the opposite direction. No faulting or extensive folding was observed within the region. That the formations have suffered pronounced erosion is shown by the present configuration of the surface and by the indications that in former times the region was covered to a considerable depth by rocks of which only traces remain. Triassic and Jurassic beds are not known in this region, though formations of Triassic age doubtless supplied much of the material composing the Pleistocene gravel beds in the Seymour formation. Hill[2] and Tarr[3] have shown the former extension of Cretaceous rocks over large areas in central Texas from which they have been removed, though Comstock[4] takes an opposite view with reference to the "central mineral region." The only Cretaceous rocks in place within the region here considered are in the eastern part of Montague County, which belongs to the main Cretaceous area lying farther east. In the region south and west of this area remnants of Cretaceous formations occur as isolated knobs and buttes, which indicate the former extension of the Cretaceous over the Carboniferous area as far north as Wichita River and possibly into Oklahoma. Cum-

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[1] Soil survey of the Vernon area: Field Operations Bur. Soils for 1902, U. S. Dept. Agr., p. 369.

[2] Hill, R. T., Geography and geology of the Black and Grand prairies, Texas: Twenty-first Ann. Rept. U. S. Geol. Survey, pt. 7, 1901, p. 108.

[3] Tarr, R. S., Am. Geologist, vol. 9, 1892, pp. 169–178.

[4] Comstock, T. B., Second Ann. Rept. Texas Geol. Survey, 1890, pp. 663–664.

mins [1] is of the opinion that the Cretaceous extended in a narrow belt across the southern border of the Carboniferous, but not as far north as Wichita River. The presence of worn Cretaceous fossils in abundance in the surficial gravels and sands in Haskell and Knox counties indicates the former extension of Cretaceous beds far beyond their present limits. The Tertiary appears to be unrepresented in this region, but the character of part of the material composing the Seymour formation (Pleistocene) suggests that some of it was derived from Tertiary beds whose remnants outcrop in the escarpment of the Llano Estacado to the west of this region. In the valley of the Wichita, in Wichita County, there are some gravels which may possibly be of Tertiary age. Prior to the Cretaceous period the Carboniferous strata suffered great erosion, and upon the beveled edges thus produced the Cretaceous sediments were laid down. As the Cretaceous beds dip toward the southeast, the rainfall in the Cretaceous area of this region is drained away in the same direction through the porous beds. The principal catchment area for the Carboniferous terranes probably lies west of the boundary of the Cretaceous formations.

As the surface of the land rises to the west, in the direction of the dip, the prospects of obtaining flowing wells are poor except in localities near the outcrop of the water-bearing beds where erosion has locally lowered the surface level below that of the artesian heads. Such localities exist in the southeastern part of Stephens County, the western part of Jack County, and the western part of Montague County.

CARBONIFEROUS SYSTEM.

PENNSYLVANIAN SERIES.

CLASSIFICATION.

The undoubted Pennsylvanian rocks of the region are divided into three formations, the division being based on differences in lithologic and stratigraphic character. From above downward these formations are as follows:

Section of Pennsylvanian formations in Wichita region, Texas.

	Feet.
Cisco formation (clay, shale, conglomerate, and sandstone with some limestone and coal)	800
Canyon formation (alternating beds of limestone and clay with some sandstone and conglomerate)	800
Strawn formation (alternating beds of sandstone and clay with some conglomerate and shale; the lower thousand feet consists of blue and black clay locally containing beds of limestone, sandstone, or sandy shale, and a coal seam at top)	1, 900

[1] Cummins, W. F., Second Ann. Rept. Texas Geol. Survey, 1890, pp. 370–371.

STRAWN FORMATION.

GEOLOGY.

The upper three-fourths of the Strawn formation as here defined consists of sandstones alternating with beds of blue clay. It contain some conglomerates and shales, but they are not abundant, and limestones are rare. The sandstones are usually massive, of a light gray color, which changes very little on exposure, and they afford a very good building stone. The rock consists largely of angular grains of white quartz with some red grains and some mica. It contains a little cement, which is mostly siliceous, though calcareous and argillaceous materials occur in some of the beds. The thickness of these upper beds is estimated to be 800 to 900 feet in this region. They thicken toward the south, in central Texas, where they are said to have a thickness of 3,000 feet. The lower portion, about 1,000 feet thick, was originally called by Cummins[1] the Millsap division, but these beds were later included by him in the Strawn formation, from which, he states, they are inseparable to the south. It is his later definitions of the Strawn formation that are here recognized, and "Millsap" is abandoned.[2] These lower beds have a comparatively small outcrop, being largely concealed by an overlap of the Cretaceous to the east. This overlap makes a very definite determination of their thickness impossible, but it is estimated at about 1,000 feet. The beds appear at the surface only in the extreme southeastern part of the region, the westerly dip carrying them below the surface in the remaining portion. These lower beds consist largely of blue and black clay, with a few beds of shale, sandstone, and limestone. The limestones are compact and hard and according to Cummins have been used for macadam on the streets of Dallas. Toward the south these beds, if present, are completely concealed from view by the Cretaceous. They reappear in the northern part of Erath County. According to Cummins[3] a deep well at Thurber passed through 1,000 feet of blue clay, with some sandstones and limestones, belonging to this division. At the top of the beds is the coal seam which Cummins designates No. 1.

WATER RESOURCES.

Portions of the lower beds of the Strawn formation are porous and water bearing and are reported to contain gas in some localities. At Gordon and Thurber gas and water are found in this part of the

[1] Cummins, W. F., Second Ann. Rept. Texas Geol. Survey, 1890, pp. 372–373.

[2] Prof. Cummins, being asked for his opinion regarding the usefulness of the term "Millsap," writes as follows, under date of November 18, 1912: "It was my intention to abandon the name 'Millsap' and include the strata in the Strawn division. In all my publications after the first and second reports the name Millsap was not used. I thought it the better plan. The beds referred to the Millsap in the northern field could not be separated from the Strawn in the southern field. The name Millsap for the Texas field ought to be abandoned."

[3] Cummins, W. F., Second Ann. Rept. Texas Geol. Survey, 1890, p. 374.

formation. The water contains too much salt to be of general use, and hence these beds can not be utilized as a source of water supply. The sandstones in the upper part of the formation likewise contain an abundance of water, and in the area of its outcrop water is obtained in shallow wells at depths ranging from 15 to 50 feet. Several flowing wells in Palo Pinto County derive their supply from this formation. In one of these, at Gordon, in the southern part of the county,[1] the water-bearing stratum was found at a depth of 485 feet. The well is reported to have a flow of 1 gallon a minute of salt water accompanied by some gas. Another well, 4 miles north of Gordon, is 498 feet deep and has approximately the same flow of water.

It is not probable that in their extension under cover westward these beds would undergo any change in character that would improve the quality of the water, and hence there is little likelihood that wells sunk to this horizon would furnish potable supplies.

CANYON FORMATION.

GEOLOGY.

The Canyon formation consists of alternating beds of blue limestones and blue clays, with some sandstones and conglomerates. The limestones for the most part are massively bedded and constitute the distinguishing feature of the formation. Many of the beds are rough and irregular in texture and unsuited for building purposes, but some ledges furnish a stone of good quality. The few sandstones are more or less friable and porous. The formation has a thickness of about 800 feet. It outcrops in a narrow belt extending northeastward across Jack County. The west boundary of the formation enters at the southwest corner of the county, passes northeastward through Jacksboro and beyond, and thence curves eastward and meets the west boundary of the overlapping Cretaceous in the northern part of Wise County.

A general section of the upper part of the Canyon formation follows:

Section of upper part of Canyon formation.

	Feet.
1. Sandstones and clays (Cisco formation).	
2. Limestone	20–25
3. Sands, sandstones, and conglomerates	100±
4. Limestone, massive, with thin beds of sand	20
5. Shales	80–125
6. Sandstones with water and in places oil	10–20
7. Shales	15–20
8. Limestone	35

[1] S. Ex. Doc. No. 222, 51st Cong., 1st sess., 1890, p. 257.

WATER RESOURCES.

Limestone rocks as a rule are too dense to permit the free movement of water, but some limestones are sufficiently porous to absorb it in considerable quantities. Limestones are usually intersected by fractures, however, which offer passageways, and these the water by its solvent action enlarges, the rate at which enlargement takes place being determined by the amount of water, its character—especially as to the carbon dioxide contained in it—and the solubility of the rock. Underground channels and caverns are thus a characteristic feature of limestone regions. Near the top of the Canyon formation is a series of massively bedded limestones whose outcrop extends across the eastern part of Stephens County and the western part of Palo Pinto County, continues northeastward past Finis and Jacksboro, and disappears beneath overlying formations near the boundary between Jack and Wise counties.

In the area where the Canyon formation crops out springs are numerous and water can generally be found in shallow wells. The water is found chiefly in the sandstone beds. The second of these from the top (No. 3 in the section) appears at the surface on Little Caddo Creek and at Finis and Jacksboro. Most of the wells, however, derive their supplies from the sands (No. 6) below the second limestone. This is the horizon of the water-bearing stratum in the wells at Jacksboro. The character of the water differs greatly in wells in close proximity. In many of the wells good water is found, but not far away from a well of good water may be one in which the water is wholly unfit for use. To the west the Canyon formation is overlain by the Cisco formation. The depth of the beds increases in that direction because of the dip of the strata and the rise in the land surface. At Breckenridge, in Stephens County, the water-bearing beds of the Canyon formation can be reached at about 250 to 300 feet, and at the west boundary of Stephens County at about 1,000 feet. In neither place are flowing wells likely to be obtained, though at Breckenridge the water would doubtless rise within 50 or 100 feet of the surface.

With increasing distance from the outcrop the water tends to become more highly mineralized, and it is doubtful if good water can be obtained from these beds at distances greater than 10 or 15 miles from the outcrop.

CISCO FORMATION.

GEOLOGY.

With the close of Canyon time the clear waters of that epoch gave place to shoal water and swamps, with a corresponding change in the character of the sedimentation—limestones becoming less conspicuous;

conglomerates, sandstones, and sandy clays increasing in importance; and coal being formed here and there. These beds constitute the Cisco formation. The limestones are usually hard and irregular in texture and occur in thin isolated beds, chiefly in the lower and upper parts of the formation. About 200 to 250 feet above the base is a bed of coal called the Chaffin bed, which outcrops in the Colorado Valley, to the south, but is not found in the region here described. Near the top of the formation thin seams of coal and an abundance of plant impressions occur in bluish and gray sandy clays and sandstones, along with a few thin beds of limestone. The main seam of coal, however, designated No. 7 in the Texas reports, is somewhat above the middle of the formation. This coal is usually from 30 to 40 inches thick, with several partings of clay or shale. The outcrops of this bed of coal appear in a belt which enters Young County 8 or 9 miles east of the southwest corner, extends northward past old Fort Belknap, bears eastward to the northeast corner of the county, thence extends eastward across the north end of Jack County, and makes its last appearance in the vicinity of Bowie, Montague County. Near Belknap it is underlain by 25 to 30 feet of shaly sandstone, beneath which is a bed of limestone underlain by another seam of coal 12 to 15 inches in thickness. This seam appears to be local, as it has not been found elsewhere.

A feature of importance in the Cisco formation and one which it shares with the next succeeding formation is the series of changes observed as the formation is traced northward along the strike. These changes relate both to variation in lithologic character and to thickness of beds. In the Colorado Valley, interstratified with the sandstones, clays, and conglomerates, are six or more beds of limestone, each from 5 to 25 feet thick and all aggregating a thickness of 100 to 150 feet. In the southern part of the Brazos Valley the calcareous divisions are only about half as thick as they are farther south, and the clays show a corresponding increase in thickness. In Young County the calcareous material diminishes northward at an increased rate until at the northern boundary of the county the limestones have practically disappeared, and beyond that point they are represented apparently by irregular nodular masses of earthy limestone in a matrix of clay. With the thinning out of the limestones the shales and sandstones increase in thickness. In Stephens County and farther south the shales are prevailingly blue and the sandstones gray. Red beds are dispersed sparingly through the formation. The blues gradually give place to reds until in the vicinity of Red River the red color dominates. In this part of the region the rocks consist, for the most part, of red sandstones, clays, and sandy shales, with a few beds of blue shale and bluish to grayish white sandstones. Limestones are conspicuously absent.

The thickness of the Cisco formation in the southern part of the region is estimated to be 700 to 800 feet. As to its thickness in the "Red Beds" area no very definite statement can be made. The transitional character of the sediments offers a serious obstacle to the determination of dip. In the main the formations appear to dip slightly west-northwest. Locally the dip may reach 40 feet or more to the mile, but for the formation in general it is believed that 25 to 30 feet to the mile is a fair approximation for both these beds and the overlying beds of the "Red Beds" area. Toward the south the strata have a slightly steeper dip.[1]

The area underlain by the Cisco is about 25 miles wide at the southern boundary of Young County, but widens somewhat to the northeast. In the southern area the boundaries are clearly defined by the prominent ledges of limestone that mark the top of the Canyon formation on the east and those at the base of the Wichita formation on the west. Owing to the changes that take place in the formation toward the north, the boundaries are not so clearly determinable in that part of the region. In northern Wise County and in Montague County the Cisco is in part covered by overlap of the Cretaceous. As the conditions of sedimentation were apparently much the same at the close of the Cisco epoch and the beginning of the Wichita epoch, no clear line of division can be made out between these formations in this area. It is to be understood, therefore, that north of Young County the boundary as indicated on the map is an approximation only. In Stephens and Young counties the Cisco is in general highly fossiliferous.

At Graham Salt Creek flows at the base of an escarpment which gave the following section:

Section on west bank of Salt Creek, Graham, Tex.

	Feet.
1. Coarse conglomerate of siliceous pebbles in a matrix of sand; locally the rock varies to a white or ferruginous sandstone; forms top of prominent ridge	10
2. Blue shale, highly fossiliferous	50
3. Layer of hard blue fossiliferous limestone	1¼
4. Dark-blue shale, darker and carbonaceous below; a layer of sandy shale 3 feet thick 10 feet above the base	50
5. Blue arenaceous shales and soft shaly sandstones	15
6. Bluish-white sandstone, irregularly indurated; bedding irregular and surface uneven; more or less conglomeratic and containing numerous impressions of plants, also iron concretions of brown iron ore; in places this bed resembles the upper conglomerate (1); exposed	5

[1] In a study of the oil and gas fields of Wichita and Clay counties, made for the Texas Bureau of Economic Geology since this report was written, J. A. Udden (Bull. Univ. Texas No. 246, 1912, pp. 61, 62) records a series of detailed observations on the attitude of the strata, from which he concludes that the strata lie essentially horizontal in an east-west line but are affected by minor flexures constituting shallow and wide anticlines and synclines trending east-southeast to west-northwest.

The shale underlying the upper bed of conglomerate is filled with excellently preserved fossils which strew the surface of the weathered slopes. The following is a list of the forms collected, a number of which are new. They were identified by George H. Girty:

Cyathaxonia n. sp.
Cyathaxonia n. sp. var.
Lithostrotion ? sp.
Syringopora ? sp.
Polypora 2 sp.
Fenestella sp.
Synocladia biserialis.
Fistulipora sp.
Rhombopora lepidodendroides.
Crania sp.
Lingulidiscina sp.
Derbya sp.
Chonetes n. sp. aff. geinitzianus.
Productus semireticulatus.
Productus nebraskensis.
Marginifera lasallensis.
Marginifera wabashensis.
Spirifer cameratus.
Ambocœlia planoconvexa.
Hustedia mormoni.
Pugnax osagensis.
Pugnax n. sp.
Nucula ventricosa.
Leda bellistriata.
Conocardium sp.
Deltopecten sp.
Solenomya sp.
Edmondia gibbosa.
Astartella vera.
Patellostium montfortianum.
Bellerophon percarinatus.
Euphemus nodicarinatus.
Trepospira sphærulata.
Pleurotomaria conoformis?
Pleurotomaria subconstricta?
Pleurotomaria 2 sp.
Meekospira sp.
Meekospira ? sp.
Sphærodoma sp.
Euomphalus catilloides.
Orthoceras rushense.
Chonetes sp.
Crinoidal fragments.

Cummins [1] made a section in the same locality, which is practically identical with the section given above, though arranged in reverse order. The following is a list of the fossils reported by him [2] from bed No. 2:

Allorisma subcuneata.
Bellerophon percarinatus.
Bellerophon carbonarius.
Euomphalus rugosus.
Lophophyllum proliferum.
Pinna peracuta.
Pleurotomaria sphærulata.
Pleurotomaria tabulata.
Productus cora.
Productus costatus.
Productus longispinus.
Productus nebrascensis.
Schizodus wheeleri.
Spirifer cameratus.
Spirifer lineatus.
Spiriferina kentuckyensis.
Zaphrentis spinulifera.
Hemipronites crassus.
Nucula ventricosa.
Rhynchonella uta?
Myalina subquadrata.
Chætetes milleporaceus.
Orthoceras rushensis.
Conocardium obliquum.
Aviculopecten occidentalis.

Beds of red clay make their appearance south of Young County, but they increase notably to the north, especially in the upper part of the formation along with the diminution of the limestones, and they constitute the dominant feature of the formation in eastern Clay and western Montague counties.

[1] Cummins, W. F., Second Ann. Rept. Texas Geol. Survey, 1890, p. 378. [2] Idem, p. 362.

WATER RESOURCES.

Most of the sandstones of the Cisco formation are water bearing in varying degree, but there appear to be few persistent water-bearing strata. An exception is a sand in the lower part of the formation, which is the source of supply for a large number of wells in eastern Stephens and Young counties and western Jack County. The flowing wells at Wayland, in Stephens County, and those west and northwest of Jacksboro probably draw their supplies from this sand. In some wells of this area water is found in a limestone associated with the sand.

The water from surface wells in the lower beds of the Cisco is in general good, though in some wells it is strongly mineralized. The water from the higher beds is usually too strongly mineralized for general use, but there are some exceptions to the rule. The contrast in the character of the water from wells in this part of the formation is shown by the analyses of water of wells at Graham, given on page 77. On the west the Cisco formation is overlain by the Wichita formation, and the basal water-bearing beds can be reached only at considerable depths. In the vicinity of Albany, in Shackelford County, the depth to these beds is estimated to be 1,300 to 1,400 feet. Moreover, with increasing distance under cover, the water of these beds is probably too highly mineralized for use.

PERMIAN SERIES.

CLASSIFICATION.

Although much has been written concerning the beds between the Cisco formation and the Triassic beds which underlie the "Staked Plains," much detailed stratigraphic work remains to be done in this region before authoritative statements can be made about the classification of these beds. On the evidence of fossil remains found chiefly in the lower beds in Baylor and Archer counties, these strata are now assigned by most geologists to the Permian. These rocks as they exist in the Wichita region were subdivided by Cummins [1] into the Wichita, Clear Fork, and Double Mountain formations. The lowest formation, the Wichita, consisting mainly of red clays and sandstones, is seemingly a near-shore or delta deposit, and in it are found the remains of reptiles and plants of Permian age. Interstratified with the clays and sandstones in the upper part of the formation are beds of limestone containing marine invertebrates, of which a large proportion are Pennsylvanian types and few, if any, are considered characteristic of the Permian of Europe. South of Baylor County the Clear Fork formation rests conformably upon marine strata, consisting mainly of blue clays and shales, including considerable thicknesses

[1] Cummins, W. F., Second Ann. Rept. Texas Geol. Survey, 1890, pp. 400-424.

of limestone containing marine invertebrates. Neither reptilian nor plant remains have been reported from these beds. The Pennsylvanian aspect of the fauna led to the assignment of these beds, under the name "Albany," to the Pennsylvanian in the earlier reports, although they were recognized by some as being possibly of Permian age.[1]

Subsequently Cummins[2] asserted the equivalency of the Wichita and the "Albany" formations and recommended the abandonment of the name "Albany." Adams[3] corroborated Cummins's conclusion as to the equivalency of the beds included in the Wichita and "Albany" formations, but recommended the abandonment of all the names, Wichita, Clear Fork, and Double Mountain, as "having no stratigraphic significance." In a paper by the writer and others[4] Cummins's conclusion as to the identity of the "Albany" with the Wichita and likewise the Permian age of the formation is confirmed. It is shown also that the definition of the Wichita as a formation is sufficiently established to warrant the retention of the name, and that usage is followed in this report. It is to be noted, however, that some limestones in Baylor County which Cummins regarded as belonging to the Clear Fork are the equivalents of the upper beds of the "Albany" and are here included in the Wichita. The upper Permian beds included under the names Clear Fork and Double Mountain in the Texas reports have had very little study and no attempt has been made to determine a definite line of division between the two formations. In this report these beds are classed as undifferentiated Clear Fork and Double Mountain.

WICHITA FORMATION.

GEOLOGY.

