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# RECONNAISSANCE

OF THE

# GRANDFIELD DISTRICT, OKLAHOMA

BY

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# RECONNAISSANCE OF THE GRANDFIELD DISTRICT, OKLAHOMA.

By M. J. MUNN.

## INTRODUCTION.

### LOCATION OF THE DISTRICT.

The Grandfield district as arbitrarily outlined in this report embraces about 360 square miles in southern Oklahoma, including the southeastern part of Tillman County and the southwestern part of Cotton County, as shown on Plate I. This district, which is bounded on the south by Red River, includes those parts of Tps. 3, 4, and 5, Rs. 12, 13, 14, and 15 W., that lie in Oklahoma; that part of T. 4 S., R. 11 W., that lies south of Deep Red Run; the west half of the area in T. 5 S., R. 11 W., that lies north of Red River; the southeast quarter of T. 3 S., the east half of T. 4 S., and the portion of T. 5 S., R. 16 W., that lies north of Red River. The district is named from Grandfield, the largest town within it, which stands near its center.

### CHARACTER AND PURPOSE OF THE WORK.

This report discusses the general geologic conditions in this district, especially those that furnish a clue to the possible location of any oil and gas pools that may be in it. The field work for the report was begun by the writer about October 10, and continued until December 22, 1912. From about November 17 to December 22 he was assisted by Mr. Jerry B. Newby, who ran spirit-level lines over a portion of the district to determine the structure of certain outcropping beds. The work was done under a cooperative agreement between the United States Geological Survey and the Geological Survey of Oklahoma by which the latter provided funds to the amount of $500 toward paying the cost of field work and the former paid about $200 of the field expenses and all office expenses and cost of publication.

This territory was selected for reconnaissance geologic examination because the general geologic conditions in it are the same as those in the adjacent portion of northern Texas, which contains the Petrolia, Electra, and Burkburnett oil and gas fields, and because it was hoped that geologic work in this district in advance of drilling

might enable oil and gas prospectors to place their test wells most favorably and so avoid losses involved in drilling dry holes and at the same time obtain the best tests for the presence of oil and gas in paying quantities.

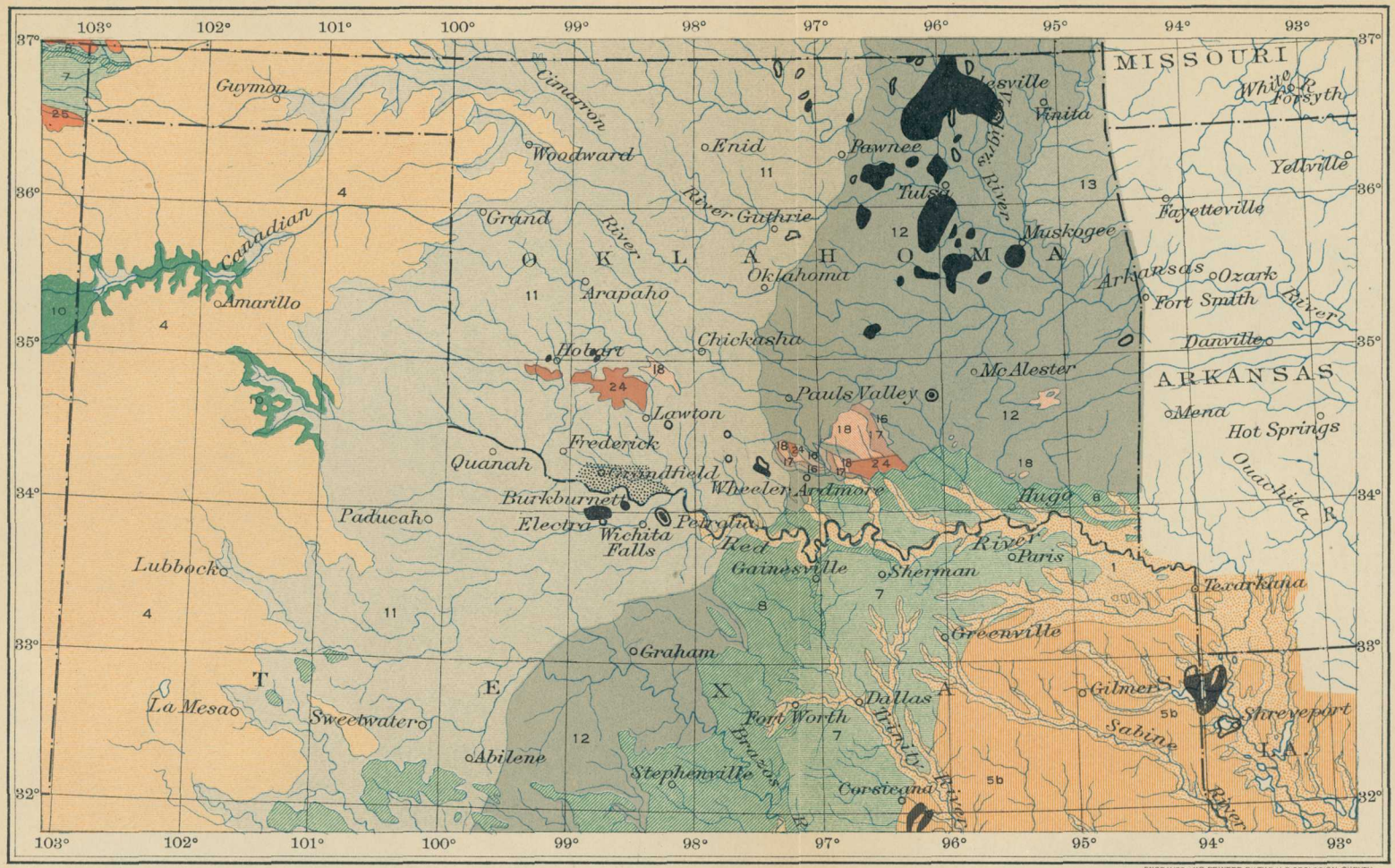
The time spent in field work was so short that the survey can be considered only a reconnaissance, during which detailed stratigraphic study of the outcropping rocks was impracticable. The principal object of the stratigraphic study was to find some widely exposed bed or series of beds having features so persistent that it might be used as a key stratum or horizon for determining roughly the structure of the Permian rocks of the district. The writer began field work in the vicinity of Grandfield, where outcrops of rocks are scarce and those that occur embrace only a few feet of the geologic section. The preliminary examination in search of a key stratum or horizon covered about 200 square miles around Grandfield, in Tps. 2, 3, 4, and 5 S., Rs. 13, 14, 15, and 16 W. This selection of territory for preliminary work was fortunate in the fact that the most easily identified series of outcropping beds are exposed there, but it was also in a measure unfortunate because the finest outcrops occur in the bluffs of Red River, near and at the extreme eastern edge of the area examined. These important outcrops on Red River were not discovered until the last few days of the field work, when time was not available to make a detailed stratigraphic study of them and a thorough search for fossils.

### ACKNOWLEDGMENTS.

The writer is indebted to Mr. D. W. Ohern, State geologist of Oklahoma, for suggestions regarding field work. A very valuable list of bench marks, which shows the elevation above sea level of points along the Wichita Falls & Northwestern Railway and on which the net of spirit levels is based, was kindly furnished to the writer by Mr. J. F. Montgomery, division engineer of the railway. The writer is also indebted to many citizens of the district for assistance rendered and courtesies shown during the progress of the field work.

## DRAINAGE AND TOPOGRAPHY.

The Grandfield district is drained by Red River and Deep Red Run, a tributary of Cache Creek, which empties into Red River from the north. Red River has an average fall across this district of 3½ to 4½ feet a mile. It flows in a relatively narrow flood plain, ranging in width from 1 to 1½ miles, bounded on both sides by bluffs covered by sand dunes and having a maximum elevation of about 175 feet above the river. The river bed is very broad in comparison with the width of its flood plain, being in most places from three-fourths of a mile to over a mile wide. At low water the river beds consist largely




From Geologic map of North America, U. S. G. S. 1911

ENGRAVED AND PRINTED BY THE U.S.GEOLOGICAL SURVEY

# GEOLOGIC SKETCH MAP OF OKLAHOMA AND NORTHERN TEXAS

Showing general classification of the rocks and the location of the Grandfield district with reference to the adjacent oil and gas pools

Scale $\frac{1}{5{,}000{,}000}$

100 0 100 200 Miles

1914

TERTIARY: 1 QUATERNARY; 4 LATE TERTIARY; 5b MARINE EOCENE

CRETACEOUS: 7 UPPER CRETACEOUS; 8 LOWER CRETACEOUS

10 TRIASSIC

CARBONIFEROUS: 11 PERMIAN; 12 PENNSYLVANIAN; 13 MISSISSIPPIAN

16 SILURIAN; 17 MIDDLE AND UPPER ORDOVICIAN; 18 CAMBRIAN AND LOWER ORDOVICIAN; 25 TERTIARY EFFUSIVES; 24 PRE-CAMBRIAN ROCKS; OIL POOLS; GAS POOLS; GRANDFIELD DISTRICT

House Doc. ; 63d Cong., 2d Sess.

of shifting sand, across which narrow, shallow streams meander. (See Pl. II, *C*.)

In contrast with Red River, Deep Red Run flows in a narrow channel, 20 to 60 feet wide and 20 to 30 feet deep, across a flat alluvial flood plain ranging in width from 1 to 1½ miles. The average fall of this stream is about 4½ feet to the mile.

The interstream area is a smooth, slightly undulating, treeless prairie, into which the smaller streams have cut very slightly except near their mouths. The notable features of the topography are (1) the broad, smooth surfaces, (2) a few low, round isolated hills adjacent to the divides, preserved by a capping of more resistant rocks, and (3) the many large "breaks" or washes (see Pl. II, *B* and *C*) similar in character to the well-known badlands of other portions of the West.

The "breaks" are of special importance to the geologist because they expose most of the beds of Permian rocks on which a map of the geologic structure of this area must be based. They consist of low bluffs, most of them roughly crescent shaped, from a few feet to half a mile in length (see Pl. II, *C*), and having heights ranging from 5 to 20 feet, though at places adjacent to the larger streams they are somewhat higher. These "breaks" have been formed chiefly by the direct action of rain falling on the steep, bare slopes of the very fine soft red clay of the "Red Beds." Most of them probably originated as small "potholes" dug out by running water of freshets pouring over small obstacles along the bottoms of "draws." "Breaks" thus started develop at all angles to the original drainage courses and some of them cut back across the crests of secondary ridges to points where water falling on the hillside, a few inches from the edge of the "break," flows directly away from it. Apparently one of the necessary conditions for the formation of a "break" is the presence of a more or less resistant layer above the soft red clay, so as to preserve a steep local slope. This resistant layer consists of a firm sod of grass at the surface or, very often, of thin beds of soft sandstone, limestone, or conglomerate embedded in the fine red clay that makes up the greater portion of the section exposed in this district.

## STRATIGRAPHY.

### ROCKS NOT EXPOSED IN THE DISTRICT.

#### PERMIAN ROCKS.

The lowest outcropping rocks in the Grandfield district are "Red Beds" of Permian age. Very few geologic facts regarding the age and character of the rocks which underlie those that outcrop have been derived directly from this district. The relatively small amount of data at hand pertaining to the rocks not exposed in this district

comes from the partial logs of three deep wells drilled for oil and gas in or near it, from logs of similar wells in the adjacent developed oil fields of northern Texas, and from outcrops of lower formations at more distant places in Oklahoma and Texas. The data indicate that the upper portion of unexposed beds is of Permian age and that this series is underlain by older Carboniferous beds of the Pennsylvanian series. The beds of the upper part of the Pennsylvanian are very similar to those of the lower part of the Permian in this district, so that the line of division between them can not be determined from the well records alone.

In Texas the contact between the Permian and the Pennsylvanian series comes to the surface south and southeast of the Grandfield district in a broad belt extending south-southwest from Clay and Montague counties, Tex., to the central part of the State. Along this belt the Wichita formation of the Permian appears to lie conformably upon the Cisco formation of the Pennsylvanian. This contact is also exposed at many places north and northeast of the Grandfield district in Oklahoma along the southern border of the Wichita and Arbuckle mountains, where the Permian "Red Beds," lying practically horizontal, rest unconformably on the sharply folded beds of the Pennsylvanian. The stratigraphic relation of these two great series of rocks in the large area that lies between the exposures of the Permian-Pennsylvanian contact and that includes the Grandfield district is not known. A brief study of each of them at the places nearest to the Grandfield district where they are best exposed may be of some value in determining the general character of the rocks underlying the beds exposed in this district.

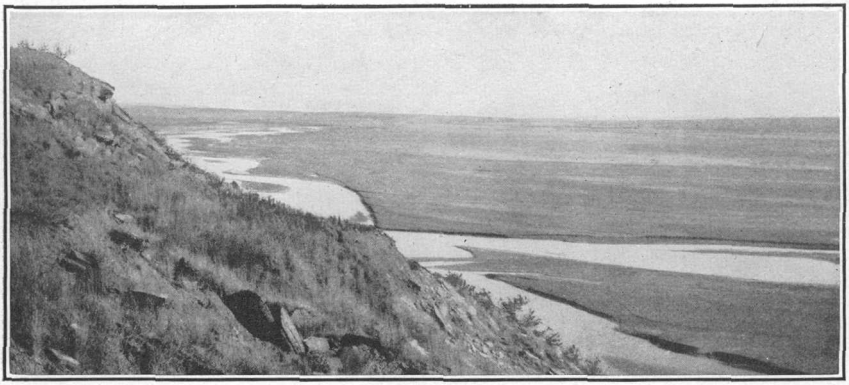
### PENNSYLVANIAN AND OLDER ROCKS.

In Clay, Montague, and Archer counties, Tex., where the rocks of the Pennsylvanian series are exposed, they are divided by Gordon[1] into the following formations, tabulated from top to bottom:

*Section of Pennsylvanian formations in Wichita region, Tex*

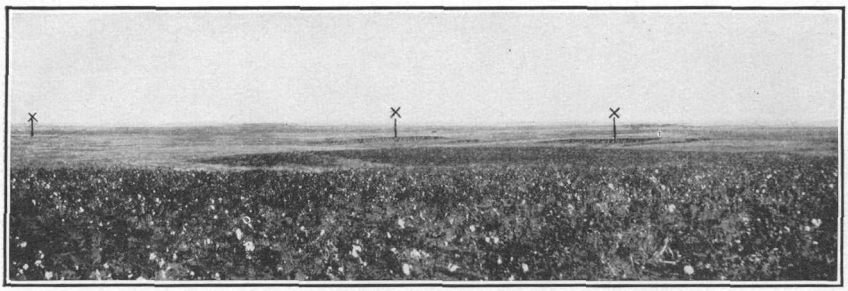
| | Feet. |
|---|---|
| Cisco formation (clay, shale, conglomerate, and sandstone with some limestone and coal) | 800 |
| Canyon formation (alternating beds of limestone and clay, with some sandstone and conglomerate) | 800 |
| Strawn formation (alternating beds of sandstone and clay, with some conglomerate and shale; the lower 1,000 feet consists of blue and black clay locally containing beds of limestone, sandstone, or sandy shale, and a coal seam at the top | 1,900 |
| | 3,500 |

[1] Gordon, C. H., Geology and underground waters of the Wichita region, north-central Texas: U. S. Geol. Survey Water-Supply Paper 317, p. 14, 1913.



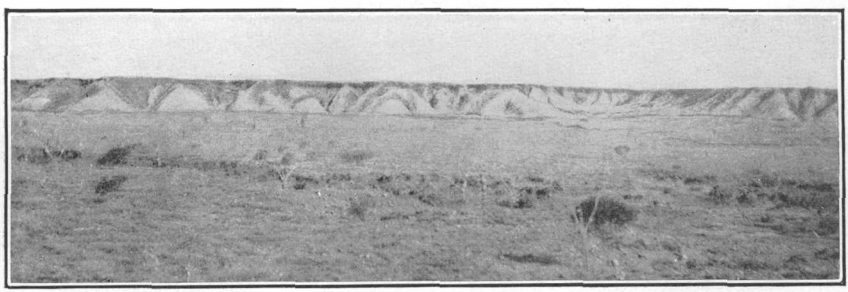
*A.* BED OF RED RIVER AT LOW WATER, FROM ADJACENT BLUFF IN SEC. 32, T. 5 S., R. 12 W.

At medium stages the river is three-fourths to 1 mile wide and very shallow, flowing over a smooth, flat surface of sand and mud. At low water interlacing threads of water meander over this flat surface.



*B.* GENERAL VIEW OF THE SURFACE IN THE GRANDFIELD DISTRICT.

Showing distant "breaks" (below × marks).



*C.* NEAR VIEW OF "BREAKS" IN WEST SIDE OF SW. ¼ SEC. 21, T. 3 S., R. 15 W.

Showing character of the rain-cut bluffs and ridges in the fine red clay and the smooth, even slope formed by outwash from the "break."

Farther southwest in Texas the upper division of the Strawn is said [1] to reach a maximum thickness of 3,000 feet, the whole formation being about 4,000 feet thick.

Under the Strawn formation in the Colorado coal field of Texas lies the Bend series of the Texas Geological Survey, consisting principally of limestone and shale, which is of Pennsylvanian age in its upper part and of Mississippian age in its lower part. Gordon [2] gives the combined thickness of the Pennsylvanian and Mississippian series at about 7,000 feet in this region.

Along the southern borders of the Wichita and Arbuckle mountains in Oklahoma north and northeast of the Grandfield district the Pennsylvanian and older rocks, originally deposited in a relatively horizontal position, have since been elevated and thrown into steep folds by the great crustal uplifts that formed the Wichita and Arbuckle mountains. The old granite floor of the ancient sea in which the oldest sedimentary beds of Cambian age were laid down now constitutes the very resistant central cores of these mountains. Much of the strata which once arched over the old igneous rocks was removed by erosion before a later subsidence of the surface and encroachment of the sea allowed the deposition of the "Red Beds" in horizontal layers across the upturned edges of the older rocks. Since the "Red Beds" were deposited the region has been elevated to its present height, and streams have cut fairly deep valleys into them at many places adjacent to the mountains, where they were thin, exposing the older folded beds beneath. In the area indicated the Pennsylvanian rocks generally dip south or southwest beneath the less folded Permian beds. The southern extent of this unconformity between the Pennsylvanian and Permian is unknown, but, as noted above, the unconformity has not been observed in the next outcrops of these beds toward the south, in Texas.

The seemingly local character of the violent crustal movements which produced the Wichita and Arbuckle mountains suggests that the disturbance did not extend far south of a line joining these mountain areas and that the unconformity between the Pennsylvanian and Permian rocks dies out rapidly toward the south, terminating at a roughly east-west line in southern Oklahoma, beyond which there was seemingly continuous deposition throughout Pennsylvanian and Permian time.

No exposures of rocks older than Permian are known to occur for hundreds of miles west of the Grandfield district, and no data are available concerning the beds in that direction that will indicate the probable character of the rocks concealed in this district within

[1] Gordon, C. H., op. cit., p. 15.

[2] Gordon, C. H., The Wichita formation of northern Texas: Jour. Geology, vol. 19, No. 2, p. 116, 1911.

reach of the drill. The presence, however, of Pennsylvanian rocks beneath the "Red Beds" on three sides of the Grandfield district suggests strongly that the ancient seas in which the beds were deposited covered territory extending westward over many thousands of square miles and that the beds beneath the "Red Beds" in the Grandfield district are probably similar to those which are exposed around it. The following generalized section of the rocks underlying the "Red Beds" at their nearest outcrops in Oklahoma, south of Wichita and Arbuckle Mountains, tabulated in natural order, from top to bottom, is condensed from a previous report on the geology of these mountains.[1]

*Generalized section of the Pennsylvanian and older formations outcropping adjacent to the Wichita and Arbuckle Mountains in Oklahoma.*

Carboniferous system:

Unconformity.

Pennsylvanian series:

Sandstone, shale, and coal. North of the eastern part of the Arbuckle uplift the Pennsylvanian sediments overlying the Wapanucka limestone and the Franks conglomerate consist of sandstones, shales, and coals aggregating in thickness 10,000 or 11,000 feet. South of the Arbuckle Mountains these deposits are partly concealed by Cretaceous and younger beds and consist of shale, sandstone, thin beds of limestone, and some limestone conglomerate. The excessive folding in this area renders exact measurements of thickness of beds impossible.

Wapanucka limestone: Deposited contemporaneously with or just after the Frank conglomerate. Thickness increases to perhaps 400 feet eastward across the Arbuckle Mountain area in Oklahoma.

Frank conglomerate: Lies unconformably upon Mississipian beds. Greatest thickness, 500 feet.

Unconformity.

Mississipian series:

Glenn formation: Bluish shale, with thin brown sandstone and some thin limestone. Exposed only on north side of Arbuckle Mountains. Thickness, 1,000 to 3,000 feet.

Caney shale: Bluish toward top and contains small ironstone concretions. Basal part is black bituminous clay shale containing limestone and argillo-calcareous segregations. Total thickness, about 1,600 feet.

Sycamore limestone: Light bluish to yellow and probably argillaceous and massive; weathers into thin beds. Ranges in thickness from a few feet to nearly 200 feet and thickens toward the west from Arbuckle Mountains.

[1] Taff, J. A., and others, Preliminary report on the geology of the Arbuckle and Wichita Mountains: U. S. Geol. Survey Prof. Paper 31, 1904.

Devonian system:

Woodford chert: Black, bituminous, fissile shale, with round calcareous concretions; in lower part also contains at places beds of chert near base. Equivalent to the "Black shale" or Chattanooga (Ohio) shale of the Appalachian region. Average thickness, about 650 feet.

Siluro-Devonian rocks:

Hunton limestone:

Semicrystalline limestone, in places cherty, interstratified with some thin marly layers. Thickness, 30 feet.

Marly and calcareous clays with some hard limestone layers in lower part. Thickness, 170 to 190 feet.

Thick-bedded limestone, crystalline at base, with hard thin limestone above. At places at the base is an oolite, 4 to 5 feet thick, which is locally silicified.

Silurian system:

Sylvan shale: Greenish, homogeneous, massive shale at top with usually several feet of dark-blue to black calcareous, and bituminous shale at base. Ranges in thickness from 60 to 300 feet in the Arbuckle Mountains area, thickening toward the west.

Viola limestone:

Light colored, coarse textured, usually rough bedded; middle portion earthy. Thickness, 300 feet.

Limestone, white to light blue, generally thin bedded; weathers white. Thickness, 300 feet.

Limestone, light colored, coarse, and usually rough bedded. Thickness, 100 feet.

Ordovician system:

Simpson formation:

Limestone, thin, with interstratified green shales, 400 feet.

Sandstone, 90 feet.

Limestones and shales interstratified, 400 feet.

Sandstone, 100 to 200 feet.

Limestone, shaly, 195 feet.

Sandstone, 33 feet.

Limestone, thin bedded, and shale interstratified, 275 feet.

Shale, greenish, with few thin layers of limestone, 245 feet.

Limestone, granular, crystalline, in thin beds, 350 feet.

Limestone, thin, with shale and some thin layers of sandstone, 29 feet.

Sandstone, white to light brown, occurring locally, greatest thickness 100 feet.

Cambro-Ordovician rocks:

Arbuckle limestone: Includes all the upper Cambrian rocks and the Calciferous of the overlying Ordovicion. Except a few thin shaly strata and some siliceous and cherty beds it is composed entirely of light blue and white limestone and cream-colored to white crystalline dolomite. Its lower portion, which is upper Cambrian, is pink to yellow, hard, massive limestone and dolomite, which weathers brown to almost black and is 500 to 600 feet thick. This portion is succeeded above by limestones of Ordovician age, which become lighter toward their top. Total thickness of formation, 4,000 to 6,000 feet.

Middle Cambrian sediments: Generally thin-bedded siliceous limestone and shaly strata containing middle Cambrian fossils. Several hundred feet thick.

Reagan sandstone:

Thin-bedded and laminated sandstone, becoming calcareous in upper part. Thickness, 60 feet.

Coarse grit and sand with some clay and green sand in upper part, generally well stratified. Thickness, 370 feet.

Quartzites and arkose conglomerates. Thickness, 30 feet.

Pre-Cambrian: Granite and porphyry which formed the floor of the Cambrian Sea.

Fortunately we are not dependent entirely upon the character of the Pennsylvanian and older beds along their line of outcrop in surmising the character of the unexposed rocks in the Grandfield district. The development of the Petrolia, Electra, and Burkburnett oil fields in northern Texas has made available the logs of many deep wells in Clay and Wichita counties, Tex., a relatively short distance south of this district. In their excellent report on the geology of the oil and gas fields of Wichita and Clay counties, Tex., Udden and Phillips[1] have carefully correlated the unexposed rocks with those that outcrop in Texas southeast of these fields. Their report contains a detailed log and a description of samples from a test well drilled to a depth of 3,985 feet by the Producers Oil Co. on the Halsell farm, 6½ miles west and 1 mile south of Henrietta, Clay County, Tex. The value of this log and of the description of the samples of rock from the well justify reprinting them below.[2]

*Log of Halsell well No. 1, drilled by the Producers Oil Co. west of Henrietta, Clay County, Tex., with description of samples of rock.*

| Driller's log. | | | Description of samples of rock. | |
|---|---|---|---|---|
| | Thickness. | Depth. | Depth at which sample was taken. | Geologist's notes. |
| | *Feet.* | *Feet.* | *Feet.* | |
| Red clay | 65 | 65 | ..... | |
| Salt water, sand | 25 | 90 | ..... | |
| Red rock | 100 | 190 | ..... | |
| Salt water, sand | 30 | 220 | ..... | |
| Red rock | 245 | 465 | ..... | |
| Salt water, sand | 40 | 505 | ..... | |
| Red rock | 125 | 630 | ..... | |
| Salt water, sand | 30 | 660 | ..... | |
| Red rock | 112 | 772 | ..... | |
| Water, sand | 25 | 797 | ..... | |
| Slate and red rock | 20 | 817 | ..... | |
| Sand, no water | 24 | 841 | ..... | |
| Red rock | 49 | 891 | ..... | |
| Sand | 20 | 911 | ..... | |
| Slate and red rock | 99 | 1,010[a] | ..... | |
| Dry sand | 6 | 1,016 | ..... | |
| Sand | 6 | 1,022 | ..... | |

[1] Udden, J. A., and Phillips, D. McN., Geology of the oil and gas fields of Texas: Univ. Texas Bull. 246, 1912.