Character.—The Wichita formation underlies practically the whole of Wichita, Baylor, Throckmorton, and Shackelford counties, a considerable part of Clay and Archer counties, and a small part of Young County. In Shackelford County it consists of blue clays and shales with thick beds of limestones which, on account of their greater resistance to erosion, crop out in a series of eastward-facing rock scarps. The limestones, which constitute about a third of the formation, are blue, gray, and yellowish and for the most part massively bedded. They are generally hard, semicrystalline to compact, but some beds are friable and chalky and others are rough and earthy in texture. Thick beds and thin and shaly beds alternate. The

[1] Drake, N. F., Fourth Ann. Rept. Texas Geol. Survey, 1893, p. 371. Tarr, R. S., Bull. Texas Geol. Survey No. 3, 1892, pp. 14-18.

[2] Cummins, W. F., Trans. Texas Acad. Sci., vol. 2, 1897, pp. 93-98.

[3] Adams, G. I., Bull. Geol. Soc. America, vol. 14, 1903, p. 198.

[4] Gordon, C. H., Girty, G. H., and White, David, The Wichita formation of northern Texas: Jour. Geology, vol. 19, 1911, pp. 110-134.

remainder of the formation consists of blue, gray, and black shales. The limestones contain an abundance of marine fossils, but well-preserved specimens are difficult to obtain.

Farther north there is a marked diminution in the proportion of calcareous sediments with a cor esponding increase in argillaceous and arenaceous materials. Some of the clay beds in Shackelford County are sandy, but toward the north the sandy sediments become more and more prominent, many of the layers taking on a red color. Red, white, and yellowish sandstone beds also make their appearance and constitute a marked feature of the formation in Archer and eastern Baylor counties. The red sediments increase in amount northward until in northern Throckmorton County and beyond the red color dominates in the formation.

Throughout the northern area the clays are red or red mottled with bluish-white and drab colors. The red clays contain an abundance of nodular concretions of irregular shape, ranging from those the size of a pea to masses 4 or 5 inches in diameter. Many are elongated or subspherical, and some are flattened and stand vertically in the clay, suggesting their origin from the filling of fissures. They consist of clay, iron, and lime, and some of them are either hollow or have their interiors filled with calcareous clay. Here and there is a bed that consists of rounded lumps of hardened clay cemented together by ferruginous matter, which Cummins called a "peculiar conglomerate." It is suggested that this deposit may have had its origin in the breaking up of a thin bed of clay soon after deposition, by the action of running water or waves.[1]

Fossils.—Traces of plants appear locally in the sandstones, and in one place the large frond of a fern was obtained. David White, of the United States Geological Survey, has collected a considerable amount of plant material from these beds at two localities, one in Cassil Hollow, 2½ miles south of Fulda station, on the Wichita Valley Railway, and the other at the breaks of the Little Wichita, 4 miles southeast of that place. These collections include the following forms as provisionally identified. The species listed in italics are characteristic of the Permian.

Cassil Hollow:
- Pecopteris arborescens.
- Pecopteris hemitelioides.
- Pecopteris densifolia.
- Pecopteris grandifolia.
- Pecopteris mertensioides.
- Gigantopteris sp. (cf. nicotianifolia).
- Neuropteris (cf. lindahli).
- Aphlebia sp.
- *Tæniopteris multinervis.*

Cassil Hollow—Continued.
- *Annularia splicata.*
- Sphenophyllum? sp.
- *Sigillariostrobus hastatus.*
- *Walchia schneideri?*
- *Gomphostrobus bifidus.*
- Cardiocarpon n. sp.
- Carpolithes sp.
- Pelecypods.
- Estheria and fish scales.

[1] Merrill, G. P., Rocks, rock weathering, and soils, pp. 33, 34. Gardner, J. H., Jour. Geology, vol. 16, 1908, pp. 452-458.

Breaks of Little Wichita:
- Pecopteris hemitelioides.
- Pecopteris grandifolia.
- Pecopteris candolleana.
- Pecopteris tenuinervis.
- Diplothmema? sp.
- *Odontopteris fischeri?*
- *Odontopteris neuropteroides.*
- Neuropteris cordata.
- *Tæniopteris coriacea?*
- *Tæniopteris abnormis.*
- *Tæniopteris n. sp.*
- *Sphenophyllum obovatum.*

Breaks of Little Wichita—Continued.
- Sigillaria sp. (leaf).
- *Gomphostrobus? sp.*
- Cordaites principalis.
- *Poacordaites cf. tenuifolius.*
- *Walchia piniformis.*
- *Aspidiopsis sp.*
- *Araucarites n. sp.*
- Cardiocarpon n. sp.
- Insect wings.
- Estheria.
- Anthracosia.
- Ostracoda and fish scales.

At Cassil Hollow the plants occur in a bed of blue and yellow laminated clay and sandy shales which crops out on the west side of a small tributary flowing into the north branch of Little Wichita River from the south. The following section was obtained at this place:

Section of Wichita formation at Cassil Hollow, 2½ miles south of Fulda, Tex.

	Feet.
1. Sandstones, thin bedded, shaly, with a fine exhibition of ripple marks. Represents the top of the section and grades into No. 2.	6
2. Blue and yellow laminated clay and sandy shale, grading horizontally into white shaly sandstones same as No. 1. The plants were found in a thin shale stratum near the middle of this division	6½
3. Hard bluish limestone which weathers to a brown. Apparently the equivalent of a limestone which outcrops on the Wichita nearly due north from this locality at the Bar X ranch. Contains an abundance of fragments of vertebrate remains, but all in such a comminuted condition as to be indeterminable	2
4. Blue clay shales	3
5. Red clay shales; same as No. 4, except in color	4
6. Gray sandy shales and sandstones to bottom of ravine	15
	36½

The limestone (No. 3) is made up of several layers, some of which are composed largely of fragmental remains of vertebrates, including plates, spines, fish teeth, etc. The stratification of the argillaceous and arenaceous sediments is very irregular, the sandstones and shales grading into each other both vertically and horizontally. Moreover, there is a monotonous likeness in both the sandstones and the shales throughout the area, which in the absence of persistent, clearly recognizable strata renders the correlation of beds, except within very narrow limits, practically impossible.

Some of the most prominent limestone divisions of the southern area persist, although in diminished thickness, as far north as Red River, perhaps farther. The limestones so well developed on Clear Creek, in the southwestern part of Throckmorton County, extend northward through Seymour, are crossed by Wichita River about 3 miles east of the Seymour-Vernon road, and are last seen on Beaver Creek, in the eastern part of Wilbarger County. The transition of limestone into sandstone is well marked in an exposure in the bluffs of the Salt Fork of Brazos River, about a mile west of Spring Creek post office, in the northwest corner of Young County. A bed of limestone 3 feet thick and an overlying bed of blue shales 5 feet thick, both filled with fossils (chiefly *Myalina permiana*), are replaced within a distance of 200 yards by a light-colored cross-bedded calcareous sandstone having a maximum thickness of 15 feet. The transition is rather abrupt in appearance, but the sandstone contains much lime and also some fossils. Farther along the limestone reappears as before.

The limestones of the Wichita formation are for the most part highly fossiliferous, though in many of the beds good specimens are hard to obtain. A list of the invertebrate fossils obtained from these beds has been published elsewhere.[1] Collections of vertebrate remains have been made at various times in Archer and Baylor counties. A list of localities where the earlier collections were made is given by Cummins.[2] In many places the remains are found at the surface, having weathered out of the clays or lime beds. Certain strata, called the "bone beds," have furnished most of the material. A chalky friable limestone exposed in a railway cut just west of Mabelle station, in Baylor County, is filled with fragments of vertebrate remains allied to Eryops, mostly indeterminable. In a recent paper Williston[3] announces the discovery of a new genus and new species of amphibian allied to Eryops, which he names *Trematops milleri*. This specimen is said to have been found on Craddock's ranch, near Seymour. The figure of the skull given by Williston shows a close correspondence to one found by the writer in the friable limestone at the railway cut near Mabelle, which was unfortunately broken and in part lost before opportunity was given for identification. It seems probable that both came from nearly the same horizon.

Copper.—In places the bluish clays are copper bearing, but efforts to mine the deposits have not proved successful. The ore occurs in the form of small nodules in the clays and also as a replacement of pieces of wood. It is the copper oxide chiefly.

Oil.—Mention has been made of indications of the presence of oil in the Wichita formation in different localities. In 1907 the only producing field in the area was at Petrolia, in Clay County, where there were several producing wells. Later the Henrietta field, in the same county, was brought in. (See p. 47.) In a well put down for water

[1] Jour. Geology, vol. 19, 1911, pp. 131–134.
[2] Cummins, W. F., Jour. Geology, vol. 16, 1908, pp. 737–745.
[3] Williston, S. W., Jour. Geology, vol. 17, 1909, pp. 636–658.

at Electra a number of years ago by Mr. Waggoner oil was struck at about 600 feet. The well was extended to 1,790 feet. The water, most of which was found below 800 feet, rose within 15 feet of the top. The oil which covered the surface of the water was dipped out and used locally by the cattlemen, and also to burn, but no further attempt had been made to determine the existence of oil in commercial quantity. Most of the wells in this neighborhood show oil in small quantities. On January 17, 1911, the Producers Oil Co. brought in the second producing well on its No. 5 Waggoner tract, about 2 miles north of the town of Electra. This well yielded 50 barrels a day at a depth of 1,825 feet. From this time drilling was extremely active, particularly by the Producers Oil Co., the Clay County Oil Co., the Magnolia Co., and others. The oil is found in sands from 10 to 30 feet thick, lying at 580, 965, 1,035, and about 1,900 feet in depth. The wells yield from 50 to 1,200 barrels by natural flow. Natural-gas pressures are light, compared with those in the Petrolia and Henrietta pools. In September, 1911, the Electra field was credited with a production of 6,000 barrels a day.

A well put down in 1899 on the farm of Mr. Carmack, 1 mile northwest of Murray post office, in the southwestern part of Young County, struck gas at about 360 feet. In 1907 the escape from this well was sufficient to form a blaze from 1 to 2 feet high. As this well is located near the eastern border of the Wichita formation, it may be that the gas comes from the topmost beds of the Cisco formation.

Conditions of sedimentation.—The character of the sedimentation and the contents of the strata in the "Red Beds" area suggest that the region was a tidal flat or a low, swampy area subject to overflow and adjoining the open area which lay toward the south and west. This view is maintained by Case,[1] who states that "the whole formation seems to be very clearly the result of deposition, either in the form of a wide delta or in very shallow water." He adds, further, that "the remains which are found on or in the sand layers were evidently washed there by currents from a distant shore, and they are generally more or less imperfect, having been dispersed by the action of the current or by predatory animals, while those found in clay were evidently animals which mired down on wide mud flats or were drifted out on the surface of the stagnant lagoons."

The clays and the sandstones are separated in some places by unconformities which are considered by Case[2] to be the result of currents that eroded channels in the clay in which the sands were afterward deposited. They do not represent apparently any considerable time interval between the two deposits. Moreover, the conglomerates containing concretions of ferruginous clay are evidently

[1] Case, E. C., Bull. Am. Mus. Nat. Hist., vol. 23, 1907, pp. 659–664.
[2] Idem, p. 661.

additional indications of transitory currents in an ordinarily quiet lagoon or over the tidal flats of a wide delta.

The red sediments evidently had their source in the degradation of the Wichita Mountains, which lie directly to the north of this region, in Oklahoma. These mountains were uplifted during or at the close of the Pennsylvanian epoch and are now, together with their accompanying elevations on the east, the Arbuckle Mountains, partly buried in the sediments they have furnished.[1]

The fact that in this region, as shown by their outcrop toward the east and by the strata penetrated in deep wells, the upper beds of the Cisco formation consist of sediments corresponding in character to those of the Wichita formation, suggests that mud flats may have characterized the closing stages of the Pennsylvanian epoch in this region.

Thickness.—In Shackelford County the thickness of the Wichita formation is estimated to be 1,000 to 1,200 feet. Two-thirds or more of the formation consists of blue clays and shales. Farther south, in the vicinity of Colorado River, limestones constitute the major part of the formation. To the north from Shackelford County the calcareous sediments diminish, and before reaching the Oklahoma border they practically disappear. No reliable estimate can be made of the thickness of the formation in this part of the region, though it is probably not less than 1,500 feet.

WATER RESOURCES.

As shown in the foregoing description of the geology of the region, the stratigraphy of the Wichita formation in the southern or "Albany" area presents a marked contrast to that in the northern or typical Wichita area.

In the southern area there are limestones at several horizons, some massive and others thin bedded, alternating with blue clay and sandy shales and sandstones. Though the shale beds greatly exceed the limestones in thickness, the latter, owing to their hardness, resist erosion better, and hence are found capping the elevations and constituting a series of parallel benches or escarpments that may be traced for long distances from the northeast toward the southwest. About two-thirds of the formation in Shackelford County consists of blue and gray clay shales, interbedded with which are some red clays and beds of sandstone. No good water-bearing bed is known to exist in the Wichita formation in the southern area. Locally the limestones and sandstones contain water, but it is usually saline. When followed northward the beds of the Wichita formation show marked diminution in the proportion of calcareous sediments and a corre-

[1] Case, E. C., op. cit., p. 664. Beede, J. W., Jour. Geology, vol. 17, 1909, p. 714.

sponding increase in sandy shales and sandstones. Moreover, the blue and gray colors of the shales and sandstones are in large part replaced by reds and browns, thus giving rise to the designation "Red Beds." In Archer, Clay, and Wichita counties the sandstones of the Wichita formation are locally porous and contain water, but owing to their transitional character and lack of persistency no correlation can be established between the sandstone beds of different localities. There are probably no persistent water-bearing beds in this region, the reservoirs being for the most part local. In Baylor and Wilbarger counties, where the upper beds appear, there are fewer sandstones and more limestones and shales, but no water-bearing beds of any importance. As a whole the Wichita formation is destitute of good water, but salt water is found at several horizons. A hole put down near Geraldine in Archer County struck water at 106, 298, 346, and 540 feet from the surface. The first water rose within 60 feet of the top and the others within 20 feet. All these waters were salt and unfit for use.

CLEAR FORK AND DOUBLE MOUNTAIN FORMATIONS.

GEOLOGY.

Overlying the Wichita formation conformably are red and blue clays, sandy shales, and sandstones, including deposits of gypsum and a few beds of earthy magnesian limestone. These rocks were subdivided by Cummins [1] into the Clear Fork and Double Mountain beds, but, as stated by that author, "no attempt has been made to determine a definite line of division between the two," and in view of the character of the sediments it is evident that the determination of such a line, if it can be made at all, will require much detailed work. Hill [2] proposed the term Brazos series to embrace "all those rocks of Texas, Oklahoma, Kansas, and New Mexico between the top of the conformable Coleman division of the Carboniferous beds below [and] the base of the unconformable Cretaceous above," but the suggestion has not been elsewhere adopted. According to Gould [3] these beds correspond to those in Oklahoma which he has termed in ascending order, the Enid, Blaine, Woodward, Greer, and Quartermaster formations.

In the lower beds red and blue clays predominate, but the upper beds are characterized by an increase in the proportion of arenaceous constituents and also of limestone and gypsum. The sandstones and limestones are friable and, together with the clays, yield readily to eroding agencies and supply a large amount of detritus to the streams, which are heavily charged with the red sediments brought down by their tributaries. In the lower beds the gypsum occurs as thin layers

[1] Cummins, W. F., Second Ann. Rept. Texas Geol. Survey, 1890, pp. 401–402.
[2] Hill, R. T., Twenty-first Ann. Rept. U. S. Geol. Survey, pt. 7, 1901, p. 100.
[3] Gould, C. N., Water-Supply Paper U. S. Geol. Survey No. 154, 1906, p. 17.

and lenses in the clays. Beds of massive gypsum 2 to 3 feet thick crop out in the hills south of Quanah. At Acme, where the material is quarried, the deposit is from 10 to 20 feet thick. In many places fibrous gypsum fills cracks which cut the alluvial clays in every direction.

The massive gypsum does not constitute persistent strata but thins out or is replaced horizontally by clays or limestones. J. J. Cyrus, a well driller of Quanah, states that the wells of that city derive their water from a porous limestone stratum at a depth of 75 feet and that no gypsum occurs in the overlying beds, which consist mostly of clay. A well put down a mile south of Quanah passed through a thick bed of gypsum at 40 to 65 feet and another at 75 to 83 feet, the latter apparently the equivalent of the limestone found in the city wells.

Except where overlain by fluviatile deposits of Quaternary age, the Clear Fork and Double Mountain formations constitute the surface rocks west of the Wichita formation as far as the escarpment that marks the eastern extension of the Triassic in Texas.

The age of these beds is generally recognized as Permian. Fossils are scarce and are confined chiefly to the limestones. The meager collections thus far made from these beds in Texas are not sufficient to warrant definite conclusions concerning them.

Cummins has assigned to these beds a total thickness of 3,900 feet, 1,900 feet to the Clear Fork and 2,000 feet to the Double Mountain. Only the lower beds of the formations are exposed in the Wichita region. Red gypsiferous shales and sands, with beds of gypsum and some limestones in the upper part, represent the formations as they appear here.

WATER RESOURCES.

Water is found in the shales and sandstones and to some extent in the limestones of the Clear Fork and Double Mountain formations. That which occurs in the shales and sandstones or near beds of gypsum is almost invariably strongly gypseous, but that in the limestone or closely related sandstones may be fairly good. Locally these waters yield supplies that are used for household purposes, but more generally they are available only for stock.

The character of the formations precludes the hope of finding potable water supplies at any general horizons.

CRETACEOUS SYSTEM.

COMANCHE SERIES.

East of the region the Carboniferous is overlain unconformably by the Cretaceous, patches of which also appear west and southwest of the region. Worn specimens of undoubtedly Cretaceous shells are found in the gravel escarpments along Wichita River in Knox and

Foard counties. The conclusion seems warranted, therefore, that the Cretaceous formerly extended over a large part if not the whole of the region. The only portion of the area, however, where Cretaceous rocks are now found in place is in the eastern part of Montague County, where the Trinity sand and the overlying Goodland limestone are recognized. The Trinity here consists of compact but easily eroded sand, usually called "pack sand," whose thickness ranges from a knife-edge at the border to 500 feet in the southeastern part of the county. Pebbles in varying amount are scattered through the formation, but only in the basal zone are they abundant enough to constitute a conglomerate. The Goodland limestone, which represents the Comanche Peak and Edwards limestones to the south, consists of a white limestone of dull or chalky texture and luster intersected with layers and seams of semicrystalline material. The thickness of the Goodland is about 15 to 20 feet.

QUATERNARY SYSTEM.

PLEISTOCENE SERIES.

SEYMOUR FORMATION.

GEOLOGY.

Over the western part of the region, including Knox and Haskell counties, portions of Foard and Jones counties, and probably adjoining areas on the west, is a deposit of fine silts, sands, and gravels 10 to 50 feet thick except where removed by denuding agencies, to which the name Seymour beds was given by Cummins.[1] The sands are mostly red varying to white and are interstratified with lenses of gravel and red clay. In Knox County Brazos River and branches of the Wichita have removed this formation over wide areas and cut their valleys down into the underlying Clear Fork and Double Mountain formations. In the breaks of these streams the gravels are well exposed. On the south side of the valley of the South Fork of the Wichita, 5 miles north of Benjamin, the gravels with their accompanying sands and clays have a thickness of 25 feet. The pebbles are well-rounded and consist of quartz and crystalline rock, mostly of igneous origin. Silicified wood is common, as are also waterworn Gryphæa shells of Lower Cretaceous age. The character of the material suggests that it was derived from the Tertiary beds whose remnants outcrop in the escarpment of the Llano Estacado west of this area. Gould[2] has referred to the presence of waterworn Gryphæa shells of Lower Cretaceous age in the gravel beds at the immediate base of the Tertiary.

[1] Cummins, W. F., Fourth Ann. Rept. Texas Geol. Survey, 1893, pp. 181-190.
[2] Gould, C. N., Water-Supply Paper U. S. Geol. Survey No. 154, 1906, p. 29.

The area known or believed to be covered by this deposit is shown on the accompanying map (Pl. I). In the region between the North Fork of Wichita River and Pease River the flat interstream areas are underlain by 6 to 8 feet of fine dark-colored silt resting upon a bed of gravel 2 to 3 feet thick. These beds, which evidently belong to the Seymour formation, overlie the red Permian clays. The western limits of the Seymour formation are not known.

At several places east of the indicated boundary of the formation, patches of conglomerate were observed which may be related to the Seymour. Some of these patches cap the higher gravel terraces of the Brazos below Seymour. Half a mile south of Round Timber the river bluff, which is about 60 feet high, is capped by a bed of gravel and sand in which the pebbles consist chiefly of quartz and quartzite. This material is also spread over considerable areas in the vicinity of the river to the south, where it forms a thin veneer of sand and pebbles. In places it is consolidated into a fine conglomerate. The principal deposits of this character lie about 90 feet above the river. Pebbles of quartzite, quartz, and other siliceous rocks evidently derived from this bed are scattered over the surface of the lower terraces and along the river bed. Another locality where deposits of the same kind were observed is in the vicinity of Mabelle station, in Baylor County. The determination of the stratigraphic relations of these deposits and their connection, if any exists, with the Seymour formation must await more detailed observations with the aid of good maps. A valley conglomerate found on Concho River at San Angelo and elsewhere in Tom Green and Concho counties evidently corresponds to the formation here described. In that locality it is composed chiefly of fragments of chert derived from the Lower Cretaceous beds.