[2] Idem, pp. 217–219.

*Log of Halsell well No. 1, etc.*—Continued.

| Driller's log. | | | Description of samples of rock. | |
|---|---|---|---|---|
| | Thickness. | Depth. | Depth at which sample was taken. | Geologist's notes. |
| | *Feet.* | *Feet.* | *Feet.* | |
| Putty | 20 | 1,042 | ..... | |
| Red rock | 50 | 1,092 | ..... | |
| Red mud | 8 | 1,100 | ..... | |
| Water, sand | 50 | 1,150 | ..... | |
| Blue mud | 25 | 1,175 | ..... | |
| Red and white sand | 65 | 1,240 | ..... | |
| Light-blue shale | 15 | 1,255 | ..... | |
| Black shale | 20 | 1,275 | ..... | |
| Red shale | 30 | 1,305 | ..... | |
| Brown shale | 8 | 1,313 | ..... | |
| Red rock | 10 | 1,323 | ..... | |
| Gray hard sand | 2 | 1,325 | ..... | |
| Red and blue mud | 30 | 1,355 | ..... | |
| Joint clay | 10 | 1,365 | ..... | |
| Light-blue shale | 10 | 1,375 | ..... | |
| White sand | 35 | 1,410 | ..... | |
| White slate | 10 | 1,420 | ..... | |
| Gray lime | 16 | 1,436 | ..... | |
| White sand | 9 | 1,445 | ..... | |
| Gray lime | 10 | 1,455 | 1,450 | Limestone and sand. The limestone contains much organic material, in which were noted Rhombopora, crinoid joints, spines of Productus, a minute apex of a gastropod, an ostracod, and *Fusulina cylindrica*. |
| Dark-blue slate | 45 | 1,500 | ..... | |
| Red and blue mud | 3 | 1,503 | ..... | |
| Rotten sand | 5 | 1,508 | ..... | |
| Sky-blue shale | 5 | 1,513 | ..... | |
| Red cave | 22 | 1,535 | ..... | |
| Dark-blue shale | 15 | 1,550 | ..... | |
| White sand | 30 | 1,580 | ..... | |
| Dark-blue shale | 64 | 1,644 | ..... | |
| Gray lime, hard | 11 | 1,655 | 1,645 | Limestone, sand, and a little shale; Chætetes noted. |
| Blue shale | 44 | 1,800 | ..... | |
| White sand | 20 | 1,820 | ..... | |
| Shale, breaks, caves | 2 | 1,822 | 1,822 | Limestone, shale, and sand. The shale is calcareous and emits sulphur in a closed tube before ignition. |
| Lime shells | 10 | 1,832 | ..... | |
| Gray sand, dry | 5 | 1,837 | ..... | |
| Blue shale | 10 | 1,847 | ..... | |
| Blue mud, caves | 10 | 1,857 | ..... | |
| Light-blue shale | 38 | 1,895 | ..... | |
| Dry sand | 10 | 1,905 | ..... | |
| Black slate | 28 | 1,933 | ..... | |
| Sand, salt water | 20 | 1,953 | ..... | |
| Blue marl | 30 | 1,983 | 1,953 | Gray calcareous shale, containing abundant Fusulina, pieces of crinoid spines, and an apex of a tall-spired gastropod. |
| Gray lime | 25 | 2,008 | ..... | |
| Blue marl | 50 | 2,058 | ..... | |
| Black slate, gritty | 67 | 2,125 | 2,120–2,125 | Dark bluish-gray shale with white porous chert containing silicified fragments of fossils. A part is sand with grains from 1 millimeter to 0.125 millimeter in diameter and showing crystalline facets, due to secondary growth. On the label of the samples was the note, "First top shell big salt sand." |
| | | | 2,125 | Yellowish-gray sand of fine texture. With this was some dark-gray shale, some crinoid fragments, and some fragments of white chert. |
| Sand, artesian flow of salt water. | 45 | 2,170 | 2,130 | Fine-textured yellow sand, with grains from 0.25 to 0.062 millimeter in diameter. Some gray shale containing calcareous material. |
| | | | 2,135 | Yellowish sand, gray, of fine texture. |
| | | | 2,140 | Dirty yellowish sand of fine texture. |
| | | | 2,145 | Dull grayish-yellow sand of fine texture. |
| | | | 2,150 | Mostly yellow sand. Some dark gray, or almost black shale, and some organic calcareous fragments. Many fragments of white chert and some of coal. The maximum ingredient of the sand is grains from 0.125 to 0.062 millimeter in diameter. |
| | | | 2,155 | Limestone, yellowish, organic, containing white and yellow chert, having a flat and rectangular cleavage. Rhombopora and crinoid stems were noted. One-fourth of the sample is bluish-gray shale. In this was noted a fragment of pyritized woody tissue. |

*Log of Halsell well No. 1, etc.*—Continued.

| Driller's log. | | | Description of samples of rock. | |
|---|---|---|---|---|
| | Thickness. | Depth. | Depth at which sample was taken. | Geologist's notes. |
| | *Feet.* | *Feet.* | *Feet.* | |
| Sand, artesian flow of salt water—contd. | 45 | 2,170 | 2,160 | Gray shale with some yellowish calcareous organic fragments and some white chert. Fusulina, crinoid stems (one was half an inch in diameter), the apex of a Murchisonia (?) and some thick spines noted. |
| | | | 2,165 | Yellowish crinoidal limestone, with some chert. There was also some dark gray shale. Fusulina present. |
| Break | 5 | 2,175 | 2,175 | Gray shale, calcareous, and containing some small flakes of mica. |
| Sand | 5 | 2,180 | 2,180 | Shale and limestone. The shale is almost black, and breaks into very thin fragments. One fragment bore the impression of a closely ribbed flat shell, half an inch to an inch in diameter, probably Aviculopecten. One-half of the sample is gray limestone, largely made up of organic fragments. The following fossils were noted: Fusulina (8 fragments), crinoid stems (20), Polypora (?) (2), Rhombopora (1), Retzia (?), very small (4), Chonetes (1), and a porcelaneous, single-apertured foraminifer (?). |
| Sand | 5 | 2,185 | ..... | |
| Do | 5 | 2,190 | 2,185 | Most of the sample is fine yellow sand. The rest is gray shale and organic yellow sand. In this were noted crinoid stems, fragments of shells, and spines of brachiopods. |
| | | | 2,185 | Dark-gray shale, with some thin layers of fine white sand. |
| Do | 10 | 2,200 | 2,190 | Gray crinoidal limestone with brachiopod spines, finely tuberculated crinoid fragments, and small pieces of shells. |
| | | | 2,195 | Dark-gray shale and yellowish limestone. Fossils noted: Fusulina, crinoid stems, spines of Productus, fragments of brachiopod shells, and some minute tests with a porcelaneous luster, from 0.5 to 1 millimeter long, oval, either a foramifer or an ostracod, and fragments of some large shell having a transverse columnar structure. |
| Hard brown shells | 15 | 2,215 | 2,200 | Dark-gray shale, minutely micaceous, containing thin and irregular layers of light gray sand of fine texture. Embedded fragments of leaves were noted. |
| | | | 2,200 | Gray shale containing calcareous fragments, and some shale containing carbonaceous fragments of vegetable origin. Fossils noted: Ostracod, apex of gastropod, bryozoa, crinoid stems, Chaetetes (?), brachiopod spines, a flat coiled small gastropod, a young Pleurotomaria, base of an echinoid spine. |
| Blue shale | 10 | 2,225 | 2,215 | Light-gray and soft sandstone with grains mostly from 0.25 to 0.062 millimeters in diameter, very slightly micaceous. There are also thin laminæ of coal showing parallel leaf-veins on the flat side. |
| Sand, dark clay | 55 | 2,280 | ..... | |
| Sand, dark gray, broken | 20 | 2,300 | ..... | |
| Sand, light gray | 15 | 2,335 | ..... | |
| Brown shale | 15 | 2,335 | ..... | |
| Hard shells | 15 | 2,350 | ..... | |
| Light blue slate | 5 | 2,355 | 2,350 | Greenish-gray, slightly micaceous shale, with abundant fragments of Chaetetes (?), spines of Productus, crinoid stems, and other fossils of unknown kinds. |
| Brown shale | 70 | 2,425 | ..... | |
| Blue slate | 25 | 2,450 | ..... | |
| Brown limestone | 50 | 2,500 | ..... | |
| Blue shale | 100 | 2,600 | ..... | |
| Do | 75 | 2,675 | ..... | |
| Shells of hard sand with streaks of gray limestone. | 25 | 2,700 | ..... | |
| Blue shale | 5 | 2,705 | ..... | |
| Lime shells and streaks of blue shale. | 5 | 2,710 | ..... | |
| Lime and streaks of hard sand. | 30 | 2,740 | ..... | |
| Light-blue shale | 228 | 2,968 | 2,958 | |

*Log of Halsell well No. 1, etc.*—Continued.

| Driller's log. | | | Description of samples of rock. | |
|---|---|---|---|---|
| | Thickness. | Depth. | Depth at which sample was taken. | Geologist's notes. |
| | *Feet.* | *Feet.* | *Feet.* | |
| Sand, 6 feet, a break of 3 feet, and solid sand, 3 feet. | 12 | 2,980 | 2,974 | About one-half of this sample is a gray calcareous shale, containing here and there minute black shreds of vegetation. Most of the rest of the sample is a mixture of calcareous fragments and gray siliceous sand. Fossils noted: A few crinoid joints, pyritized woody fiber, and a piece of brachiopod valve. |
| | | | 2,974–2,976 | Dark, almost black shale, calcareous in spots and in part minutely micaceous. Some fine sand. The shale disintegrates when washed. Fossils noted: Crinoid stems and spines. On the label was written the word "brake." |
| Very black shale | 240 | 3,220 | 3,015 | Dark bluish-gray shale of fine texture, slightly calcareous, with occasional black, indistinct shreds of vegetation and minute flakes of mica. Fossil fragments exceedingly scarce. |
| Limestone shells | 130 | 3,350 | 3,330 | Black shale showing indistinct impressions of shreds of vegetation on fractured surfaces. Small embedded flakes of coaly material. Some shale shows alternate laminæ of fine gray sand. All this shale is fissile and sparingly micaceous. One-half or more of the sample is yellowish sand, with grains from 0.5 to 0.062 millimeter in diameter. There are also some limestone fragments. |
| Dark shale | 32 | 3,382 | ..... | |
| Light-gray sand (shows little water). | 12 | 3,394 | 3,382–3,394 | Dove-colored, slightly micaceous sandy shale and fine-grained sandstone, in about equal quantities. |
| Dark slate | 21 | 3,415 | ..... | |
| Sand | 25 | 3,440 | 3,418–3,440 | The greater part of the sample is black shale, slightly micaceous, splitting into long and slender shoepeg-like flakes, calcareous. Heated in a closed tube this shale decrepitates, gives off strong sulphurous fumes, and becomes magnetic. The sample included some sand and calcareous material. Two fragments of coal were noted. On the label is the note: "No water." |
| | ..... | ..... | 3,430 | Yellowish-white sand of mechanical composition about as follows: 0.5 to 0.25 millimeter, 5 per cent; 0.25 to 0.125 millimeter, 80 per cent; 40.125 to 0.062 millimeter, 15 per cent. With the sand are some large fragments of dark calcareous shale of fine texture. On the label was the note: "Middle of sand." |
| Dark-blue shale | 255 | 3,695 | ..... | |
| Dark shale | 285 | 3,970 | 3,850 | Dark-gray shale, with very thin layers of calcareous material. Minute flakes of mica noted, and also some crinoid stems. The shale emits sulphurous odor when heated in a closed tube. |
| | ..... | ..... | 3,901–3,904 | Dark-gray, almost black shale, of fine texture, very stiff and hard. When rubbed and washed in water, it hardly disintegrates at all, notably less than all the shale above this depth. A part of the sample is calcareous sandstone, light gray, containing a number of green grains (glauconite?). Heated in a closed tube it gives off sulphur fumes and becomes magnetic. Yellow chitinous flakes were noted in the shale. Fossils noted: Crinoid stems, cylindric straight spines, fragments showing rectangular cancellations, apparently of organic origin (seen under a ¼-inch objective), and an undoubted organic structure consisting of fragments of perforate shells of some foraminifer-like Endothyra. On the label was the word "top." |
| | ..... | ..... | 3,904–3,906 | Shale and organic fragmental limestone as in the preceding sample. Also some black shale and coal among all sizes of fragments. Crinoid stems noted. |
| | ..... | ..... | 3,906–3,911 | Black, indurated shale like the preceding two samples. When heated in a closed tube it emits bituminous fumes and oil. Fossils noted: Crinoid joints and fragments of shells. |
| Dark-gray lime; lost tool. | 15 | 3,985 | ..... | |

For the purpose of comparing the position of the oil-producing sands and other unexposed beds in the Petrolia, Electra, and Burkburnett oil fields of northern Texas with the strata encountered in deep wells drilled in the Grandfield district, a few typical logs of wells in these oil fields and vicinity are plotted to scale on Plate III (in pocket). The writer has not attempted to correlate the beds in these sections, but has accepted the correlations given by Udden and Phillips[1] as being much more thorough than he could possibly make, especially as he has not had the advantage of field work in that area.

These authors say:

> The limestone at 1,445 feet below the surface in the Halsell well is found to contain this fossil [*Fusulina cylindrica*], and no rock higher up in this well seems to be of a kind in which this fossil is at all likely to occur, excepting the other thin limestone reported at the depth from 1,420 to 1,436 feet. This part of the Halsell well section is doubtless also the equivalent of the deeper productive oil and gas sands in the two fields under investigation. These consist of shales, limestones, and sandstones, which lie at from 1,500 to 1,700 feet below the surface in the wells near Petrolia and at from 1,800 to 2,000 feet below the surface in the Electra field. This general correlation seems to be warranted by paleontologic evidence as well as by evidence based on the lithologic character of the beds explored by drilling.

The discussion of many well logs and a large amount of other extremely interesting data are given by these authors in the above cited report, and the correlations of these beds are summed up as follows:[2]

> To sum up the essential correlations for these fuel fields [referring to Electra and Petrolia oil and gas fields]: The Bend formation is perhaps present near 3,900 feet below the surface in the southeast part or the areas studied. From about 3,900 to 1,800 feet below the surface the bedrock is an equivalent of the lower half of the Cisco, the Canyon, and probably the Strawn divisions on the Colorado River. The Bull Creek coal and its associated dark shales and other beds are probably the stratigraphic equivalents of the dark shales and productive sands lying at from 1,500 to 1,800 feet below the surface in the wells near Petrolia and at from 1,700 to 1,900 feet below the surface in the Electra wells. Some thin coal seams noted in the lower part of the Albany sediments in the Colorado River basin may be the stratigraphic equivalents of the zone producing some oil at about 750 feet below the surface in a part of the field at Petrolia and of the productive sands at about 1,000 feet below the surface near Electra.
>
> We have shown that it is more than likely that the gas-bearing sands which lie from 550 to 700 feet below sea level in the Henrietta field are at the same horizon in the general section as the oil-bearing beds in the Electra fields, which lie some 200 or 300 feet deeper 40 miles farther west. We have presented three groups of facts which bear out this conclusion. The Beaverburk limestone shows that the Wichita beds lie practically horizontal on an east and west line for about 15 miles. Combining 90 observations made on dips in the area between Electra and Petrolia, we have found that if these dips be taken to represent the general structure of the terranes between these two points, the beds lie nearly horizontal. Comparing the strata explored in the two fuel fields we have also found that there is in the formations themselves a resemblance which

[1] Op. cit., p. 83.

[2] Op. cit., pp. 90–92.

confirms our belief that the deep productive sands in the two fields, as well as the upper sands, are to be correlated with each other.

Fortunately, however, we are not limited to evidence which makes our conclusions on this point almost certain, but still questionable. There is other evidence which, in connection with that already mentioned, must be fairly conclusive, even if the basis of facts involved is somewhat slender. This consists in the presence in the deeper oil-bearing deposits in both fields of a few identical fossils. The finding of these fossils also enables us to roughly correlate the underground section in this region with the general section of the Pennsylvanian in Texas.

The principal object of Plate III is to show the depths reached by wells in the Grandfield district and those at which oil and gas has been found in the fields of northern Texas and to show the apparent variations in depths below sea level of these sands where productive. From this plate it is evident that only one of the four wells drilled in the Grandfield district reached a depth sufficient to test the deeper and more widely productive sands. No definite correlations of surface beds have been made between the oil fields at Petrolia, Burkburnett, and Electra and the wells of the Grandfield district, but such work as has been done suggests that the rocks at the surface in the Electra and Burkburnett fields are not very far in vertical distance from those at the surface at both the George Cabella, the Big Pasture, and the Grandfield wells.

This plate shows all the information now available regarding the correlation of the unexposed rocks of the Grandfield district with the oil sands of the surrounding region.

## ROCKS EXPOSED IN THE DISTRICT.

### AGE AND GENERAL CHARACTER.

In most of the Grandfield district the hard rocks are hidden beneath a surficial mantle of loose, unconsolidated material consisting of (1) dune sand, spread over a broad belt adjacent to Red River; (2) a dark or reddish sandy to clay soil, largely wind-blown, covering most of the smooth slopes of the interstream areas; and (3) a red clay-silt alluvium found in the broad, flat valleys of Deep Red Run and its tributaries. Beneath this thin veneer of Quaternary beds, exposed in many places in breaks and along the valley sides, lies a thin bed of coarse, hard quartz-lime conglomerate (here named the Grandfield conglomerate), very persistent and rarely exceeding 5 feet in thickness, which has been variously classified as of Quaternary or of late Tertiary age.[1] It is underlain unconformably by "Red Beds" of Permian age which are correlated with the Wichita formation of northern Texas.

[1] Udden, J. A., and Phillips, D. McN., Geology of the oil and gas fields of Texas: Univ. Texas Bull. 246, p. 107, 1912.

## CARBONIFEROUS SYSTEM (PERMIAN SERIES).

### THICKNESS AND SUBDIVISIONS.

In the Grandfield district the lowest outcropping rocks are "Red Beds" of Permian age, but the total thickness of these beds can not be determined accurately from the data now available. In northern Texas, where more carefully studied by geologists, the "Red Beds" have been divided into three formations, the Wichita at the base and the Clear Fork and Double Mountain formations above. Gordon[1] estimates the thickness of the Wichita formation in Shackleford County, Tex., at 1,000 to 1,200 feet. Cummins[2] says: "These beds [the Wichita formation] are heaviest along the Big Wichita River, where they attain a thickness of 2,000 feet." He also assigns a thickness of 1,900 feet for the Clear Fork and 2,000 feet for the Double Mountain, thus giving the Permian series a maximum total thickness in northern Texas of about 5,900 feet.

It seems probable that the Clear Fork and Double Mountain formations are not present in the Grandfield district, the Permian series being represented by the lower portion of the Wichita formation. In the absence of an abundance of fossils there is no sure means of determining in well sections where the Permian leaves off and the Pennsylvanian begins. Udden[3] says:

> We know that the upper 300 feet or more at Electra belong to the Wichita formation, and that the shales and sands penetrated from 1,400 to 2,000 feet under the surface belong to the Cisco, but how much of the intervening 1,200 feet should be allotted to each we can only guess from the lithologic appearance of the section as made known by the driller's records.

This conclusion agrees with the writer's observations.

### WICHITA FORMATION.

#### CHARACTER AND OCCURRENCE.

In Shackleford County, Tex., the Wichita formation consists of blue clays, blue, gray, and black shales, and thick beds of blue, gray, and yellowish limestones. Northward from that county the thickness of the limestone decreases abruptly and the thickness of the sandstone and shale correspondingly increases. In Archer and Baylor counties the formation contains prominent beds of red, white, and yellowish sandstone. The limestone diminishes in amount northward and practically disappears from the formation south of Red River, and in the same direction there is a rapid increase in the amount of red material,

[1] Gordon, C. H., Geology and underground waters of the Wichita region, north-central Texas: U. S. Geol. Survey Water-Supply Paper 317, 1913.

[2] Cummins, W. F., Texas Geol. Survey Second Ann. Rept., p. 401, 1890.

[3] Udden, J. A., and Phillips, D. McN., Geology of the oil and gas fields of Texas: Univ. Texas Bull. 246, p. 86.

consisting largely of red clay and soft sandstone. The upper portion of the Pennsylvanian series apparently shows the same change from blue to red sediments northward toward Red River from Young County, Tex., and where the contact between these two series is not exposed at the surface in Wichita and Clay counties it becomes more and more difficult to trace it northward by well records to the Grandfield district.

As already noted, the lowest rocks exposed in the Grandfield district belong to the Wichita formation. They outcrop along the bluffs of Red River in T. 5, Rs. 11 and 12 W., and consist of gray and red sandstone, red and gray shale, red, gray, and purplish clay, and thin layers of reddish to gray clay-limestone conglomerate. The greatest single outcrop of rocks in this district is in the S. ½ sec. 30, T. 5 S., R. 12 W., where the following section was measured:

*Beds exposed in "breaks" on north side of Red River in sec. 30, T. 5 S., R. 12 W.*

| | Feet. |
|---|---|
| Quaternary: | |
| 1. Sand, loose brownish to reddish, coarse, massive; seems to be wind blown; capping bluff | 15–30 |
| Permian (Wichita formation): | |
| 2. Sandstone, reddish, thin bedded, ripple marked; poorly exposed under the loose sand | 4 |
| 3. Clay or shale, whitish, with some thin-bedded shaly sandstone | 2 |
| 4. Clay, red to grayish (mostly red), with some soft, reddish, thin, smooth, gray calcitic lime concretions; the slumping clay almost conceals a few thin beds of very soft clayey sandstone near the base | 40 |
| 5. Sandstone and clay. Sandstone reddish, blocky to platy, cross-bedded and very irregular bedded. Changes to red clayey sandstone with light-colored streaks, thence to red clay carrying many roundish clay-lime concretions having a very rough surface and a burnt brick-red color. The beds change from sandstone to clay and back to sandstone within short horizontal distances | 15 |
| 6. Clay and sandstone; deep-red clay, interbedded with and changing locally to reddish and grayish clayey sandstone. The clay in many places contains smooth roundish gray clay-limestone concretions | 10 |
| 7. Sandstone; top part soft, locally massive, yellowish to greenish in places, contains near middle large round to flattish black concretions single and twinned, some of which are more than a foot in diameter; bottom part thin and irregular bedded, weathers reddish with canary-yellow streaks. These sandstones and concretions change horizontally into red clay and shale and are extremely variable in occurrence | 11 |

| Permian (Wichita formation)—Continued. | Feet. |
|---|---|
| 8. Sandstone, dark gray and yellowish at base with black specks; changing to dark and harder limy irregularly bedded sandstone in middle, which carries flattish irregularly bedded layers of a very hard, close-grained, reddish to dark rock, which seems to be composed of rather coarse subangular grains of quartz cemented with limestone. These lenses resist erosion better than the adjacent beds and remain on the surface as irregular slabs after the other portions have been disintegrated | 9 |
| 9. Sandstone, grayish to light canary-yellow, rather massive | 7 |
| 10. Sandstone, massive, soft canary-yellow to dark leaden gray, containing remains of fossil plants and small amounts of copper ore in lower 5 feet | 12 |
| 11. Clay and shale, whitish to light gray, changing to deep purple blocky clay with lumps and streaks of copper ore and shale or clay pebbles | 2 |
| 12. Shale, clayey, red and gray to green | 10 |
| 13. Conglomerate, clay-limestone; soft, gray to reddish, contains in places fragments of bones. This bed is in many places absent | 2 |
| 14. Clay, deep red to purplish with one or more thin layers of soft impure whitish sandstone near base; clay contains in lower part considerable number of rather small gray, roundish calcitic clay-limestone concretions | 8 |
| 15. Sandstone, 2-foot layer at top of soft whitish to gray sandstone which has the appearance of having become bleached and which in weathering forms cylindrical holes in upper surface (one-fourth to one-half inch in diameter) which trend in all directions in top layer. These holes appear to have been made by burrowing animals or worms in the ancient sand beach. Under this layer is a massive reddish irregular-bedded impure sandstone having many thin dark streaks made up of small round black specks which are slightly more resistant to weathering and appear as ridges on face of cliff. Near base is a massive layer carrying many round black cannonball-like concretions, the largest a foot in diameter. Sandstone very irregular bedded with many cross-bedded zones and whitish layer at base | 21 |
| 16. Clay, deep red, with thin purplish and ashen-colored layers, a few very thin layers of soft gray sandstone, and a layer of clay pebbles in gray calcareous clay at the bottom | 20 |
| 17. Sandstone, reddish, at top, changing to grayish toward bottom, massive irregular bedded | 10 |

| Permian (Wichita formation)—Continued. | Feet. |
|---|---|
| 18. Clay, principally deep red, with thin layers of sandstone and sandy shale, beds very poorly exposed with about 10 feet of greenish clay or shale at river level; about | 50 |
| | 233 |

This section was measured hurriedly, the writer expecting to return later and study in great detail the changes which each bed undergoes within this outcrop of more than a mile, but he was unable to do so. If several sections were made at different places along this outcrop, they would probably show considerable variation, especially above bed 11. In fact, at some places the sandstone above that bed is much thinner and in others is probably replaced entirely by red clay and shale. Sandstone 15 above is the most persistent stratum in the section, and the white bed at its top can be picked out with considerable certainty. A collection of poorly preserved fossil plants obtained from the lower 5 feet of sandstone 10 shows that the beds are of Permian age. Other sections of the formation along Red River are given below:

*Section in bluff on north side of Red River in NW. ¼ sec. 5, T. 5 S., R. 11 W.*

| | Feet. |
|---|---|
| Quaternary: | |
| 1. Sand, river, loose, massive, yellowish, unstratified, wind blown, at top of bluff | 18 |
| Permian (Wichita formation): | |
| 2. Clay, red | 4 |
| 3. Clay, red, with a few thin layers of light-colored sandstone | 4 |
| 4. Sandstone, reddish, thin, fairly smooth bedded | 5 |
| 5. Sandstone, reddish, thin bedded, platy to massive, with black hard limy plates and lenses which contain olive-green and canary-yellow clay pebbles | 6 |
| 6. Concealed | 1 |
| 7. Sandstone, yellowish to grayish, changing to whitish in places, weathers in peculiar tiny spirelike columns | 3 |
| 8. Clay, whitish sandy clay with canary-yellow streaks | 1 |
| 9. Concealed (probably ashen clay) | 7 |
| 10. Clay, dark red | 2 |
| 11. Clay, red | 1 |
| 12. Sandstone, white, clayey | 1 |
| 13. Clay, dark red, with thin white sandstone lens in middle | 6 |
| 14. Sandstone, white, shaly | 1 |
| 15. Clay, blocky, bright red | 2 |
| 16. Clay, reddish at bottom, changing to ashen above, with white sandy blotches | 6 |
| 17. Sand and alluvium of present flood plain down to water of river | 8 |

About a mile farther east the following incomplete section was measured:

*Incomplete composite section of rocks exposed in bluff on north side of Red River near middle of north line of sec. 4, T. 5 S., R. 11 W.*

| | Feet. |
|---|---|
| Quaternary: | |
| 1. Sand, soft, loose, yellowish, capping bluff | 4–20 |
| 2. Gravel, quartz, quartzite, and yellow clay pebbles, fragments of chert limestone, etc., unconsolidated | 1–2 |
| Permian (Wichita formation): | |
| 3. Sandstone, gray to reddish, with dark limy harder layers | 3 |
| 4. Clay, red to grayish, free from concretions, concealed at base | 10 |
| 5. Concealed, about | 10 |
| 6. Concealed on terrace by soft, unconsolidated windblown sand, unstratified and of Recent age | 14 |
| 7. Clay, red, with thin whitish to reddish layers of sandstone, shaly at base | 7 |
| 8. Sandstone, greenish or bluish to gray, sharp, fine grained, thin bedded, reddish platy layers at base | 6 |
| 9. Sandstone, reddish, generally thin, cross-bedded and very irregular bedded, carrying dark hard limy concretions; at top a thin soft limy layer containing many small black specks | 7 |
| 10. Conglomerate, clay-limestone, containing interstitial calcite, clay, and chert pebbles, many of which are yellow or brown; very irregular bedded and variable in occurrence | 3 |
| 11. Sandstone, smooth bedded, reddish | 1 |
| 12. Clay, red, containing thin plates of reddish sandstone | 6 |
| 13. Sandstone, reddish, thin bedded, laminated, usually platy and cross-bedded, becoming coarse, massive, irregular bedded toward base; makes prominent cliff in bluff | 10 |
| 14. Clay, red, to concealed beds | 4 |
| 15. Concealed or poorly exposed to water of Red River; seems to be largely red clay with a few thin beds of red sandstone, about | 55 |
| | 141–158 |

The above sections are typical of the larger exposures of the Wichita formation along Red River east of R. 13. West of that range the outcrops of Permian rocks along the north bank of Red River are very scarce and are uniformly of small vertical extent. The beds exposed are usually red clay and irregular beds of gray or reddish sandstone, which can not be correlated from one outcrop to another.

AUGER CONGLOMERATE LENTIL.

An exception to the rule just stated—that correlation of the Permian from outcrop to outcrop is impossible west of R. 13—was noted along the river bluff in the northwestern part of T. 5 S., R. 15 W., and northward for several miles on the "breaks" on the east side of Auger Creek. At these places occur imperfect exposures of a thin series of gray to reddish sandstone beds separated by red clay and containing a peculiar conglomerate consisting principally of limestone with small included balls of red and gray clay. These beds are so characteristic that they may be recognized with certainty at many places over the area back from Red River. The clay-limestone conglomerate and its associated beds of sandstone are here named the Auger conglomerate lentil, from the exposures on Auger Creek and also at "Old Fort Auger," the site of which is in the N. ½ sec. 6, T. 5 S., R. 15 W. The following is a fairly typical section of this series of beds:

*Section of Auger conglomerate lentil and associated rocks exposed in "break" near head of small run in NW. ¼ sec. 6, T. 4 S., R. 15 W.*

| | Feet. |
|---|---|
| Quaternary: | |
| 1. Soil concealing rocks at top of break | 15–20 |
| Permian (Wichita formation): | |
| Auger conglomerate lentil: | |
| 2. Clay and sandstone; thin beds of whitish to reddish clayey sandstone in red clay, sandstone being very irregular bedded, reddish layers very thin and platy but false bedded | 5 |
| 3. Sandstone, bluish white, clayey, some layers ripple marked, weathering in curly irregular layers. Other beds are characteristically cross-bedded at angles up to 20° from horizontal; grades below into rather massive sandstone layers that are reddish in places. At other places has thin bed of red clay near the middle; lower beds very irregular bedded | 5 |
| 4. Conglomerate, clay-limestone, containing small clay pebbles interbedded with sharp gray to reddish sandstone in which occur many tiny black specks. The conglomerate appears in two layers in places, one near top and another near bottom. It is very irregular in bedding and thickness. Upper beds generally very hard and reddish, lowest bed often bluish gray. The matrix of the conglomerate is principally limestone and fine clay, cementing together small red and greenish to gray balls of clay | 5–8 |
| 5. In places the lower conglomerate is cut out by a soft bluish-white sandstone; maximum thickness | 2 |

| | Feet. |
|---|---|
| Permian (Wichita formation)—Continued. | |
| Auger conglomerate lentil—Continued. | |
| 6. Clay, bright red, jointed, containing roundish gray to reddish limestone concretions. Base of clay concealed below the bottom of the river | 15 |
| | 45–55 |

These beds change greatly in thickness and appearance within the length of this outcrop and from one exposure to another. The conglomerate layers are everywhere very variable and are in places entirely absent. The sandstones are also very changeable in character and appearance, but the series taken as a whole, where well exposed, can be identified with reasonable certainty. Fortunately for the determination of the structure in this district the Auger conglomerate lentil outcrops at many places on streams tributary to Red River from the north and on Deep Red Run and its tributaries from the south, from Rs. 11 to 16 W. A typical outcrop of this conglomerate in the vicinity of Deep Red Run is given below:

*Section of Auger conglomerate lentil and associated beds exposed on south side of valley of Deep Red Run in E. ½ NE. ¼ sec. 27, T. 3 S., R. 14 W., about 3½ miles northeast of Grandfield, Okla.*

| | Feet. |
|---|---|
| Quaternary: | |
| 1. Soil, reddish, sandy, concealing rock at top of break | 12 |
| Permian (Wichita formation): | |
| Auger conglomerate lentil: | |
| 2. Sandstone, reddish to grayish, very soft | 3 |
| 3. Conglomerate, clay-limestone, light gray to reddish, very hard in places and very irregularly bedded and changeable in thickness, embedded in sandstone; maximum thickness | 3 |
| 4. Sandstone and clay-limestone conglomerate. The sandstone is soft, sharp, massive, very irregular bedded, reddish to gray, the gray layers near top and bottom carrying numerous little black specks, presumably of some manganese mineral, which range in size from that of a pinhead to a quarter of an inch in diameter. These give the bed a peculiar speckled appearance. This sandstone also carries numerous small disk-like sandstone concretions, from 1 to 2 inches in diameter. The clay-limestone conglomerate is interbedded with sandstone near the middle and ranges in thickness from 6 inches to 2 feet. It is reddish, hard, principally limestone, with some calcite, and includes many small lumps and balls of reddish to grayish clay | 8 |
| 5. Conglomerate, clay-limestone; grayish limestone, carrying bluish and whitish clay lumps and balls. Very irregular in occurrence; frequently appears to be cut out by the overlying sandstone; maximum thickness | 2 |

| Permian (Wichita formation)—Continued. | Feet. |
|---|---|
| Auger conglomerate lentil—Continued. | |
| 6. Clay, bright red, tough, containing considerable numbers of roundish grayish limestone concretions at top and larger reddish rough roundish ones near the bottom; also a 2-inch layer of clayey limestone near base and another 7 feet above base | 22 |
| 7. Conglomerate, clay-limestone, soft, grayish, composed largely of small calcareous clay balls poorly cemented together by lime; less than | 1 |
| 8. Clay, red, with a few calcareous concretions, down to alluvium of valley | 4 |

No single exposure is typical of this conglomerate lentil, because each bed is variable from place to place. However, the lentil as a whole does not change so much from one outcrop to another that it may not be recognized wherever exposures are good. Toward the east, in Rs. 12 and 11, the clay-limestone conglomerate bed becomes more sandy and loses its characteristic lumpy conglomeratic appearance. If the writer's correlations are correct the conglomerate bed becomes darker and harder toward the east, and in many places has the smooth-grained appearance of a calcareous, somewhat ferruginous sandstone and weathers out of the inclosed sandstone as irregular, slablike lenses or more or less round to flattish concretionary masses, some of which are several feet in length.

The thin layers of sandstone in the red clay noted near the base of the above section appear to grow thicker toward the east, and in that direction other sandstones appear in the red clay at points in the stratigraphic section farther below the Auger lentil. The clay-limestone bed of the Auger lentil is generally present along the south side of Deep Red Run through R. 13, but in Rs. 12 and 11 the clay pebble content seems to be largely replaced by sand, making dark, hard, very limy sandstone concretions and slablike lenses in the gray "speckled" sandstone. The following section is generally typical of the Auger conglomerate in Rs. 11 and 12 W.

*Section of Auger conglomerate lentil exposed in a small butte in SW. ¼ NE. ¼ sec. 13, T. 4 S., R. 12 W., about 4 miles northeast of Randlett.*

| | Feet. |
|---|---|
| 1. Sandstone, whitish to dark, with many large dark platelike to roundish sand-limestone lenses from 1 to several feet in length. These lenses seem to be colored by a dark brittle substance, probably a manganese mineral | 4 |
| 2. Sandstone, soft, whitish, rather massive to thin bedded, carrying a "speckled" layer (gray sandstone with small black specks) toward the top and a dark, mottled grayish to very dark sand-limestone bed at the base, which seems to contain considerable quantities of mineral resembling wad | 4–6 |

| | Feet. |
|---|---|
| 3. Sandstone, soft, white (in places bluish white), thin-bedded to massive; very irregular in distribution and thickness; seems to be cut out in places by underlying red clay; greatest thickness | 3 |
| 4. Clay, bright red, with very few grayish limestone concretions and some scattered gray spots a few inches in diameter | 9 |
| 5. Sandstone, massive, lumpy, reddish, very clayey; disappears to sandy red clayey shale within 100 feet | 7 |
| 6. Clay, red, tough; changes in places to clayey shale | 10 |
| 7. Sandstone, milk-white to bluish white (very conspicuous), massive, blocky, very irregular in distribution, changes to a few inches of ripple-marked reddish clayey thin-bedded sandstone within 50 feet; greatest thickness | 4 |
| 8. Clay, red, containing concretions of rough roundish limestone of peculiar burnt brick-red color. Other beds of this clay carry roundish concretions from 2 to 4 inches in diameter containing beautifully developed crystals of barite and also some peculiar brownish-yellow limestone concretions which fracture into halves. The thickness of these beds of clay could not be determined but is probably about | 15 |
| 9. Sandstone, reddish, massive to thin bedded, very irregular-bedded and poorly exposed. This sandstone, with interbedded red clay, extends down to bed of Deep Red Run | 20 |
| | 69–78 |

In this exposure sandstones 1 and 2 are very probably beds of the Auger lentil, which in the previous section included the lower layer of the clay-limestone conglomerate, but they may represent the upper layer of the Auger conglomerate, which in some places occurs a few feet above the speckled sandstone layer. Sandstone 3 is probably the irregular bluish-white layer that normally underlies the upper conglomerate layer of the Auger lentil.

The beds at the base of the above section are better exposed about 2 miles west of the section, where the rocks outcrop along the edges of a large " break " or " wash " covering several hundred acres.

*Composite section of rocks exposed in a " break " in N. ½ sec. 15, T. 4 S., R. 12 W.*

| | Feet. |
|---|---|
| Quaternary: | |
| 1. Concealed by soil (maximum thickness) | 10 |
| Permian (Wichita formation): | |
| 2. Limestone, very sandy, with some red clay. In places a very limy sandstone and in others forms large roundish concretions as much as 4 feet in diameter. Usually the impure limestone is dark to reddish, close, very hard and brittle and occurs as flattish slablike lenses in soft grayish to reddish irregular-bedded sandstone. Usually found as slabs, bowlders, and concretionary masses cap- | |

| Permian (Wichita formation)—Continued. | Feet. |
|---|---|
| ping the tops of the breaks and scattered irregularly over the surface above the "breaks;" greatest thickness | 5 |
| 3. Sandstone ("speckled" bed), gray to slightly reddish, soft, sharp, with many small black specks. Sandstone has same sharp, brittle, homogeneous character wherever seen | 2–4 |
| 4. Sandstone, soft, bluish, white, cross-bedded, and laminated, very irregular in occurrence; greatest thickness | 2 |
| 5. Conglomerate; soft gray to red clay-limestone beds, the balls of clay being very small and as a rule not closely cemented; very irregular in occurrence and appears to be at places locally unconformable on the red clay below | 1 |
| 6. Clay, bright red, with occasional small white splotches (same as the clay below the typical Auger conglomerate lentil) | 4–10 |
| 7. Clay or sandstone, generally red but containing purplish and ashen zones; very tough; changes frequently to sandy clay or shale, which at many places is replaced by reddish to white or bluish, very soft, blocky, massive, very irregular-bedded sandstones. At places where these sandstone layers are thin or absent the clay contains many rough roundish, burnt brick-red clay-limestone concretions, the largest 6 or 8 inches in diameter, with very rough, sharp surfaces | 8–20 |
| 8. Sandstone, reddish to gray, shaly, choppy, ripple-marked; poorly exposed; concealed at top and bottom | 3 |
| 9. Concealed | 2 |
| 10. Sandstone, dark, hard, thin bedded, limy | 1 |
| 11. Concealed (probably of red color) | 1 |
| 12. Sandstone, grayish, with dark to reddish-brown hard balls from one-fourth to three-eighths inch in diameter, composed of iron-manganese minerals and limestone. In places this bed is black, with gray splotches | 2–4 |
| 13. Concealed (probably red clay) | 3 |
| 14. Sandstone, whitish to gray; hard, thin bedded | 1 |
| 15. Sandstone, reddish, cross-bedded; very thin platy layers which in places are extremely smooth, breaking out in sheets 2 by 3 feet by one-half inch in thickness; characteristic fine threadlike ridges of grayish limestone run at different angles across plates | 1–2 |
| 16. Clay red | 1–3 |
| 17. Sandstone, red, thin bedded to massive, very irregular bedded; lower bed cross-bedded | 3 |
| 18. Clay, red, and thin, irregular-bedded, rather clayey sandstone | 4 |

| Permian (Wichita formation)—Continued. | Feet. |
|---|---|
| 19. Sandstone; soft, reddish, choppy, ripple marked, with thin grayish bed at top | 2–3 |
| 20. Sandstone, massive, deep red, irregular bedded, with dark, harder layers one-fourth inch thick, which are reddish on fresh fracture | 8 |
| 21. Sandstone, reddish, hard, limy, interbedded with red clay and clayey thin-bedded sandstone | 3 |
| 22. Sandstone, whitish, soft, irregular bedded; somewhat massive cross-bedded layer at top and changing to red sandstone below; very irregular in occurrence; exposure suggests an unconformity at bottom; greatest thickness | 3 |
| 23. Sandstone, red, impure, massive, blocky, irregular bedded, extending down to bed of creek | 3–5 |
| | 101 |

These sections have been selected to show the general character of the Permian rocks exposed in the Grandfield district. They will serve as guides in the more detailed discussion of other and generally poorer exposures of the Auger conglomerate, which are used to determine the general structure or dip of the Permian strata in this territory. (See description of the rocks by townships, pp. 34–74.)

## TERTIARY OR QUATERNARY SYSTEM.

### GRANDFIELD CONGLOMERATE.

In this district there was observed at many places a thin bed of peculiar reddish conglomerate, consisting of a matrix of red clay and limestone inclosing many pebbles of quartz, quartzite, and a few of granite, together with fragments of chert and occasional pieces of limestone and silicified wood. The pebbles are waterworn and in general fairly well rounded, and the largest are 3 inches or more in diameter. This conglomerate is a compact, indurated bed, surprisingly uniform in character and probably averaging 3 or 4 feet in thickness. It is widely exposed, outcropping at many places on the broad divide between Red River and Deep Red Run and along both sides of the valley of the latter stream across the district. It is here named the Grandfield conglomerate, from the town of Grandfield, where it is well exposed on the south rim of the hill on which the town is built. It lies just below the surface at many places in this town. It also caps a dome-shaped hill, known locally as Curtis Hill, in the N. ½ sec. 13, T. 4 S., R. 15 W., and is found along the noses of the hills adjacent to most of the large tributaries to Deep Red Run from the north in this district.

The Grandfield conglomerate everywhere lies unconformably upon the Wichita formation (Permian), and displays a structure that is surprisingly conformable to the present topography, being high on

the divides and low near the valleys. For want of time in the field little study was given to this conglomerate and the data obtained were noted incidentally in mapping the Permian rocks. By further work it will probably be correlated with some portion of the Seymour formation, in Wichita County, Tex., described by Gordon[1] and referred by him to the Pleistocene. It very closely resembles the conglomerate seen by Udden and Phillips[2] on some of the higher ridges near and north of the Electra oil fields, which they describe as follows:

A conglomerate which has been variously classified as of Pleistocene or of late Tertiary age should perhaps be noted, for the reason that it has been mistaken by some for a part of the terranes whose structure determines the oil accumulations in these fields.

This conglomerate is of so late an origin that its distribution is clearly to some extent related to the topography developed by the present drainage. It lies high up on the divides and low down in the larger valleys, and can therefore not have the remotest connection with the structures of the Paleozoic series. It was noted on some of the highest hills on the divide between the Wichita and the Red River east from Electra, and on some of the hills north and west of Iowa Park. It caps the bluffs on the north side of the Wichita at several points southwest of Iowa Park. It was noted on the north shelf of Beaver Creek, at a point nearly due south of Electra, and again it was found capping the highest point of land on the divide between this creek and the Wichita River, in the southwest corner of Wichita County. Everywhere this conglomerate resembles stream gravel except as to its indurated condition. It is cemented with copious calcareous material, often of a cinnamon color. Cross-bedded sand is generally interbedded with the gravel, and occasionally it contains streaks of yellow and calcareous silt. It appears that this conglomerate is one of the remnants of a long series of stream sediments which have been laid down on the Plains during a time dating back from the later Tertiary age to the late Pleistocene.

The writer did not attempt to trace the outcrops of this conglomerate in the Grandfield district. A casual study of exposures, however, suggested strongly that the Grandfield is not the only quartz conglomerate there present, but that at places along Deep Red Run and many of its larger tributaries there are local thin beds of quartz and quartzite pebbles which are distinctly younger than the Grandfield conglomerate and which were probably derived from that bed by weathering and were redeposited along the streams. These secondary quartz pebble beds are usually unindurated or very poorly cemented and, as a rule, appear to contain a larger percentage of pebbles. The writer was able to distinguish with considerable certainty between the Grandfield and these younger gravels, but made no attempt to gather data to fix exactly their relative ages.

The Grandfield is surprisingly uniform in composition, appearance, thickness, and hardness throughout the district, and its uniform

[1] Gordon, C. H., U. S. Geol. Survey Water-Supply Paper 317, p. 30, 1913.
[2] Udden, J. A., and Phillips, D. McN., Univ. Texas Bull. 246, p. 107, 1912.

character suggests that it may not be a stream deposit. Its structure does show a very marked relation to the topography, the bed being present along the higher divides and in the points of the low hills adjacent to the larger streams. Notwithstanding the unconformity between this conglomerate and the underlying Permian rocks the structure of the two formations is very much alike, as may be seen from the elevations shown in Plate IV (in pocket). This suggests that the Grandfield conglomerate may have been deposited on a fairly smooth, even surface and later subjected to slight deformation, and that subsequent streams working in the soft fine sand and clay beds above this hard resistant layer have carved the surface roughly conformable to it.

The unconformity at the base of this conglomerate is clearly marked. It seems to be least at the south, where in places as much as 50 feet of red clay intervenes between the Grandfield conglomerate and the Auger conglomerate lentil below, and greatest toward the north, where in places the Grandfield conglomerate cuts out entirely the Auger lentil and rests on red clay several feet below its horizon.

### QUATERNARY SYSTEM.

*Gravels.*—Thin beds of loose gravel consisting largely of quartz, quartzite, and some chert were found at a number of places adjacent to the larger streams. As stated above, this gravel was probably derived from the disintegration of the Grandfield conglomerate and deposited at favorable places by the streams. Some of these beds of gravel seem to occupy poorly preserved terraces a few feet above the present valleys. A thin bed of fine quartz gravel, prevailingly amber colored, underlies the deep dune sand at the top of the bluffs at a few places on the north side of Red River in Rs. 11 to 15, inclusive, but a detailed study of this bed was not made.

At a number of places scattered quartz and quartzite, well-rounded to subangular pebbles, the largest 4 inches in diameter, were seen on the surface along the broad divide between Red River and Deep Red Run. The position of some of these pebbles seems to preclude the possibility that they were derived from the Grandfield conglomerate, and it seems probable that they are, in part at least, remnants of later deposits.

*Alluvium.*—Deep Red Run and all its larger tributaries flow in relatively broad, flat, alluvium-filled valleys. This alluvium is a fine to sandy red clay and silt, derived from the exposed rocks of the interstream areas. Red River, which, as already stated, has a very narrow flood plain and a broad bed, is closely bordered by dunes of wind-blown sand that rise as much as 100 feet above flood level. Throughout most of the year the bed of the river is dry, thin threads

of water meandering from side to side across flat bars of sand and mud. A typical view of the bed of this river is given in Plate II, *A*, page 8.

*Dune sand and soil.*—A belt of country, 1 to 2 miles wide, adjacent to Red River, extending across this district, is covered by hills of drifting sand, some of which reach a height of probably 75 feet above the general level. Permian beds lying inland from these sand dunes are covered by a thick bed of wind-blown sand, which forms a fairly even surface and through which the streams have trenched narrow ditchlike valleys. Farther back from Red River, toward the top of the divide between that stream and Deep Red Run, the mantle of wind-blown material grows thinner and finer until in places it has the general appearance of a coarse loess, and in other places the soil is dark or black and seems to contain a relatively small amount of wind-blown material.

## STRUCTURE.

The structure of the rocks in the Grandfield district has not been determined in detail, and in some parts of the district it is too obscure to be mapped with any degree of certainty. This structure is shown on Plate IV by numbers indicating the elevation above sea level of the Auger conglomerate lentil and also by structure contours connecting points of equal elevation on this bed. These contours are drawn on the horizon of the Auger conglomerate, but owing to the variability of the beds that make up this conglomerate no definite layer could be used as a key horizon throughout the area, so the elevations of this lentil as shown on Plate IV may be locally as much as 10 feet in error.

### DEVOL ANTICLINE.

The most important structural feature recognized in this brief reconnaissance of the district is an anticline that crosses it in a sinuous line trending generally east-southeast and west-northwest. Along the axis of this anticline lie a number of small elongated domes that are separated by low structural saddles. The rocks over the entire district generally dip eastward, and this dip is shown in the height of the Devol anticline. The axis of this fold in the Auger conglomerate dips from an elevation of about 1,160 feet at the western side of the district to about 1,040 feet at its eastern edge, a distance of about 24 miles. Within the district the highest portion of this anticline is in its western part, on one of two local domes, one near the center and the other in the extreme northwest corner of T. 4 S., R. 15 W., and the adjacent portions of T. 3 S., R. 15 W., and Tps. 3 and 4 S., R. 16 W. From near the center of T. 4 S., R. 15 W., the rocks dip in all directions but mostly to the north and south. There is

evidence that a secondary fold trends almost south from the center of this dome through secs. 21 and 22 and possibly into or through secs. 27, 28, 33, 34, and 35, and in this general direction to Red River, but no direct evidence of this fold was obtained farther south than secs. 27 and 28. From this dome another secondary fold appears to trend eastward to the vicinity of Curtis Hill in sec. 13, and from this point southeastward its axis passes through secs. 9, 28, 29, 30, 33, and possibly sec. 34, T. 4 S., R. 14 W. The axis of this fold is rather definitely located as far south as sec. 29, T. 4 S., R. 14 W., and there is some evidence of its presence still farther southeast, but its position could not be determined with certainty beyond the point indicated. From this dome eastward along the axis of the fold the rocks pitch slightly to the northeast corner of T. 4 S., R. 15 W. They rise again to the top of a small elongated dome in the vicinity of Grandfield.

A similar dome occurs in secs. 6, 7, 8, 9, and 16, T. 4 S., R. 13 W. This is separated from the dome at Grandfield by a flat saddle in the northern portion of sec. 2, T. 4 S., R. 14 W.