Cummins,[1] who first described the Seymour formation, asserted its Pleistocene age and gave a list of fossils collected from beds presumably of this horizon, though the correlation was not definitely made. Fossils other than the worn fragments of extraneous source already mentioned are not abundant. The fragments of bones of Pleistocene mammals occasionally found include Mastodon and Equus. At Knox City Mr. C. A. Benedict showed the writer the tooth of a mastodon which was found in a well at a depth of 40 feet, also a femur of the same species which was found in a ravine in the vicinity. Cummins[2] states that 14 miles east of Benjamin he collected fragments of the bones of Mastodon and Equus, among which was a femur 4 feet 2 inches in length.

Cummins considered these beds to have been formed in an inland lake which extended from Seymour westward to the range of gypsum hills bounding the formation on the west and which was drained

[1] Cummins, W. F., Fourth Ann. Rept. Texas Geol. Survey, 1892, pp. 181–190. [2] Idem, p. 182.

when Brazos River cut through the limestones at Seymour. The character and general relations of the sedimentation, however, suggests deposition by streams rather than in a lake. As shown by W. D. Johnson,[1] the heterogeneous distribution of clays, sands, silts, gravels, and conglomerates such as characterizes the Quaternary in the High Plains is the result of branching streams of desert habit. From Haskell north to the Brazos the formation has a thickness of 40 to 50 feet and is composed of about 30 feet of reddish calcareous silt or clay, with some sand and gravel, resting upon about 10 feet of sands and gravels. In the upper 1 or 2 feet the formation contains a large amount of lime which has partly consolidated to form an impure limestone or conglomerate. Calcareous deposits of this character, which have a wide distribution in arid regions, are known as caliche. The deposit is harder and more regular in structure at the top than below and is usually hidden from view by a slight covering of soil. The caliche surrounds and includes sand grains, gravels, and earthy materials, cementing them together, but does not usually become sufficiently hard to constitute a solid rock. Blake,[2] who has described such deposits in Arizona, states that "the formation is clearly the result of the upward capillary flow of calcareous water, induced by constant and rapid evaporation in a comparatively rainless region."

WATER RESOURCES.

An abundant supply of good water is usually found in the gravel beds that constitute the basal part of the Seymour formation. Where these lower beds are exposed by erosion under favorable conditions springs may be found, as at Haskell.

In the vicinity of streams which cut through the formation into the underlying Permian the supply is largely lost through seepage. In places in the upland areas also the beds are destitute of water, many wells extending through the gravels into the Permian beds called "Birdseye" by the drillers. The localization of the water in the gravels may be due to collection in basins in the unevenly eroded surface of the Permian.

The water is in general of fair quality and in places very good. It usually contains some gypsum, the amount differing with the locality.

RECENT SERIES.

GEOLOGY.

The stream valleys are floored throughout the greater part of their courses by gravels, sands, and silts which have been transported from higher levels to their present position by the present streams. The

[1] Twenty-first Ann. Rept. U. S. Geol. Survey, pt. 4, 1901, p. 655.

[2] Blake, W. P., Trans. Am. Inst. Min. Eng., vol. 31, 1901, pp. 220-226.

valleys of the larger streams, such as Wichita, Brazos, and Pease rivers, are usually wide and along their sides may be found remnants of terraces to a height of 60 feet. These terrace deposits consist of gravel, sand, and silt of recent origin and are not to be confounded with the somewhat similar Pleistocene materials composing the Seymour formation and the apparently related high-level Pleistocene gravels and conglomerates mentioned on page 31. The bottom lands of Brazos and Wichita rivers are in places from 1 to 2 miles wide and are covered over large areas by sands that have been exposed during low stages of the river and on drying have drifted into mounds and ridges along the adjoining flats. Outside of the ordinary flood plains there are in places wide belts of excellent farming land, as seen on the Wichita north of Holliday and on the Brazos in southeastern Baylor County. Being derived for the greater part from the Permian red beds, the alluvial clays are in many places reddish in color.

In certain areas there are accumulations of sand of greater or less extent caused by the action of the wind. As to their mode of origin these sands are of two kinds—those blown from the stream channels, as already noted, and those derived from the disintegration of rocks in place and heaped up by the winds. The dunes of the first kind occur along the flood plains of practically all the larger streams and are composed of white or nearly white rather fine sand grains. For the most part they are barren of vegetation, but in places they are covered with a scanty growth of grass and bushes.

Sand hills of disintegration occur chiefly in the northwestern part of the region, in Wilbarger and Hardeman counties, and appear to be confined mostly to the areas underlain by the Seymour formation. They are best developed in the uplands north of Pease River, where they constitute ridges 6 to 8 miles long and 3 to 5 miles wide. Corresponding ridges of less extent occur along the south side of Pease River. Gould[1] states that the material of these upland sand hills has been derived largely from the disintegration of the underlying rocks. As the Tertiary and Pleistocene deposits are especially susceptible to the action of weathering agencies, sand hills of this character are most common in the regions to the west and north, where rocks of these ages are best developed. As the clay and silt present in the formations are removed by the action of water, the sand and the gravel remain behind and the finer materials are then rearranged by the action of the wind. As to the deposits of Pease River, however, the view has been advanced[2] that they were formed before the rivers had reached their present levels, and were blown out from the adjacent mud flats of the wide river or estuary,

[1] Gould, C. N., Water-Supply Paper U. S. Geol. Survey No. 154, 1906, p. 30.

[2] Lapham, J. E., and others, Soil survey of the Vernon area, Texas: Field Operations Bur. Soils for 1902, U. S. Dept. Agr., pp. 369, 372, 373.

and have been left behind by the recession of the streams. There can be little doubt that the sands were derived through the disintegration of the underlying rocks. It is not necessary to infer, however, the presence of a former large river or body of water from whose shores the sands were drifted inland. The disintegration of the rocks under the effects of weathering, the removal of the clay and silt through rainwash, and subsequent heaping of the sand by the winds would seem to offer an adequate explanation of the phenomena.

On Red River at Red Bluff, northeast of Vernon, there is said to be a deposit of volcanic ash,[1] the sole indication of igneous action so far as known within the area. It occurs near the top of the bluff and is overlain by fine sandy loam which is evidently of eolian origin and has apparently been modified more or less by the volcanic ash. The writer had no opportunity to examine this deposit, the source of which is wholly conjectural.

WATER RESOURCES.

In the vicinity of the main streams the alluvial sands and gravels usually contain ample supplies of good water. In the valleys of Wichita and Brazos rivers an abundance of good water is generally obtained at depths of 18 to 25 feet. Wells on the higher filled terraces have to go deeper, being from 40 to 60 feet deep, according to location.

In general the water in the valley deposits is of good quality, but locally, especially in the Permian area, it may be affected by the intrusion of waters from the adjoining beds.

SUMMARY AND RECOMMENDATIONS.

The present investigations have shown the occurrence of abundant supplies of underground water in this region, but almost invariably the water was found to be highly charged with mineral matter. This is especially true of most of the supplies obtained in beds belonging to the Carboniferous period. Exceptions are found in wells located near the outcrop of certain sandstone beds occurring near the contact of the Canyon and Cisco formations. Throughout a considerable area in the western part of the region good water is found in sands and gravels of Pleistocene age (Seymour formation) and is reached by wells from 20 to 50 feet in depth. Some of these beds furnish springs, as at Haskell. To these sources are to be added the shallow wells in the valleys, which derive their supplies from the alluvial deposits of Recent age.

Over a large part of this region the surface waters constitute the chief source of supply, both for domestic use and for stock. Away from the main valleys the rainfall is stored in surface tanks for use

[1] Lapham, J. E., op. cit., p. 369.

during the dry part of the year. Owing to the generally friable character of the rocks, the surface waters are charged with fine reddish silt which settles very slowly. The large amount of this red silt in the surface waters makes it desirable that the water be cleared in a settling tank before being used. Wichita Falls derives its supply from an artificial lake 7 miles long outside of the city. This water is decidedly red in color before it is filtered. An analysis of this water is given on page 54.

In view of the importance of surface waters as a source of domestic supply in this area, especial care should be exercised for the preservation of these supplies against pollution by animals or other means. "It is now universally recognized that the degree of prevalence of typhoid fever in a given community is a reliable measure of the extent to which sewage is an ingredient of its drinking water. The prevalence of typhoid in cities is a true index of the quality of the water supplies."[1]

Shallow wells and springs are especially susceptible to contamination from vaults, cesspools, broken sewers, slops thrown on the ground, pigpens, stables, and other sources of filth which readily passes into the ground. For the elimination of such contamination the location and care of a surface tank are important considerations. The tank should be placed at a considerable distance from any known source of contamination, in an open, clear drainage basin, preferably grass covered, from which stock and other agencies of pollution are rigorously excluded. Moreover, it should be frequently and carefully inspected to guard against the accidental access of contaminating substances.

Although the fine red silt so abundant in the waters of this region is not especially harmful to health, its presence in domestic supplies is objectionable and means should be employed for its removal. This may be accomplished in cities by the use of settling tanks in which the water is clarified before it enters the city mains. In smaller places recourse may be had to filters.

DESCRIPTION BY COUNTIES.

MONTAGUE COUNTY.

PHYSIOGRAPHY.

Montague County lies along the State boundary line. It has an area of 976 square miles and its population according to the census of 1910 was 25,123. The mean annual rainfall is 35 inches.

There are two drainage systems in the county separated by a divide which extends from the southwest corner northeastward past Bowie to St. Jo. The area on the north and west of this line is drained

[1] Ann. Rept. Connecticut State Board of Health, 1896, p. 21.

by several small northward-flowing tributaries of Red River, and that on the south and east by Clear Creek, Denton Fork, and other tributaries of Trinity River. Most of the streams which head in the sands near the divide carry perennial though small supplies of water. Those tributaries of Red River which lie wholly within the area of the Carboniferous rocks are for the most part wet-weather streams. In this area the relief is moderate and belongs to an advanced stage of dissection of a preexisting plain, the interstream areas being reduced to irregular hills and knobs of the more resistant sandstones. The altitude of the general plain surface is about 875 to 900 feet above sea level. Along the boundary of the Cretaceous the surface rises rather abruptly from 50 to 200 feet, with here and there irregular knobs and hills composed of the more resistant conglomeratic phases of the Cretaceous sands. Several elevations of this character, known as Cougar, Grindstone, Norton, and Rattlesnake mountains, exist near and to the southwest of Bowie. Queens Peak is a rather prominent elevation about 4 miles north of Bowie, and to the northeast of it are the Belknap Hills. Southeast of this range of hills is a belt of rolling sands, which toward the northeast is much dissected by the streams flowing northward into Red River. The southeastern boundary of this sandy area is marked by an escarpment, and sandstone knobs are noticeable features of the landscape. One of the most prominent elevations is Gordon Mountain, a narrow limestone-capped ridge 4 or 5 miles long just north of St. Jo.

GEOLOGY.

The geology of the county is simple. Underlying the whole area are rocks of Carboniferous age, and resting unconformably upon these in the southeastern part of the county are sands and limestones belonging to the Cretaceous. The Carboniferous rocks lie nearly horizontal or dip toward the west; the Cretaceous rocks dip southeastward. The boundary of the Cretaceous crosses the south line of the county about 6 miles east of the southwest corner and passes northward through Bowie and thence northeastward to the northeast corner of the county. The boundary as thus delineated is irregular and serrate, as a result of the erosion of the formations which once undoubtedly covered the whole of the county.

The Carboniferous rocks which constitute the surface formation over the northwest half of the county belong to the upper part of the Cisco formation and consist of variegated red, brown, and blue sandy shales and shaly sandstones that grade horizontally and vertically into cross-bedded yellowish and white sandstones. The sandstones are locally conglomeratic and, owing to their greater resistance to erosion, in places cap elevations or project in ledges above the general surface. Coal which Cummins regards as his coal seam

No. 7 crops out about 4 miles southwest of Bowie, and attempts were at one time made to mine it at this locality. A tunnel 400 feet long was driven into the side of the hill, and 1½ miles farther north shafts were put down to coal, which was reached at a depth of 150 feet. In all the shafts water was encountered in the sandstone above the coal. The following section was made by Cummins[1] at the mouth of the tunnel:

Section at mouth of tunnel near Bowie, Tex.

	Ft.	in.
Sandstone	6	
Clay	20	
Sandstone	15	
Slate	3	
Coal	2	
Slate		6
Coal	1	4
Fire clay		10
	48	2

The dip of the coal, according to Cummins, is to the northwest. The coal shaft of the Max Edser mine, now abandoned, is reported by the owner, C. H. Boedeker, of Bowie, to be 160 feet deep and the coal to be 48 inches thick, including a slate seam of about 4 inches. A hole drilled 200 feet deeper failed to show other beds of coal. The records of this drill hole were not obtainable. Six miles northwest of Bowie, on the north side of the track of the Fort Worth & Denver City Railway, is an abandoned coal shaft which is now filled with water within 30 feet of the top. This shaft is reported to be 412 feet deep, but no reliable data concerning it could be obtained. The dump shows a considerable amount of black carbonaceous shales as the last material taken out. The only other occurrence of coal in the county of which information is at hand is in a well 4 miles north of Bowie and 1 mile east of the Peak schoolhouse. The well starts in sandstone of the Cisco formation and is said to have reached coal at 62 feet. The seam is 6 inches thick. When the coal was reached, water was encountered which probably came from the overlying sandstone. It rose within 25 feet of the top of the well. On the assumption that the coal in these several localities belongs to the same seam, which is probable, it is estimated that the northwest dip of the beds is about 70 feet to the mile.

The southeast half of the county is underlain by sands and conglomerates belonging to the lower division (Trinity sand) of the Cretaceous. Overlying these sands and capping the higher elevations in the eastern part of the county is a limestone which in Oklahoma is known as the Goodland limestone. It represents the forma-

[1] Cummins, W. F., Second Ann. Rept. Texas Geol. Survey, 1890, p. 508.

tions to the south called the Comanche Peak and Edwards limestones. The Trinity formation in Montague County consists of compact but easily eroded sand, usually called "pack sand," whose thickness ranges from a knife-edge at the borders to 500 feet in the southeastern part of the county. Pebbles in varying amount are scattered through the formation, but only in the basal zone are they abundant enough to constitute a conglomerate. In this zone the pebbly beds are locally of considerable thickness and are in some places loosely consolidated and in others indurated to form a hard, resistant rock. The Belknap Hills, Queens Peak, Brushy Mound, and other elevations along the border of the Cretaceous area owe their relief to the resistance to erosion offered by these beds. As shown by Hill [1] the Goodland limestone is exposed along the western border scarp of the Grand Prairie and in the numerous inlying areas of the valleys of the many tributaries of the Trinity and the streams which score its surface. It is a white limestone of dull or chalky texture and luster, intersected with layers and seams of semicrystalline material. The thickness of the limestone is about 15 to 20 feet.

WATER CONDITIONS.

WELLS.

CARBONIFEROUS AREA.

Most of the water supply of the county is derived from shallow wells. In the Carboniferous area water is found in the sandstones at depths varying from 30 to 250 feet, and throughout a large part of the county water may be reached at 20 to 50 feet. The water in these shallow wells is usually hard and often impregnated with objectionable salts. The supply is rather scanty, and it is necessary in some areas to go deeper for satisfactory quantities. Other horizons are reached at depths ranging from 50 to 200 feet, but owing to the varying character of the formations no correlation can be made between the wells at different horizons.

At Nocona water is found in the northeastern and southwestern parts of the town at 20 to 40 feet in depth. The wells in a belt extending through the town from northwest to southeast are reported to be from 100 to 250 feet deep. The most common depth is 100 to 130 feet. In the shallow wells the water stands about 18 feet below the surface and in the deep wells, according to the principal of the public schools, it stands at about 80 feet. A well put down by G. A. Stafford for Carmichael Bros. yields when pumped 7,000 gallons a day. It is cased with 6-inch pipe for 217 feet and with 4-inch pipe for the remaining 42 feet. The water varies in

[1] Hill, R. T., Twenty-first Ann. Rept. U. S. Geol. Survey, pt. 7, 1901, p. 217.

quality, being good in some wells and poor in others. In general, the water from the deeper wells is soft and that from the shallow wells is hard.

About 2½ miles north of McCallums, on the farm of John Morris, a well 134 feet deep was put down in 1892. For a time the water was fairly good, but later it became so highly charged with mineral salts that it could not be used. Another well 84 yards to the northeast struck water at 137 feet. The record of this well, given by Mr. Morris, is as follows:

Record of well on farm of John Morris, near McCallums, Tex.

	Feet.
1. Surface sand and clay	28
2. Soft sandstone	36
3. Black clay	8
4. Mixed clay, sand, and lime, in part concretionary	15
5. Pack sand	40
6. Dark-red clay, almost black	6
7. Hard rock	4
8. Sand with gravel and water.	

Nos. 1 to 5 represent the basal portion of the Trinity sand; Nos. 6 to 8 belong to the Cisco formation of the Carboniferous. The water in this well is fairly good.

At Belcherville the public well is 165½ feet deep; the water, which is of fairly good quality, rose rapidly, when the bits were drawn, within 90 feet from the surface. The water of other shallow wells in the vicinity is said to differ considerably in quality, but no analyses have been made. In 1895 a well put down by John Witherspoon was extended to a depth of 961 feet. William M. Cassel, the foreman in charge of the work, makes the following statement concerning it:

> The principal water-bearing stratum was reached at 600 feet. Several other water-bearing strata were passed through above this, but they were cased off. The water from the 600-foot level rose within 100 feet of the surface. Deposits of coal, "granite," sulphur, and salt were passed through, but nothing definite is now known concerning them. Analysis was made of the water, but this has been lost. It is known, however, that the water was highly charged with salt and sulphur.

At Ringgold water is obtained at depths of 20 to 200 feet. The water in this vicinity is predominantly brackish. Cisterns constitute the main source of supply, the statement being made by residents that there is "no good water outside of cisterns."

In the vicinity of Stoneburg water is found in shallow wells at depths of 25 to 40 feet. In these wells the water rises within 10 to 20 feet from the surface. At depths varying from 72 to 160 feet water is struck which supplies flowing wells in favorably situated localities. A. S. Jamieson's well, located 200 yards south of the Chicago, Rock Island & Gulf Railway Station, is 160 feet deep. The water flows out in a small stream and is said to be fairly good for general use, but hard on boilers. The elevation of the top of the well is about 930 feet above sea level. The drill is reported to have passed through 5 to 6 feet of soil, about 8 feet of white sand containing plenty of soft water, and blue shale and sandy clay with alternating beds of sandstone down to about 145½ feet. Water was found in a clay or quicksand formation underlying a "honeycomb" rock, probably a sandstone. The fine material pumps up and chokes the well.

About 200 yards south of the Jamieson well is one put down by the Chicago, Rock Island & Gulf Railway Co., the following record of which was furnished by Mr. Paul Friesen, acting chief engineer:

Record of Chicago, Rock Island & Gulf Railway Co.'s well at Stoneburg, Tex.

	Thickness.	Depth.
	Feet.	*Feet.*
Surface material	2	2
Quicksand with water	11	13
Clay	11	24
Blue sandrock and slate	34	58
Sandrock	12	70
Red clay	10	80
Clay and slate	26	106
Sandrock and some water	12	118
Red clay	11	129
Hard sandrock	13	142
Quicksand with water, which flows out at top	3	145
Hard honeycomb rock	⅓	145⅓

The water was struck at 143 feet. The well flows at the rate of 1,000 gallons a day and affords about 17,000 gallons a day when pumped. The rocks penetrated in this well belong wholly to the Cisco formation. At this place the elevation of the water beds is approximately 890 feet above sea level.

About 1¼ miles south of the Stoneburg station a flowing well was obtained by James Anderson at a depth of 98½ feet. The exact elevation of the top of this well is not known, but an estimate based on the contour map of the region indicates that the water is reached here at a level 40 feet higher than at the station.

Three-fourths of a mile farther south W. T. Small has a flowing well 72½ feet deep. The top of the well is possibly 10 feet lower than that of the railway well. It is estimated that water is reached in this well at about 835 feet above sea level, or 63 feet higher than at Stoneburg. It seems probable that all these wells terminate in the same stratum, which has a northward inclination of about 32 feet to the mile. As the real dip of the strata is to the northwest, the data here given harmonize with others showing the dip to be about 70 feet to the mile (p. 37). The character of the water from the Small well is shown by the following analysis, by Walton Van Winkle, of the United States Geological Survey:

Analysis of water from well of W. T. Small, near Stoneburg, Tex.

[Parts per million.]