There appears to be a somewhat smaller dome in secs. 25, 26, and 27, T. 4 S., R. 13 W., but owing to lack of outcrops south of this location the outline of this dome could not be determined. From the center of this dome eastward the rocks appear to pitch gradually along the axis of the fold to some point near the center of sec. 26, T. 4 S., R. 12 W., from which they rise slightly to a small dome in secs. 24 and 25, T. 4 S., R. 12 W., and possibly in sec. 30, T. 4 S., R. 11 W., beyond which point the position of the axis of this fold could not be traced.

### DEEP RED SYNCLINE.

Another important structural feature of this district is a broad, flat syncline or structural trough which lies north of and roughly parallel to the Devol anticline. The axis of this fold pitches slightly toward the east, but is somewhat modified by one or two shallow basins. The exact position of the axis of this syncline at many places could not be determined. The available data indicate that it passes a short distance south of Loveland in a northwest-southeast direction that is roughly coincident with the trend of the valley of Slough Fork of Deep Red Run. From the map (Pl. IV) it will be noted that there appears to be a small shallow basin in the bottom of this trough west and northwest of Loveland, in sec. 8, T. 3 S., R. 14 W. From this basin the axis of the trough seems to rise slightly to a point southwest of Loveland and thence to pitch eastward at a very low angle to some point near the northwest corner of sec. 21, T. 3 S., R. 14 W., which is the bottom of a small basin along this trough.

A similar larger and deeper basin along the axis of this trough is in sec. 13, T. 3 S., R. 14 W., and secs. 17 and 18, T. 3 S., R. 13 W. From the center of this basin there seems to be a slight rise in the trough to the southwest corner of sec. 16, T. 3 S., R. 13 W. From this point eastward the depth and position of this trough is uncertain, but the available evidence suggests that it becomes deeper and lower toward the east.

### MINOR ANTICLINES.

The numbers and contours on Plate IV indicate the presence of several minor folds in the Grandfield district, the most important of which is a clearly marked anticline that is partially revealed by outcrops in the bluffs of Red River in the southwestern portion of T. 5 S., R. 12 W. These outcrops, in secs. 30, 31, and 32, show a very marked dip to the northwest, amounting probably to as much as 100 feet within less than 1½ miles. The accompanying view (Pl. V, *A*, taken from the bed of Red River opposite the bluffs in the NE. ¼ sec. 31, T. 5 S., R. 12 W., shows faintly the dip of the beds toward the west. To represent this dip the contour lines on Plate IV have been drawn in two directions. In one set the contours trend a little north of west and in the other set they have a general northeast-southwest direction. There is not enough geologic evidence available to show which of these two sets of contours is more nearly correct.

Udden[1] maps a very pronounced fold, with a northeast-southwest trend, in the Petrolia oil and gas field in the northern part of Clay County, Tex. His larger map,[2] which shows the general dip of the rocks of the region, gives some evidence that this fold continues toward the northwest and that it may cross Red River somewhere in the southern part of T. 5 S., R. 12 W., in the Grandfield district; so it seems barely possible that the relatively steep dip shown by these exposures in the southwestern part of this township may be on the west limb of this fold. If this is true, the fold may have a north-northwest trend through this township, the axis crossing the northwestern part of T. 5 S., R. 13 W., and joining the Devol anticline at the small dome in the southeastern part of T. 4 S., R. 13 W., but there is no direct geologic evidence to substantiate this suggestion. On the other hand, it seems probable that the Burkburnett oil fields, which lie between 4 and 5 miles west-southwest of these outcrops, may be on an anticline, and that, if this anticline trends east-northeast south-southwest, it may be the same as that shown by the outcrops in the southwestern part of T. 5 S., R. 12 W. If this is true, the axis of the Burkburnett fold may continue north-

[1] Udden, J. A., and Phillips, D. McN., Univ. Texas Bull. 246, Pl. II, 1912.
[2] Idem, Pl. I.

eastward and be shown by the exposures in secs. 9, 10, 15, and 16, and 1 and 2 of T. 5 S., R. 12 W. The evidence for each of these two structural conditions is about equal. It is impossible to determine the structural conditions in T. 5 S., R. 12 W., except that the southern portion of this township, especially secs. 28, 29, 32, and 33, are on or near the axis of a pronounced anticline, the trend of which is uncertain.

The rocks north of the Deep Red syncline appear to rise rather uniformly, but the exposures are too poor and too scarce to permit a close delineation of the structure. Attention should be called, however, to the relatively rapid rise in the beds from this syncline northward in the northeastern part of T. 3 S., R. 14 W. The trend of the contours in this area also suggests that a local dome or anticline may be situated a short distance north of sec. 2 in T. 2 S., R. 14 W. There is also some evidence of a low fold in portions of sec. 9, T. 3 S., R. 13 W.

### LOCAL SYNCLINES.

South of the Devol anticline there appears to be a local syncline, the axis of which crosses T. 4 S., R. 14 W., in a northwest-southeast direction and seems to cross the valley of Big Blue Creek near its junction with Little Blue Creek and roughly to parallel the valley of the latter stream to the middle western part of sec. 7, T. 4 S., R. 14 W. The axis of this fold pitches to the southeast, but there is little or no evidence to show its trend southeast of the valley of Big Blue Creek.

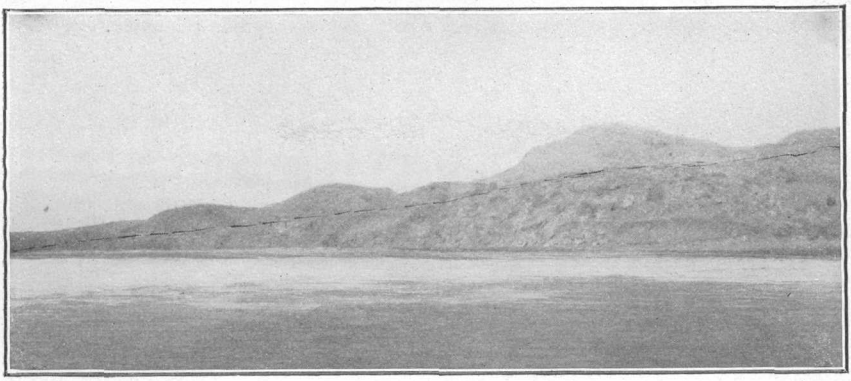
A small secondary syncline appears to parallel the valley of Auger Creek in the southwestern portion of T. 4 S., R. 15 W., the pitch of the fold being somewhat steep toward the south. A similar fold is believed to lie somewhat west of the valley of Curtis Creek, in the southeastern portion of T. 4 S., R. 15 W., but owing to the poor exposures in both of these areas the exact position of these troughs can not be determined.

North of the Devol anticline the contour lines on Plate IV show many small local synclines branching off from the Deep Red syncline and dying out against the north limb of the Devol anticline, but none of these requires special description.

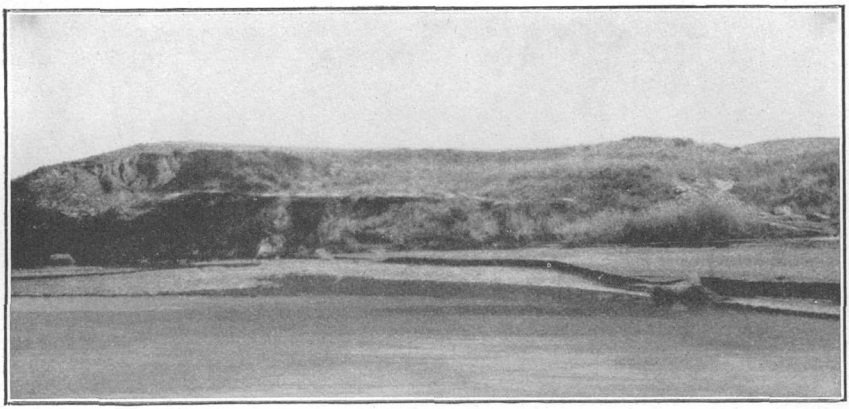
## DETAILED STRATIGRAPHY AND STRUCTURE OF EXPOSED ROCKS, BY TOWNSHIPS.

### T. 5 S., R. 16 W.

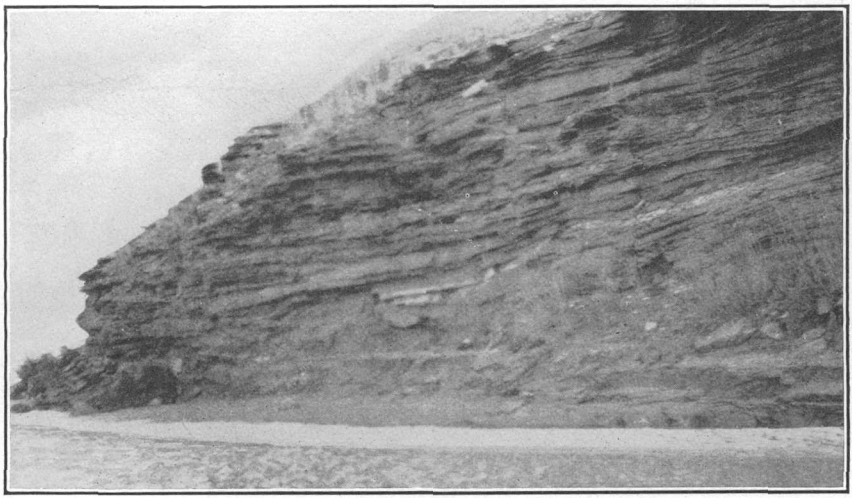
Red River cuts across the northern boundary of T. 5 S., R. 16 W., so that only a narrow strip of the northern tier of sections east of sec. 6 is on the north side of the river. This area is covered entirely by sand dunes, but Permian rocks outcrop in the bluff on the south side



*A.* NORTH BLUFF OF RED RIVER IN NE. ¼ SEC. 31, T. 5 S., R. 12 W.
Showing westward dip of Permian rocks.



*B.* SOUTH BLUFF OF RED RIVER IN T. 5 S., R. 16 W.
Showing westward dip of Permian sandstone.



*C.* EASTERN PART OF BLUFF SHOWN IN *B*.

(Texas side) of the river in the southern part of sec. 3. The accompanying views (Pl. V, *B*, *C*) and the following section show the general appearance and character of the best of these outcrops.

*Section in bluff on south side of Red River in sec. 3, T. 5 S., R. 16 W.*

| | Feet. |
|---|---|
| 1. Concealed by dune sand at top, probably | 40 |
| 2. Sandstone (not shown in Pl. V, *C*) massive, reddish, capping bluff east of exposure shown in Pl. V, *C*. Appears to be resting on red clay, but base is poorly exposed | 20–25 |
| 3. Clay, red (poorly exposed in Pl. V, *C*), which appears to contain a soft whitish sandstone or clay-limestone conglomerate toward top; probably | 5–15 |
| 4. Sandstone, reddish, thin bedded, laminated with some whitish layers, and containing several lentils of reddish clay-limestone conglomerate which ranges in thickness from 1 foot to as much as 10 feet, within length of exposure. This sandstone seems to lie unconformably on the red clay below and to be very irregularly bedded throughout | 10–25 |
| 5. Sandstone, whitish, clayey, lumpy, embedded in red clay (not shown in Pl. V, *C*); greatest thickness probably | 4 |
| 6. Clay, bright red, at base above water level; greatest thickness | 10 |
| | 75–119 |

East of the above section a grayish clay-limestone conglomerate bed outcrops along the river bluffs beneath dune sand. Below this conglomerate a white massive sandstone 4 feet thick is poorly exposed a few feet above the river. Higher bluffs farther back from the river contain other outcrops of thin beds of gray and reddish sandstone and reddish clay-limestone conglomerate which appear to rise toward the east. This rise is also suggested by the exposure shown in Plate V, *B*. These clay-limestone conglomerate beds resemble closely those of the Auger conglomerate lentil, though the associated sandstone beds are not typical. If this is the Auger conglomerate, it is one of the most westerly exposures observed. It probably ranges in elevation between 1,040 and 1,070 feet above sea level at this locality.

### T. 4 S., R. 16 W.

Red River crosses the southwest corner of T. 4 S., R. 16 W., and Settler Creek, flowing from north to south through the central part of the township, drains most of it. The south half of the township is covered largely by dune sand and a deep sandy soil, which is mostly, if not all, wind blown. Permian rocks come to the surface at few places. One of these outcrops is in a small break on the east

bank of Settler Creek, almost in the center of the NW. ¼ sec. 27, where the following section is exposed:

*Section in NW. ¼ sec. 27, T. 4 S., R. 16 W.*

| | Feet. |
|---|---|
| 1. Top concealed by dune sand. | |
| 2. Gravel at top of break, largely quartz, unindurated; looks like stream gravel of Recent age | 1–3 |
| 3. Sandstone, reddish, massive, irregularly bedded at base changing to thin bedded and clayey at top | 3 |
| 4. Sandstone, gray, with black specks; soft, with typical appearance of "speckled" bed of the Auger conglomerate lentil, about | 1 |
| 5. Sandstone, soft, bluish white, clayey, looks like basal bed of Auger conglomerate | ½–1 |
| 6. Clay, bright red | 8 |
| 7. Sandstone, red, soft, clayey, badly weathered to bed of creek | 4 |
| | 17½–20 |

Bed 4 of the above section seems to be at the horizon of the clay-limestone conglomerate of the Auger lentil, which is locally absent. If this correlation is correct, there seems to be not more than 15 feet dip in the beds from this place to the outcrops described above in south bluff of Red River 3 miles farther south. No other exposures of recognizable Permian beds were seen on Settler Creek in this township. An extensive break occurs in red clay on the east side of the valley along a part of the west edge of sec. 10, and some small exposures of red clay were seen in the SW. ¼ sec. 3 and the SE. ¼ sec. 4.

The dump from a shallow water well in the southwest corner of the SW. ¼ sec. 2 contained some bowlders of red sandstone in red clay which could not be correlated with any other Permian exposures. Near the head of a small tributary to Red River, in the NE. ¼ of sec. 23, a bed of quartz and quartzite pebbles is exposed on the east side of the run, and below this bed is a poor outcrop of reddish clay-limestone conglomerate which may belong to the Auger conglomerate lentil. No elevation of this outcrop was obtained. At the southeast corner of sec. 23 a bed of quartz and quartzite gravel outcrops beneath dune sand and at places this bed is cemented by lime into a thin bed of reddish quartz conglomerate that resembles the Grandfield conglomerate.

The low divide between Settler Creek and Auger Creek traverses the W. ½ sec. 13 and the E. ½ sec. 14 from northeast to southwest. Two or three low domes on this divide are capped by a bed of quartz and quartzite pebbles, which may have come from the disintegration of the Grandfield conglomerate in place.

No examination was made of a large part of the area in this township west of Settler Creek because it appeared to be destitute of good exposures of recognizable Permian beds.

### T. 3 S., R. 16 W.

Only the southeastern part of T. 3 S., R. 16 W., was examined and this in the briefest manner. The lack of good exposures over the area covered showed the uselessness of attempting to map with accuracy the structure of the Permian rocks in it. The writer did not go north or west of lines running through the middle of sec. 16.

Red clay, seemingly of Permian age, is revealed by low "breaks" along tributaries to Deep Red Run in parts of secs. 13, 14, 15, 16, 21, 22, 27, and 28. At a few places at the top of these breaks is a thin bed of clayey sandstone, generally reddish in color, but showing many round gray spots, ranging from tiny specks to patches probably 2 inches in diameter. A precisely similar sandstone, which lies a few feet above the Auger conglomerate, was noted at many places farther east. For convenience of description this bed is referred to as the "spotted sandstone layer." The gray patches are thinnest across the bedding planes and many of them are very thin in comparison with their diameter. At a few places in these breaks a layer of soft grayish limy clay, from 6 inches to a foot or more in thickness, is exposed in bright-red clay a few feet below the "spotted sandstone layer." A few feet above this sandstone is a bed of quartz and quartzite pebbles, most of which are well rounded. This bed is poorly exposed and apparently unindurated, but there were in places small bowlders of reddish limy matrix, including a few quartz pebbles, looking very much like the Grandfield conglomerate, and it seems probable that this conglomerate lies a few feet below the surface over most of the southeast quarter of the township, as similar material is frequently seen at the mouths of the burrows of prairie dogs. A spotted layer of sandstone, very similar in appearance to that described above, was thrown out of a 5-foot hole dug for water near the middle of the east line of the NE. ¼ sec. 26. If this is the same layer as that seen in the south bank of a small run at the southern border of the SW. ¼ sec. 14 there is a slight northward dip between these exposures.

### T. 3 S., R. 15 W.

T. 3 S., R. 15 W., is drained by Deep Red Run and its tributaries. The Wichita Falls & Northwestern Railway crosses it from northeast to southwest. The town of Loveland is situated near its center, in secs. 9 and 16. In the part of the township that lies northeast of Slough Fork of Deep Red Run the surface is very flat, and the

larger streams have wide alluvium-covered valleys and low bluffs. The soil is generally a fine stiff clay, dark brown to red. In this part of the township not more than 6 good exposures of sandstone and clay-limestone conglomerate were seen. One of these is a rather thick reddish bed of clay-limestone conglomerate and some light to reddish sandstone, encountered from 16 to 18 feet below the surface in a dug well on the south edge of the SE. ¼ sec. 5. This bed closely resembles, and probably belongs to, the Auger conglomerate. It stands about 1,062 feet above sea level. This conglomerate is thought to be at the same horizon as one that outcrops on the road south of Loveland, near the southeast corner of the town. The outcrop at that place stands about 1,066 feet above sea level.

On the south side of the valley of Middle Fork of Deep Red Run and on the east side of the NE. ¼ sec. 14 a typical outcrop of the "speckled sandstone layer" of the Auger conglomerate shows along the road and in the bluffs toward the west. Here the lower layer of the clay-limestone conglomerate of the Auger lentil is absent in places and is replaced by white clayey sandstone. This is unquestionably at the Auger horizon. Its elevation ranges from about 1,058 to 1,062 feet above sea level, the rise being a local one, toward the east. Near the center of the SE. ¼ sec. 13, at a small pond, is a rather poor outcrop of the "speckled sandstone layer" of the Auger lentil having a few feet above it a quartz-gravel-limestone conglomerate, probably the Grandfield. Other sandstones, exposed a short distance north of this outcrop in the southern part of the NE. ¼ sec. 13, help to identify definitely the "speckled sandstone layer" as the Auger lentil. It has an elevation here of about 1,036 feet. The outcrops along this line continue eastward through T. 3 S., R. 14 W., and are discussed under that township. On the south bank of the creek, near the eastern border of the SW. ¼ sec. 3, is a bed of coarse to fine partly indurated quartz gravel, which in places is as much as 10 feet thick. This gravel seems to be younger than the Grandfield and is probably a local stream deposit, the quartz and quartzite pebbles of which come from the disintegration of the Grandfield at near-by places. Similar gravel beds were noted along the sides of the valley of this stream in secs. 2, 3, and 4. A low, round hill capped by a quartz conglomerate closely resembling the Grandfield stands near the middle of the SW. ¼ sec. 1.

A deep well was completed in 1912 just north of Loveland, near the center of the NE. ¼ sec. 9. This well did not produce oil or gas in paying quantities and is said to have been abandoned. A partial section of this well is given in Plate III (in pocket).

South of Slough Fork of Deep Red Run and adjacent to the valley of that stream is a broad belt of badland country, in which occur a great many "breaks" or washes, developed in fine red clay of

Permian age. The character of the rocks exposed in these breaks and the distribution of the exposures renders the determination of the structure very difficult. The Auger conglomerate is typically exposed on the township line south of the northeast corner of sec. 25 and at another place in the SW. ¼ SE. ¼ sec. 17. At these places the "speckled sandstone layer" and other associated beds of the Auger conglomerate are present. This conglomerate is in two well-marked divisions. The lower layer is below, or interstratified with, the "speckled sandstone bed." The upper conglomerate layer is associated with thin beds of reddish impure sandstone and red clay and at places seems to be as much as 12 to probably 18 feet above the lower one. Each layer and its associated beds have local characteristics which render identification possible where good exposures occur, but it is impossible to trace the beds by continuous outcrop. A collection of fossil bones was obtained from the red clay immediately overlying what appears to be the upper layer of the Auger conglomerate where it is exposed in a large break in the east-central part of the NW. ¼ NW. ¼ sec. 28. These were identified by Mr. C. W. Gilmore, of the National Museum, as belonging to the Permian reptile Dimetrodon, but "the bones are too fragmentary to permit the determination of the species."

Over much of this part of the township the sandstones accompanying the lower conglomerate of the Auger lentil are not present, their horizons being occupied by red sandy clay with limestone nodules. The sandstones of the lower part of the Auger lentil are absent from the Permian outcrops along the creek in the northern halves of secs. 17 and 18, but here the upper part of the Auger lentil, consisting of clay-limestone conglomerate in red clay, is exposed in the breaks with a bed of thin reddish platy limy sandstone having the characteristic choppy ripple marks and round grayish spots of the sandstone in T. 3 S., R. 16 W., already described as the "spotted sandstone layer." The following section exposed in a great break in sec. 31 is typical of the Permian outcrops in this vicinity.

*Section of rocks exposed in break in the NE. ¼ SE. ¼ sec. 31, T. 3 S., R. 15 W.*

| | Feet. |
|---|---|
| Tertiary or Quaternary (Grandfield conglomerate): | |
| 1. Quartz and quartzite pebbles, the largest 4 inches in diameter, conglomerate badly disintegrated, with bed of residual pebbles in soil at top of hill | 2–3 |
| Permian (Wichita formation): | |
| 2. Concealed on hill slope above break, probably | 3 |
| 3. Sandstone, reddish, rather thin, platy (plates 4 feet square, less than one-half inch thick), caps top of break, very similar to sandstone accompanying clay limestone in secs. 17 and 18 | 3+ |

| Permian (Wichita formation)—Continued. | Feet. |
|---|---|
| 4. Conglomerate, clay-limestone, soft, whitish, variable; this is probably upper bed of Auger conglomerate lentil, greatest thickness | 2 |
| 5. Clay, dark, dull red | 3 |
| 6. Sandstone and clay, red; thin-bedded sandstone interbedded with red clay | 5 |
| 7. Sandstone, whitish, false bedded, soft, lumpy, very irregular in occurrence, greatest thickness | 2 |
| 8. Clay, bright red, with many roundish grayish limestone nodules; typical under clay of the Auger conglomerate lentil | 10 |
| 9. Clay, whitish, limy, almost clay-limestone, conglomerate in places | 1 |
| 10. Clay, bright red, with typical roundish, rough-surfaced burnt red limestone-clay concretions, down to base of breaks | 5 |

The above section is by no means typical of the Auger conglomerate farther east, in the vicinity of Grandfield, but there seems to be enough stratigraphic evidence to justify the conclusion that the sandstone beds thin greatly toward the west across the district and that this section accords with this general decrease in thickness of these beds.

Spirit-level lines were run to many exposures of the clay-limestone conglomerate beds in the southwestern part of this township, but at many places the outcrops were so poor that the upper and lower layers of the Auger conglomerate could not be distinguished. For this reason the local dip of these beds at places is somewhat in doubt, but as a whole they gradually rise toward the south and west across the township. (See Pl. IV, in pocket.)

From the exposures in the SW. ¼ SE. ¼ sec. 17 to those near the center of the south line of the township in sec. 34 the beds appear to rise between 35 and 40 feet. From the northeast corner of sec. 25 to the southwest corner of sec. 34, a distance of 3½ miles, they seem to rise about 50 feet. From the NW. ¼ NE. ¼ sec. 17 to the NE. ¼ SE. ¼ sec. 31, a distance of 3½ miles, they rise about 70 feet, which seems to be about the maximum for this township. In the northwest quarter of the township they are too poorly exposed to furnish much data of value, but they appear to be practically horizontal.

The important geologic facts derived from a study of this township are (1) that the rocks dip at a very low angle from the southern and western sides toward the north and east as far north as Slough Fork of Deep Red Run, and that north of that creek the dip of the beds can not be determined with accuracy but appears to be slightly toward the east and south; (2) that fossil bones of a Permian reptile appear in place above what appears to be the upper bed of the Auger conglomerate; and (3) that the Grandfield conglomerate of Tertiary

or Pleistocene age caps the tops of the hills along the southern border of the township just above the Auger conglomerate and also bears the same relative position to the Auger lentil in exposures at a much lower level along the creek in the north-central part of sec. 17 and at other places in secs. 13 and 14. This fact is especially important because the Auger lentil and Grandfield conglomerate are separated by an unconformity representing a hiatus of at least hundreds of feet of strata, yet the two beds show practically the same structure, not only in this township, but to a large degree throughout the district.

### T. 4 S., R. 15 W.

The broad, flat divide between Deep Red Run and Red River runs from east to west, north of the middle of T. 4 S., R. 15 W. The "breaks" in T. 3, just described, extend southward into parts of secs. 3, 4, 5, and 6, T. 4. The tributaries of Red River are Auger Creek on the west and Curtis Creek and Little Blue Creek on the east. Practically all exposures of Permian rocks are on or near these streams and in the "breaks" near the northern edge of the township. The southern portion of the interstream area is covered by a deep brown or reddish loose sandy soil, composed largely of wind-blown sand. Along the divide in the northern part of the township the soil is rather dark and close, though it contains some sand, but it presents a marked contrast to that of the "breaks," which is deep red in color and has a heavy clayey texture.

In the northern part of this township there is an exposure of the "speckled sandstone layer" of the Auger conglomerate near the road at about the middle point of the south line of the SE. ¼ sec. 4. At this outcrop the lower conglomerate of the Auger lentil is not exposed and may be absent. The upper layer of conglomerate is soft, thin, and red to grayish, and is embedded in red clay a few feet above the "speckled sandstone layer." At a number of places in this section the bluish-white soft cross-bedded sandstone of the Auger lentil is characteristically exposed, some cross beds having slopes of 10° to 20° that closely resemble true dips. The upper conglomerate layer outcrops at many places in the "breaks" in the W. ½ sec. 3 and E. ½ sec. 4. The "speckled sandstone layer" and associated beds also outcrop in the creek bluff at the west side of the SW. ¼ sec. 4. Between these exposures the "speckled sandstone layer" dips toward the northwest 12 to 20 feet, but this may be largely if not wholly due to the general northerly dip in this vicinity rather than to a local syncline passing through or west of the SW. ¼ sec. 4. West of this quarter section the rocks seem to rise again to a point 1 mile due west of this exposure in the east part of SE. ¼ sec. 6, where a large "break" occurs near the top of the hill. The Grandfield conglomerate, badly

weathered, caps the top of this hill. Three or four feet below it in the "break" is a soft reddish or grayish clay-limestone conglomerate which looks like the upper bed of the Auger lentil, but which may be a bed still higher in the geologic column.

The valley of Little Blue Creek in this township is very shallow, the creek being in fact no more than a shallow drain, the bottom of which is sodded in places. A bed of sandstone, grayish, false bedded and speckled, is exposed at two or more places in sec. 12 at heights less than 6 feet above the bottom of the stream. This bed is probably the "speckled sandstone layer" of the Auger conglomerate, but the identification is by no means positive. The Grandfield conglomerate or a younger gravel lies close above this sandstone wherever it is exposed on Little Blue Creek. These outcrops suggest a slight rise in the rocks upstream.

On Auger Creek near the center of sec. 18 there is exposed a massive layer of clay-limestone conglomerate, overlain by a grayish clay 6 or 8 feet thick, which contains small white limy, irregular concretions, and above that lies a bed of loose quartz and quartzite gravel. Below the clay-limestone conglomerate is a bed of bright-red clay containing roundish gray limestone concretions, which looks very like the clay below the Auger conglomerate, but no sandstone beds were found. This conglomerate is probably the lower layer of the Auger lentil. This correlation seems to be strengthened somewhat by the abrupt increase in thickness of the sandstones of the Auger lentil from northwest to southeast in this vicinity. In the NW. ¼ NW. ¼ sec. 20 the "speckled sandstone layer" of the Auger lentil, interbedded with clay-limestone conglomerate, is 3 feet thick in the bank of the creek, but pinches out entirely within 200 yards toward the northwest. This thinning suggests a local unconformity between this sandstone and a bright-red clay containing gray limestone concretions lying below it. About five-eighths of a mile a little south of east from the above exposure the Auger lentil shows the following section:

*Partial section of Auger conglomerate lentil on west side of run in southeast corner of NW. ¼ NE. ¼ sec. 20, T. 4 S., R. 15 W.*

| | Feet. |
|---|---|
| Quaternary and Tertiary (?): | |
| 1. Soil | 5 |
| Permian (Wichita formation, Auger conglomerate lentil): | |
| 2. Pebbles (loose), quartz, and quartzite | 1–2 |
| 3. Clay, reddish to gray, with white limy concretions | 2 |
| 4. Sandstone, white, choppy, wave marked, false bedded, and thin, irregular clay-limestone conglomerate lentils | 3 |
| 5. Clay, red and whitish, with some thin-bedded red clayey sandstone | 1–2 |

| | Feet. |
|---|---|
| Permian (Wichita formation, Auger conglomerate lentil)—Con. | |
| 6. Clay-limestone conglomerate lentil, reddish to gray | ½–1 |
| 7. Sandstone, thin bedded, reddish, platy, shaly, false bedded | 2 |
| 8. Clay, bright red | ½–1 |
| 9. Sandstone, soft, white to reddish, massive, in irregular beds | 4–6 |
| 10. Concealed, probably red clay or clay-limestone conglomerate | 1–2 |
| 11. Sandstone, soft, red, massive, to bed of creek | 1–2 |
| | 28 |

Excellent outcrops of the sandstones associated with the clay-limestone conglomerate of the Auger lentil occur in the S. ½ sec. 20 and the N. ½ sec. 29. These sandstones as well as the conglomerate vary greatly in character and thickness from place to place in this area. The time available for field work was too short to permit a detailed study of the Permian beds in the "breaks." The Auger conglomerate was easily recognized wherever its horizon was noted, but at places its character is very different from that shown in its outcrop at the type locality in the NW. ¼ sec. 6, described on page 23.

On the west bluff of Auger Creek, in the central part of the NW. ¼ sec. 29, a rather hard conglomerate, consisting largely of waterworn quartz and quartzite pebbles embedded in a brownish-red limy clay matrix, is exposed at a number of places. This bed looks very much like the Grandfield conglomerate but may be younger.

The general dip of the Auger conglomerate along Auger Creek is downstream, and seems to be about 30 feet from the middle of sec. 18 to the middle of sec. 31, a distance of 3 miles. The general strike of the beds seems to range from almost east-west to northwest-southeast. From the head of the "break" in the NE. ¼ NW. ¼ sec. 32 the elevation of the uppermost hard sandstone, compared with that of the first hard beds found in shallow water wells drilled near by, toward the northeast and southeast, suggests that there is a local dip of considerable angle in that direction. There are also indications of a syncline crossing Auger Creek near the middle line of sec. 29, which further strengthens the suggestion of a local syncline trending either almost north-south, as shown by contours on Plate IV, or else northwest-southeast across secs. 29, 32, and 33.

Between the exposures on Auger Creek and the headwaters of Curtis Creek, in secs. 22 and 23, a single thick layer of clay-limestone conglomerate, very hard and compact, outcrops through the sandy soil in the road near the middle of the east line of the NE. ¼ sec. 21. This conglomerate has no quartz or quartzite pebbles and has the appearance and texture of the Permian clay-limestone conglomerates of this district. It may be either the upper or the lower bed of the Auger conglomerate or it may be a conglomerate coming higher in

the Wichita formation. If it belongs to the Auger lentil, which seems most probable, there is a dip of about 40 feet from this outcrop both to the east and to the west within 1 mile. If it is a higher clay-limestone conglomerate, this dip is probably much less or none at all, as the exposures of the Auger on Auger Creek are at practically the same elevation as those on Curtis Creek.

Near the middle of the west side of the NW. ¼ SW. ¼ sec. 23 a fine exposure of clay-limestone conglomerate from 2 to 5 feet thick occurs in the bank and bed of a small tributary to Curtis Creek. The upper layers of this bed are reddish, hard, and compact, the clay balls being small. The bottom layer contains in places many chert and limestone nodules as well as clay pebbles. This conglomerate is very irregularly bedded and very variable in thickness. It is exposed again on Curtis Creek about one-fourth mile farther southeast, in the SW. ¼ sec. 23, and appears again at the same elevation on the east side of the SE. ¼ sec. 23. In the S. ½ sec. 24, on a tributary of Curtis Creek, the "speckled sandstone layer" and other associated sandstone beds are exposed with the conglomerate beds of the Auger lentil. On the road just south of the northeast corner of sec. 25 a quartz conglomerate that resembles closely the Grandfield conglomerate was found just above the horizon of the Auger. The Grandfield conglomerate here has an altitude of about 1,095 feet above sea level. In the top of Curtis Hill, a conspicuous round hill near the center of the north half of sec. 13, less than 2 miles farther north, it has an elevation of approximately 1,174 feet above sea level, showing a rise of over 40 feet to the mile. This bed also outcrops in a small hill in the center of sec. 23, where it has an altitude of probably 1,120 feet. The general rise of the Auger lentil northwest and north along Curtis Creek and its tributaries seems to be somewhat less than that of the Grandfield. From the southeast corner of the NW. ¼ sec. 24 these beds rise about 15 feet, and in the same direction across sec. 23 the rise is probably not more than 12 feet. The slope of the surface suggests that the Auger lentil is farther below the Grandfield conglomerate in Curtis Hill than it is at the northeast corner of sec. 25.

The important facts brought out by the above discussion of the exposed beds of this township are (1) that the clay-limestone conglomerate exposed on the road near the middle of the west line of the NW. ¼ sec. 22 possibly belongs a few feet above the upper layer of the Auger conglomerate, but that there is no direct evidence to show that it is not the upper layer of the Auger; (2) that levels on the various beds associated with the Auger show a rise in them to the south and west in secs. 3, 4, 5, and 6, and a corresponding but slighter rise in them from south to north in exposures along Auger and

Curtis creeks; (3) that the Grandfield conglomerate, of Tertiary or Quaternary age, notwithstanding the fact that it lies unconformably upon the Wichita formation, of which the Auger lentil is a part, seems to conform rather closely to the structure of the latter; (4) that structurally the highest territory in the township is probably somewhere in secs. 6, 7, 8, or 9, and that there is some evidence of an anticline or structure high in parts of secs. 21 or 22, but that the trend of this anticline, if it exists at all, can not be determined because of lack of exposures in the territory farther south.

### T. 5 S., R. 15 W.

Red River enters T. 5 S., R. 15 W. near its northwest corner and flows south of east through secs. 6, 5, 9, 10, 14, 13, and 12. The territory south of the river was not examined. Permian beds are exposed in this area at a few places along the river bluff in secs. 5, 6, and 9. The Auger conglomerate outcrops near the base of the river hill at a point in the SW. ¼ SE. ¼ sec. 5, where it is at an elevation of about 1,041 feet. This shows a dip of about 36 feet toward the southeast in less than 2 miles from the exposure near the center of sec. 31, T. 4 S., R. 15 W. Sandstones of the Auger lentil outcrop at many places along the base of the bluffs from this point for almost a mile toward the northwest in secs. 5 and 6, but the exposures are poor. In secs. 9 and 10 there are a few scanty outcrops of red clay, a reddish thin-bedded impure sandstone, and a thin bed of clay-limestone conglomerate, which could not be correlated. The general appearance of these exposures suggests a slight rise of the beds toward the east from some point near the southeast corner of sec. 5, but there are not sufficient outcrops to make this at all certain.

The remainder of this township toward the east and northeast is covered deeply by dune sand, and no outcrops of Permian rocks were found in it.

Attention might be called to a deposit of quartz and quartzite gravel at the base of the dune sand, overlying red nodular clay, in the river bluff near the southwest corner of sec. 4. The gravel here is locally somewhat cemented into an indurated bed, but a short distance to the east it is rather loose. This bed is probably between 40 and 65 feet above the water of the river and between 1,050 and 1,075 feet above sea level.

### T. 5 S., R. 14 W.

All of T. 5 S., R. 14 W., except sec. 6 and portions of secs. 4, 5, 7, and 8 lies in and south of Red River and has not been examined for this report. No exposures of Permian rocks are known in it north of the river, the entire surface being covered by dune sand.

T. 4 S., R. 14 W.

Red River cuts across the southern parts of secs. 33, 34, 35, and 36 in the southeastern part of T. 4 S., R. 14 W. This area is drained by Big and Little Blue creeks, Curtis Creek (tributaries of Red River), and by a number of small streams flowing northward into Deep Red Run.

Except along the larger streams and in a few "breaks" adjacent to them, the surface is covered by a deep sandy to fine soil composed largely of wind-blown material. A strip of land from 1 to 2 miles wide along Red River is covered by sand dunes or by a deep mantle of wind-blown sand.

The most southern outcrop of Permian rocks on Curtis Creek is in the west bank of the creek, in the SE. ¼ SW. ¼ sec. 30. Here about 5 feet of red clay at the base of the bluff is overlain by 2 or 3 feet of reddish thin-bedded clayey sandstone, above which is 2 feet of sóft lumpy clay-limestone conglomerate. This bed contains no quartz pebbles but is doubtfully correlated with the upper part of the Auger conglomerate. It has an elevation of 1,063 feet and is overlain by some red clay, above which is a layer of loose pebbles, largely quartz and quartzite, overlain by loose sand. This bed of pebbles has a distinctly younger appearance than the Grandfield conglomerate. The upper conglomerate of the Auger lentil and its associated sandstone beds outcrop in the south bank of Curtis Creek near the center of the W. ½ sec. 30. This conglomerate has an elevation of about 1,062 feet. Here also the Permian beds are overlain by the layer of quartz and quartzite pebbles underlying wind-blown sand.

In the NE. ¼ sec. 30 two outcrops of the same bed of clay-limestone conglomerate occur. One of these is near a small pond in the northwest corner of the quarter section, where the conglomerate is close, hard, grayish to reddish, and resembles closely the lower bed of the Auger conglomerate where best developed. It has an elevation of about 1,078 feet. The other outcrop occurs in the road on the east side of the SE. ¼ of this quarter section. It is here reddish to grayish, very close and compact, and seems to be in two layers, having a total thickness of possibly as much as 6 feet. Its elevation is approximately 1,100 feet above sea level. This bed forms a beautiful dip slope between the two outcrops, a distance of almost half a mile. At the residence just north of this outcrop in the NE. ¼ sec. 30 a well over 40 feet deep, located on the hill at a slightly higher elevation than the outcrop, is in red clay, showing no trace of clay-limestone conglomerate or sandstone. A few feet away and at about the same elevation another well found 4 or 5 feet of clay-limestone conglomerate and, at a depth of from 5 to 12 feet from the surface, a soft gray sandstone containing many small black specks. A shallow well

about 150 yards north of this point shows clay-limestone conglomerate and gray sandstone beds at a shallow depth. These data suggest strongly that the clay-limestone conglomerate outcropping at an elevation of about 1,100 feet is the lower layer of the Auger lentil and that there is a dip in it of probably 35 feet from the middle of the east line of the NE. ¼ sec. 30 southwest to Curtis Creek, a distance of less than three-fourths of a mile. A poor exposure of clay-limestone conglomerate, which seems to be the same as that described above, occurs in the road near the southeast corner of the NE. ¼ NE. ¼ sec. 29, where it has an altitude of about 1,085 feet above sea level. About half a mile north-northwest of this outcrop, on the south bank of Little Blue Creek, there is a peculiar grayish lumpy clay-limestone-sandstone bed which can not be definitely correlated; but its association with gray sandstones and bright red clay of Permian age a short distance farther to the east suggests that it is probably the basal bed of the Auger lentil. This outcrop has an elevation of 1,056 feet. Within one-fourth mile toward the east this bed and its accompanying sandstone layers disappear. They either grade into sandy, nodular, red clay or are cut out by a local unconformity. From this exposure eastward, in secs. 21, 22, 23, 27, and 28, red nodular clay and thin fragments of clay-limestone conglomerate are the only Permian rocks outcropping. At a number of places along this part of Little Blue Creek is a bed of quartz and quartzite pebbles, which, though somewhat indurated at places, is evidently younger than the Grandfield conglomerate.

A number of exposures of the Permian beds were found along the sides of the valley of Little Blue Creek in secs. 20, 17, 18, and 7. Most of these outcrops are such as to leave the identification of the beds somewhat in doubt, but at a few places the Auger conglomerate seems to be fairly typically exposed. At one of these places, in the east bank of the creek, in the SW. ¼ SW. ¼ sec. 17, irregularly bedded grayish to reddish sandstones contain a rather thin variable bed of soft reddish clay-limestone conglomerate. These beds lie very unevenly upon red clay and are overlain unconformably by a quartz conglomerate that resembles closely the Grandfield, and this, in turn, is overlain by a dark to bluish or grayish clay containing small white limestone concretions. The layer of clay-limestone conglomerate has an elevation here of about 1,064 feet. There is a local thickening of these sandstone layers in the NE. ¼ SE. ¼ sec. 18, where they were quarried in a small way for building stone. At this place they have an elevation of 1,075 feet. Northwest of this location, in secs. 18 and 7, poor outcrops of clay-limestone conglomerate and a quartz conglomerate which resembles the Grandfield were seen at a few places, but most of these could be definitely correlated.

On the east bank of Big Blue Creek, near the center of the SE. ¼ sec. 26, a layer of grayish clay-limestone conglomerate, from 1 to 2 feet thick, was observed just above creek level. In this bed fragments of fossil bones were found. It has an elevation of about 996 feet above sea level. It is overlain for 5 or 6 feet by soft whitish clayey sandstone layers interbedded with red clay, and above this is red to purplish clay about 30 feet thick, with "twisted or knotted" limestone concretions, and at the top of the bluff is about 25 feet of loose brownish sand. At places a little farther north a bed of coarse quartz and quartzite conglomerate, cemented by lime into a reddish hard mass, 1 to 5 feet thick, lies near the base of the wind-blown sand. This conglomerate resembles very much the Grandfield conglomerate, though it may be reworked material from that bed. At this place the Auger lentil could not be identified with certainty. The clay-limestone conglomerate noted above as carrying fragments of bones may be the upper layer of the Auger and may lie at the horizon of the bones found in the NW. ¼ NW. ¼ sec. 28, T. 3 S., R. 15 W. However, it is most probably a clay-limestone conglomerate underlying the bright-red clay bed seen at a few places about 40 feet below the Auger lentil. This outcrop suggests a general dip toward the east. About 100 yards north of the above exposure, near the north end of a high bluff on the east side of Big Blue Creek, there is a rather poor exposure of dark, limy, ferruginous sandstone which seems to dip at a high angle toward the north. This dip is also strongly suggested by poor exposures of clay-limestone conglomerate and by divisions in the beds of clay. In the short time at his disposal the writer was unable to determine with certainty the structure of the rocks at this place.

Near the southern edge of the NE. ¼ NE. ¼ sec. 35 several rather thick beds of whitish to reddish sandstone alternating with red clay outcrop for 100 yards along the west bluff of Big Blue Creek. The writer was unable to identify definitely these beds. They are very irregularly bedded and range from massive to thin bedded. The bedding planes show a decided dip toward the north, the angle being greatest at the southern end of the exposure. The writer is inclined to believe that these sandstone beds underlie the Auger conglomerate, and that they dip toward the north and pass below Big Blue Creek, a short distance upstream. If this is true, the structure of the rocks is similar to that shown by the contours on Plate IV. A few poor outcrops of massive grayish sandstone, which could not be correlated with the Auger lentil, were seen a few feet above the river bluff in secs. 34, 35, and 36. This sandstone seemed to be practically horizontal.

No outcrops of Permian rocks were seen along Big Blue Creek in sec 23, but on the west side of this creek near the southwest corner of

the SE. ¼ SE. ¼ sec. 14 a good outcrop of the clay-limestone conglomerate of the Auger lentil occurs at an elevation of 1,039 feet above sea level. The conglomerate is here overlain by loose clayey stream gravel and underlain by the bluish white and speckled sandstone layers of the Auger lentil, the typical bright-red clay lying below. A few yards farther west, in the same outcrop, the overlying stream gravel cut out the Auger lentil and lies unconformably on the bright-red clay.

At the southwest corner of sec. 13 the clay-limestone of the Auger lentil outcrops in a massive layer at the top of a small break at an elevation of 1,048 feet. At an outcrop about one-fourth mile to the northeast it has an elevation of 1,060. At this place and at an outcrop near the center of the NW. ¼ SW. ¼ sec. 13 the bluish-white and speckled sandstone layers accompany the clay-limestone conglomerate. At the latter outcrop the conglomerate has an elevation of 1,053 feet. These four outcrops show a local rise in the beds toward the east at the rate of probably 40 feet to the mile. A doubtful outcrop of the conglomerate of the Auger lentil occurs in the railroad cut on the east bluff of Big Blue Creek, at an elevation of 1,045 feet. The clay-limestone of the Auger lentil outcrops on the west bank of this creek 150 yards south of the north line of sec. 14, also just south of the road across the east fork of Big Blue Creek at the north side of sec. 13, and again about 300 yards north of this crossing, on the west side of the creek. These outcrops are, respectively, at elevations of 1,055, 1,049, and 1,052 feet. Near the northwest corner of the SE. ¼ SW. ¼ sec. 12 is an outcrop of typical Grandfield conglomerate which contains many quartz and quartzite pebbles and stands at an elevation of 1,045 feet. Either this conglomerate lies directly upon the Auger lentil or the latter is cut out entirely by the unconformity. Some of the upper sandstone beds of the Auger are exposed along Big Blue Creek in the southeastern part of sec. 11, and the clay-limestone conglomerate probably lies just below the bottom of the stream to the north edge of this section, where it again outcrops at an elevation of 1,058 feet. About a mile north-northeast of the above outcrop, near the middle of the north line of the NW. ¼ sec. 1, a speckled sandstone bed inclosing a thin layer of clay limestone conglomerate closely resembling the conglomerate of the Auger lentil stands at an elevation of 1,102 feet above sea level.

In sec. 15, on a large tributary flowing into Little Blue Creek from the north, Permian rocks are exposed at a number of places. The most southern outcrop of the Auger conglomerate found on this tributary is on its west side about 50 yards south of the north line of sec. 22, where it is at an elevation of about 1,059 feet. Near the northeast corner of the SW. ¼ sec. 15 thick beds of the bluish-white

and "speckled" sandstones of the Auger lentil, inclosing three layers of clay-limestone conglomerate, outcrop at an elevation of about 1,064 feet. The sandstone is here very irregularly bedded and seems to lie unconformably on red clay. Other exposures of the same beds along this creek northward to the section line stand successively 1,069, 1,078, and 1,079 feet above sea level. This creek forks near the center of sec. 15, and on the west fork near the east side of sec. 16 the Auger conglomerate is exposed a few feet above stream level at an elevation of about 1,082 feet and is capped by a typical deposit of the Grandfield conglomerate, which seems to form a dip slope to this point from its outcrop on the ridge at the west side of sec. 16. Reworked gravel from this bed was seen at many places along the creek in sec. 15. The Grandfield conglomerate is also exposed in a shallow railroad cut east of the road in the NW. ¼ sec. 10 at an elevation of 1,110 feet. It also outcrops at an elevation of about 1,081 feet in the east bank at the forks of the creek, at a large pond in the SW. ¼ sec. 10. At its type locality in the southeastern part of Grandfield, the Grandfield conglomerate seems to form a thin layer at or near the top of the hill. Generally it is not well exposed here except on the road southeast of the town, but it has been encountered at many places in digging storm cellars and is usually a hard reddish conglomerate containing many quartz and quartzite pebbles held together by a limestone-clay matrix. In the southeastern part of Grandfield this conglomerate has a maximum elevation of between 1,145 and 1,155 feet.

On several small streams which flow northward to Deep Red Run from Grandfield in secs. 4 and 5 are a number of outcrops of the Auger lentil. One of these outcrops is in a small ditch on the south side of the railroad a short distance west of the water tank at Grandfield. Here, at the base, there is a bed of bluish-white sandstone, which contains many small black specks and which is overlain by 4 or 5 feet of reddish thin-bedded laminated sandstone, at places false-bedded. These beds resemble very much the sandstones of the Auger lentil. They are overlain by red clay containing residual quartz gravel from the Grandfield conglomerate. Less than half a mile north of this exposure the "speckled sandstone layer" overlies a thin reddish clay-limestone conglomerate believed to be the lower layer of the Auger conglomerate lentil. At no exposure in sec. 5 is the Auger lentil typically exposed, the lower layers of sandstone and the clay-limestone conglomerate beds being either unusually thin or absent altogether. Traced northward into T. 3 S., R. 14 W., these beds seem to assume their normal thickness, outcropping along the bluffs of Deep Red Run. The speckled bed near the water tank at Grandfield has an elevation of about 1,097 feet. From this point the dip is between 20 and 30 feet to the north line of the section. Per-

mian beds consisting largely of red clay outcrop in places in secs. 34 and 36, but at none of these could the Auger lentil be definitely recognized.

The important geologic facts regarding this township brought out in the above description are (1) that there is a general low dip toward the south from the most northerly exposures of the Auger conglomerate on Big and Little Blue Creeks and their tributaries; (2) that this southerly dip is very probably interrupted by a low anticline passing south of east through parts of secs. 19, 20, 29, 28, 27, 33, 34, 35, and 36, or 20 and 25, as indicated by the elevation of the Auger conglomerate in and near secs. 29 and 30 and by the probable dip toward the north of the sandstone near the mouth of Big Blue Creek; (3) that the beds are in general higher toward the west and north than toward the east and south and that the axis of an anticline trending roughly east-west seems to lie somewhere between the exposure in sec. 15 and those in sec. 5; and (4) that the Grandfield conglomerate, though lying unconformably upon the Wichita formation, which includes the Auger conglomerate lentil, shows the same general structure as the latter, and also has a dip of probably 55 or 60 feet in the first mile and a half southeast of Grandfield, suggesting that there may be a similar dip in the Auger lentil in this locality.

### T. 3 S., R. 14 W.

T. 3 S., R. 14 W., is drained by Deep Red Run, which flows from west to east. Its valley and the valleys of its tributaries are broad, flat, and alluvium-covered. The interstream areas are smooth and fairly level and are covered with a thick layer of fine sandy to stiff reddish and dark soil.

All the exposures of the recognized Permian beds occur along the valley bluffs and in a few breaks adjacent to them. The Auger conglomerate is well exposed at a number of places on the south bluffs of Deep Red Run. A section of a typical outcrop of the Auger in the NE. ¼ sec. 27 has been given on page 24. About a mile west of this place the massive speckled sandstone of the Auger lentil outcrops in a large break near the middle line of the west side of sec. 27 at an elevation of 1,069 feet, the lower clay-limestone conglomerate being at about 1,065 feet. One-half mile farther west a poor outcrop of clay-limestone conglomerate, doubtfully correlated as belonging to the Auger lentil, has an elevation of 1,044 feet. Less than a half mile south of this exposure, in the NW. ¼ SE. ¼ sec. 28, the "speckled sandstone" has an elevation of 1,050 feet, the clay-lime conglomerate being thin and poorly exposed. About three-fourths mile farther south, in the S. ½ NE. ¼ sec. 33, the conglomerate and accompanying sandstones of the Auger lentil outcrop in a number of small breaks at elevations ranging from about 1,059 to 1,065 feet above sea level.

Near the township line, in the SW. ¼ SW. ¼ sec. 34, the "speckled sandstone" bed and clay-lime conglomerate of the Auger lentil is found in a shallow well at 7 to 12 feet from the surface and at an elevation of about 1,083 feet.