Silica (SiO_2)	4.8
Iron (Fe)	.08
Calcium (Ca)	32
Magnesium (Mg)	8.2
Sodium (Na) and potassium (K)	121
Carbonate radicle (CO_3)	.0
Bicarbonate radicle (HCO_3)	365
Sulphate radicle (SO_4)	49
Chlorine (Cl)	61
Nitrate radicle (NO_3)	1.06
Total solids	457

This analysis shows that the water comes within the limit of ordinary river water in the proportion of calcium and magnesium, but is higher in chlorine and bicarbonates. It is used for household purposes and for stock and would apparently do well in boilers.

Water from the well of C. M. Chase, near the Small well, May, 1907, gave the following results according to the same analyst:

Analysis of water from well of C. M. Chase, near Stoneburg, Tex.

[Parts per million.]

Silica (SiO_2)	7.2
Iron (Fe)	.3
Calcium (Ca)	6.4
Magnesium (Mg)	10
Sodium (Na) and potassium (K)	174
Carbonate radicle (CO_3)	.0
Bicarbonate radicle (HCO_3)	381
Sulphate radicle (SO_4)	25
Chlorine (Cl)	36
Nitrate radicle (NO_3)	.97
Total solids	458

This water, although slightly higher in alkalies and lower in chlorine, corresponds fairly with that from the Small well. The flow is small but constant.

About 3½ miles east of Stoneburg, on the farm of C. H. Bacon, are two wells 113 and 96 feet deep. Both are flowing wells and when cased up the water stands 2 feet above the level of the ground. These wells are located near the border of the Cretaceous at the northwest base of the Belknap Hills. Their flow is small but regular. A bucketful taken from the basin will cause the flow to cease for a few seconds.

Bowie is situated near the southwest corner of the county, just within the border of the Cretaceous area. The thickness of the Trinity sand here, as shown by well records, is about 40 feet. The increase in thickness toward the east is rapid and in that part of the county, so far as known, no wells extend through the Trinity sand. There are several deep wells in the town which extend through the Trinity into the underlying Cisco formation. The Bowie ice plant and the Bowie Oil Co. each have wells about 500 feet deep. The old well of the city waterworks derived its supply from a depth of 540 feet, but this proving insufficient, a new well was finished in 1907 at a depth of 640 feet and gives, according to Mayor C. H. Boedeker, "an inexhaustible supply of good water."

Its record is as follows:

Record of new well of city waterworks, Bowie, Tex.

[Elevation at top of well, 1,145 feet above sea level.]

	Thickness.	Depth.
	Feet.	*Feet.*
Trinity sand (Cretaceous):		
1. Soft sandy soil with some gravel and water	30	30
2. Hard yellow clay	10	40
Cisco (Carboniferous);		
3. Hard sandstone	38	78
4. Hard soapstone rock	18	96
5. Slate; traces of coal	4	100
6. Hard soapstone or fire clay	8	108
7. Conglomerate (concrete rock)	132	240
8. Shale	11	251
9. Hard concrete, similar to No. 7	54	305
10. Gritty shale, "hardpan"	75	380
11. Hard concrete rock, difficult to drill	55	435
12. Red shale	13	448
13. Sandstone	32	480
14. Red shale	18	498
15. Hard shale, "hardpan"	12	510
16. Sandstone	9	519
17. Sand with water	9	528
18. Sandstone	4	532
19. Soapstone, shale, and slate	69	601
20. Sand with water	19	620

The water in bed No. 20 stands 180 feet below the top when pumped. This water was analyzed by Walton Van Winkle in March, 1907, with the following results:

Analyses of water from new city well, Bowie, Tex.

[Parts per million.]

Silica (SiO_2)	5.4
Iron (Fe)	.3
Calcium (Ca)	21
Magnesium (Mg)	9.5
Sodium (Na) and potassium (K)	772
Carbonate radicle (CO_3)	.0
Bicarbonate radicle (HCO_3)	382
Sulphate radicle (SO_4)	129
Chlorine (Cl)	972
Nitrate radicle (NO_3)	1.86
Total solids	2,119

This is a soft water high in chlorine and alkalies.

CRETACEOUS AREA.

In the Cretaceous area water may be obtained as a rule at depths of 20 to 150 feet. Most of the wells are from 30 to 80 feet deep. The differences in the depths of the wells are due in part to the character of the relief as related to the position of the water table, and in part to the changes in the character of the beds themselves, the sands in places containing more clay or being finer grained and more compact. For the most part water for domestic purposes is obtained from shallow wells. There are no deep wells within the area except near the border, as at Bowie (p. 42). At that place the deep wells find water in the underlying Cisco formation. The water in the Trinity sand is generally mineralized to a greater or less extent, and hence it is in many places necessary to rely upon cisterns both for domestic use and for stock. Owing to the compactness of the sands, the movement of the ground water in them is slow and generally the supply from these beds is small. E. B. Sizemore put down a well at Newharp, near the southeast corner of the county, and says that it is 129 feet deep, is nonflowing, and furnishes about 10,000 gallons a day. The water is used for running a large gin. The drill passed through the following beds, according to Mr. Sizemore:

Record of well of E. B. Sizemore at Newharp, Tex.

	Thickness.		Depth.	
	Ft.	*in.*	*Ft.*	*in.*
1. Soil	4		2	
2. Packsand or sandrock	40		44	
3. Blue clay and struck water	......		......	
4. Packsand; water at 80 feet	41		85	
5. Red bottom clay	2		87	
6. Unrecorded	27		112	
7. Stone coal		2	112	2
8. Sandstone	26	10	129	

The beds to and including No. 4 are Trinity and those below No. 4 are evidently Cisco. Water is reported from the Trinity at 44 and 80 feet. No mention is made of water in the Cisco formation.

Four miles southeast of Nocona is a well 235 feet deep. The record of this well is not available, but it was learned that the drill passed through sandstone, red sandy shale with some hard rock, and, near the bottom, soft sand with water which rose within 60 feet of the top. This well is situated on a hill near the border of the Trinity sand. The water is soft and evidently comes from the underlying Cisco. The elevation at the top of the well is 1,050 feet above sea level. About a quarter of a mile northeast of this well is an old well, 73 feet deep, in which the water is hard. The top of the old well is about 20 feet lower than that of the other well, and the water in it is evidently in the basal part of the Trinity.

Montague, the county seat, is located on the Trinity sand, in which water is found at depths of 60 to 80 feet. The water contains a considerable but varying amount of mineral matter, wells near together showing marked differences. The courthouse well is 60 feet deep, as is also the parsonage well, located 600 feet farther south. The "old well" on the square, which is 80 feet deep, contains somewhat better water than either of the other two. About 500 feet west of the courthouse well is the "wagon house" well, which is about 40 feet deep. All these wells derive their supply from the Trinity. Analyses of the waters are given below.

Analyses of water from wells at Montague, Tex.

[Parts per million. W. M. Barr, analyst. Samples collected December, 1906.]

	Court-house well.	Parson-age well.	Wagon house well.
Silica (SiO_2)	19	26	21
Iron (Fe)	Tr.	3.6	.05
Calcium (Ca)	327	96	270
Magnesium (Mg)	74	27	29
Sodium (Na) and potassium (K)	284	26	88
Carbonates (CO_3)	.0	.0	.0
Bicarbonate radicle (HCO_3)	442	334	249
Sulphate radicle (SO_4)	262	54	104
Chlorine (Cl)	653	43	186
Nitrate radicle (NO_3)	102	Tr.	334
Total solids	2,075	446	1,272

Owing to the large proportion of iron the water from the parsonage well has a disagreeable taste and is not used. The porous character of the sandy formation underlying the town is decidedly favorable to the contamination of the ground waters by sewage.

SPRINGS.

Springs in Montague County are few and are for the most part small and unimportant. Most of them are in the Trinity sand area and along its border. Near Gladys and Forestburg are small springs and one near Forestburg is reported as yielding a "never-failing" supply of warm water. The springs supplying cold water usually run dry in summer. The water of these springs is hard. A few soft-water springs occur in the Cisco area, notably near Stoneburg and Ringgold. Their flow is small.

CLAY COUNTY.

PHYSIOGRAPHY.

Clay County has an area of 1,250 square miles, and its population in 1910 was 17,043. The mean annual rainfall is 32 inches. The county is drained chiefly by Little Wichita River, which flows northeastward through the middle of the county into Red River. The Wichita flows through the northwestern part of the county.

The surface is for the most part a timberless, moderately dissected plain. The soils consist of fine sand or sandy clays derived from the underlying sandstones and shales.

GEOLOGY.

The rocks outcropping in this county consist of white, brown, and red sandstones and red sandy shales, the colors in places varying to blue. Except in a small area of the Cisco formation in the southeastern part of the county the indurated rocks belong to the Wichita formation. Owing to their apparently conformable relations, their lithologic correspondence, and the lack of good exposures the boundary between the formations is nowhere clearly defined and can therefore be indicated only approximately.

The Cisco consists of sandstones and shales, mostly red, the sandstones appearing here and there over the plain surface in outcropping benches and low escarpments. Just over the line in Jack County, near Postoak, the upper part of the formation consists of 25 to 30 feet of conglomerate overlying red shales grading into sandy beds. The conglomerate is composed of partly worn subangular fragments of siliceous limestone and chert in a matrix of sand. In places it grades into brown ferruginous sandstone. In general the fragments are of the size of peas or navy beans, but locally they are larger or smaller. This conglomerate is apparently identical with that seen at Graham, in Young County, and it is believed to represent about the same horizon. No exposures of this bed were seen in Clay County, but the indications are that it is present in the southeast corner of the county and across the boundary in Montague County.

In the area underlain by the Wichita formation the exposures are mostly low ledges of sandstone scattered over the plain capping low elevations and stream slopes. The main part of these ledges is composed of red and variegated shales with intercalated lenses of sandstones. The thickness of the Wichita in Clay County is not known.

A short distance west of Henrietta copper is said to occur in the red sandstones and shales, chiefly in the shales. The ore, which consists of small nodules disseminated through the shales, according to reports, assays about 60 per cent of copper.

At Petrolia oil is found at depths of 278, 358, 438, 650, and 750 to 800 feet. The principal supply is derived from beds at the 278-foot and 438-foot horizons. The deepest bed supplies one well only. The first 10 wells in this district were put down by J. L. Jackson, of Jackson & Moore, of Wichita Falls, from whom the following record was obtained:

Record of oil wells in the Petrolia oil field.

[Elevation of top of wells, 1,025 feet above sea level.]

	Thickness.	Depth.
	Feet.	*Feet.*
1. Red shale, with a few feet of soil on top	100	100
2. Sand, with showing of oil	5	105
3. Red shale	75	180
4. Sand, with trace of oil	8	188
5. Red shale	75	263
6. Blue shale	15	278
7. Oil sand	15	293
8. Red shale	40	333
9. Blue shale	10	343
10. Sand, with some oil	15	358
11. Red shale	72	430
12. Blue shale	8	438
13. Sand, with oil	10	448

The first oil produced in the field came from the sand (No. 7) at 278 feet. When first put down, in 1903, the wells produced from 5 to 55 barrels a day; in 1907 the wells had declined to about 3 barrels a day. Later wells were extended to the sand at 448 feet, from which in 1907 the chief production was obtained. The oil from the lower sand is said to have a higher specific gravity than that from the upper sand.

Well No. 1 of the Corsicana Petroleum Co., of Corsicana, Tex., is located on the farm of Byers Bros. It is the deepest hole that had been put down in the field at the time when this investigation was made (1907). No oil or gas was found. The well is located about 3 miles northeast of Petrolia. It is cased with 6-inch pipe down to a depth of 367 feet and with 4-inch pipe to 1,002 feet. No notice was taken of water horizons. The following record was made by M. W. Bahan:

Record of well No. 1 of Corsicana Petroleum Co., near Petrolia, Tex.

[Elevation of top of well, about 1,025 feet above sea level.]

	Thickness.	Depth.
	Feet.	*Feet.*
1. Sand, sandstone, and clay	243	243
2. White sand, with small show of oil	6	249
3. Sandrock and clay	118	367
4. Sandrock and red shale	629	996
5. Sandrock and shale, with some sand (indications of gas)	9	1,005
6. Hard red rock	49	1,054
7. Hard sandrock	5	1,059
8. Hard red rock	33	1,092
9. Soft shale	51	1,143
10. Red shale	157	1,300

Neither of the records obtained gives any satisfactory evidence as to the location of the plane of separation between the Wichita and the Cisco formations. From Mr. James Darling it was learned that in some of the wells a conglomerate bed 12 feet thick was found at a depth of 490 feet. If this is upper Cisco, then the Wichita is probably penetrated at a depth of 263 feet. The major part of the development of the field is in an area less than 3 miles in diameter, the center of which is about $1\frac{3}{4}$ miles southeast of Petrolia.

WATER CONDITIONS.

In the valley of Red River, at the north end of the county, plentiful supplies of potable water are found at a depth of 25 feet. Along the bluffs bordering the valley there are numerous small springs, but no deep wells are reported from this or any other part of the county, except as already mentioned.

In the upland areas water is found in the sandstones at depths varying from 30 to 130 feet. Shallow wells and cisterns furnish water for domestic use. Water for stock is obtained from artificial pools and to some extent from wells.

At Henrietta the wells are from 25 to 40 feet deep. A few miles out of town it is necessary to sink to a depth of 72 to 100 feet. The town supply is obtained from two wells located in a draw about three-fourths of a mile south of town. The supply is insufficient to meet the demand during portions of the year when the gins are in operation, and it is then supplemented by pumping from a surface tank near by. At the time of the writer's visit the surface of this tank was covered by slime and the water appeared to be unfit to drink. No record is kept as to the amount of tank water that is mixed with that of the wells in the mains. If a sufficient quantity of water can not be obtained by sinking other wells, steps should be taken to construct a tank in a location where it will be free from the danger of contamination. In some wells the water is brackish or alkaline; in others it is fairly good.

In the vicinity of Bellevue two water horizons are reported, the first at 30 to 35 feet and the second at 100 to 110 feet. The water in the shallow wells is soft and that in the deeper wells is hard. There is no public supply of water for the town of Bellevue, but a supply may be obtained from a lake in the vicinity covering 40 acres, which is fed by underground springs and is said to be practically inexhaustible.

Since 1907, when this field was examined, there has been a marked development in oil operations, especially in the vicinity of Electra, in Wichita County. The region including Clay and Wichita counties is said to be now producing 10,000 barrels of oil a day.[1] The principal oil area is in Wichita County and the principal gas area is in Clay County. According to the report cited, which is based on investigations made by J. A. Udden, the oil and gas have accumulated in lentils of sand that were originally bars and beaches in the Cisco and Wichita seas. "The Henrietta-Petrolia gas and oil field is an irregular elongated dome about 200 feet high, having an area of 6 or 7 square

[1] Press letter, Bur. Econ. Geology, Univ. Texas, W. B. Phillips, director, Mar. 15, 1912.

miles. It is about twice as long as broad, and the longer axis extends in a west-northwest and east-southeast direction." The author quoted considers that the oil and gas bearing sands of this field occur in the upper part of the Cisco formation or the lower part of the Wichita formation, and that they are contemporary in deposition with the coal beds occurring at this horizon farther south. This places the plane of separation between the Cisco and Wichita formations here at 700 to 900 feet from the surface, a position which accords with the writer's view.

Two logs of borings kindly furnished by Mr. Udden are given below. In each of these borings six water-bearing sands were noted. In the Byers well No. 3 a fresh-water sand was found at 137–172 feet which was not encountered in the Myers farm well No. 1, and the latter well shows a water sand at 955-975 feet which did not appear in the former. The correlation of the other water beds seems to be fairly well established, but it should be remembered that in formations of such irregularity in lithologic character the determinations are provisional only. There is probably little doubt that all the waters except that at 137 to 172 feet in the Byers well were saline.

Log of Myers farm well No. 1, near Henrietta, Tex.

Elevation of Henrietta, 915 feet above sea level (Weather Bureau). Began drilling May 27, 1909. Finished drilling December 31, 1909. Set 176 feet of 12½-inch casing, 589 feet of 10-inch casing, 1,310 feet of 8-inch casing, 1,924 feet of 6-inch casing. All pipe pulled when well was abandoned.

	Thickness.	Depth.
	Feet.	*Feet.*
Red mud	280	280
Gray water sand (B)	20	300
Red cave	15	415
Gray slate	10	425
Red cave	75	500
White water sand (C)	25	525
Red cave	10	535
Broken sand	15	550
Gray salt sand	10	565
Red cave	10	575
White slate	15	590
Red and white, mixed	25	615
Salt-water sand (D)	21	636
Red cave	19	655
White slate	20	675
Red and blue mud	10	685
White slate	15	700
Red cave	5	705
White slate	5	710
White salt sand	25	735
Broken gray sand	10	745
Hard brown sand, oil	10	755
Loose white sand	45	800
Broken gray sand	10	810
Red cave	10	820
White slate and shell	5	825
Red cave	20	845
Gray shells	10	855
Red cave	10	865
White sand	10	875
Water sand (E)	10	885
Slate	10	890
Dark-gray shells	10	900
Light slate	10	910

Log of Myers farm well No. 1, near Henrietta, Tex.—Continued.

	Thickness.	Depth.
	Feet.	*Feet.*
Red bed	15	925
White sand	15	940
Red rock	15	955
Gray water sand (X)?	20	975
Blue slate	5	980
Red rock	25	1,005
Blue slate	5	1,010
White salt sand	10	1,020
Red marl; streaks of blue shale	10	1,030
Light-gray sand	10	1,040
Red marl	15	1,055
Dry gray sand	5	1,060
Red marl	25	1,085
White salt sand	15	1,100
Broken sand	15	1,115
Soft white sand	10	1,125
Broken sand	15	1,140
Blue slate	10	1,150
Dry white sand	5	1,155
Dark-blue slate	25	1,180
Sand; streaks of shale	20	1,200
Red marl	25	1,225
Gray sand	5	1,230
Red marl	40	1,270
Brown shells	10	1,280
Red marl	50	1,330
Brown sand (F)?	20	1,350
Blue slate	30	1,380
Red marl; streaks of white sand	90	1,470
Brown slate	25	1,495
White slate	11	1,606
White salt sand	22	1,628
Blue shale	20	1,648
White salt sand	15	1,663
Blue shale	37	1,700
White shale	15	1,715
White salt sand	12	1,727
Black gumbo	10	1,737
Gray sand	7	1,744
Blue shale	46	1,790
Sand; streaks of blue shale	20	1,810
White salt sand	10	1,820
Blue shale	20	1,840
Gray sand	10	1,850
Blue slate; streaks of black slate	80	1,930
Blue slate	243	2,173
Gray salt sand	7	2,180

Log of Byers well No. 3, Petrolia field, Tex.

Elevation of Petrolia, 967 feet above sea level at station. Began drilling October 20, 1908. Finished well April 14, 1909. Set 127 feet of 12-inch casing, 697 feet of 10-inch casing, 1,466 feet of 8-inch casing, 1,789 feet of 6-inch casing, and 1,959 feet of 4½-inch casing.

	Thickness.	Depth.
	Feet.	*Feet.*
Red clay	75	75
Sand shell	2	77
Blue mud	20	97
Red cave	40	137
Big fresh-water sand (A)	35	172
Red and blue mix	35	207
Red mud	20	227
Dry sand	15	242
Sandy blue mud	20	262
Red mud	40	302
Water sand (B)	8	310
Red and blue rock	175	485
Sand	8	493
Shale	4	497

Log of Byers well No. 3, Petrolia field, Tex.—Continued.

	Thickness.	Depth.
	Feet.	*Feet.*
Sand; salt water (C)	50	547
Blue gumbo and gravel	8	555
Red gumbo and gravel	40	590
Blue shale	10	600
Very dark red shale	45	645
Blue shale	5	650
Dark-red shale	28	678
White shale	12	690
Water sand (D)	38	728
Water shale	3	731
Red and blue mix	50	781
Blue shale	91	871
Very red shale	50	921
Broken sand	5	926
Red shale	15	941
Black slate	64	1,006
Red and blue mix	45	1,051
Red shale	25	1,076
Blue shale	17	1,093
Water sand (E)	35	1,128
Shale hard	20	1,148
Sand	15	1,163
Blue shale	38	1,201
"Duke's Mixture"	10	1,211
Sky-blue shale	10	1,221
Brown gritty shale	10	1,231
Rotten sand	25	1,256
Blue shale, sand shells	60	1,316
Dark-red shale	15	1,331
Water sand (F)	30	1,361
Blue shale	8	1,369
Sand	6	1,375
Dark-blue shale	4	1,379
Sand	2	1,381
Blue shale	24	1,405
Dark sand	15	1,420
Dark-blue shale	36	1,456
Very hard dark-blue shale	1	1,457
Blue shale	43	1,500
Hard black sand	2	1,502
Dark-red shale	8	1,510
Dark sand	8	1,518
Dark-blue shale	7	1,525
Blue lime	4	1,529
Sky-blue shale	85	1,614
Gas sand	1	1,615
Black shale	30	1,645
Fine dark sand	17	1,662
Dark-blue shale	27	1,789
Hard shell lime	1	1,790
Shale	16	1,806
Soft sand (fine oil)	11	1,817
Brown shale	2	1,819
Black shale	4	1,823
Light-blue shale	37	1,860
Oil sand	27	1,887
Black slate	62	1,959
Sand	5	1,964
Blue shale	10	1,974
Big salt sand, "Gulf of Mexico"	536	2,510
Abandoned.		

WICHITA COUNTY.

PHYSIOGRAPHY.

Wichita County has an area of 606 square miles, and its population according to the census of 1910 was 16,094. The mean annual rainfall is 25 inches.

The surface is an eastward-sloping plain incised on the south by Wichita River and its tributaries and on the north by a few insignificant tributaries of Red River. The general surface rises toward the west or northwest at the rate of about 7 feet to the mile. The main valley of Wichita River is a wide alluvial plain about 60 feet below the general surface. The river flows in a narrow channel sunk 25 feet below the valley bottom. According to the railway profiles the station at Wichita Falls, the lowest point in the valley, has an elevation of 946 feet above sea level. The stations at Iowa Park and Electra are on the plateau level and have elevations, respectively, of 1,037 and 1,229 feet.

GEOLOGY.

The rocks exposed at the surface in Wichita County belong wholly to the Wichita or lowermost formation of the Permian series. Exposures within the county are not abundant and are confined chiefly to the gullies and ravines along the sides of the Wichita Valley. As noted elsewhere the rocks consist of red and variegated shales and sandstones. The shales are generally sandy and in places contain an abundance of ferruginous concretions. The sandstones are of varying hardness. In places the strata are 5 to 10 feet thick and grade horizontally and vertically into the associated shales. Owing to the nonpersistent character of the sandstones it is difficult to correlate rocks of different localities. With the disappearance of a sandstone in its horizontal extension, new beds of exactly similar constitution appear at higher or lower levels, and these in turn give way to others. About 3 miles west of Wichita Falls the following section was obtained in the breaks of the Wichita:

Section near Wichita Falls, Tex.

	Feet.
1. Red clay filled with ferruginous concretions	10
2. Red and variegated sandstones, cross-bedded, and for the most part in thin layers	8
3. Red nodular clays to bottom of ravine	20

This bed of sandstone (No. 2) can be traced three-fourths of a mile to the west and then disappears below the bottom of the valley. The transitional character of the sandstones is well shown in a mound about 4 miles northwest of Holliday. The top of the mound, which covers about an acre, consists of soft gray sandstone resting upon red concretionary clays. On the north side the sandstone is about 10 feet thick and 25 feet of clay lies below it. On the south nearly the whole side of the hill is composed of sandstone in place, only about 5 feet of the clay being exposed.

Limestones representing higher horizons make their appearance in the bluffs of the Wichita about 5 miles north of Dundee station, on the west side of Horseshoe Lake, where the section following is exposed:

Section in bluff on west side of Horseshoe Lake, Wichita County, Tex.

	Feet.
1. Limestone, hard, dark blue, brown on exposure, cavernous	4
2. Blue clay	4
3. Red concretionary clays	25
4. Soft red shaly sandstone	15
5. Red concretionary clay	4
6. Red shaly sandstone	9
7. White and red variegated sandstone, more massive than Nos. 4 and 6	6
8. Nodular clay ("conglomerate")	1
9. Red concretionary clay	15
10. Nodular clay or "conglomerate"	$\frac{1}{3}$
11. Red concretionary clay	25
	$108\frac{1}{3}$

Scattered over the upland surface in the vicinity of Electra are fragments of limestone that were weathered out of the clays, but no limestones were seen in place in the northern part of the county. About three-fourths of a mile southwest of Electra some thin nodular limestones are exposed, interbedded with blue nodular clays, calcareous shales, and sandstones.

Recent deposits are represented in the main valleys by considerable thicknesses of alluvial sands and gravels. In the valley of the Wichita these deposits are from 20 to 30 feet thick. Their thickness in the valley of Red River is not known. Traces of the presence of similar but older deposits appear in the upland areas in the form of rounded pebbles of quartz and other crystalline rocks scattered over the surface. In places small patches of these gravels have been consolidated into a conglomerate a few feet thick. They are possibly of Tertiary or early Pleistocene age.

A prospect well for oil was put down at Electra some years ago by W. T. Waggoner, but no authorized record of this well can be obtained. The hole is located near the railroad station, which has an elevation of 1,229 feet above sea level. The driller was B. P. Gates. Information concerning this well was supplied by Mr. Estes, who assisted in the sinking of the well. He states that the drilling was extended to a depth of 1,790 feet, passing through the following strata:

Record of the Waggoner oil well, Electra, Tex.

	Thickness.	Depth.
	Feet.	*Feet.*
1. Surficial material	8–10	10
2. Red concretionary clay	50	60
3. Red joint clay	45	105
4. Red variegated clays and shales, sandy shales alternating with blue	645	750
5. Sand with some oil; water struck at bottom of sand rose within 15 feet of the surface	50	800
6. Shale, alternating with other rock; blue shale at 1,200 feet	990	1,790

Water was first reached in quantity at 800 feet. Above this there was only a slow seepage. The water at the 800-foot horizon is salty and mingled with a small amount of oil, which stands at the surface and is dipped out for use locally by cattlemen.

Since 1907 borings in the vicinity of Electra have revealed the presence of extensive deposits of oil in that region. As stated elsewhere (p. 47), the principal oil area is in the western part of Wichita County, in the vicinity of Electra. The region as a whole now produces about 10,000 barrels of oil a day, the larger part of which is derived from the Electra field. There are several oil-bearing sands, of which the one most explored lies 900 to 1,000 feet below the surface, in the lower part of the Wichita formation. Below this are others with which have been correlated some that occur in the Henrietta-Petrolia field.

WATER CONDITIONS.

WELLS.

In the alluvial flats along Wichita and Red rivers plentiful water supplies are found at depths of 20 to 25 feet.

In the valley of the Wichita supplies are obtained generally from wells varying from 18 to 25 feet in depth. At the Tom Jones ranch, northwest of Holliday station, an abundant supply of very good water is obtained from a well 22 feet deep. The section is as follows:

Section of well on Tom Jones ranch, near Holliday, Tex.

	Thickness.	Depth.
	Feet.	*Feet.*
Soil and sandy clay	8	8
Gravel	4	12
Sandy clay	6	18
Sand with a plentiful supply of good water	4	22

In the upland areas few good wells are found. The water in these wells is derived from the red shales and sandstones of the Wichita formation and is usually too highly mineralized for use. Some of the shallow wells yield supplies for stock, but few of them are available for domestic use. The depth of these wells is from 16 to 50 feet, the principal supplies being obtained at about 45 feet. The water from these shallow upland wells is rich in salt and gypsum, as is shown in analysis No. 2 of the subjoined table. The water from the deeper horizons shows a much greater content of mineral matter, as indicated by analysis No. 3. This water is absolutely unfit for domestic or industrial use or for irrigation.

The character of the water from the wells at Wichita Falls is shown in the following analyses:

Analyses of well waters from Wichita Falls, Tex.

[Parts per million.]

	1	2	3	4
Silica (SiO_2)	9.6	12	7	117
Iron (Fe)	Tr.	.05	.05	6.4
Aluminum (Al)			4	34
Calcium (Ca)	28	187	1,397	18
Magnesium (Mg)	42	86	411	15
Sodium (Na)	252	739	16,611	14
Potassium (K)			43	
Carbonate radicle (CO_3)	19	.0	.0	.0
Bicarbonate radicle (HCO_3)	395	289	93	60
Sulphate radicle (SO_4)	292	294	512	20
Chlorine (Cl)	102	1,380	29,077	22
Nitrate radicle (NO_3)	Tr.	33	.02	.88
Suspended matter	2.8			120
Total dissolved solids	927	2,953	48,726	310
Turbidity	5			165

1. Elevator well in alluvial deposits. Depth, 20 feet. W. M. Barr, analyst. Sample collected Oct. 1, 1906.
2. Edson A. Chamberlin's well, Bluff Street. In red shales and sandstone of Wichita formation. Depth, 40 feet. Walton Van Winkle, analyst. Sample collected in 1906.
3. Well owned by F. D. Keona (?). Depth, 220 feet. J. B. Bailey, analyst. Sample collected June 8, 1911.
4. City water from artificial lake. W. M. Barr, analyst. Sample collected Oct. 1, 1906.

According to R. B. Dole, of the United States Geological Survey, the water of the Keona well will yield on evaporation a residue containing 86 to 88 per cent of sodium chloride (common salt), the chief impurities of which would be calcium chloride and calcium sulphate. He considers it worth investigating as a possible local source of salt. The percentage composition of the anhydrous residue computed from the analysis is as follows:

Percentage composition of anhydrous residue from water of Keona well, Wichita Falls, Tex.

Chlorine (Cl)	60.5
Sodium (Na)	34.5
Calcium (Ca)	2.9
Magnesium (Mg)	.8
Sulphate radicle (SO_4)	1.1
Potassium (K)	.1
Carbonate radicle (CO_3)	.1
	100.0

In the upland areas cisterns and tanks constitute the chief source of water supply for domestic use and for stock. The water thus stored holds in suspension a large amount of red sediment derived from the adjacent soils. This matter settles very slowly, and the rivers and ponds are rarely clear. The city of Wichita Falls is supplied from a reservoir 7 miles long. The character of the water, as shown by a sample taken from the pipes before filtering, is indicated by analysis No. 4. The water is red-brown in color and is not clear after filtering. The high content of silica, aluminum, and iron is due to the ferruginous clay held in suspension.

SPRINGS.

There are a few springs in the county along the sides of the valleys of the main streams or their tributaries. Most of them are the result of the deepening by erosion of the valley to the level of the water table in the alluvial deposits. One of these springs is located about 4 miles northwest of Electra, in the valley of a small tributary of Red River. The water issues from the west bank of the stream for a distance of 100 yards. The main spring is about 25 yards back from the stream. It yields a considerable flow of slightly brackish water.

ARCHER COUNTY.

PHYSIOGRAPHY.

Archer County has an area of 960 square miles. The population according to the census of 1910 was 6,525; the county seat is Archer City. The county lies at an altitude of 1,000 to 1,200 feet. The mean annual rainfall is 30 inches.

The northern and southern portions of the county consist of extended rolling plains. The middle portion of the county is dissected by Little Wichita River, which flows from west to east directly across the county.

GEOLOGY.

With the possible exception of a small area in the extreme southeast corner of the county the rocks appearing at the surface belong to the Wichita formation of the Permian series. They consist for the most part of the red shales and sandstones characteristic of the formation in this part of the State. Near the western boundary thin beds of limestone appear at wide intervals, alternating with blue and red clays and sandstones. These strata constitute the lower portion of a series of limestones which belong to the upper part of the formation. The bones of vertebrates and the remains of plants that have been collected at different places in the middle and western parts of the county have contributed to the determination of the Permian age of the Wichita formation.

Deposits of copper have been found in the county, and at one time development was attempted, but the results were not satisfactory. The ore occurs in the form of nuggets and masses (some due to replacement of wood) distributed in beds of blue clay which are themselves highly impregnated with copper.[1]

WATER CONDITIONS.

There are very few wells in this county. Water supplies are drawn chiefly from cisterns and artificial ponds or "tanks." D. M. Segler, a well driller, states that he has drilled many wells in this region and

[1] Cummins, W. F., Second Ann. Rept. Texas Geol. Survey, 1890, pp. 449-455. Schmitz, E. J., Copper ores in Permian of Texas: Trans. Am. Inst. Min. Eng., vol. 26, 1896, pp. 97-108.

has found but one good well in the northern part of Archer County. The water from shallow wells is in general strongly mineralized, but some wells yield water that can be used. These wells are from 16 to 30 feet deep. At depths between 60 and 600 feet from the surface are found four or five beds which contain an abundance of water, but it is invariably salty and unfit for use. The water from these beds rises on being struck by the drill, but usually fails to reach the surface.

In 1906 three wells were put down in the vicinity of Geraldine by the Geraldine Coal & Oil Co. in the search for oil, of which only traces were found. The record of one of these wells was furnished by the driller, Mr. F. D. Kerns:

Record of well No. 3 at Geraldine, Tex.

	Thickness.	Depth.
	Feet.	*Feet.*
Surface soil, followed by red joint clay	90	90
Gray sandstone, water in lower part	16	106
Red clay	2	108
Brown clay	20	128
Red clay	15	143
Brown clay	55	198
Gray clay and fine sand	30	228
Red clay	24	252
Yellow clay	28	280
Gray sandstone with salt water which came within 20 feet of the top of the well	18	298
Red clay	22	320
Blue soapstone	18	338
Red shale with water at top	8	346
Quicksand with a thin seam of coal; water in the quicksand	4	350
Soapstone	2	352
Red shale; showing of oil and gas	178	530
Soft blue sandstone, water at top; water salty and flows out at top	10	540
Fine white sand	30	570
Red shale	2	572

At Archer City several attempts were made to find potable water in the deeper beds. The courthouse well is said to be 480 feet deep, and salty water was found in it at 125 and 180 feet. The following is the record of a well put down at Archer City, according to F. E. Roesler:[1]

Record of well at Archer City, Tex.

	Thickness.	Depth.
	Feet.	*Feet.*
Red clay	25	25
Sandrock	10	35
Red clay and hardpan	500	535
Black soil	5	540
Light-red clays	30	570
Cap rock	½	570½
Red clay	100	670½
White rock	10½	681
Sandrock	14	695
Soft white rock	7	702
Red clay	5	707
Sandrock	6	713
Soapstone	11	724
Gravel with water	1	725
Sandrock (water)	12	737

[1] S. Ex. Doc. No. 222, 51st Cong., 1st sess., 1890, p. 262.

The water found in the gravel and sandrock at the bottom rose but did not flow out at the top. Elsewhere in the same report[1] mention is made of salt water occurring at 500 feet.

No wells have been put down in the vicinity of Holliday, water being obtained from ponds and cisterns.

At Dundee also cisterns and ponds constitute the source of supply both for domestic use and for stock. There are no wells in the town and very few in the surrounding country. Small supplies are found at depths of 18 to 24 feet.

At Windthorst wells range in depth from 16 to 170 feet. The most common depth is 40 feet, but the largest supplies are found at a depth of 65 feet. In the shallow wells the water is mostly soft, and in the deeper wells it is alkaline. In this vicinity wells and cisterns are relied on for water for domestic use and ponds for stock.

At Geraldine water is found in shallow wells at depths of 20 to 40 feet, but cisterns and ponds are the most satisfactory source for all uses. In the borings made for oil (p. 56) water was found at 90–106, 280–298, 338, and 530 feet. The water from the lowest bed flowed 6½ feet above the surface and would probably rise higher. In all the borings the water was strongly salty.

WILBARGER COUNTY.

PHYSIOGRAPHY.

Wilbarger County includes the area between Baylor County and Red River and is bounded on the east by Wichita County and on the west by Hardeman and Foard counties. It has an area of 932 square miles and a population of about 12,000 (census of 1910); the county seat is Vernon. The mean annual rainfall is 28 inches.

The relief of the county is that of an eastward-sloping plain, or high rolling prairie, intersected by the wide, flat valleys of Pease River and Beaver Creek and their tributaries. The northern half of the county is drained chiefly by Pease River, which flows northeastward across the county into Red River. Beaver Creek drains the southern part of the county; it has a general eastward course and empties into Wichita River in Wichita County. From Electra, in Wichita County, to Harrold, in Wilbarger County, the Fort Worth & Denver City Railway runs along the crest of the divide between Beaver Creek and Red River. The elevation at Harrold is 1,235 feet above sea level. Vernon is situated on the south side of the Pease River valley, and the elevation at the St. Louis & San Francisco Railroad station is 1,205 feet. A prominent physiographic feature of the northern part of the county is a high sand ridge which runs northeastward about 6 miles north of Pease River. This ridge is several miles wide and rises about 100 feet

[1] S. Ex. Doc. No. 222, 51st Cong., 1st sess., 1890, p. 298.

above the surrounding prairie, which is estimated to be from 100 to 120 feet above the level of Pease River at Vernon. Pease River flows in a rather wide valley, following closely the northern bank and in places cutting into it. The valley plain on the south side of the river is about 1½ miles wide and is bordered on the south by terraced slopes. Within this valley the river flows in a channel about one-fourth of a mile wide. The water of Pease River fails entirely during times of extreme drought, and the same is true of Red River above the North Fork. The water of both streams, more especially of Pease River, is saline, because of the salt received from the beds through which it passes near its source. The great cattle trail leading from central Texas to Dodge City, Kans., passed through the present site of Vernon and crossed Red River at Doans. In 1885, according to J. E. Lapham,[1] there were driven through Vernon 300,000 head of cattle, 200,000 head of sheep, and 190,000 head of horses. The same writer says:

> The climate of the Vernon area is comparatively dry and is characterized by high winds and light annual rainfall. The temperature during the summer months is generally pretty uniform, averaging about 80° for the months of June, July, and August with a few sudden changes. In the fall and winter months, however, considerable fluctuation is noticed. Cold winds of great severity sweep down from the north without warning, changing the temperature through many degrees in the space of a few hours and causing at times much suffering to men and animals exposed to their force. During the months of July and August the winds sometimes carry with them the other extremes of temperature, the hot blasts at times resulting, in the course of a few hours or a day, in the total destruction of a crop of corn, wheat, or cotton.

GEOLOGY.

The rocks constituting the substructure of the county belong to the Wichita, Clear Fork, and Double Mountain formations of the Permian series. The southeastern part of the county is underlain by rocks of the Wichita, consisting of red clays and red sandstones interstratified at certain horizons with white and gray earthy magnesian limestones. These limestones represent the northern extension of the strata exposed in the bluffs of the Wichita north of Seymour. The most northerly exposures of these limestones occur on Beaver Creek 9 miles southwest of Electra. The diminution in the proportion of limestones in the formation and the change in the character of the beds themselves toward the north, as noted elsewhere (p. 23), is readily seen by comparing these exposures with those on the Wichita and at Seymour.

The western half of the county is underlain by sandstones, red clays, and conglomerates belonging to the Clear Fork formation. Limestones are few and mostly of earthy magnesian type. Irregular conglomerate beds constitute a noticeable feature of the formation. These beds appear to be composed of a mixture of clay and limestone

[1] Soil survey of the Vernon area: Field Operations Bur. Soils for 1902, U. S. Dept. Agr., pp. 365-381.

constituents, the proportion of lime carbonate being sufficient to give decided effervescence with acid.

The Quaternary deposits are represented by patches of the Seymour formation (Pleistocene) which cover the higher areas between the streams and the alluvial deposits in the valleys. The sands and gravels of this formation are from 30 to 40 feet thick in the western part of the county but thin out almost entirely in the eastern part. A line drawn from the northeast corner of Wilbarger County southwestward through Seymour will mark approximately the eastern limit of the Seymour formation. East of this line the formation seems to be represented only by small isolated patches of coarse conglomerates. The streams have cut entirely through the formation in that part of Wilbarger County in which it is found, and it appears therefore only as finger-like extensions in the interstream areas.

The bottoms of the main valleys, such as those of Pease and Red rivers, are covered to a considerable depth by alluvium, the product of the rivers themselves, and along the bluffs in the lower part of the Pease River valley and in adjacent parts of the valley of Red River is a deposit of sandy loam which may be of eolian origin and considerably older than the alluvium. Underneath this sandy loam at Red Bluff and near Doans Crossing is a bed of volcanic ash.[1]

WATER CONDITIONS.

In the valleys of Red and Pease rivers water is obtained in wells from 12 to 60 feet deep. In the Red River valley the most common depth is 12 to 20 feet. In the sandy areas adjoining the main valleys the depth is somewhat greater. The water in these wells is somewhat gypseous but as a rule is fairly good. The springs found in some places along the borders of the valleys have their origin in the old alluvial deposits now found as terrace remnants along the sides of the valleys or at the base of the Seymour formation. A notable spring of this character occurs at Doans. The flow here comes from a cluster of springs which yield a small stream that persists throughout the year. It does not reach the river on the surface, but sinks into the sands about a mile from its source.[1] Another notable spring is Condon's Spring, situated 2 miles west of Vernon at the south side of the Pease River valley. The flow here comes from several springs which issue from the base of the Seymour formation. The water is good, and a good flow is maintained throughout the year.

In the upland areas north of Pease River and south to the breaks of Beaver Creek water can be obtained in wells usually at depths of 20 to 30 feet, except where the Seymour formation has been removed by erosion. The eastern boundary of the Seymour formation is about 5 or 6 miles east of Vernon, and beyond this boundary good supplies of water in shallow wells seem not to be common.

[1] Lapham, J. E., op. cit., p. 369.

[1] Idem, p. 370.

HARDEMAN AND FOARD COUNTIES.

PHYSIOGRAPHY.

The area of Hardeman County is 532 square miles and that of Foard County is 636 square miles. The population of Hardeman County is 11,213; that of Foard County 5,726. The mean annual rainfall for the two counties is about 25 inches.