On the south side of the valley of Deep Red Run, at the western edge of sec. 28, the conglomerate and sandstones of the Auger lentil are revealed by a cut made for the road, at which place the top of the conglomerate is 1,031 feet above sea level. Between this point and the exposure on the west side of a tributary valley to Deep Red Run from the south near the middle of sec. 29 there is a rise of about 16 feet in the Auger lentil. Along this tributary the beds rise continuously toward the south through secs. 29 and 32. The top of a typical section of these beds near the southern border of the SE. ¼ sec. 32 is at an elevation of about 1,070 feet. The rise of these beds, as has been shown in the discussion of T. 4 S., R. 14 W., continues to the town of Grandfield, a mile farther south, showing a total dip of between 60 and 70 feet northward from the station at Grandfield to the valley of Deep Red Run.

Near the center of the SW. ¼ sec. 20 two outcrops of massive gray sandstone beds occur along the southern bluff of Deep Red Run at elevations about 1,052 feet. Near the southeast corner of sec. 19 there is a fine outcrop of Auger lentil at which the "speckled sandstone layer," accompanying the lower portion of the clay-limestone conglomerate, is at an elevation of 1,047 feet. This exposure occurs in the bank of a small tributary to Deep Red Run and in an adjacent break, the vertical section being about 20 feet. At the base of this section is about 5 feet of reddish, irregular-bedded sandstone which has the appearance of being overlain unconformably by red clay, in which occur two or three thin layers of white and gray sandstones and clay-limestone conglomerate, some of which are smooth bedded, the other layers being very irregular bedded and variable in thickness. At another place in this break, about 12 feet above the base of the section, there is exposed about 2 feet of a soft bluish-white sandstone showing a characteristic cross-bedding, which in most outcrops of the bed has the appearance of being a true dip. At this place the layers slope toward the southwest at an angle of 10° to 15°. This bed is is overlain by 2 to 3 feet of red clay which has above it about 5 feet of cross-bedded sandstone, which is in turn overlain by about 15 feet of bright-red clay containing roundish clay-limestone concretions. Near the top of the break on the south side of the road at this place the upper layer of the Auger conglomerate outcrops as a rather massive bed of clay-limestone conglomerate, at an elevation of 1,067 feet. This conglomerate outcrops again near the middle of the east line of the NE. ¼ sec. 30, where it has an elevation of 1,071 feet. It is exposed at many places near the center of sec. 30, the best outcrop

being near a pond in the southwest corner of the NE. ¼, where it has an elevation of 1,055 feet.

In the southern part of sec. 30 the Auger lentil becomes very thin and is poorly exposed in the shallow breaks. A doubtful exposure of the upper layer of the Auger conglomerate in the SE. ¼ SW. ¼ of this section, at an elevation of 1,051 feet, suggests a continuation of the dip from northeast to southwest across this section. Near the center of sec. 31 is a poor exposure of gray and red sandstone and a thin layer of clay-limestone conglomerate, which is doubtfully correlated as Auger lentil. This clay-limestone has an elevation of about 1,076 feet and shows a slight dip toward the northeast.

In the southeastern part of this township the lower clay-limestone conglomerate of the Auger lentil is at many places unusually thick and massive. At one of the outcrops in the southwest corner of the NE. ¼ sec. 26 this bed has a total thickness of 5 or 6 feet and at places forms a low bluff along the valley side. It is here very hard, reddish to gray in color, contains a few fossil bones, and stands at an elevation of 1,047 feet. A short distance northeast of this exposure the clay-limestone conglomerate bed is underlain by 8 or 10 feet of massive irregular-bedded sandstone, a layer of which contains the characteristic black specks of the "speckled sandstone layer" of the Auger lentil.

Near the southeast corner of the NW. ¼ NW. ¼ sec. 35 the Auger lentil is typically exposed in the east bank of the small run, at an elevation of 1,062 feet. The upper portion of this bed is in poor outcrop about one-half mile farther southeast, where it has an elevation of between 1,070 and 1,080 feet.

In the road near the middle line of the south side of the SE. ¼ sec. 35, a clay-limestone conglomerate thought to belong to the Auger lentil outcrops. This has already been mentioned as being at an elevation of about 1,096 feet, showing a rise of about 34 feet in this bed toward the southeast within a distance of a mile. The outcrop of the "speckled sandstone layer" and clay-limestone conglomerate at the southern border of the SE. ¼ SW. ¼ sec. 36, at an elevation of 1,102 feet, was described under T. 4 S., R. 14 W.

About three-fourths mile due north of this exposure, near the center of the NW. ¼ sec. 36, some soft bluish-white sandstones were seen with soft beds of clay-limestone conglomerate that are very doubtfully correlated with the upper portion of the Auger lentil. If this correlation is correct the conglomerate shows considerable change from the adjacent exposures to the west and it also shows a dip of 60 feet toward the north from the southern border of the township.

In the western part of the NE. ¼ sec. 25 a very poor exposure of clay-limestone conglomerate occurs at the top of a small break at an altitude of 1,031 feet. This may possibly be the lower conglomerate

bed of the Auger lentil. Near the southeast corner of the SE. ¼ sec. 24 on the east bluff of a large tributary to Deep Red Run a fine outcrop of the conglomerate of the Auger lentil stands at an elevation of 1,030 feet. About a mile northwest of this exposure, in the NE. ¼ NE. ¼ sec. 23, typical clay-limestone conglomerate of the Auger lentil, accompanied by the "speckled sandstone layer," occurs on the east bank of Deep Red Run, where it ranges in elevation from 1,014 to 1,025 feet above sea level, the dip being to the north. About three-fourths mile almost due west of this exposure, near the northwest corner of sec. 23, the conglomerate of the Auger lentil outcrops in a low hill at the edge of the valley at an elevation of 1,036 feet. This bed may be traced for some distance to the west and is everywhere accompanied by bluish-white and speckled sandstone layers underlain by bright red clay containing clay-lime concretions. About 1¾ miles due west of the above exposure, on the north line of the NW. ¼ sec. 21, the Auger conglomerate is at an elevation of 1,020 feet. In the NE. ¼ SW. ¼ sec. 18, on the south bank of the Middle Fork of Deep Red Run, a fine outcrop of Auger conglomerate has an elevation of 1,036 feet. No outcrops of this conglomerate were found in the northwest quarter of this township north of the two exposures named above in secs. 21 and 18. A lime-sandstone and an impure sandy clay-lime conglomerate, doubtfully identified as the Auger lentil, occur near the middle part of the northern border of the NW. ¼ sec. 14, at approximately 1,044 feet. About a mile eastward on the same line, just south of the road, the lower portion of the Auger lentil outcrops at an elevation of 1,013 feet on the east side of a tributary to Deep Red Run from the north. At this place a quartz-conglomerate having very much the appearance of the Grandfield conglomerate cuts out the upper portion of the Auger lentil and a little farther south the Auger lentil is absent, the Grandfield being in contact with the bright-red clay below. No elevations were obtained on the Auger lentil farther north in this township, but it is well exposed on the bluffs in the NW. ¼ sec. 10 and in a number of places in the E. ½ sec. 3, the highest outcrop being on the north line of the NW. ¼ NW. ¼ sec. 2, where it is only a few feet below the top of the ridge and probably at an elevation between 1,090 and 1,110 feet above sea level. Along this line of exposures in secs. 10, 3, and 2 the Grandfield conglomerate immediately overlies the Auger lentil and forms a low bench along the hillsides. No other exposures were seen in sec. 2 or in sec. 11, but from the character of the outcrops to the west it seems very probable that the broad, low, dome-like hill in the central part of sec. 2 is capped by the Grandfield conglomerate, the Auger lentil lying below, and that the broad, even slopes to the south, southeast, and for a short distance to the west are really dip

slopes on the Grandfield conglomerate. In the northern part of sec. 1 the Grandfield conglomerate is exposed at a number of places and the character of the topography suggests strongly that it underlies the surface at a very shallow depth over the southern part of sec. 1 and over all the interstream area of sec. 12 to a point where it outcrops at creek level in the NE. ¼ NW. ¼ sec. 13, as described above.

All the evidence cited above and found in the field shows that the rocks in the southern portion of this township south of Deep Red Run dip to the north. This dip probably does not average more than 20 or 25 feet to the mile, but locally it may range as high as 50 or 60 feet to the mile. The strike of the rocks appears to be in general east and west. North of Deep Red Run the structure of the Auger conglomerate is not well known, because of the few exposures in that area. The outcrops that were found indicate strongly that from the vicinity of the valley of Deep Red Run the Permian beds, as well as the Grandfield conglomerate, rise to the north, the valley of Deep Red Run marking roughly the position of a syncline having a general east-west trend and pitching slightly toward the east. Here, as elsewhere, the Grandfield conglomerate shows the same general structure as that of the Permian rocks, though it is clearly unconformable on these beds.

### T. 3 S., R. 13 W.

Deep Red Run enters T. 3 S., R. 13 W., from the west near its middle and flows south-southeast, leaving it about 1¼ miles north of its southeast corner. The valley of the run is from three-fourths of a mile to a mile wide, very flat, and alluvium covered. A number of large tributaries enter this stream from the north and the south, and the Auger lentil is at many places exposed on them. The clay-limestone conglomerate beds of the Auger lentil are relatively very thick and massive over most of this township, especially in the southern portion. The upper conglomerate layer ranges from less than 10 feet to probably as much as 15 feet above the lower, which is embedded in the "speckled sandstone layer." A typical exposure of the upper layer occurs near the middle of the south line of the SW. ¼ sec. 32, where it is 2 to 4 feet thick, reddish, and contains clay pebbles, the largest an inch in diameter, and also some fragments of bones. At this point it has an elevation of 1,062 feet. It is exposed again a short distance north of the center of sec. 31, where it has an elevation of 1,068 feet. From this point the conglomerate dips northeastward and is typically exposed near the eastern edge of the SW. ¼ SW. ¼ sec. 29 at the top of a break, where it has an elevation of 1,038 feet, showing a dip of 30 feet in about three-fourths of a mile. Between these two exposures, in the central part of the NE. ¼ sec. 31 and in the SE. ¼ SE. ¼ sec. 30, the lower conglomerate of the Auger

lentil and its accompanying sandstones are exposed at several places at elevations ranging from 1,026 to 1,035 feet. The upper conglomerate is also well exposed near the top of the hill in the NW. ¼ SW. ¼ sec. 33, where it stands at an elevation of 1,072 feet. A little over one-half mile due north of this point the same bed outcrops on the hill slope to the north at an elevation of 1,059 feet, from which point it dips rapidly to the north to an elevation of 1,020 feet near the south line of the NW. ¼ sec. 28 and about 150 or 200 yards southeast of a deep well drilled for oil on the George Cabalcha farm by the Oklahoma-Electra Oil Co. A similar dip in this bed was noted from the center of the SE. ¼ sec. 38 northward to the valley of Deep Red Run, at which point the lower clay-limestone conglomerate is practically at the level of the valley. A bed of the clay-limestone that resembles the lower conglomerate of the Auger lentil outcrops near the northeast corner of the SE. ¼ sec. 20 at an elevation of 1,025 feet, but the character of the expcsure at this point is such as to render this identification doubtful. West and northwest of this exposure, in secs. 20, 18, and 19, several outcrops of the Grandfield conglomerate were noted which appear to be at elevations between 1,010 and 1,025 feet.

Along a low escarpment trending northeast-southwest across the NW. ¼ sec. 19 the Auger lentil is exposed in a number of places at an elevation ranging from about 1,040 to 1,045 feet. Less than a half-mile northwest of this escarpment, on the township line, a thin bed of clay-limestone conglomerate, badly weathered, outcrops near the top of a small hill which is capped by the Grandfield conglomerate. If this is the upper conglomerate of the Auger lentil, it shows a dip toward the northeast of between 35 and 40 feet within less than half a mile. The character of the exposure, however, is such as to leave its identification very much in doubt.

In the southeastern portion of this township a fine outcrop of the Wichita formation containing the horizon of the limestone of the Auger lentil occurs on the middle line of sec. 35, about 200 yards south of its northern edge, at an elevation of 1,013 feet. This bed also outcrops on both sides of the road about 200 yards west of the southeast corner of sec. 27, where it stands at an elevation of 1,004 feet.

Traced southwestward from this exposure the limestone rises 14 feet in the first half mile and 34 feet in the first 1¼ miles and 68 feet in 2 miles to the outcrop, already described, in the SW. ¼ sec. 33. Traced southward from the southeast corner of sec. 27 this bed rises much more rapidly to a high hill on the township line a short distance east of the southeast corner of sec. 34, where it has an elevation of about 1,081 feet, showing a dip to the north of about 77 feet in 1 mile.

A number of other exposures in this vicinity show clearly that there is a well-marked dip to the north in secs. 28, 33, 34, and 35.

No outcrops of the Auger lentil were found in secs. 25 and 36 in the southeastern corner of this township, but in the SW. ¼ sec. 36 there are several exposures of a grayish thin-bedded curly ripple-marked sandstone, weathering dark or black, which in places contains considerable iron in small concretionary masses. This bed is only a few feet above the valley of Deep Red Run, and seems to correspond to a similar bed exposed farther east, which lies a short distance below the lower conglomerate of the Auger lentil. Because of its peculiar appearance this sandstone was noted in the field as the "black curly sandstone layer." No outcrop of this bed was found farther west, and it seems to grade into sandy red clay in that direction and to thicken rapidly toward the east and south, where it becomes one of the more conspicuous sandstone layers of the Wichita formation.

On a small tributary just north of the valley of Deep Red Run, a short distance southeast of the center of sec. 16, the clay-limestone beds of the Auger lentil are unusually thick. At this place the two beds of clay-limestone have a total thickness of probably 15 feet and are separated by a few feet of red clay. Just east of this outcrop, in the top of a small round hill, typical Grandfield conglomerate containing many large quartz and quartzite pebbles, held together by a reddish clay-limestone matrix, lies about 22 feet above the top of the upper conglomerate of the Auger lentil. Traced northwestward along the valley bluffs the Auger lentil and Grandfield conglomerate approach each other and within a half-mile the upper layers of the Auger lentil are cut out by the Grandfield, and half a mile farther northwest all the Auger seems to have been cut out and the Grandfield lies directly on the bright-red clay below the horizon of the Auger.

Southeastward from the exposure near the center of sec. 16 the Auger lentil outcrops at many places along the low bluffs to near the center of the NE. ¼ sec. 22, where it is again cut out by the unconformity between it and the Grandfield conglomerate, which is found unconformably on red clay at an horizon below the Auger. From this point to the eastern edge of the township on the north side of the valley of Deep Red Run the Auger lentil is not exposed, the Grandfield conglomerate being present at a number of places at altitudes only a few feet above the valley.

A large tributary to Deep Red Run from the north flows through secs. 2, 11, 14, and 23, and on it a few outcrops of the Auger lentil were seen in the northern portion of sec. 14 and the western parts of secs. 11 and 2. The altitude of this conglomerate above sea level was obtained at only two places along this stream. One of these,

taken on an exposure in the NW. ¼ NW. ¼ sec. 14, found the bed at an altitude of 1,012 feet. The other place, in the NW. ¼ NE. ¼ sec. 14, has an elevation of 1,000 feet above sea level. These outcrops show a general rise of the Auger lentil toward the north at a very small angle, keeping a few feet above stream level to the northern edge of the quadrangle. At an exposure in the central part of sec. 16 the upper layer of the Auger is at an elevation of about 1,029 feet. On the northern border of this section, near the middle, it is at a height of 1,043 feet. One-half mile west of this exposure, at the northwest corner of sec. 16, the Grandfield conglomerate has an elevation of about 1,025 feet, and about three-eighths mile still farther west, on the section line, a typical exposure of the Auger lentil occurs at an elevation of 1,004 feet. Near the south side of the NE. ¼ NE. ¼ sec. 8 a fine outcrop of the lower clay-limestone conglomerate of the Auger lentil, accompanied by the "speckled sandstone layer," is at an elevation of 1,038 feet. These beds rise slowly toward the central part of sec. 4, where they have an elevation of about 1,043 feet. A number of outcrops of the Auger lentil were found in the NE. ¼ NW. ¼ sec. 8 and the SE. ¼ SW. ¼ sec. 5, where the lower part has an elevation of about 1,015 to 1,035 feet and the upper a maximum elevation of about 1,045 feet. From this vicinity to the northern edge of secs. 5 and 6 there appears to be a slight rise in the beds, though no elevations were determined. Near the northwest corner of the NE. ¼ sec. 18, a few feet above the flood plain of Deep Red Run, a good outcrop of the lower layers of the Auger lentil, underlain by bright-red clay and overlain by the Grandfield conglomerate, occurs on the east bank of a small tributary to Deep Red Run at an elevation of 995 feet. One-half mile northeast of this outcrop the sandstones of the Auger lentil show in the bed of a creek at elevations of 1,013 to 1,019 feet, showing a rise toward the northwest of probably 18 to 20 feet within one-half mile.

Along the streams over most of the area north of Deep Red Run in this district a thin bed of loose or poorly cemented quartz and quartzite gravel is exposed at many points. The appearance of this gravel suggests that it is material derived from the disintegration of the Grandfield conglomerate, but at many other places the typical indurated bed of Grandfield conglomerate is present.

The important structural features to be noted in this township are (1) the relatively steep dips of the Auger lentil toward the north over most of the territory south of the valley of Deep Red Run, especially in secs. 35, 34, 33, and 23; (2) the very definite rise of the beds northward from the valley of Deep Red Run or adjacent to it; (3) the synclinal character of this valley; (4) the general decrease in elevation of the strata, both Permian and younger, from west to east across the township; and (5) the similarity of the structure of the

Auger conglomerate lentil and the Grandfield conglomerate regardless of the fact that they are respectively Permian and probably Quaternary in age and are separated by a well-marked unconformity.

### T. 4 S., R. 13 W.

The divide between the waters of Red River and Deep Red Run crosses T. 4 S., R. 13 W., from northwest to southeast. The town of Devol is located in the W. ½ sec. 20. Most of the exposures of Permian beds in this township are on the headwaters of the creeks emptying into Deep Red Run. Along the divide is a broad area in which very few outcrops occur and of the structure of which very little is known.

In the discussion of T. 3 S., R. 13 W., a description was given of an outcrop of the upper limestone conglomerate bed of the Auger lentil at the south edge of the township, near the southwest corner of sec. 32, where it stands at an elevation of 1,062 feet. One mile south-southeast of this exposure the bed outcrops again near the center line of the south side of the SE. ¼ sec. 5, where it has an elevation of 1,091 feet above sea level, showing a rise of 39 feet toward the south in about a mile. Some poor exposures of the speckled sandstone layer and accompanying lower clay-lime conglomerate of the Auger lentil occur along a small stream in the NW. ¼ sec. 8. These show a rise of the rocks to the south almost to the center of sec. 8, beyond which for more than a mile toward the south no recognizable outcrops were seen.

A low escarpment facing the northwest crosses sec. 3 from northeast to southwest. Northwest of this escarpment are a number of deep breaks and steep gullies which drain into a large tributary of Deep Red Run and in which the Auger lentil outcrops at many places. These beds have a well-marked dip toward the north in the NE. ¼ sec. 3. A similar dip to the north in sec. 4 is suggested by poor exposures in the southern portion of SE. ¼ and the NE. ¼ NW. ¼ of that section. In secs. 1, 2, 10, 11, and 12 the surface has a very smooth, even slope toward the southeast and no recognizable Auger strata are exposed, though it seems very probable that this is to a large extent a dip slope, either on the hard sandstone beds of the Auger lentil or else on the overlying Grandfield conglomerate. From the character of the exposures it seems very probable that along the edge of this escarpment in the southwestern part of sec. 3 the Auger lentil lies between 1,075 and 1,090 feet above sea level.

A dark irregular-bedded curly ripple-marked sandstone, 1 to 4 feet thick, occurs in a break on the south side of the stream near the center of the NE. ¼ sec. 11. This bed is underlain at places by a soft grayish to red clay-lime conglomerate, in places as much as 2 feet thick, which is underlain by 10 to 15 feet of bright-red to purplish

clay containing many roundish gray limestone concretions, the largest 3 inches in diameter. At other places farther west, in the SW. ¼ sec. 11, this sandstone is grayish in color and in places shows small black specks similar to those of the typical speckled bed of the Auger lentil. At other places the basal portion of this sandstone is very limy, the lime appearing in the form of small nodular masses which, being more resistant to weathering than the rest of the rock, appear as small lumps on the weathered surface of the sandstone. At still other places this sandstone is overlain by thin beds of limy, reddish sandstone, usually very thin and platy and frequently cross-bedded. In places at the top of these beds there is a thin layer of soft clay-lime conglomerate, resembling in a general way the upper conglomerate layer of the Auger lentil. The general appearance of these beds suggests that they are the Auger lentil, but greatly changed in character from exposures farther north and west, the greatest change being in the clay-limestone conglomerate, which is more sandy and which here seems to be represented by a calcareous sandstone containing a large percentage of clay. The calcareous sandstone in the SE. ¼ sec. 11 stands at an elevation of 1,032 feet. The same horizon exposed in the SE. ¼ NE. ¼ sec. 15 has an elevation of 1,036 feet, and the rocks rise very slightly toward the southeast. If the upper clay-limestone bed exposed along this stream belongs to the Auger conglomerate lentil, this bed rises between 60 and 80 feet from its outcrop in NE. ¼ sec. 15, to a characteristic outcrop of the Auger lentil on a hilltop near the middle of sec. 16, a distance of about 1½ miles. This correlation, however, is by no means certain and it is possible that the beds exposed along the creek in secs. 11, 14, and 15 underlie the Auger conglomerate. If this is true the dip between these outcrops is not so pronounced.

The Wichita formation outcrops in secs. 13 and 14 but consists largely of red clay and at no place was the Auger conglomerate lentil found in typical outcrop. A spirit-level line to a few poor outcrops along the eastern border of sec. 14 suggests that the beds are either horizontal or rise slightly toward the south.

In the SE. ¼ NW. ¼ sec. 16, the characteristic outcrop of the clay-limestone conglomerate of the Auger lentil caps the top of the small round hill mentioned above at an elevation of 1,015 feet, the underlying sandstone being present on the south slope of the hill. On this hill the conglomerate shows a pronounced dip to the southwest. A mile in that direction, in the SW. ¼ SE. ¼ sec. 17, a short distance northeast of Devol, the lower clay-limestone conglomerate of the Auger lentil and accompanying sandstone beds come to the surface in a creek bank at an elevation of 1,058 feet, showing a dip of 40 to 50 feet toward the southwest in this distance.

On the south line of sec. 20, near its southeast corner, in the east bank of a small stream, a 2-foot bed of thin-bedded platy reddish sandstone, characterized by narrow light-colored threadlike limy, concretionary raised markings on the smooth surface of the plates, outcrops at an elevation of 1,050 feet, with bright-red clay below. This sandstone is like that in the outcrops mentioned above as occurring in the SW. ¼ sec. 11, the NW. ¼ sec. 14, and the NE. ¼ sec. 15. At the last place it has an elevation of about 1,039 feet above sea level. A sandstone very similar in appearance, splitting into very thin, smooth layers with the peculiar threadlike limestone concretions on the surface, has been seen at many places near the top of the sandstone beds of the Auger lentil. Though this evidence alone is not sufficient to justify a definite correlation of these beds, the character of the underlying clay and other data suggest that this sandstone most probably lies between the horizons of the two clay-limestone conglomerates of the Auger lentil. If this is true, neither of these conglomerates is present at this point nor to the south, in secs. 28 and 29, nor still farther south, along the creek, in sec. 32. This reddish platy sandstone bed, with concretionary threads of limestone on the surface of the plates, was also recognized in a small exposure near the southwest corner of the NW. ¼ sec. 28, where it stands at an elevation of about 1,035 feet. The Permian rocks from this point south along the stream are poorly exposed because of the thick covering of wind-blown sand, and it is impossible to trace the beds from point to point along the creek. In the NE. ¼ sec. 32, near the northern edge, an exposure of massive reddish sandstone occurs a few feet above creek level. This sandstone is badly altered by weathering, showing a very uneven surface, filled with small holes, which in the weathered surface have the general appearance of fossil worm holes. The upper layer of this sandstone is usually white or light-gray in color and is the same as the bed exposed in the creek near the center of the NW. ¼ sec. 35. A little farther south there is exposed near the top of the break a thin layer of reddish thin-bedded limy sandstone, which in places is dark and ferruginous. This is underlain by a purplish joint clay about 30 feet thick, in which occur roundish concretions of burnt red ferruginous clay-limestone having a very rough irregular surface. At the base of this clay is exposed the light-colored to whitish sandstone mentioned above. A number of similar outcrops of these beds occur in the southern part of sec. 32, along the streams and in the railroad cut near the west side of the SE. ¼ of the section. No elevations were obtained on these outcrops, but they show a slight general dip toward the south. In the SW. ¼ sec. 34 the following section was seen in a large break on the east side of the stream.

*Section of Wichita formation exposed in a break near the northwest corner of the SW. ¼ sec. 34, T. 4 S., R. 13 W.*

| | Ft. | in. |
|---|---|---|
| 1. Wind-blown sand at top of break. | | |
| 2. Sandstone, dark, hard, limy, thin-bedded | 2– 3 | |
| 3. Clay, bright red | 2– 4 | |
| 4. Sandstone, light bluish to gray and white; very smooth bedded, thin layers 1 to 8 inches thick | 2– 3 | |
| 5. Sandstone, dark to black, very soft, bituminous; rarely exceeds | | 6 |
| 6. Conglomerate, clay-limestone, thin, soft, lumpy, very irregular; greatest thickness | | 10 |
| 7. Clay, bright red, with some purplish bands between and containing at many places whitish splotches a few inches in diameter; at other places it has a large number of roundish burnt red ferruginous clay-limestone concretions which have a maximum thickness of as much as 1 foot and have a very rough, irregular surface. Most of the concretions come from a thin zone near the middle of the bed | 25–30 | |
| 8. Sandstone, whitish to dark red, very hard, and in places appearing to be a lean iron ore or very ferruginous sandstone | 1 | |
| 9. Sandstone, very light bluish, white in a single layer, in places reddish | 1– 2 | |

This section corresponds closely in general to that already described in the NE. ¼ sec. 32. It is believed that the lumpy clay-lime conglomerate (bed 6) is equivalent to the lower clay-lime conglomerate of the Auger lentil which changes abruptly in character toward the east and southeast. The sandstone at the top of the section appears to be the same as that in the southeast corner of sec. 20, already described. This correlation strengthens the assumption that the outcrop in sec. 20 is a part of the Auger lentil. No elevation was obtained on this exposure.