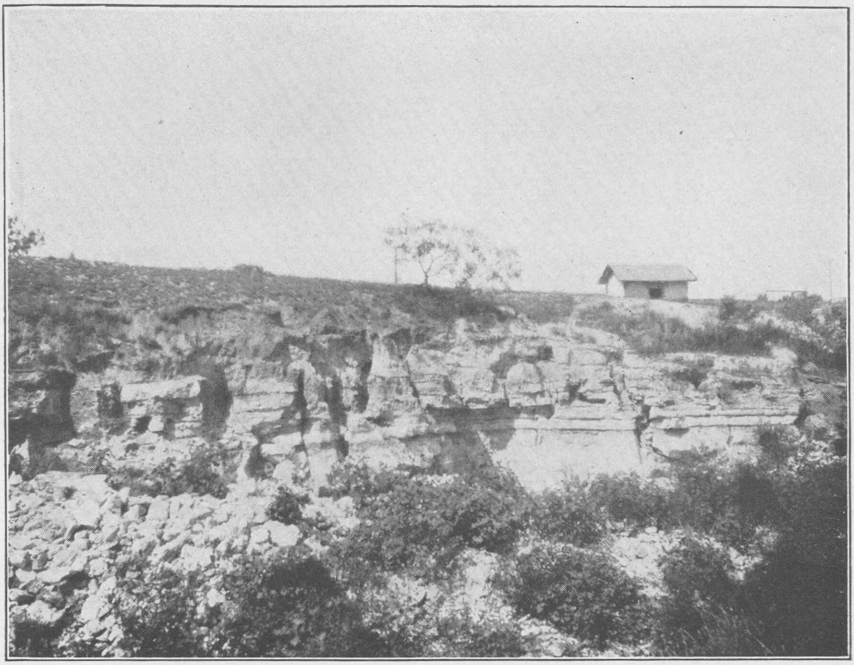
The relief of the area resembles that of Wilbarger County in its essential features, comprising a high rolling eastward-sloping plain dissected by a number of eastward-flowing tributaries of Red and Wichita rivers. The elevation of the plain surface at Quanah is 1,568 feet above sea level and at Acme, 5 miles west, it is 1,578 feet, according to railroad profiles. The northern part of Hardeman County is drained by the tributaries of Red River and the southern part by Pease River, which constitutes in part the boundary between Hardeman and Foard counties. The North Fork of Wichita River drains the western part of Foard County; the eastern part is drained by the upper tributaries of Beaver Creek. In general the streams have wide valleys, but considerable tracts of level land make up the interstream areas.

GEOLOGY.

These counties are underlain by rocks belonging to the Clear Fork and Double Mountain formations of the Permian series. Over considerable areas these beds are covered by later formations, but exposures are numerous along the sides of the valleys and in the ravines tributary to them. In the eastern part of the counties the rocks consist of red clays, red sandy shales, and red sandstones, with a little gypsum in thin scattered seams. The slight westward dip of the strata, combined with the eastward slope of the surface, brings later beds to view in the western part of the counties, where the rocks consist of red clays and sandstones alternating with blue clays and sandstones, beds of gypsum, and some limestones. The gypsum occurs in lenses from a few inches to 8 or 10 feet thick. The lack of persistency in the gypsum beds and their associated magnesian limestones and the varying position of the beds vertically render ineffectual any attempt to correlate the different deposits except within small areas. A composite section taken between Crowell and Quanah shows the following formations:

Section showing rocks exposed between Crowell and Quanah, Tex.

	Feet.
Soil, dark; thins out on approaching breaks of Pease River.	
Limestone	5
Blue clay	15
Gypsum	3
Red and blue clays, with thin layers of limestone	10
Gypsum	2
Blue clays	15
Gypsum	2



A. OUTCROP OF GYPSUM AT ACME, TEX.

B. SPRING FROM THE CANYON FORMATION AT JACKSBORO, TEX.

	Feet.
Red and blue clays, with some thin beds of red sandstones	20
Red sandstones, cross-bedded	4
Red clays, with thin beds of sandstone	10
Bluish-white sandstones, cross-bedded	5
Red clays, with seams of gypsum	15

The uplands south of Pease River in the vicinity of Crowell and south to the breaks of North Fork of Wichita River are covered by fine black silt 6 to 8 feet thick underlain by gravel (Seymour) 2 to 3 feet thick. The gravels rest upon red joint clay of the Permian. A well drilled in the southeastern part of Quanah by J. J. Cyrus gave the following section:

Section of well at Quanah, Tex.

[Elevation, 1,570 feet.]

	Thickness.	Depth.
	Feet.	*Feet.*
1. Black dirt	5	5
2. Red clay	5	10
3. Blue clay	5	15
4. Limestone	5	20
5. Red and blue clay	20	40
6. Gypsum and clay	25	65
7. Red and blue clay	10	75
8. Gypsum, replaced locally by limestone	8	83
9. Thin bed of gravel with water	2±	85±
10. Light-colored clay	10±	95±

In the center of town bed No. 6 is all clay and No. 8 is replaced by limestone.

Gypsum is quarried at Acme (Pl. II, *A*), 5 miles west of Quanah, and also at Gypsum, 10 miles west.

The Seymour formation appears in the interstream areas in thin beds of gravel resting upon the eroded surface of the Permian red clays. These clays when struck in wells are called "Birdseye" by the drillers, from their variegated appearance. In Foard County the Seymour formation is about 10 to 15 feet thick and consists of gravel below and a dark silt above. This formation was apparently deposited in a small body of fresh water, which long ago vanished.

The wide bottoms of the streams are covered by alluvial deposits of considerable depth. The rivers are constantly at work upon these deposits and change their channels from time to time, making the maintenance of bridges expensive and troublesome. Hence bridges are few and the streams are usually crossed by fording.

WATER CONDITIONS.

In Hardeman County the Seymour formation is thin or absent, and supplies of well water are found in the Permian rocks at depths of 40 to 150 feet. The water obtained in these wells differs greatly in quality, but in general it is highly mineralized. For the most part cisterns are relied upon for domestic supplies.

At Quanah water is found in the center of town in a porous limestone (No. 8, p. 61) at a depth of 75 feet. Locally this limestone is replaced by gypsum and the water occurs in a thin stratum of gravel below the gypsum bed. The city supply is drawn from this zone. The limestone is not uniformly porous and considerable differences exist in wells put down to this horizon. The water found in limestone is of fairly good quality, but that in other rocks is gypseous.

At Acme wells and creeks supply water for general purposes. Most of the water for drinking is shipped in, and the supply for other domestic uses is obtained from cisterns. The wells are from 60 to 160 feet deep, the most common depth being 100 feet. Acme is situated on South Grosbeck Creek, a perennial stream supplied from springs.

In Foard County water for domestic use is derived mostly from shallow wells and cisterns. Over a considerable part of the county water is found in the Seymour formation at depths of 10 to 20 feet. Elsewhere the Seymour formation is thin or altogether absent, its water supply is small, and in places it is dry. Springs which derive their supply from it occur in many places along the sides of valleys where the streams have cut through the formation. Some wells extend into the Permian clay below. The water from these wells is usually too highly mineralized for general use. Some of the water from the gravels of the Seymour formation is fair, but as a rule it is more or less mineralized.

At Margaret water for domestic use is obtained from wells about 20 feet deep. Artificial ponds furnish water for stock.

In the vicinity of Thalia both wells and cisterns are used for domestic supplies, the water being found at depths of 12 to 50 feet.

At Crowell most of the water used is obtained in the gravel underlying the black soil at 12 to 20 feet. This supply is inadequate, however, and is supplemented by cisterns and tanks.

Analyses of water from wells at Quanah are given below:

Analyses of water from wells at Quanah, Tex.

[Parts per million. Analyst, B. L. Glascock.]

	1	2
Silica (SiO_2)	16	18
Iron (Fe)	.6	1.2
Aluminum (Al)	2.2	1.0
Calcium (Ca)	406	252
Magnesium (Mg)	79	85
Sodium (Na)	46	74
Potassium (K)	13	12
Carbonate radicle (CO_3)	.0	.0
Bicarbonate radicle (HCO_3)	249	151
Sulphate radicle (SO_4)	1,141	816
Nitrate radicle (NO_3)	5.0	19
Chlorine (Cl)	60	173
Total solids	1,988	1,618
Turbidity	0	0
Date of collection	Sept. 12, 1907	Sept. 24, 1907

1. Well of Bert Abbott. Depth, 65 feet. Upper Permian.
2. Well at ice plant. Upper Permian.

The following note has been prepared by R. B. Dole:

Both waters are too high in mineral content, and especially in sulphates, to be very good for domestic use, though they are drinkable. They would be corrosive and contain too great quantities of scale-forming ingredients to be suitable for boiler use. The chemicals necessary to correct the scaling and corroding tendencies would render them likely to foam badly in boilers.

KNOX COUNTY.

PHYSIOGRAPHY.

Knox County, which adjoins Foard County on the south, is rectangular in outline and contains an area of 947 square miles. Its population is 9,625. The county seat is Benjamin. The mean annual rainfall is 25 inches.

The surface consists of a rolling eastward-sloping plain intersected by the wide valleys of the Salt Fork of Brazos River and the North and South forks of Wichita River. Considerable areas between the drainage systems remain undissected. The soil in these upland areas is generally of excellent quality and well suited to agriculture. The bottom lands, where not subject to overflow, offer favorable conditions for farming, but at the sides of the valleys there are considerable areas of badlands due to the erosion of the Permian shales and sandstones. The present valley of the Salt Fork has a depth of about 75 feet below the general plain level, which ranges from 1,475 to 1,525 feet above the sea. The valleys of Wichita and Brazos rivers are 3 to 4 miles wide, the main valley plains having a depth of about 50 feet below the general surface. Within these older valleys and about 10 feet below their level the rivers have cut later valleys with terraced slopes. The rivers flow in channels about 10 feet deep in the bottoms of these later valleys.

GEOLOGY.

The substructure of Knox County consists entirely of the red clays and sandstones, with their associated blue shales and gypsum, belonging to the Clear Fork and Double Mountain formations of the Permian series. These formations outcrop extensively along the valleys of the streams, but in the upland areas they are covered by the sands and gravels of the Seymour formation. A section taken in the breaks of the South Fork of the Wichita near the road leading north from Benjamin shows the following formations:

Section in breaks of the South Fork of Wichita River.

	Feet.
Pleistocene:	
Sand and gravel with lenses of red clay. Gravels contain numerous worn shells of Gryphæa (Seymour formation)	25
Permian:	
Red clay with white spots ("Birdseye" of drillers)	10
Bluish-white clay grading horizontally into magnesian limestone	1–5
Red clays mottled with white ("Birdseye" of drillers) with lenses of limestone and gypsum	15

In the southern part of the county the surface formations consist of 30 feet of the sand and red silts underlain by gravels (Seymour formation). In these are often found the bones and teeth of mammals, Mastodon and Equus, as noted elsewhere (pp. 31).

WATER CONDITIONS.

Where well developed the Seymour formation usually contains water of good quality. The supply is not everywhere abundant, however, and some wells extend through the Seymour into the Permian beds before obtaining water.

The red clays of the Permian constitute the source of supply in many wells, but the water from them is always mineralized, so much so in places that it can not be used. The wells are of varying depth, usually more than 50 feet.

The deep-water conditions are not such as to warrant the expectation of finding potable supplies of water within the range of practicable drilling.

HASKELL COUNTY.

PHYSIOGRAPHY.

The surface of Haskell County consists of a high rolling plain which rises toward the west. The county has an area of 843 square miles, and its population in 1910 was 16,249, an increase of over 500 per cent in the decade since 1900. The county seat is Haskell. The mean annual rainfall is 25 inches. There are few streams in the county, and these are small and unimportant. The eastern part of the county is drained by Paint and Millers creeks, the former flowing eastward into the Clear Fork and the latter northeastward into the Salt Fork south of Seymour. In the western part of the county the Double Mountain Fork of the Brazos swings eastward into the county, but leaves it again before reaching the northern boundary.

At Haskell the elevation at the station of the Wichita Valley Railway is 1,574 feet above sea level. At Rule, on the open plain about 10 miles west of Haskell, the elevation is 1,672 feet at the Kansas City, Mexico & Orient Railway. Carney, near the northern boundary of the county, nearly due north of Rule, on the same railway, is 1,560 feet above sea level.

GEOLOGY.

The geology of Haskell County does not differ essentially from that of Knox County. The Seymour formation has a thickness of about 30 feet over the eastern part of the county but thickens toward the west to 50 or 60 feet. For the most part the streams cut through this formation into the red beds of the Permian below. The larger part of the Seymour formation consists of fine red and yellow calcareous clay or silt containing a varying amount of sand. The red clays, which are 20 to 30 feet thick, rest upon about 10 feet of sand and gravel. In places the calcareous clays are consolidated in their upper portion into an irregular deposit of impure limestone, the caliche of the semiarid regions (p. 32).

WATER CONDITIONS.

At Haskell water is obtained from the gravel bed at the base of the Seymour formation. The wells are generally from 20 to 35 feet deep in the vicinity of the town. As the formation thins toward the south, the wells are shallower in that direction. Where the streams have sunk their channels through the gravels, springs may appear, as, for example, the Rice spring at Haskell.

West of Haskell the wells in the gravels increase somewhat in depth, owing to the thickening of the formation. On approaching the Double Mountain Fork, whose channel extends considerably below the level of the gravels, these beds appear to be bereft of water and the wells extend some distance into the red clays (Permian) before striking water, which, as elsewhere in this series, is of poor quality.

The following table gives several analyses of Haskell County waters:

Analyses of ground waters in Haskell County, Tex.

[Parts per million. Analyst, B. L. Glascock.]

	1	2	3	4	5
Silica (SiO_2)	23	29	20	37	20
Iron (Fe)	.35	.6	1	.3	.2
Aluminum (Al)	5.6	.4	3.8	.8	.4
Calcium (Ca)	464	30	311	70	259
Magnesium (Mg)	301	16	120	30	106
Sodium (Na)	2,377	133	190	72	195
Potassium (K)	25	6.5	8	8	25
Carbonate radicle (CO_3)	19	19	4.8	2.4	0
Bicarbonate radicle (HCO_3)	571	283	202	373	150
Sulphate radicle (SO_4)	3,512	134	1,237	50	1,148
Nitrate radicle (NO_3)	1.06	26	4	11	2.5
Chlorine (Cl)	2,512	102	169	21	174
Total solids	9,469	626	2,320	446	2,065
Turbidity	0	0	0	0	0
Date of collection	Sept. 6, 1907	Sept. 6, 1907	Sept. 24, 1907	Sept. 24, 1907	Sept. 12, 1907

1. Well of J. W. Westbrook, at Haskell, Tex.; depth, 10 feet. Seymour formation.
2. Courthouse well at Haskell, Tex.; depth, 20 feet. Seymour formation.
3. Well "Harder water," at Rule, Tex.; depth, 75+ feet. Upper Permian.
4. Well, "Softer water," at Rule, Tex.; depth, 40-50 feet. Seymour formation.
5. Foster & Jones's hotel well at Rule, Tex.; depth, 60 feet. Seymour formation.

The following note regarding the usefulness of these waters has been prepared by R. B. Dole, of the United States Geological Survey:

The first water is so strong that it is unfit for use. Analyses 2 and 4, of calcium-carbonate waters only moderately mineralized, represent the best supplies. These two waters are fairly well adapted to irrigation and to use as boiler feed and are acceptable for domestic service. The waters represented by analyses 3 and 5 are similar to each other, being sulphate waters of too high mineral content to be very acceptable ford omestic use, though they are drinkable and may be classed as fair for irrigation; they are unfit for supplying steam boilers.

At Rule the well of Werner Rule, located in the southwestern part of the town, gives the following record, according to the driller, E. F. Heller:

Record of Rule well, at Rule, Tex.

	Thickness.	Depth.
	Feet.	*Feet.*
Soft dark sandy soil	3	3
Hard white marl	24	27
Soft white sand and gravel	14	41
Hard reddish rock	2	43
Hard white clay	2	45
Hard red clay, water bearing	2	47
Hard red clay	17	64
Hard white clay, water bearing, yielding one-half gallon a minute	2	66

The well of Mr. Williams, located on the north side of the town, is 105 feet deep, with the following record:

Record of Williams well, at Rule, Tex.

	Thickness.	Depth.
	Feet.	*Feet.*
Soft dark soil	3	3
Hard gray marl	27	30
Soft red sand and gravel	10	40
Hard reddish rock	2	42
Hard gray clay	1	43
Hard red clay, water bearing	12	55
Hard white clay, water bearing	2	57
Hard red clay	28	85
Hard grayish clay, water bearing	2	87
Hard red clay	8	95
Hard grayish clay, water bearing	5	100
Hard red clay	5	105

Ten miles northwest of Rule, on the farm of W. E. Pyeatt, is a well whose record, according to the driller, E. F. Heller, is as follows:

Record of Pyeatt well, near Rule, Tex.

	Thickness.	Depth.
	Feet.	*Feet.*
Soft dark sandy soil	5	5
Hard red sand	15	20
Hard gray marl	5	25
Soft red sand	52	72
Hard red clay	5	82
Hard white clay, water bearing	1	83
Hard red clay	24	107
Hard red clay, water bearing	1	108
Hard red clay	4	112

About 12 miles southwest of Rule, on the farm of C. Boardner, is a well 70 feet deep, with the following record, according to the same authority:

Record of Boardner well, near Rule, Tex.

	Thickness.	Depth.
	Feet.	*Feet.*
Black firm soil	3	3
Hard chalky soil	9	12
Reddish soft sand	4	16
Hard red stone	3	19
White soft sand	2	21
Hard red clay	31	52
Hard grayish clay, water bearing	1	53
Hard white sandstone	16	69
Soft blue clay, water bearing		70

The water in the Boardner well is said to rise within 40 feet of the surface.

Many wells in the western part of Haskell County derive their supplies from the Seymour formation at depths of 40 to 50 feet. The water from this horizon is reported as "soft" and fairly good. The water in the deeper wells is obtained from the Permian beds and is more highly mineralized.

BAYLOR COUNTY.

PHYSIOGRAPHY.

Baylor County has an area of 957 square miles and in 1910 had a population of 8,411. The mean annual rainfall of the county is 38 inches. The altitude of the county is approximately 1,500 feet above sea level. The north half of the county is drained by Wichita River, formed by the junction of the South and North forks in the western part of the county. The Salt Fork of Brazos River flows in a southeasterly direction across the southern part of the county. For the most part these streams flow in rather wide valleys. At Seymour the Salt Fork cuts across a belt of limestone, and in this part of its course its valley is narrower.

The surface of the county in the interstream area is a high rolling plain. In the valley of the main stream and over portions of the uplands the soil is fertile and capable of producing abundant crops.

GEOLOGY.

The indurated rocks of the county belong to the Permian series. The Wichita formation crops out over the eastern half of the county, and in this area some of the most interesting Permian fossils have been found. The rocks, which consist of blue and red shales and white to bluish-gray magnesian limestones, constitute the upper portion of the Wichita formation. At Seymour, where the river has cut into the formation, the following section was obtained:

Section at Seymour, Tex.

	Ft.	in.
Light-reddish sandy soil at surface, underlain by dark-red sandy soil	20 to 25	
Blue shale, with thin ledges of magnesian limestone	6	
Limestone in massive beds, passing horizontally into shaly beds	5	
Dark clay shale	1	6
Concretionary calcareous shale and limestones		6
Limestone in two massive ledges separated by 1 to 4 inches of blue clay shale	3	
Blue shale	10	
Argillaceous limestone and dark-blue shale	3	
Limestone with varying proportions of shale	4	
Blue clay	3	
Red clay	5	
Blue clay	2	
Limestone	2	
Blue clay shale	5	
Limestone		6
Blue clay shale	4	
Limestone	1	6
Blue shale, with lenses of limestone	3	
Blue clay shale, interbedded with thin limestone	2	
Limestone	16	
	102	

These limestones outcrop in a belt extending southward from this point across Throckmorton County and beyond. North of Seymour they were observed in the valley of Wichita River, east of the Seymour-Vernon road, and also on Beaver Creek. In their northward extent the limestones diminish in thickness, and there is a corresponding increase in the proportion of red clays and shales. Many of the limestones are white and chalky and in beds of this kind near Mabelle abundant fragments of vertebrate remains were seen, among them being the piece of a jaw of a vertebrate, but vigorous search failed to bring to light remains sufficient for identification. Williston [1] has recorded the discovery in 1909 in Baylor County of the remains of vertebrates, among which are several forms new to science. Some of these were found about 6 miles east of Seymour and others on West Coffee Creek.

The Seymour formation constitutes the formation at the surface over the upland areas west of the town of Seymour, which lies upon the sand of this formation. The formation does not occur generally east of Seymour, but in some places, as near Mabelle station, there are patches of conglomerate which possibly represent outliers of the formation.

[1] Jour. Geology, vol. 17, 1909, pp. 636–658; vol. 18, 1910, pp. 526–536, 585–600; vol. 19, 1911, pp. 232–237.

WATER CONDITIONS.

In the eastern part of the county cisterns are in common use for supplies of water for domestic purposes, but tanks are the chief resource for stock. Some wells are used in the upland areas, where, however, the water is not generally of satisfactory quality. In the western part of the county fairly good water is found in the Seymour formation, and in the sands and gravels along the main valley. The depth of the wells in this area is from 15 to 45 feet, the most common depth being 20 to 25 feet. Some wells extend below the Seymour formation into the underlying formation, but these invariably yield gypseous water.

The character of the water obtained from the Seymour formation at Seymour is shown by the following analysis of the water from the roundhouse well:

Analysis of water from roundhouse well, Seymour, Tex.

[Parts per million. W. M. Barr, analyst. Sample collected Nov. 1, 1906.]

Silica (SiO_2)	22
Iron (Fe)	.05
Calcium (Ca)	61
Magnesium (Mg)	32
Sodium (Na) and potassium (K)	183
Carbonate radicle (CO_3)	.0
Bicarbonate radicle (HCO_3)	401
Sulphate radicle (SO_4)	86
Chlorine (Cl)	152
Nitrate radicle (NO_3)	9.7
Total solids	746
Suspended matter	0

Along the valley of Salt Fork water is found in the sands and gravels at depths of 15 to 25 feet. In some places the water is of good quality, but generally it contains a considerable amount of mineral matter.

The following are analyses of water from two wells at Round Timber:

Analyses of water from wells at Round Timber, Tex.

[Parts per million. Samples collected Oct. 9, 1906.]

	Gin well; depth about 20 feet.	Well 200 yards northeast of the store; depth 40 feet.
Silica (SiO_2)	24	28
Iron (Fe)	.6	.4
Calcium (Ca)	139	82
Magnesium (Mg)	51	54
Sodium (Na) and potassium (K)	79	323
Carbonate radicle (CO_3)	.0	.0
Bicarbonate radicle (HCO_3)	437	414
Sulphate radicle (SO_4)	172	173
Chlorine (Cl)	130	401
Nitrate radicle (NO_3)	4.3	40
Total solids	839	1,318
Turbidity	0	5

The differences in the analyses of these waters are probably due to the fact that the well at the store derives its supply in part from the Wichita formation. The character of the water, considered in connection with the depth and location of this well near the side of the valley, indicates that the bottom of the well is in the shales of the Wichita formation.

At Shady, in the southwestern part of the county, water is obtained chiefly from open wells, ranging from 15 to 40 feet in depth, the most common depth being 35 feet. These wells have their source of supply in the Seymour formation. The well of J. F. Jones is 93½ feet in depth, and evidently finds water in the Permian clays underlying the Seymour formation.

Springs are rare in the county. They exist chiefly where streams have cut their channels to the level of the ground water in the Seymour formation. The most notable spring in this region is owned by Albert Par, of Shady.

THROCKMORTON COUNTY.

PHYSIOGRAPHY.

Throckmorton County lies south of Baylor County and east of Haskell. It has an area of 821 square miles and a population, according to the census of 1910, of 4,563; its county seat is Throckmorton, situated near the center of the county. The mean annual rainfall is 28 inches.

The surface is high and rolling and there are few streams of importance. The Clear Fork of the Brazos cuts off a small triangular area in the southwest corner and the Salt Fork a like area in the northeast corner of the county. The county is drained by these two streams and their tributaries. The interstream areas, which are either flat or gently rolling, constitute remnants of an extensive plain into which the tributaries have cut wide and shallow valleys. The topography is characterized by a benchlike structure resulting from the resistance offered to erosion by a series of heavy beds of limestone. The eastward-facing scarps of these limestones constitute a series of rock terraces that extend in a north-northeastward direction through the middle of the county. These terraces have their best development, however, farther south in Shackelford and Stephens counties.

GEOLOGY.

Except in small areas in the northwestern part of the county and along the eastern boundary the rocks outcropping in Throckmorton County belong to the Wichita formation. The beds strike nearly north and south and dip slightly to the west. The upper part of the formation is made up of heavy beds of hard limestone alternating with thicker beds of blue and red shales and sandstones. The limestones appear about 8 miles east of Throckmorton and cap the higher levels throughout the middle and western portions of the county. These beds outcrop in prominent escarpments on the north side of the Clear Fork and farther north wherever the streams have eroded their channels through them.

The limestones vary in color from grayish white to blue and in texture from earthy and granular to hard and compact. Some of the layers are thick and massive, and although the limestones constitute the minor part of the formation, their resistance to erosion makes them, in the area of their outcrop, the dominant features of the landscape. The character of some of these exposures will be seen from the following section of the bluff facing the Clear Fork:

Section of Wichita formation on north side of Clear Fork.

	Feet.
Soil, from a few inches to a few feet in thickness.	
Blue shales and thin beds of limestones	30
Hard earthy limestone	1
Blue shale	2
Fossiliferous limestone, earthy and containing more or less gypsum. Upper 4 feet hard, blue, and full of remains of brachiopods and gastropods, mostly changed to gypsum or calcite	10
Blue and red shales, some portions grading locally into sandy shales and sandstones. The upper part contains considerable gypsum; the lower has an abundance of iron concretions. Contains also thin lenses of limestone and gypsum; exposed	40

Three miles north of Throckmorton a 10-foot ledge of limestone yielded the following fossils:

Derbya cymbula.
Myalina deltoidea.
Aviculipinna peracuta.
Pleurophorus aff. calhouni.
Annelid n. g., n. sp.

The eastern part of the county is underlain by lower beds consisting mostly of sandy shales and sandstones with some limestones. Some hills in the southeastern part carved out of these formations by erosion are known locally as Fane Mountain. The section obtained here shows chiefly sandy shales and sandstones, blue clay shales, and scattered lenses of blue limestone. In some of the beds there is a profusion of *Myalina permiana*. Some buttes in the northern part of the county, on the Throckmorton-Seymour road, apparently belong to this horizon. They consist mostly of shales with a few thin beds of limestone and some sandstones. Many specimens of *Myalina permiana* are scattered over the surface. Red colors dominate over blue in the shales of this locality, but at Fane Mountain the reverse is true.

Beds of upper Permian age appear in the extreme western and northwestern parts of the county.

With the possible exception of a small area of Seymour formation in the western part of the county, the only deposits later in age than the Permian are the alluvial deposits along the valley bottoms.

The soils are exceedingly fertile in the limestone areas and only slightly less so in the more sandy areas.

WATER CONDITIONS.

Except in the valleys, the principal water supply is derived from pools and cisterns. Here and there a well on the upland areas furnishes good water.

Two wells in Throckmorton find water that is said to be soft at a depth of 50 feet. Few wells in the county reach a depth of more than 100 feet. Plenty of water may be found at different depths in the underlying rocks, but it is more or less mineralized and unfit for use. There is little prospect that good water can be obtained in the deep-seated beds. A few good springs occur in the county.

YOUNG COUNTY.

PHYSIOGRAPHY.

Young County adjoins Throckmorton County on the east. In shape it is rectangular (approximately square) and has an area of 821 square miles. Its population according to the 1910 census was 13,657. The county seat is Graham. The mean annual rainfall is 30 inches.

The surface of this county is more or less irregular and broken and may be characterized topographically as a plain in which denudation has proceeded to the extent of removing a large portion of the original surface and has developed a moderately mature system of drainage. The underlying rocks include several series of hard beds, whose resistance to erosion is expressed in a succession of escarpments extending from southwest to northeast. The heights of these escarpments vary according to the relative thickness of the hard and soft formations. The creeks and rivers have transected them in many places, leaving isolated hills and elevations, some of considerable size. The highest of these hills are locally called mountains, as the Belknap Mountains, near old Fort Belknap, and Flat Mountain, in the northeastern part of the county.

The county is drained by the Salt Fork of Brazos River and its tributaries, except a small area in the northeast corner, which is drained by small tributaries of the West Fork of Trinity River. The Salt Fork enters the county near the northwest corner, and after making a wide detour toward the south, receiving the Clear Fork from the southwest, passes out at the southeast corner. The principal tributary lying wholly within the county is Salt Creek, which, with its affluents, drains the northeastern portion of the county.

GEOLOGY.

By far the larger part of the rocks outcropping in Young County belong to the Cisco formation, but the Wichita formation occupies a narrow belt along the west side of the county. In the extreme southeast the Salt Fork has cut through the Cisco, exposing the canyon formation in the immediate vicinity of the stream.

The beds exposed in the western part of the county consist of sandy shales and sandstones, blue shales, and a few limestones, representing the lower division of the Wichita as seen in eastern Throckmorton County. The surface is covered with a mantle of residual soil which hides the indurated rocks more or less completely. Moreover a close correspondence in lithologic character exists between the lower beds of the Wichita formation and the upper beds of the Cisco, and hence the boundary line between the two formations as shown on the accompanying map is to be considered as approximate only.

The Cisco, which underlies the larger part of the county, consists chiefly of sandy shales and clays, sandstones, and conglomerates, with a few beds of limestone and two or more beds of coal. The conglomerates are made up of waterworn siliceous pebbles in a sandy matrix, with numerous concretions of iron ore, often in hollow nodules. They pass locally into pebbly sands and coarse-grained sandstones. Owing to their resistance to erosion, the conglomerates cap many of the hills and escarpments. The sandstones are mostly coarse grained and yellowish to red and white. The clays are blue, yellow, and red, or in places variegated. There is a transition in color from blue, which prevails at the south side of the county, to red, which is the predominating color at the north. The limestones are scattered through the formation, but are more characteristic of the upper part. They range in thickness from a few inches to about 2 feet. The banks of the Salt Fork expose several strata of limestone, one of which is underlain by a bed of coal. This coal appears at the bridge crossing, west of Graham, and at Millers Bend crossing several miles above. The combined section obtained in these two places is as follows:

Section between Millers Bend crossing and bridge crossing.

	Ft.	in.
Soil.		
Limestone		10
Shales, blue, some layers sandy	70	
Limestone	1	
Blue shales	2	
Limestone, fossiliferous	2	
Coal; not well exposed; thickness estimated at about 1 foot.		
Fire clay filled with brown iron ore	6	
Blue clay shales with alternating layers of red clays containing iron concretions	10	
Sandy shales and sandstones	15	
	106	10

In the vicinity of old Fort Belknap coal is mined from a seam lying above the one indicated in this section. In 1907 Williams & Merrill were taking out coal from the bed of a small stream about a mile north of Fort Belknap by stripping. The coal is exposed for some distance in the bed of the stream and at the place worked has a thickness of 3 feet. Within a distance of 25 yards upstream it thins to 20 inches of impure shaly coal. About 150 yards north of this point at Clark & Merrill's mine, the same seam is reached by a short slope. The coal here is 3 feet thick and is overlain by 20 feet of sandy shales with a thin seam of coal near the top. Above these are sandstones 30 to 40 feet thick. A detailed description of the coal formations of Young County is given by Cummins.[1]

A section of the rocks exposed in the bank of Salt Creek opposite the gin at Graham is given on page 19.

A well put down at Graham a number of years ago gave the following section:[2]

Section of well at Graham, Tex.

	Thickness.	Depth.
	Feet.	*Feet.*
Sandy loam	16	16
Blue sandy clay	3	19
Gravel and sand	8	27
Conglomerate	16	43
Cream-colored clay	8	51
Yellowish and bluish sandstone	10	61
Hard yellow sandstone	5	66
Coal	1	67
Coarse yellow soft sandstone	4	71
Hard quartzose sandstone	13	84
Fire clay, bluish	42	126
Hard brown clay	5	131
Brown sandstone, porous (gas)	5	136
Clay and slate	9	145
Brown clay, very hard	8	153
Variegated clay	148	301
Fire clay with thin stratum of shale	70	371
Black "slate" with gas	8½	379½
Red shale	10	389½
Sandstone	1½	391

The record of a prospect hole 3½ miles southwest of Belknap was kindly furnished by the owner, Judge R. F. Arnold, of Graham. This hole is located in what is known as Sugar Hollow, on Gibbon Creek. The drill began near the top of the Cisco but did not penetrate the full thickness of that formation.

[1] Cummins, W. F., Second Ann. Rept. Texas Geol. Survey, 1890, pp. 492-502. [2] Idem, p. 505.

Record of Belknap well, 3½ miles southwest of Belknap, Tex.

	Thickness.	Depth.
	Feet.	*Feet.*
1. Rock concrete (conglomerate)	3	3
2. Yellow clay	4	7
3. Carbonaceous limestone	4	11
4. Gray clay	2	13
5. Limestone	1½	14½
6. Fire clay	3½	18
7. Rock (?)	2	20
8. Spotted clay	5	25
9. Sandstone	8	33
10. Slate	3	36
11. Coal ("Belknap coal")	2½	38½
12. Soapstone	7½	46
13. Sandstone	3	49
14. Soapstone	5	54
15. Limestone	3	57
16. Blue clay	1	58
17. Carbonaceous limestone	2	60
18. Soapstone	6½	66½
19. Slate	4½	71
20. Fire clay	5	76
21. Carbonaceous limestone	2	78
22. Blue clay	1	79
23. Carbonaceous limestone	2½	81½
24. Blue clay	1½	83
25. Carbonaceous clay	5½	88½
26. Coal, "of good quality"	2½	91
27. Blue clay	10	101
28. Fire clay	6	107
29. "Mineral" clay	10	117
30. Blue rock (very hard)	2	119
31. Blue clay	11	130
32. Carbonaceous limestone	20	150
33. Sandstone ("contains some gas")	42	192
34. Shale	12	204
35. Blue rock	3	207
36. Blue clay	2	209
37. Blue rock	3	212
38. Blue clay	13	225
39. Sandstone (gas)	7	232
40. Green shale	25	257
41. Sandstone (gas)	7	264
42. Dark shale	6	270
43. Sandstone (water)	33	303
44. Carbonaceous limestone	5	308
45. Blue shale	6	314
46. Sandstone	21	335
47. Rock concrete (conglomerate)	37	372
48. Gray rock (gas)	13	385
49. Blue shale	45	430
50. Black muck	5	435
51. Blue clay	16	451
52. Limestone	5	456
53. Blue shale	5	461
54. Black gumbo	6	467
55. Blue shale	12½	489½
56. Gray sandstone	4½	504
57. Salt sandrock	22	526
58. Shale	136	662
59. Rock (water)	22	684
60. Blue clay	2	686
61. Rock (oil)	8	694
62. Dark-blue clay	8	702
63. Hard sandstone	18	720
64. Soft rock (water)	6	726

The upper coal (No. 11) is the one mined near Belknap, and the lower seam (No. 26) is probably the stratum seen in the banks of the river (p. 73). Beds 47 to 56 are believed to represent the outcrop shown in the banks of Salt Creek at Graham. (See section, p. 19.) Indications of gas and oil were reported at several horizons, but not in commercial quantities.

One mile northwest of Murray post office a well put down in 1900 struck gas at a depth of 364½ feet. Pressure has decreased since the well was first opened, but in 1907 the escape was sufficient to furnish a blaze about 18 inches high.

In the eastern part of the county the indurated beds consist principally of sandstones and some conglomerates interbedded with blue and yellow clays. At a number of places outcrops of thin beds of limestone were observed. These belong near the base of the Cisco formation. There are several of these limestone beds, ranging from a few inches to 1 or 2 feet in thickness and interbedded with shales. The southeastern part of the county is underlain by sandstones and conglomerates and a few thin beds of limestone interbedded with blue and yellow clays. These rocks rest upon the limestones of the Canyon formation, small exposures of which appear in the banks of the Salt Fork of the Brazos, in the extreme southeast corner of the county. The country is much dissected by erosion, the hills being for the most part capped by conglomerate.

WATER CONDITIONS.

Water for domestic use is obtained largely from cisterns and shallow wells. The wells derive their supplies from the residual sands or upper portions of the sandstones. In many places the underground waters are unsatisfactory and supplies are difficult to obtain. Creeks and storage tanks are relied upon for stock.

Many of the sandstones of the Cisco are porous and contain abundant supplies of water, but for the most part the water is more or less impregnated with sodium chloride and other mineral salts, although a few wells of moderate depth in the sandstone furnish water of fair quality. Salt Creek owes its name to the fact that during dry seasons salt was found incrusting the rocks and gravel in the bed of the stream. The water found in quantities in the deep well put down at Graham (p. 74) is reported to contain 22 to 25 per cent of salt. The largest supply of water is found at a depth of 200 to 300 feet. No flowing wells are known in this locality, the water in the deep wells rising no higher than 30 feet from the surface.

Samples from a number of wells were analyzed in the Survey laboratory, with the results shown in the following table:

Analyses of water from wells in Young County, Tex.

[Parts per million.)

	1	2	3	4	
Silica (SiO_2)	7.6	13	12	8.4	14
Iron (Fe)	4.0	1.8	Tr.	.45	Tr.
Calcium (Ca)	898	554	83	504	116
Magnesium (Mg)	230	534	16	222	46
Sodium (Na) and potassium (K)	7,316	166	70	295	164
Carbonate radicle (CO_3)	.0	.0	.0	.0	.0
Bicarbonate radicle (HCO_3)	164	445	339	242	354
Sulphate radicle (SO_4)	42	2,934	55	1,887	154
Chlorine (Cl)	13,580	293	56	158	245
Nitrate radicle (NO_3)	2.2	8.2	4.2	16	28
Turbidity	(a)	....	5	(a)	.0
Total solids	22,579	[b] 5,334	451	3,223	945
Date of collection	December, 1906	February, 1907	December, 1906	December, 1906	October 11, 1906

[a] A slight turbidity, probably due to precipitation of iron after collection of sample.
[b] Phosphate radicle (PO_4), 0.0.

1. Judge R. F. Arnold's well, Graham; depth, 110 feet. W. M. Barr, analyst.
2. Barber shop well, Graham; depth, 61 feet. H. S. Spaulding, analyst.
3. John C. Kay's well, Graham; depth, 65 feet. W. M. Barr, analyst.
4. Well on lot 10, block 11, Graham. W. M. Barr, analyst.
5. Pandy's well, 3 miles southeast of Spring Creek; depth, 20 feet. W. M. Barr, analyst.

The following notes on the quality of these waters have been furnished by R. B. Dole, chemist, United States Geological Survey:

1. Probable scale-forming ingredients, nearly 3,000 parts per million; foaming ingredients, 20,000 parts; water is probably corrosive. This is a sodium-chloride water, unfit for boiler use, for irrigation, or for water supply.

2. Probable scale-forming ingredients, 2,500 parts per million; foaming ingredients, 450 parts; water is probably corrosive. This is a calcium-sulphate water, which would be bad for domestic use on account of its high mineral content. Its high scale-forming content and the probability of corrosion make it very bad for boiler use; if it were purified by the use of lime and soda ash, the foaming ingredients would thereby be increased to a degree almost prohibitive. The water could be called only fair for irrigation.

3. This seems to be the best water. It is a calcium-carbonate water of moderate mineral content and fair for boiler use. It could be improved by softening. The probable scale-forming ingredients are 280 parts per million; foaming ingredients, 190 parts; water is noncorrosive. It would be entirely acceptable for use in irrigation.

4. Calcium-sulphate water of high mineral content; probable scale-forming ingredients, 1,800 parts per million; foaming ingredients, 800 parts; water is probably corrosive. This water is unfit for boiler use without purification and softening, which would increase the foaming ingredients and render the water likely to foam badly. It is potable but would probably have a distinct "gypsum" taste. It probably could be used for irrigation on loose sandy soils where there would be good opportunity for thorough underdrainage.

5. A water of fairly high mineral content; probable scale-forming ingredients, 430 parts per million; foaming ingredients, 440 parts; corrosion uncertain; water bad for boiler use in its raw state, but could be purified. It would be acceptable for domestic use but would be considerably harder than No. 3. The remark on No. 4 regarding its use for irrigation applies to No. 5.

There are few springs in the county, and none of any importance as a source of water supply.

There is scarcely any probability that flowing wells can be obtained in this county, except possibly at a few localities in the eastern part. Wells put down to the basal beds of the Cisco formation find supplies of water which in a few places may reach the surface. The limestones of the Canyon formation should be reached in the eastern part of the county at depths of 250 to 500 feet. Farther west they lie at greater depths from the surface, possibly at 800 to 1,000 feet. Aside from the fact that the water would probably not rise to the surface, the unfavorable prospects for obtaining desirable deep-seated supplies in this part of the county are enhanced by the probability that with the increased distance from the outcrop the water would become too highly impregnated with mineral matter for use.

JACK COUNTY.

PHYSIOGRAPHY.

Jack County, which adjoins Young County on the east, is rectangular in shape and has an area of 858 square miles. Its population is 11,817 (1910). The mean annual rainfall is 33 inches. The county seat is Jacksboro.

The surface of the county is made up of hills and ridges, interspersed with broad valleys and plateaus. The striking features of the topography of this county are the broad, flat prairies, flanked by hills and ridges, a result of the varying resistance offered to erosion by the different rock formations. Northeast of Jacksboro the hills are capped by sandstone and conglomerate; the valleys are located upon the more easily eroded limestones.