In the road at the southwest corner of sec. 24 a typical outcrop of the Auger lentil, including the "speckled sandstone layer," occurs at an elevation of about 1,081 feet. At this place the clay-limestone conglomerate of the Auger appears to be very thin and sandy. The fragments of it that were seen came from a near-by well at about the horizon of the Auger, and at places thin slabs were found on the surface. South of this exposure no outcrops occur in secs. 25, 26, 35, and 36 except one near the center of the NW. ¼ sec. 35, where a massive, light gray to whitish sandstone outcrops in the bottom of the small run, with a thin layer of clay-limestone conglomerate above. This clay-limestone conglomerate was also seen on the north side of the creek near the middle of the west line of sec. 35, but its elevation above sea level was not obtained at either point. It is probable that it is not higher than 1,050 feet above sea

level. These exposures are tentatively correlated with the Auger lentil, but the beds change so much in character from west to east that it is very difficult to correlate unconnected exposures even for short distances.

The outcrops described and the elevations given above show that there is a general rise in the Auger lentil for about a mile toward the south from the northern edge of T. 4 S., R. 13 W., secs. 3, 4, 5, and 6 and in portions of sec. 8, and that the beds dip to the south-southwest from near the center of sec. 16; also that from sec. 16 toward the northeast there is a corresponding dip, which may be as much as 100 feet, to the eastern edge of the township. Also, that in the southeast quarter of the township the exposures of Permian beds are too few to give more than a general clue to the structure. The fact that the Auger lentil is exposed in the southwest corner of sec. 24 at an elevation of 1,081 feet shows that there is a dip in the beds from this point for at least 2 miles to the north and also a dip of several feet at least from this point to the outcrop near the center of the NW. ¼ sec. 35, about 1½ miles to the southwest. Between these points, in the W. ½ sec. 26, all of sec. 27, and the south halves of secs. 22 and 23, no exposures occur and the axis of the anticline therefore can not be definitely located. Southwest of Devol, in secs. 30, 29, 31, and 32, no decisive outcrops occur west of the railroad, and it is impossible to determine the structure. In the southern part of sec. 31, along the bluff of Red River, massive light-gray and red sandstones are poorly exposed at a number of places, but these exposures can not be correlated with exposures in other portions of the township and are therefore of little value in determining the structure in this part of the township.

### T. 5 S., R. 13 W.

Red River enters T. 5 S., R. 13 W., at the northwest corner of sec. 6 and flows southeastward, leaving it in sec. 25. Most of the township is covered with sand hills, on which no exposures of Permian rocks were found.

In the NW. ¼ sec. 5, along the river bluff northwest of the railroad bridge across Red River, a massive, irregular-bedded light-red sandstone, locally as much as 10 feet thick, outcrops a few feet above the river level and in places is underlain by a purplish to deep red blocky clay. This sandstone can not be correlated with the Auger lentil and is probably below that horizon. It lies practically horizontal for a distance of less than a mile, in which it is here and there exposed. Along the west bank of the small creek in the SW. ¼ SW. ¼ sec. 3 a thin-bedded, compact, false-bedded sandstone, containing round black manganese concretions about an inch in diameter, is overlain by a few feet of reddish to purplish clay containing gray limestone

concretions. This sandstone seems to be the same as the one exposed at the top of the break in the SW. ¼ sec. 34, T. 4 S., R. 13 W. If this correlation is correct there is a dip of probably 30 feet toward the southeast between these exposures, a distance of about a mile.

From a point near the northwest corner of sec. 14 southeastward along the river bluff, there are several small outcrops of a white, rather massive sandstone, which stands at an elevation of 15 to 20 feet above the water of the river. Upon this sandstone lies purplish-red clay, 20 feet thick, containing peculiar roundish red clay-iron-limestone concretions like those noted in the clay overlying the white sandstone in secs. 32 and 34, T. 4 S., R. 13 W., and it is believed that this is the same horizon that is exposed there. If so, there is a dip of probably as much as 40 feet between these outcrops. Other small outcrops of sandstone extend southeastward through the SE. ¼ sec. 14 and the NW. ¼ sec. 24. These beds are best exposed, however, in the SE. ¼ sec. 24, where they form a continuous outcrop a few feet above valley level for three-fourths of a mile, which shows the following section:

*Section of beds outcropping in north bluff of Red River in SE. ¼ sec. 24, T. 5 S., R. 13 W.*

| | Feet. |
|---|---|
| Quaternary: | |
| 1. Sand, wind blown to top of bluffs | 40–50 |
| Permian (Wichita formation): | |
| 2. Sandstone, light to dark, hard, limy, showing choppy ripple marks | 2 |
| 3. Clay, bright red with white and gray spots and a great many peculiar round, rough-surfaced reddish clay-iron-limestone concretions, the largest 6 inches in diameter | 12 |
| 4. Sandstone, soft, white to light blue, massive and at places coarse bedded | 3 |
| 5. Sandstone, reddish, massive, very irregular bedded, containing limy concretionary masses 2 to 5 feet long and 1 to 4 feet thick. This sandstone contains also, 3 to 4 feet from top, a thin, irregular bedded reddish, very sandy clay-iron-limestone conglomerate similar in general appearance to that of the Auger conglomerate lentil, but very much more sandy | 14 |
| 6. Débris, concealing rocks to level of valley | 8 |
| | 79 |

The white sandstone layer beneath the bright-red clay is in almost continuous exposure for more than half a mile and lies practically horizontal except near the northwest corner of the SE. ¼ sec. 24, where it shows a slight dip toward the northwest.

No other important outcrops of Permian rocks were found in this township north of Red River.

### T. 5 S., R. 12 W.

Red River enters T. 5 S., R. 12 W., in the western part of sec. 30 and describes a broad curve to the south through secs. 31, 32, 33, 34, 35, 36, 25, 24, and 13, leaving the township near the center of the east side. Most of the area is drained by Slough Creek and its tributaries, which flow from northwest to southeast through the central part of the township.

The finest outcrops of the Wichita formation in this township are along the high bluff of Red River in secs. 30, 31, and 32. A generalized section of the exposed rocks is given on pages 19–21 and a view of the bluffs in Plate V, *A* (p. 34).

These outcrops occur in a series of deep breaks that have been cut back for half a mile or less from the river, and at all places the Permian beds are overlain by dunes of wind-blown sand. With the material now available it is not possible to locate the horizon of the Auger lentil in the rocks exposed in these breaks along Red River in secs. 30 and 32. The clay-limestone conglomerate (No. 13) of the section on page 20 may possibly be equivalent to the upper clay-lime conglomerate of the Auger lentil, the lower layer belonging in the massive reddish and white sandstones, bed 15 of that section. There is, however, considerable evidence that the horizon of the Auger lentil is much higher in this stratigraphic section and that it may, in fact, be represented by either beds 7 and 8, or 5, or more nearly by beds 2 and 3 at the top of the section.

A very much more detailed study of these exposures and further correlation of them toward the east in T. 5 S., R. 11 W., will be necessary before the Auger lentil, if present at all, in these exposures can be definitely located.

From a point near the southwest corner of the NW. ¼ sec. 32 the white sandstone layer at the top of bed 15, in the section on page 20 may be traced continuously northwestward for three-fourths of a mile, in which distance it shows a dip of more than 50 feet. Beyond this point to the northwest, across the NW. ¼ sec. 30, higher sandstone beds show a decided dip northwestward, which amounts to probably as much as 50 feet within three-fourths of a mile. In the area east of the southwest corner of the NW. ¼ sec. 32, to the eastern edge of the breaks near the south-central portion of sec. 32, the sandstone beds appear to lie practically horizontal. Farther east in this township no outcrops of Permian rocks were found along the bluffs of Red River, and it is not possible to determine with certainty the trend of the anticline that crosses the river in this vicinity.

A number of small breaks on the south side of the north fork of Slough Creek in the SW. ¼ sec. 10, SE. ¼ sec. 9, and adjacent portions of secs. 15 and 16 reveal the presence of about 5 feet of coarse

grayish to yellowish sandstone bearing numerous small black specks and containing a number of hard flattish limy concretionary masses from 1 to several feet long and from 1 to 2 feet thick. Beneath this sandstone lie several feet of purplish and bright-red clay showing light-colored splotches and containing rough reddish clay-lime-iron concretions. Near the bottom of this clay is a thin, irregular layer of yellowish limy sandstone that contains fossil plants of Permian age. This sandstone in places becomes a rather thick bed of coarse yellowish sandstone, very closely resembling bed 7 of the Red River section given on page 19. These beds appear to be the same as those exposed in T. 4 S., R. 12 W., along the south side of Deep Red Run, which have been correlated with the Auger lentil. From the S. ½ SW. ¼ sec. 10 there is a local dip toward the northwest, amounting to about 15 feet in the first half mile, and a dip of probably 5 feet for the same distance toward the southeast. In the NE. ¼ NE. ¼ sec. 16 the sandstone mentioned above, at the top of the break, is exposed at an elevation of about 990 feet above sea level. Three-fourths of a mile southeastward, near the eastern edge of the SW. ¼ sec. 15, on the south bank of the creek, it is at 971 feet, showing a dip of 19 feet in about three-fourths of a mile. Between this point and the exposure on the bluff of Red River in secs. 32 and 33 no outcrops of Permian rocks are found which could be correlated with either of these. Two to three feet of cross-bedded compact platy grayish sandstone containing many black manganese concretions, the largest an inch in diameter, was seen in the west bluff of Slough Creek in the SE. ¼ SE. ¼ sec. 14, at an elevation of 930 to 940 feet above sea level, but this sandstone can not be correlated definitely with any of the beds of the Red River section (pp. 19–21), and therefore is of little value in determining the structure in this part of the township. This sandstone is underlain by about 15 feet of bright-red to ash-colored clay containing clay-limestone concretions and light splotches.

Massive light-gray to reddish sandstones form a low cliff along the river bluff in the SE. ¼ sec. 12. These beds appear to rise slightly toward the southwest, and at places above them there are exposed purplish and red clays containing rough roundish iron-clay-limestone concretions similar to those found in different places in this township and already described. These sandstones are at an elevation of about 935 to 940 feet above sea level, but their correlation with beds outcropping farther west is not certain. They probably underlie the horizon of the Auger lentil.

In the E. ½ sec. 1 a massive gray sandstone bearing many small black specks and underlain by a bright-red clay, several feet thick, containing roundish rough clay-limestone-iron concretions like those noted in other places, occurs at the top of a large break on the

south side of the stream. Above this sandstone is a darker, more reddish limy sandstone containing concretionary lenses similar to those found in the southwest corner of sec. 10, already described. At this place the beds have a general dip to the northwest, the maximum being about 18 feet within half a mile. The highest elevation of the upper sandstone bed in these exposures is near the center of the SW. ¼ sec. 1, where it is about 990 feet above sea level. It is lowest in the eastern portion of the NE. ¼ sec. 2, where it stands at an elevation of about 970 feet. There seems no doubt that these are the same beds that are exposed in secs. 9, 10, 15, and 16, and they are at about the same elevation. No outcrops of recognizably Permian beds were found farther west along the northern tier of sections. A few small outcrops of Permian beds were noted on the road between secs. 17 and 18 and at one place west of the NW. ¼ sec. 20, but no elevations were obtained on them, as the exposures are too poor to permit close correlation.

The outcrops of Permian rocks in this township are too few to enable the structure to be determined in detail. The unusual dip in the rocks toward the northwest from near the center of the NE. ¼ sec. 31 suggests the presence of an important anticline somewhere in secs. 28, 29, 32, or 33, but the trend of this fold was not determined. At first glance the facts that the three sets of outcrops in secs. 1 and 2, 9, 10, 15, and 16, and 30, 31, and 32 are on a line from northeast to southwest and that each shows a local dip to the northwest suggest that they may be exposures on the west flank of the same fold. On the other hand, Udden[1] shows what appears to be the axis of the Petrolia anticline trending northwest from Petrolia, in Clay County, Tex., and crossing the river near the northwest corner of Clay County about at the southeast corner of this township, the fold having a general trend northwest-southeast. This trend appears to be more nearly parallel with the general trend of the fold farther north, in the area studied for this report. The evidence, therefore, seems fairly evenly divided, and it is not possible to say whether the trend is northeast-southwest or northwest-southeast.

The facts that there is no direct evidence against a general northwest-southeast trend of this anticline, and that this is more nearly the direction of the large anticlines of this district, seem to favor somewhat the suggestion of a northwest-southeast trend. If this is an extension of the Petrolia anticline, which seems barely possible, it probably enters the township from the south near its middle, with a local trend more nearly north-northwest. No reliance, however, should be put on these suggestions until more evidence is available in regard to the dip of the beds in the area south of Slough Creek and

[1] Udden, J. A., and Phillips, D. McN., A reconnaissance report on the geology of the oil and gas fields of Wichita and Clay counties, Tex.: Univ. Texas Bull. 246, Pl. I, 1912.

northeast of the exposures along the bluffs of Red River, in secs. 30 and 32. This area is covered by wind-blown sand, and the structure of the underlying Permian beds can be determined only by test wells. Perhaps detailed geologic work on the south side of Red River in Texas may throw some light on this problem. The relatively rapid rise in the rocks along the bluff toward the southeast, in secs. 30 and 32, and the horizontal position of these beds in the eastern part of the SW. ¼ sec. 32 suggest that the axis of the anticline is not far to the east or north of the center of sec. 32. The beds exposed in secs. 9, 10, 15, and 16 appear to be equivalent to beds that are at a much higher elevation in the exposures in secs. 30 and 32.

### T. 4 S., R. 12 W.

The divide between the waters of Deep Red Run and those of Red River passes through the southern portion of T. 4 S., R. 12 W., in an east-west direction. Deep Red Run enters the township near its northwest corner, in sec. 5, and flows in an easterly direction, leaving it near the southern border of sec. 12. The town of Randlett is in the S. ½ secs. 28 and 29. South and west of this town, in secs. 29, 30, 31, 32, 33, and 34, no outcrops of Permian beds were seen that could be definitely correlated with other exposures in this township.

A good outcrop of the "white speckled sandstone layer" of the Auger lentil occurs on a small stream in the N. ½ sec. 35 and the N. ½ sec. 36. It is overlain by a sandstone containing dark clay-lime-sandstone concretionary lenses very similar to those found in T. 5 S., R. 12 W., and described above. At one or two places a thin, soft layer of clay-limestone conglomerate was noted above these sandstone layers. The "speckled sandstone layer" lies at an elevation of about 980 feet at the middle line between secs. 35 and 36 and of about 990 feet in the north-central part of sec. 35, and thus shows a dip of 10 or 15 feet toward the southeast within half a mile. The same beds are exposed in the NW. ¼ sec. 26, at the head of a "break" on a tributary to Deep Red Run, where the "speckled sandstone" has an elevation of about 1,005 to 1,018 feet above sea level. The Permian beds outcrop at many places in a large area in secs. 22, 23, and 24 and in the northern part of secs. 25, 26, 27, and 28, which is covered by breaks, but at few places could they be correlated and no elevations were obtained on them. In the NE. ¼ sec. 24 there is a tall butte, bordered on the east, west, and north by deep "breaks." This butte is capped by a thin layer of dark, limy sandstone, containing darker lenses of a very calcareous clay limestone and underlain by a soft light-gray sandstone showing many dark specks, which in turn is underlain by bright-red clay containing the characteristic roundish rough-surfaced clay-iron-limestone concretions seen at many places. This is believed to be the Auger lentil,

the lower clay-lime conglomerate being represented by the dark limy concretionary masses in the limy sandstone at the top of the breaks. At this place the dark sandstone layer shows an elevation of from 1,047 to about 1,019 feet above sea level, its dip being toward the north from the center of the NE. ¼ sec. 24, and slightly toward the south from this point to the southeast corner of this quarter section. The same beds outcrop about a mile farther north on a small butte on the SW. ¼ NE. ¼ sec. 13, where they are at an elevation of about 993 feet, showing a dip to the north in 1 mile of approximately 55 feet. A detailed description of this outcrop in sec. 13 is given on pages 25–26.

In the NW. ¼ sec. 21 and adjacent portions of this section the sandstone beds of the Auger lentil and some clay-limestone conglomerate are exposed near the top of a break, the bright-red clay lying below. These beds are highest at the southernmost outcrop, where they have an elevation of 1,047 feet. The dip toward the north is very uniform to a point on the east side of a small tributary of Deep Red Run in the SW. ¼ SW. ¼ sec. 9, where the dark limy bed is at an elevation of 978 feet above sea level, showing a dip of almost 6[illegible] feet in a little less than 2 miles. From the south end of this break in the NW. ¼ sec. 21 the dip toward the northeast is indicated by exposures in the SE. ¼ sec. 16, the W. ½ sec. 15, and the S. ½ sec. 10, and is about 30 feet to the mile. The dark limy layer at the top of what appears to be the Auger lentil in this township is poorly exposed in the NE. ¼ sec. 28 and the NW. ¼ sec. 27, at the head of the breaks on a large tributary of Deep Red Run, and also in the eastern part of the town of Randlett. No elevations were obtained on these outcrops, but their general position with reference to the divide indicates that they stand at altitudes between 1,000 and 1,030 feet above sea level.

A few poor exposures of the dark limy bed at the top of the Auger lentil and the "speckled sandstone layer" below it were noted on the road between secs. 19 and 20 and 17 and 20 and also at one or two places in sec. 18, on the west side of the creek. No spirit-level lines were run to any of these exposures, and the structure of the beds in this part of the township is not known except that there appears to be a general dip toward the north from near the southern portion of sec. 19.

In a break near the northeast corner of the SE. ¼ sec. 7 what appears to be the upper clay-lime conglomerate of the Auger lentil outcrops at an elevation of 984 feet above sea level. This bed is also exposed near the middle of the north line of the NE. ¼ sec. 7, at an elevation of 987 feet, and also near the southeast corner of the NW. ¼ sec. 6, at which place no elevation was obtained.

No outcrops of the Auger lentil or other Permian sandstones were found on the north side of Deep Red Run in this township.

In the NW. ¼ sec. 2, on both sides of the small tributary to Deep Red Run from the north, there are a number of fine exposures of a quartz conglomerate which in character and general appearance closely resembles the Grandfield conglomerate. It here overlies a bright-red clay, which in places shows a purplish to ashen band, contains roundish gray clay-limestone concretions, and is similar to the clay underlying the Auger lentil at a number of places farther west. This quartz conglomerate is exposed for almost half a mile along both sides of this stream and shows a slight dip toward the south. It is here only a few feet above the alluvial plain of Deep Red Run and is at an elevation of between 950 and 960 feet above sea level. Very similar exposures of this conglomerate were seen along the tributary of Deep Red Run next to the east, in the western part of the NW. ¼ sec. 1. It was also seen a few feet above valley level in the northeastern portion of the NE. ¼ sec. 9.

It will be noted from the elevations given on the upper portion of the Auger lentil of this township that there is a general and fairly uniform dip of the beds toward the north from near the divide between the waters of Deep Red Run and of Red River, which traverses the township from east to west through the second tier of sections from the southern border, and that there is some evidence of a corresponding dip from this divide toward the south, so far as indicated by the poor exposures in the southern portion of the township. On the north side of Deep Red Run there are no exposures to indicate the character of the dip of the Permian beds, but farther north there is a slight dip to the south, and it is believed that the valley of Deep Red Run in a general way lies near the axis of a broad, shallow syncline trending from north-northwest to east-southeast.

### T. 3 S., R. 12 W.

Deep Red Run and its tributaries drain the southwestern half of T. 3 S., R. 12 W. Streams in the northeastern part of the township flow into West Cache Creek, which crosses its northeast corner in secs. 1, 2, 12, and 13. The Permian rocks in the central part of the township and the interstream areas are covered with a thick mantle of soil, which is seemingly composed largely of wind-blown material. The outcrops of Permian beds in this township are confined to a few small exposures of red clay and grayish sandstone beds and, rarely, thin layers of clay-limestone conglomerate. These exposures were too few to justify the running of spirit-level lines to them. A fairly typical outcrop of the clay-limestone conglomerate and the accompanying gray sandstones of the Auger lentil was found in the low break in the northern portion of the SW. ¼ sec. 8, where the lower portion of the clay-lime conglomerate is underlain by a bright-red clay containing roundish gray limestone concretions

typical of the clay underlying the Auger lentil in the type locality. A poor exposure of what appears to be the same bed was seen on the west side of the creek in the SE. ¼ NE. ¼ sec. 17. No other outcrops of the Auger lentil were found along either bank of the large tributary to Deep Red Run that flows through secs. 6, 8, 16, 17, 21, 28, and 33. Two layers of soft white sandstone, 2 or 3 feet in thickness, occur in the NE. ¼ NE. ¼ sec. 26, and what appears to be a thin clay-limestone conglomerate was found on the northern border of this quarter section. No other recognizable outcrops of Permian rocks were seen in this township, but just over its eastern edge, adjacent to the SE. ¼ sec. 13, at Rocky Ford crossing of Cache Creek, the clay-limestone conglomerate and "speckled sandstone layer" of the Auger lentil are typically exposed, together with the dark limy layer containing flattish dark hard concretionary masses, such as were seen in T. 4 S., R. 12 W. Here the lower clay-limestone conglomerate is at or near water level of Cache Creek.

Near Fairview schoolhouse, in the southeast corner of sec. 5, a number of bowlders of clay-limestone conglomerate were seen on the surface by the roadside, but it is possible that these have been hauled to this point. Thin layers of quartz gravel also were seen at a few places, but no characteristic exposures of the Grandfield conglomerate were found.

From the data cited above it is evident that the structure of the Permian beds in this township can not be definitely shown. The position of the outcrops of the Auger lentil suggests that there is a gentle rise of the rocks toward the north from the valley of Deep Red Run and also that the beds dip slightly toward the east, but at a very low angle. A long, broad ridge extends northwestward from near the center of sec. 26, passing diagonally through secs. 22, 16, 9, and 5. The character of the slopes to the east from the top of this ridge and to the south from the northern borders of secs. 26, 27, and 28 suggests that they may represent a general dip slope similar to that seen at a number of places in the townships farther south and southwest, but there is no direct evidence of this surface slope being even roughly parallel with the dip of the rocks.

### T. 4 S., R. 11 W.

Deep Red Run empties into West Cache Creek in the northwest corner of sec. 17, T. 4 S., R. 11 W. The latter stream flows a little south of east and near the center of sec. 13 empties into Cache Creek, which flows southeastward into Red River. No geologic work was done north of the valley of Deep Red Run and Cache Creek in this township. Along the south side of this valley are many large breaks in which occur numerous outcrops of the Wichita formation, including the Auger conglomerate lentil. An exposure of the Auger lentil

in the NE. ¼ sec. 24, T. 24 S., R. 12 W., at an elevation of 1,047 feet above sea level, has already been described. From this point northeastward across the NW. ¼ sec. 19 there is a decided dip in the beds to a point where the Auger lentil is again exposed in some low buttes in the S. ½ SE. ¼ sec. 18, where it is less than 1,000 feet above sea level. No elevations were obtained on the key horizon in this part of the township, but there appears to be a slight dip in the beds in the southeast corner of sec. 18, which extends eastward for about 1½ miles. The steepest dip, however, is from north to south. The sandstone and clay-lime conglomerate beds of the Auger lentil which outcrop along the southern edge of the breaks in the northern portions of secs. 30, 29, and 28 dip toward the north at a rate that brings them only a few feet above valley level on the points of the hills adjacent to Deep Red Run. This dip is well shown by outcrops in the W. ½ sec. 22, where, within half a mile, it amounts to probably as much as 25 or 30 feet. In the SW. ¼ NW. ¼ sec. 22 the lower conglomerate layer of the Auger lentil and the accompanying "speckled sandstone layer," together with the soft bluish-white cross-bedded sandstone beds overlying them, are typically exposed, and beneath the sandstones is the bright-red clay, 15 to 20 feet thick, containing the characteristic roundish gray clay-limestone concretions so frequently seen in it. From this point these beds may be traced with ease along the breaks southeastward through secs. 26, 35, and 36 to the southeast corner of the township. Throughout this distance they appear to be practically horizontal, and it seems probable that this is roughly the direction of strike of the beds which dip toward the northeast from the point where they outcrop in the breaks adjacent to the Red River in secs. 32, 33, and 34. A typical section of the rocks exposed in this area is given on page 21. At the head of the large break near the center of the NE. ¼ sec. 32 a massive gray sandstone bed, beautifully exposed, shows a decided dip toward the north and northwest. The outcrop in this instance may be traced across the southwest corner of the NW. ¼, the northern portion of the SW. ¼, and in the SE. ¼ sec. 33. In this distance it shows a general rise toward the east, but the amount and exact direction of this dip was not determined. The very irregular bedding and changeable character of the sandstones outcropping in these breaks make it very difficult to determine accurately the direction and amount of the general dip by taking angles on the beds themselves. This dip can be accurately measured only by running spirit-level lines to the various outcrops and getting their elevation above sea level. Unfortunately, this work could not be extended over this area in the time available for field work.