The larger part of the county is drained mainly by the West Fork of Trinity River, which enters at the northwest corner and flows in a southerly direction across the county. A small area in the southern part of the county is drained by small tributaries of the Salt Fork of the Brazos.

GEOLOGY.

All three of the formations of the Pennsylvanian in Texas, the Strawn, Canyon, and Cisco, outcrop within the boundaries of Jack County. The Strawn underlies a small triangular area in the southeast corner of the county; the northern and western portions, constituting more than half of the county, are underlain by the Cisco. The intervening belt is occupied by the Canyon formation. All these formations dip toward the northwest at approximately 30 to 40 feet to the mile.

The character of the Cisco is much the same as in Young County. Sandstones, shales, and conglomerates, with a few limestones, constitute most of the formation. Coal outcrops in places in the valley of the West Fork in the northern part of the county. A drill hole put down in 1900 to a depth of 340 feet on the land of D. L. Knox on

Lost Valley Creek, near Squaw Mountain, failed to penetrate the Cisco formation. Three water-bearing beds were passed through, the first at a depth of 130 feet, the second at 189 feet, and the third at 228 feet. The water, which is of fairly good quality, flows out at the surface. Shales and sandstones make up the larger part of the section, as shown by the following record furnished by the owner, Mr. D. L. Knox, of Jacksboro:

Record of well on Lost Valley Creek, near Squaw Mountain, Tex.

	Thickness.	Depth.
	Ft. in.	*Ft. in.*
Soil and yellow clay	8	8
Yellow "soapstone"	16	24
Red "soapstone"	8	32
Light-blue "soapstone"	14	46
Blue limestone	9	55
Blue "soapstone"	24	79
Coal	8	79 8
Blue clay	3	82 8
Sand and "soapstone"	8	90 8
Red "soapstone"	7	97 8
Blue "soapstone"	4	101 8
Red "soapstone"	6	107 8
Blue "soapstone"	8	115 8
White sandstone; first flow of water	15	130 8
Blue "soapstone"	2	132 8
Red "soapstone"	6	138 8
Blue "soapstone" and sandstone	7	145 8
Red "soapstone" and sandstone	8	153 8
Blue "soapstone" and sandstone	10	163 8
Red sandstone	2	165 8
Blue "soapstone" and sandstone	13	178 8
White sandstone; second flow of water	11	189 8
Blue "soapstone"	9	198 8
White sandstone; third flow of water	30	228 8
Blue sandy "soapstone," with vegetable matter, and thin layers of sandstone one-half inch to 8 inches thick	111 4	340

The well starts below the coal, which outcrops at the foot of Squaw Mountain. The coal has been mined to some extent for local use.

The following record of a boring made for oil on the Bazette ranch, 10 miles a little east of north of Jacksboro on the Postoak road, has been furnished by Mr. Charles A. Lee.

Record of boring for oil on Bazette ranch, 10 miles north of Jacksboro, Tex.

	Thickness.	Depth.
	Feet.	*Feet.*
1. Surface soil	5	5
2. Black shale	95	100
3. Sand with some oil; in other near-by wells this sand appears to be 10 to 12 feet thick; yielded 3 gallons of oil a day	6	106
4. Sand with salt water	10	116
5. Shale and some sand	134	250
6. Running sand, with salt water	10	260
7. Unknown, record missing	230	490
8. Hard sandrock; oil with salt water under it	10	500
9. Shale with shells	100	600
10. Hard crystalline limestone	50	650
11. Conglomerate, soft	5	655
12. White crystalline limestone	100	755
13. Sandstone and shale	35	790
14. Sandstone saturated with oil and gas	10	800
15. Black shale	50	850
16. Shale and "rock"	40	890
17. Unknown	10	900
18. Sandstone with gas; pressure sufficient to throw water over derrick shed; not penetrated	30	930

The upper 600 feet of this section apparently belongs to the Cisco, and the remainder (Nos. 10 to 18) to the Canyon formation. Several borings were made in this vicinity in the search for oil. A small amount of oil and some gas were found.

Jacksboro is located on the western margin of the outcrop of the Canyon formation. The limestone beds exposed are about 20 feet thick and belong to the upper series (No. 10) shown in the foregoing section. In the Texas reports [1] they are called the Campophyllum beds, from the great number of the cup coral (*Campophyllum torquium*) that they contain. These beds are underlain by 5 to 75 feet of sandy clays and sandstones, locally conglomeratic, called by Drake the Bluff Creek bed. Below this in the Colorado coal field, as shown by Drake, are five series of limestones, each 25 to 75 feet thick, separated by corresponding thicknesses of clays and sandstones. The wells put down at Jacksboro show a greater proportion of clays and less limestone than in the region farther south. A quarry, located near the track of the Chicago, Rock Island & Gulf Railway at Jacksboro, is operated by the railroad company for ballast material. The beds furnish a good building stone, which has been used for some of the most prominent structures in the town. The rock is a hard bluish-gray compact fossiliferous limestone. The upper strata are rather irregular in bedding. The lowest stratum quarried is a dark-blue limestone about 15 inches in thickness, and from this stratum the best building stone is obtained.

A number of wells have been put down in the town, the records of some of which follow:

Record of well of Judge Horton, in the western part of Jacksboro, Tex.

	Thickness.	Depth.
	Feet.	*Feet.*
Soil and clay	35	35
Blue shale	15	50
Limestone	16	66
Dark-blue shale or clay, with two or three streaks of limestone	139	205
Sand and blue shale ("mixed with oil")	20	225
Shell formation, with salt water	2	227
Sand and salt water	27	254
Blue shale (not penetrated).		

Record of well of M. W. Cooper, near center of Jacksboro, Tex.

	Thickness.	Depth.
	Feet.	*Feet.*
Clay	52	52
Limestone	22	74
Blue shale	25	99
Clay	14	113
Shale	20	133
Limestone	10	143
Shale	57	200
Shale and sand ("some sulphur")	12	212
Blue shale (not penetrated)	3	215

[1] Drake, N. F., Report on the Colorado coal field: Fourth Ann. Rept. Texas Geol. Survey, 1892, p. 400.

A well put down in 1899 about 12 miles south of Jacksboro for D. L. Knox, by W. F. Nawatny, gave the following record:

Record of drill hole 12 miles south of Jacksboro, Tex.

	Thickness.	Depth.
	Feet.	*Feet.*
1. Soil and earth	6	6
2. Yellow sandstone	20	26
3. "Concrete rock"	2	28
4. Blue soapstone	42	70
5. Red soapstone	20	90
6. Dark-blue soapstone, with hard iron nodules	188	278
7. Hard carbonaceous sandy shale	76	354
8. Soft blue "slate" (caving)	13	367
9. Blue flinty limestone	4½	371½
10. Blue soapstone	2½	374
11. Blue flinty limestone	7	381
12. Blue soapstone	16	397
13. Very hard limestone, with chert and pyrites	30	427
14. Dark streaky limestone	12	439
15. Soft blue soapstone (caving)	22	461
16. Limestone	15	476
17. Gray sandy soapstone	21	497
18. "Limy" sandstone	6	503
19. Soft light-blue to gray streaky soapstone	79	582
20. Sandstone	2	584
21. Flinty limestone	4	588
22. Hard sandstone, honeycombed	12	600

This well evidently starts in rock below any shown in the Jacksboro wells. In comparing this record with Drake's section[1] the following correlation can be fairly well established:

Correlation of Drake's section and record of Knox drill hole, near Jacksboro, Tex.

Drake's section (Canyon division)	Knox drill hole.
12. Campophyllum bed 11. Bluff Creek bed	Not represented.
10. Home Creek bed [limestone] 9. Hog Creek bed [clays and sandstones]	Nos. 2 to 8.
8. Chert bed [cherty limestones]	Nos. 9 to 14.
7. Bed No. 7	Nos. 15 to 18.
6. Clear Creek bed [clay, some limestone]	No. 19.
5. Cedarton bed [sandstone]	No. 20.
4. Adams Branch limestone	No. 21.
3. Brownwood bed [upper sandstone]	No. 22.

On the Lee farm, 9 miles north of Jacksboro, on the West Fork of Trinity River, the Amber Petroleum Co., of Pittsburgh, Pa., sunk a well 2,200 feet deep in prospecting for oil. This well was begun in February and finished in July, 1907. The drillers were Joseph Kerr and Edward Wasson. The record as given by Mr. Kerr follows.

[1] Fourth Ann. Rept. Texas Geol. Survey, 1892, p. 387.

Record of prospect hole of Amber Petroleum Co., 9 miles north of Jacksboro, Tex.

[Diameter of well at mouth, 13 inches; at bottom, $5\frac{3}{16}$ inches.]

	Thickness.	Depth.
	Feet.	*Feet.*
1. Soft yellow earth	30	30
2. Soft black "cement" rock	80	110
3. Soft black sand and gravel	10	120
4. Soft black "cement" rock	85	205
5. Red "mineral rock"	30	235
6. White sand; hardness variable; first water, salt	25	260
7. Soft black "cement" rock	90	350
8. Red rock, caved (probably shale)	10	360
9. Hard gray sand; second water, salt	40	400
10. Soft gray and red "asphalt" rock	175	575
11. Hard red limerock	15	590
12. Soft black broken lime	45	635
13. Dark "asphalt" rock	15	650
14. White sand; salt water (third), and oil	52	702
15. Soft black slate	48	750
16. Sand and slate; salt water (fourth) at 800 feet	100	850
17. "Asphalt" rock	10	860
18. Soft white sand	30	890
19. Hard black "asphalt"	10	900
20. Soft white sand (show of red oil)	60	960
21. Soft dark "asphalt"	194½	1,154½
22. Soft white sand; salt water (fifth)	30	1,184½
23. Soft black slate (thin stratum).		
24. Soft white sand; salt water (fifth)	70½	1,255
25. Soft black slate	43	1,298
26. Soft black "asphalt"	6	1,304
27. Medium black slate	80	1,384
28. Medium gray sandy lime (show of oil and water)	88	1,572
29. Soft white sand; salt water (sixth) in upper part	103	1,675
30. Hard gray lime (almost flint)	25	1,700
31. Medium black slate	75	1,775
32. Hard gray sandy shale	40	1,815
33. Soft black slate	85	1,900
34. Very hard gray sand	30	1,930
35. Soft white slate	50	1,980
36. Soft black slate	80	2,060
37. Shelly brown and gray sand (smelled of oil and gas)	30	2,090
38. Soft white slate	110	2,200

The rock called "asphalt" by the driller was so named because of its "smell and from the fact that it mixed with water." It was probably clay impregnated with oily matter. A clearly recognized bed in the record is the "cherty limestone" of the Canyon (No. 30). Beds Nos. 11 and 12 are apparently the top beds of the Canyon; and if so, the section would be interpreted as Cisco from 1 to 10, inclusive, 575 feet, and Canyon for the remainder. The sandstones of the Strawn were not reached. Two facts of interest in this section are the great increase in thickness of the Canyon (from about 800 feet on the Colorado to over 1,645 feet on the West Fork of the Trinity) and the thinning out of the limestones, their place being taken by clays. It is of interest to note also that the "cherty bed" of the Canyon (No. 8 of Drake's section) is an excellent guide in the classification of well records in this region. The large amount of chert contained makes it the despair of the driller and leaves little doubt of its identity. It seems to have been the source of the cherty pebbles so abundant in some of the conglomerates of the Cisco.

In its northeastward extension the Canyon formation passes from sight beneath overlying beds several miles east of Cundiff.

The Strawn formation occupies all that part of the county southeast of the Canyon area. The formation has a thickness of about 4,000 feet and consists principally of sandstones alternating with thinner beds of blue clay.

WATER CONDITIONS.

Over a considerable part of the Cisco area the water conditions are essentially the same as in Young County. Water for domestic use is obtained from wells of moderate depth, generally in a porous sandstone, though locally in the overlying residual sands and clays. The water is likely to be charged with mineral matter, especially in the deeper wells. The part of the county underlain by the Cisco contains three areas in which flowing wells may be obtained. One is in the vicinity of Squaw Mountain, where there is a flowing well, the record of which is given on page 79. The second is at Gertrude; and the third is in the vicinity of Jeannette, 7 miles west of Jacksboro. In none of these wells is the flow strong. The wells all draw their supply apparently from a sandstone near the base of the Cisco formation. Flowing wells in the southeast corner of Stephens County are supplied essentially from the same horizon. Whether flows could be obtained in the intervening belt has not been determined, but such data as are available indicate that they could not. In most wells in the region the water rises less than 50 feet above the bed in which it occurs. In the Cisco belt, however, it rises from 100 to 350 or 360 feet. For example, the Squaw Mountain well is 340 feet deep and the water is said to have overflowed from a pipe 18 to 20 feet above the curb. The flowing wells at Gertrude are from 118 to 130 feet deep; how far the water from them will rise above the surface is not known. At Jeannette two flowing wells are reported, one 96 feet deep, the other 105 feet.

In the vicinity of Antelope dug wells are from 20 to 60 feet deep, and larger supplies are found at depths of 90 to 150 feet, but there are no flowing wells. In wells 150 feet in depth the water is said to rise within 70 feet of the surface. The water of some of the shallow wells is of good quality; in others it is too highly mineralized for use. The deeper waters usually show a higher content of mineral salts, and some of them are so salty that they are not available for domestic use or even for stock.

Springs are of rare occurrence in the Cisco area. In the vicinity of Antelope there are several springs in the sandrock, one of which, on the farm of Mr. Adkins, is reported to be of considerable size.

The Canyon formation constitutes the most important water-bearing formation in the area studied. The limestones contain water in caverns and underground solution channels. These are the source of numerous springs which appear along the outcrops of the beds, at the contact with the underlying shale. (See Pl. II *B* p. 60.) The occurrence of such cavities and passages, however, is very irregular, and although deep wells in limestone regions are likely to strike one or more such passages there is much uncertainty as to the outcome.

Most of the wells in this area find water in the sands that are interbedded with the limestones. The principal water bed at Jacksboro is reached at depths of 145 to 230 feet. This is between the second and third limestones from the top of the Canyon formation. The beds included between the first and second limestones are locally water bearing, and some wells find their supplies at this horizon. M. W. Cooper, who has drilled many wells in this vicinity, states that the records will average about as follows:

General section of deep wells at Jacksboro, Tex.

	Thickness.	Depth.
	Feet.	*Feet.*
Soil and clay	4	4
Sandrock	8	12
Clay	20	32
Blue shale	4–20	52
Limestone	18–28	80
Shale, in some wells containing sand and water	80	160
Limestone	10–16	176
Shale	5–15	191
Sandstone, chief water bed	40	231

The water rises within about 75 feet of the surface in the deeper wells. In early days, according to Mr. Cooper, many of the wells flowed, but there are now no flowing wells in the town. The average depth of the wells is from 160 to 175 feet, depending on the location of the top and the differences in thickness of the beds. The water-bearing sand (No. 9) is not uniformly developed and is reported to thin out toward the east and north. In some wells the second limestone (No. 7) is replaced by sands and shales impregnated with oil, and the water found at this horizon is usually of bad quality. In some wells located on low ground the water flows out at the surface.

The water in many of the wells at Jacksboro shows marked differences in quality within short distances. A black oily substance is sometimes encountered in the upper part of the sandstone formation, but in the lower part of the beds good water may be found. The only attempt to find water supplies in deeper beds in this vicinity was that of D. L. Knox, who sunk a well at his residence to a depth of 550 feet. The main water bed appears to be absent here, and the water at deeper horizons was found to be highly impregnated with salt. Although the amount of potable water available at the main horizon is considerable, it is insufficient to meet the demands made upon it by the growth of the town, and this, coupled with the fact that in so many wells the water is unfit for use, will soon make it necessary to consider the possibility of other sources of supply. As to this problem the data at hand offer little light. So far as known the Jacksboro water horizon is one of the best in the series. As in beds at other horizons, however, the water is affected locally by injurious ingredients, and as the beds dip westward under cover the water doubtless becomes more highly mineralized. As to water from deeper horizons, the data in hand indicate that though abundant, it is almost sure to be saline.

In the western part of the Canyon area the conditions will be found much the same as at Jacksboro. Throughout most of this belt the Jacksboro water horizon will doubtless yield ample supplies. The conditions as to depth and pressure will manifestly vary with the locality. On the east this belt is bounded by the outcrop of the cherty limestone beds.[1] The areas farther east were not included in the present investigation, but the data available indicate that the water from deep wells in that region is likely to be more or less affected by mineral salts.

Thomas Owen, living 2 miles southeast of Adieu, has a well 300 feet deep. He reports the following record:

Common earth about 15 feet, soapstone for about 82 feet, and struck a gray sandstone with water, which came up about 36 feet in the well. Continued boring but found no more water and finally struck a hard white rock into which the boring was continued for 20 feet.

This water-bearing sandstone was doubtless the same as that in the wells at Jacksboro and the "hard white rock" the cherty limestone which underlies it.

Gibtown is situated in the southeast corner of the county, on the outcrop of the Strawn formation. In this vicinity water for domestic use is obtained from open and drilled wells ranging in depth from 20 to 65 feet. The supplies are found in the superficial portion of the sands of the Strawn formation. The water is said to be hard, and the supplies are ample for the present needs of the community.

Analyses of waters from a number of wells in Jack County are given on page 86.

[1] These beds are those designated No. 8 in Drake's report on the Colorado coal field (Fourth Ann. Rept. Texas Geol. Survey, 1892, p. 395).

Analyses of ground waters in Jack County, Tex.

[Parts per million. Analyst, B. L. Glascock. Samples collected Sept. 24, 1907.]

	1	2	3	4	5	6	7	8	9	10
Silica (SiO_2)	12	20	32	15	14	10	2.5	10	5.0	5.0
Iron (Fe)	.94	.9	.62	.7	.75	.75	.8	.8	.85	.8
Aluminum (Al)	2.0	3.0	2.4	.5	1.3	2.3	1.3	2.0	1.0	1.3
Calcium (Ca)	10	20	105	197	224	8.5	9.0	26	102	96
Magnesium (Mg)	3.0	3.5	54	138	153	3.0	11	11	31	33
Sodium (Na)	330	963	114	1,040	1,109	291	293	944	664	689
Potassium (K)	8.0	13	7.8	13	15	5.3	34	12	132	15
Carbonate radicle (CO_3)	14	22	7.2	7.2	.0	4.8	29	7.2	.0	.0
Bicarbonate radicle (HCO_3)	517	610	439	756	766	659	669	549	224	266
Sulphate radicle (SO_4)	137	166	303	1,590	1,758	80	100	231	1,603	1,468
Nitrate radicle (NO_3)	1.8	1.33	.44	4.9	1.33	1.33	3.1	3.1	.44	1.1
Chlorine (Cl)	139	1,040	55	795	870	37	50	1,125	181	115
Total solids	907	2,568	922	4,190	4,595	758	844	2,766	2,806	2,513
Turbidity	0	0	0	0	0	0	0	0	0	0

1. Well of J. R. Edmondson at Jeanette, Tex.
2. Well of the postmaster at Finis, Tex.
3. Vineyard mineral water at Vineyard, Tex.
4. Helm's well, 12 miles east of Jacksboro, Vineyard, Tex.
5. Well of W. L. Vesner, at Vineyard, Tex.
6. Well of W. F. Worden, 1 mile west of courthouse, Jacksboro, Tex.
7. Well of H. Hensley, 1½ miles west of courthouse, Jacksboro, Tex.
8. Well at Phipp's place, 2 miles northeast of courthouse, Jacksboro, Tex.
9. Hensly & Johnson's farm well at Hess, Tex.
10. Well at Hannible Pass place, Hess, Tex.

The following notes regarding the usefulness of these waters have been prepared by R. B. Dole, chemist, United States Geological Survey:

1. Estimated scale-forming ingredients, 50 parts per million; foaming ingredients, 900 parts; water is noncorrosive, but would foam in boilers. It is high in mineral content, especially in alkalies, and would be poor in irrigation; it is potable.

2. Very high in mineral content and unsuitable for use.

3. A sulphate and carbonate water of rather high mineral content but notably lower in alkalies and in chlorides than most of the other waters. Estimated scale-forming ingredients, 450 parts per million; foaming ingredients, 350 parts; water is noncorrosive; good for irrigation; hard, but potable.

4 and 5. Sodium sulphate waters of very high mineral content and unfit for use except possibly for irrigating land where thorough drainage and other precautions to prevent accumulation of alkali have been adopted.

6 and 7. Sodium carbonate waters of moderately high mineral content and similar composition; poor for irrigation; low in scale-forming ingredients but too high in foaming ingredients to be suitable for boilers.

8. A water of very high mineral content; unsuitable for use in boilers or for irrigation, and too salty to be good for domestic use, though drinkable.

9 and 10. Sodium sulphate waters of very high mineral content and similar composition; would foam in boilers; potable but not very good for domestic use; poor for irrigation.

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