At the time field work was done for this report a test well for oil and gas had been started near the southeast corner of sec. 30. This

well is reported to have reached a depth between 400 and 500 feet, after which drilling was suspended. The altitude of the ground at the mouth of this well is about 1,001 feet above sea level. No detailed record of it was obtained.

From the exposures in the southern part of this township it is not possible to locate closely the axis of the anticline that enters it from the west in some portion of sec. 30. It seems probable that the broad, relatively flat divide that trends almost northwest-southeast across secs. 30, 29, 32, and 33 may mark approximately the axis of this fold. From the edge of the breaks in the northern parts of secs. 28, 29, and 30 there is a fairly steep dip to the north, and it appears that the beds exposed along the northern edge of the breaks in secs. 32 and 33 are at a higher elevation than the same beds where they are exposed in secs. 29 and 36. It therefore seems probable that the well located in the southeast corner of sec. 30 is a short distance south of the axis of this fold.

### T. 5 S., R. 11 W.

Only a part of secs. 1 to 7, 12, and 18 lie north of Red River in T. 5 S., R. 11 W. Exposures of Permian rocks occur in the river bluff almost across the township, but these beds have been studied only in parts of secs. 4, 5, 6, and 7. On the south side of the creek, in the SW. ¼ SW. sec. 6, these massive sandstone beds, which are believed to lie considerably below the horizon of the Auger conglomerate lentil, outcrop at an elevation of about 935 feet, or about 31 feet above the water of the river. These beds seem to show a slight dip toward the east along the river bluff in secs. 7 and 6 and the western part of sec. 5, and from that point to the mouth of a small tributary near the center of the north line of sec. 4, from which they seem to rise slightly. The structure was not studied along the river bluffs farther east. At this point the top of a "speckled sandstone layer" overlying a reddish clay-limestone conglomerate that contains many yellowish clay pebbles (beds 9 and 10, p. 22) is at an elevation of between 955 and 965 feet above sea level. There is some question as to the correlation of the Auger lentil in these exposures, and it seems possible that the dark limy sandstone containing flattish dark to black concretionary masses which outcrops at the very top of the breaks at elevations between 1,015 and 1,030 feet above sea level may be equivalent to the Auger conglomerate. Work in this portion of the township was done at the very close of the season, and sufficient time was not available to permit a more careful study of the outcrops of these sandstones with a view of correlating them with those exposed adjacent to the Auger conglomerate on the south side of the valley of Deep Red Run. This line of outcrops is important structurally, because it shows that no

definite anticline crosses the river at this point, although one is suggested by the trend of the structural "high" across the middle portion of T. 4 S., R. 12 W. It therefore indicates that the axis of the "high" may lie just north of the breaks in the southern part of T. 4 S., R. 11 W.

## SUGGESTIONS TO PROSPECTORS.

Shortly after the field work was completed for this report a press bulletin was issued, which described the favorable places for test wells as follows:

In his preliminary statement to the Survey of the main results of the examination, Mr. Munn reports that an anticline appears to cross Red River in or near the SW. ¼ sec. 32, T. 5 S., R. 12 W. The dip within 1½ miles along the western limb of this fold is probably between 50 and 75 feet, the character of the rocks exposed rendering an exact measurement impossible. The trend of this fold is uncertain, but it may be stated that almost any portion of sec. 32, T. 5 S., R. 12 W., appears favorable, structurally, for oil and gas. The northwest quarter of the section seems most favorable. If an oil and gas pool is present in this vicinity it very probably extends to adjacent portions of secs. 33, 28, 29, and 31.

In T. 4 S., R. 12 W., some good exposures of Permian sandstone and clay-lime conglomerate suggest strongly that a structural "high" exists a short distance north of the town of Randlett. It is not possible at this time to outline definitely this anticline or structural dome, but it seems likely that the crest is situated somewhere in the SW. ¼ of sec. 21, the SE. ¼ of sec. 20, the NE. ¼ of sec. 29, or the NW. ¼ of sec. 28, T. 4 S., R. 12 W. The "high" may be a dome of small extent, or it may be a part of a fairly definite anticline trending eastward, leaving the township in either sec. 24 or 25. There may be a secondary structural dome in sec. 24, T. 4 S., R. 12 W., because the beds dip about 50 feet from the top of the large butte in the northeast quarter of this section to a small butte about a mile north of it, in sec. 13, and also at about the same rate toward the northeast. The structure of the rocks south of the large butte for almost 2 miles can not be determined. In the NW. ¼ sec. 26 the beds are several feet lower. The trend of this anticline is probably S. 50° or 60° E. The position of this fold was not determined in T. 4 S., R. 11 W. It seems most likely to pass across some portion of sec. 32 and 33, but it is probably becoming lower and flatter toward the southeast. The shallow test well drilled in the southeast corner of sec. 30 probably lies half a mile south of the axis of this fold. This location seems on the whole favorable for testing, but a still better one would be about 1¼ miles northwest of it, as the rocks there are probably 30 feet higher structurally. If a test well is sunk near Randlett it should be located near the center of either sec. 21 or 27, T. 4 S., R. 12 W.

In T. 4 S., R. 13 W., the strata at the southwest corner of sec. 24 seems to be between 40 and 50 feet higher than they are in secs. 35 and 11. Other available data suggest that the high, long hill in secs. 22, 23, 24, 25, 26, and 27, T. 4 S., R. 13 W., is in part structural and therefore somewhat more favorable for oil and gas than portions of the adjacent territory. There seems to be little preference in a location for a test here. Probably as good a place as any would be in the NE. ¼ sec. 26.

In a general way the northwestern part of T. 4 S., R. 13 W., would appear worth a trial for oil or gas if pools are found in other areas. Secs. 8, 9, 16, and 17 are probably somewhat more promising than the adjacent ones. A small round hill in the NW. ¼ sec. 16 is capped by a thick clay-limestone conglomerate that is probably 40 feet higher at this place than at the northern edge of Devol, a mile to the southwest. It is also about 20 feet higher than at an exposure near the northeast corner of sec. 8, but its altitude at intervening points is not known. This clay-limestone conglomerate bed dips about 15 feet in the first 1½ miles to the north from the northwest corner of sec. 8, and from that point dips about 55 feet more in the next 1½ miles northward to the dry hole in the NW. ¼ sec. 28, T. 3 S., R. 13 W. It seems very probable that if this well had been located a mile farther southeast it would have been on the axis of the anticline that plunges steeply toward the north. So far as structure is concerned the location of this dry hole is very unfavorable, and it should not be considered a fair test for this vicinity. In fact, it is thought that test wells located in the SW. ¼ sec. 33 or on or near the high hill in the southwest corner of sec. 35, T. 3 S., R. 13 W., or in the NE. ¼ sec. 8 or the NW. ¼ sec. 9, T. 4 S., R. 13 W., will perhaps have as good chance of developing oil or gas as any part of this territory.

North of Deep Red Run rock exposures are meager. If a test well is contemplated in T. 3 S., R. 13 W., north of Deep Red Run it might as a venture be placed in the N. ½ sec. 9 or adjacent territory to the northeast.

In Tps. 3 and 4 S., R. 14 W., the principal structural feature is a "high" vaguely outlined by exposures on Big Blue and Little Blue creeks and on streams flowing north into Deep Red Run. Spirit-level lines to these outcrops show that from the divide between Red River and Deep Red Run the rocks dip rather uniformly but at a low angle to both of these streams. The exact position and character of this structural feature is not fully determined. It is probably a broad, low, irregular fold with a somewhat sinuous east-west trend and may be a continuation of the "high" in the northwest part of T. 4 S., R. 13. It seems to continue westward through portions of T. 4 S., R. 15 W. A test well in the area east of Grandfield should be located either in the north tier of sections of T. 4 S., R. 14 W., or in the southern tier of T. 3 S., R. 14 W. Probably the central part of sec. 1, T. 4 S., R. 14 W., should receive slight preference.

When the field work was being done a derrick had been built in the southwest corner of sec. 9, T. 4 S., R. 14 W., about a mile south of the station at Grandfield. This seems to be a rather favorable location for a wildcat test, though the available data are too meager to support a more definite statement.

In T. 3 S., R. 14, north of Deep Red Run, the rocks rise very gently, but the exposures are so rare as to furnish no evidence of decided folds if they exist.

There is some good evidence that a small anticline crosses Big Blue Creek in the SE. ¼ sec. 26, T. 4 S., R. 14 W., less than a mile above its mouth. The axis of this fold seems to trend almost east-west. A test in this vicinity should be located near the east-west line through the middle of secs. 26, 27, 28, and 29.

In T. 4 S., R. 15 W., the beds appear to rise at a very small angle from the east, south, and north to a broad level area in secs. 7, 8, 9, 10, 11, 14, 15, and 16, in which very few exposures occur.

The structure of T. 3 S., R. 15 W., also is not definite. The most prominent feature is a gentle rise of the rocks toward the west and southwest, across the township.

A dry hole located in the NE. ¼ sec. 9, less than a mile north of the station at Loveland, seems to be near the middle of a very broad, flat syncline in which the rocks are practically level.

Work was done in the eastern parts only of Tps. 3, 4, and 5 S., R. 16 W. Few exposures are present in this territory and but little geologic information is available regarding the structure. The character of the topography suggests a general dip toward the west from east of the middle of T. 4, but this evidence taken alone is of very little value.

According to the present incomplete data, it is suggested that the first wells in Tps. 3, 4, and 5 S., Rs. 15 and 16 W., should be located in some parts of the high, smooth prairie country south of the "breaks" in T. 4 S., R. 15 W. Also, it is suggested that any producer who may be inclined to wildcat in the Quanah district should locate on the old town site of Quanah or in the W. ½ sec. 31, T. 3 S., R. 15 W.

In offering these suggestions for the use of drillers in choosing locations for test wells ("wildcatting"), the geologists are assuming that the formations containing the oil-bearing sands in the Electra, Burkburnett, and Petrolia fields of northern Texas underlie adjacent portions of Oklahoma. This assumption is warranted, to some extent at least, by the evident continuity of the outcropping beds from one district to the other. It has been assumed that the formations containing the oil sands in northern Texas also contain the same or similar oil-bearing beds in southern Oklahoma. It is quite certain that the general structural conditions are similar in the two areas, and, on the whole, there seems to be no reason, determinable in advance of drilling, why portions of southern Oklahoma do not contain pools of oil and gas of commercial size. One object of the governmental examinations is to give the driller some aid in choosing locations for tests. The tests must be made before the question of the occurrence of oil may actually be settled. The locations mentioned as good places for wildcatting are based almost wholly on the structure or the dip of the rocks and the probable height of the oil sands here as compared with their height where they are productive in the Burkburnett, Electra, and Petrolia fields. It should be remembered that the areas suggested for tests may not be all that are favorable for tests in the region, but they are the more apparent ones brought to notice during the course of the field work. The actual difference in elevation of the probable oil sands at various points in this area can be determined only after further study of the field notes. It is believed that test wells located according to the suggestions given by the Geological Survey in this district will offer much better chances of finding oil or gas than those on locations made in the ordinary unscientific way, though it must always be borne in mind that in most new and unproved regions, even where the conditions for the determination of structure are favorable (as they are not in this region), no human agency can at present determine with certainty, in advance of drilling, whether oil or gas will be found at any given point in commercial quantities.

A more detailed study of the field notes for the complete report shows that, in the main, the above statement requires little modification to conform to the structure as mapped on Plate IV. One correction of minor importance is that the small dome in the southeast quarter of T. 4 S., R. 13 W., may prove to be much steeper on the north side than on the south, and that a secondary fold may extend southeastward from it and connect with the fold seen in the bluffs of Red River in secs. 30, 31, and 32, T. 5 S., R. 12 W.

Also, the dome mentioned as being in secs. 8, 9, 16, and 17, T. 4 S., R. 13 W., seems to be much larger and more prominent than at first stated. The structure contours on Plate IV suggest that this dome

embraces not only all or parts of the above sections, but also extends across secs. 6 and 7, T. 4 S., R. 13 W., and sec. 1, T. 4 S., R. 14 W. From this dome the contours show a broad, flat secondary anticline or structural nose jutting out toward the south and pitching steeply to Red River at the southwest corner of T. 4 S., R. 13 W. The contours show two other secondary folds, trending north and northeast, respectively. The general position of these structural "highs" was indicated in the press bulletin, but not with the definiteness given by the contour lines on Plate IV (in pocket).

The structural "high" reported in T. 4 S., Rs. 14 and 15 W., is shown by the contours to be a part of the Deval anticline, the axis of which rises to a small dome at Grandfield. The structure as mapped indicates that this dome is a favorable place for a test. A suggestion was made in the press bulletin that in T. 4 S., R. 15 W., the best location is "in some part of the smooth prairie country south of the 'breaks.'" The reason for this suggestion is illustrated by the contours on Plate IV, which show that a high, broad dome covers a considerable area in the central part of this township. In fact, so far as known, this is one of the most favorable places for oil or gas in the district. The contours show a high anticlinal nose jutting southward from the center of this dome. Unfortunately, this fold can not be traced very far in that direction because of lack of exposures. It seems probable, however, that it may extend to Red River and possibly beyond, in which case the south-central part of T. 4, R. 15 W., may be favorable for oil and gas.

The contours also show a minor anticline trending east-southeast from the above dome across the southwest corner of T. 4 S., R. 14 W. This fold appears to be low and irregular but may be large enough to afford a favorable place for the accumulation of oil and gas.

The dome in the northwest corner of T. 4 S., R. 15 W., and adjacent area in R. 16 is one of the highest in the district, and, other geologic conditions which can not be determined from the surface being equal, is one of the best locations in it for a test well. South-southwest of this dome, along the ridge between Settler Creek and Auger Creek, favorable places for tests may exist, but the available data concerning that area is too scanty to be reliable.

North of Deep Red Run the most favorable place for a test in the district is on the high hill in the N. ½ sec. 2, T. 3 S., R. 14 W. There may be several other favorable locations in this part of the district, but they could not be picked out because of lack of good outcrops.

In conclusion, the fact can not be overemphasized that favorable structure is only one of a number of equally important conditions for the accumulation of oil and gas. Among these are (1) the thickness, number, and position of beds which contain, or have contained, the organic material from which the oil and gas were derived; (2)

the stratigraphic relation of beds carrying salt water to those in which the oil and gas originated; (3) the thickness, variability, and stratigraphic position of porous lenses or irregular beds of sand that may serve as reservoirs; and (4) the structural changes through which these beds have passed since they were deposited. In fact, it seems probable that pools of oil and gas have been accumulated by the combined effect of all of the above factors or agencies working under varying geologic conditions through long periods of geologic time, together with others about which little is known. It should be remembered, however, that the accumulation of oil and gas is not fully explained by the much quoted "anticlinal theory," which accounts for the accumulation of pools of oil and gas at certain favorable places by the difference in weight of gas, oil, and salt water, where the water is under hydrostatic (still) conditions. This theory assumes that these three substances were once mixed in the rocks and that subsequently the gas, oil, and salt water arranged themselves in certain porous beds according to their respective gravities, the gas, being lightest, collecting at the tops of the anticlines, or above that part of the porous bed containing the water at places where this porous bed is overlain by an impervious one; the oil collecting below the gas; and the salt water remaining in the porous stratum below the oil. According to this theory, areas of close, hard sand in the oil-bearing stratum have offered barriers to the upward movement of the oil and gas, thus forming pools on the lower sides of the barriers. Conversely, where no salt water is present in an oil or gas sand it is assumed that both these substances have drained down the dip through the porous stratum and collected in a pool in the bottom of the syncline or on the upper side of some local barrier of impervious material. Therefore the central idea of the anticlinical theory is that the oil and gas traveled from their place of origin to their place of accumulation through the motionless interstitial water, and that their power to move was due entirely to the differences between their weights and that of the water.

Though this theory has been very successfully applied to many oil fields it has not satisfactorily accounted for (1) the closed pressure of gas pools (in some pools amounting to 1,500 pounds to the square inch); (2) the presence of oil and gas pools that completely occupy sandstone lenses which are surrounded on all sides by shale and furnish no salt water; (3) the presence of oil and gas under high pressure in porous pay streaks in sandstone of ordinary texture and porosity; (4) the presence in a dry sand of large pools of both oil and gas that do not conform to structure lines, but extend across minor anticlines and synclines alike; (5) the occurrence of pools in pay streaks differing greatly in porosity; (6) the difference in the initial closed pressure of gas wells in a given area; and many other

phenomena of a local nature, the signifiance of which can not be discussed at length in this paper. Furthermore, experimental work with oil and water in capillary tubes of glass shows conclusively that water will not displace oil placed at the bottom of the tube even if the diameter of the capillary is increased to many times that of the largest pores in the average oil sand.

The fact that the anticlinal theory does not provide a satisfactory explanation of the above-named phenomena, which are encountered in almost all fields by producers, leads the writer to believe that the idea on which it is based—namely, the accumulation through difference in gravity of gas, oil, and salt water—is wrong. On the other hand, the writer does not wish to be understood as denying the very evident fact that geologic structure has determined the position of many pools of oil and gas, but he can not believe that the known facts regarding the modes of accumulation of oil and gas justify the assumption that difference in weight of oil, gas, and water is the principal factor of accumulation.

The phenomena which the writer has observed lead him to believe that the accumulation of oil and gas in pools is due to the action of large bodies of water moving under both hydraulic and capillary pressure. If this is the true mode of accumulation, oil and gas pools of commercial size have been formed by bodies of water that moved along the bedding planes and collected ahead of or in them a portion of the oil and gas contained in the porous bed. This oil or gas may have been indigenous to the porous bed or it may have been forced into it from above or below by previous invasions of water traveling more or less vertically from water-bearing beds by capillary pressure, aided by hydraulic pressure, through the shale or other fine-grained petrologenic rock. One objection frequently raised against previous statements of this theory is that it does not seem to provide an adequate explanation of the fact that gas is generally found in the porous bed above the oil and the oil above the water. It should be remembered, however, that in a body of oil and water moving, say, horizontally, two forces act in different directions on a given globule of oil or gas. One of these forces is gravity, which tends to pull the water down and shove the oil and gas upward by an amount equal to the difference in specific gravity of the water and the oil or gas. This force is exerted in a vertical direction. The other force acting on the particle of oil or gas is that exerted by the horizontal flow of the water through the porous bed. The latter force is many times greater than the former, but the resultant of the two forces is a line slightly rising from the horizontal in the direction of the flow.

Therefore it is possible that an oil or gas particle may rise to the top of a bed saturated with water if the water is moving, and its

motion involves only kinetic friction on the oil or gas particle, whereas, if the water were still, the static friction would be far too great to permit any movement of the oil or gas, no matter what length of geologic time might be involved.

According to this theory, favorable places for accumulation are places in the porous bed that present great differences in porosity, whereby the oil is mechanically separated or strained out of the oil-water fluid, or other places where there is great variation in the rate of movement of different parts of the edge of the invading body of water, the oil being thereby confined between saturated portions of the oil-bearing bed, which have been filled by water moving in opposite directions. Pitching axes of anticlines, structural domes, monoclines of irregular trend, and places where the porosity of the oil sand changes greatly are favorable locations for trapping portions of the oil and gas accumulated by the moving water. It seems probable that much of the gas has been evolved by slow chemical change from the oil after it was accumulated into pools. This theory has been stated in greater detail elsewhere[1] and need not be repeated here, attention being called to it simply to make clearer the following suggestions to prospective operators in the Grandfield district.

The existence of an anticline at a certain location does not necessarily indicate that that spot is the most desirable for a test well. The prospector should keep in mind the fact that anticlines have relatively great length in comparison with their breadth, that the axes of folds vary in altitude from place to place, and that each fold has what may be termed a critical altitude for each oil sand, at which oil and gas are most likely to accumulate. The critical altitude of an oil sand seems to depend on its content of water, which in turn depends on many important factors, such as the regional distribution of the sand, its character—whether uniformly coarse and open, fine and close, or porous at some places and hard and close at others—the general structure of the oil-bearing rocks, and the source of the water in them and its head. Unfortunately, the value of all these factors can not be determined definitely in any region in advance of the drill. Their combined effect, however, is to cause certain portions of each oil sand to be saturated with water under sufficient head to furnish a flow into wells drilled into it, the height to which this water will rise in a well differing greatly and reaching a maximum of several hundred or even thousands of feet. The portion of a given sand most likely to be productive forms a belt of greater or less width along the margin of that part which is just saturated with water or where this water in it is under a low head. This saturated belt does

[1] Munn, M. J., The anticlinal and hydraulic theories of oil and gas accumulation: Econ. Geology, vol. 4, No. 6, Oct., 1909; U. S. Geol. Survey Geol. Atlas, Sewickley folio (No. 176), 1911. Munn, M. J., and Shaw, E. W., idem, Foxburg-Clarion folio (No. 178), 1911.

not everywhere occupy a horizontal plane in the sand out, as already stated, may vary greatly in height from place to place. Therefore the critical altitude at which pools are most likely to occur on one anticline in a given sand may be, and generally is, very different from the critical altitude for the same sand on another anticline some distance away, and also for other sands having different water conditions.

The hydraulic hypothesis of accumulation lends itself readily to the explanation of pools in and around which no water is found in the oil sand, because it assumes that the lack of porosity of the rocks surrounding oil pools is due largely to the sealing of the pores by interstitial water. The water content of a given sand, as well as the water pressure in it, may change materially with the lapse of geologic time by reason of the modification of the shape of the bed by both upward and downward movements of the earth's crust, the development of local folds in the strata, changes in the size, character, and height of the intake area from which the water is derived, climatic changes, and many other phenomena which are commonly incident to the geologic history of every region. It is therefore not safe to assume, because a given "sand" shows no water in wells sunk around an oil or gas pool in it, that this sand contains no water and that the pool was not accumulated by moving water. Where pools occur in "dry" sands—sands that show no water—it is not safe to go further than to assume that the water in the sand has little or no hydraulic head and therefore little or no pressure to force it into the wells. The very fact that oil and gas pools do exist under high pressure in porous "sands," many of which have great horizontal extent, justifies the assumption that the rocks above, below, and entirely surrounding the "pay sands" of these pools are impervious to the oil and gas; otherwise the great pressure not only would have dissipated the pool long ago, but would have been an ever-present impediment to the accumulation of such pools. It is a well-established fact, however, that the rocks which inclose these "pay sands" contain considerable pore space, ranging from probably 1 per cent up to perhaps 10 per cent or more of the rock mass. Therefore the only conclusion possible is that the pores of the rocks in contact with "pay sands" of oil and gas pools must be filled temporarily with something that renders the rocks impervious to oil or gas under high pressure. The only substance, apparently, which will universally satisfy this requirement is water, and it seems safe to assume that the rocks surrounding oil and gas pools are always saturated with water, and that where no water is obtained from the oil sands in wells surrounding pools the head or pressure of this water is too small to force it through the pores of the rock in

appreciable quantities because of the very great resistance due to friction. This pressure may have been many times greater at some other geologic period—sufficient, in fact, to force the water through the rocks and to accumulate the pools ahead of it, as described above. It seems probable, therefore, that the geologic time actually involved in the accumulation of any given oil or gas pool was relatively short, and when once formed the pool became a firmly fixed, very permanent part of the rock mass and since has suffered little or no change either in its stratigraphic or geographic position.

The principal object of this paper, however, is not to discuss the theories of oil and gas accumulation, but to show the local structure of the Grandfield district, and to emphasize the fact that, regardless of the various modifying factors of accumulation in a given area, the location of the larger percentage of pools is influenced more or less by the structure, and that a detailed knowledge of the structure in a given area is often sufficient to enable a company to greatly increase its chances of finding oil or gas, and that a lack of this information often leads to the drilling of holes in unfavorable territory. This fact is illustrated by the four wells drilled in the Grandfield district. The George Cabella well No. 1 (No. 12 of the well-section sheet, Pl. III), in the NW. ¼ sec. 28, T. 3 S., R. 13 W., is almost exactly in the trough of a small syncline adjacent to the Deep Red syncline. The "Big Pasture well" at Loveland, in T. 3 S., R. 15 W., is also near the bottom of this trough at a very unfavorable location. The shallow well in the SE. ¼ sec. 30, T. 4 S., R. 11 W., seems to be some distance south of the axis of the Devol anticline, but is still very favorably located for oil or gas. However, the chances of getting oil or gas in this well could have been materially increased if it had been located a mile to the northwest. But, as is shown on Plate III (well-section sheet), these wells very probably were not drilled deep enough to be regarded as tests, and the time and money spent upon them were wasted.

The fourth well, drilling at this date (July, 1913) at Grandfield, is located in a fairly favorable place on the south limb of a small dome, but the chances of finding oil or gas in this vicinity would have been slightly increased by locating it half a mile northwest of the point selected. The domes shown by the contours on Plate IV should be tested first in this district. The higher the domes the better. If first wells so located furnish gas in commercial quantities in any sand, they will show that the general conditions in the area were favorable for its accumulation and that the same sand at a lower level on the anticline is very likely to contain good pools of oil. If, however, the domes prove to contain no oil or gas and carry salt water under considerable head in the various sands down to 3,000 feet, the prospect of finding gas or oil in the district as a whole is

unfavorable. If, on the other hand, the higher domes carry no salt water, oil, or gas in any sand, the lower domes and secondary anticlines should be tested, especially those nearest the Burkburnett field. The fact that these beds carry oil in the Burkburnett field suggests that the lower domes and secondary anticlines in the eastern part of the district bring the oil sands up to about the right elevation for accumulations, in which case the higher domes to the west may carry gas almost exclusively. At all times it must be remembered that the three favorable factors to get in combination are (1) an anticline, (2) a good open sand, and (3) the right height on the anticline with reference to salt water in the porous sand. It is evident that in wildcat tests only one of these factors—structure—can be determined in advance of the drill, but, having it given, the chances are at least increased one-third. Once the combination of all three is found the test for an oil or gas pool, whether successful or not, is at least complete for that vicinity.

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