Water-Supply and Irrigation Paper No. 148

Series { B, Descriptive Geology, 72
{ O, Underground Waters, 47

DEPARTMENT OF THE INTERIOR

UNITED STATES GEOLOGICAL SURVEY

CHARLES D. WALCOTT, DIRECTOR

GEOLOGY AND WATER RESOURCES OF OKLAHOMA

BY

CHARLES NEWTON GOULD

WASHINGTON
GOVERNMENT PRINTING OFFICE
1905

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DEPARTMENT OF THE INTERIOR,
UNITED STATES GEOLOGICAL SURVEY,
RECLAMATION SERVICE,
Washington, D. C., August 19, 1904.

SIR: I transmit herewith a manuscript, with illustrations, by Prof. C. N. Gould, on the "Geology and Water Resources of Oklahoma," and recommend its publication in the series of water-supply papers.

The paper was prepared under the direction of Mr. N. H. Darton, geologist in charge of the western section of the division of hydrology. It throws light upon the water resources of this section, regarding which but little has hitherto been known, and will be of considerable value in the development of this portion of the country.

Very respectfully,

F. H. NEWELL,
Chief Engineer.

Hon. CHARLES D. WALCOTT,
Director United States Geological Survey.

GEOLOGY AND WATER RESOURCES OF OKLAHOMA.

By Charles Newton Gould.

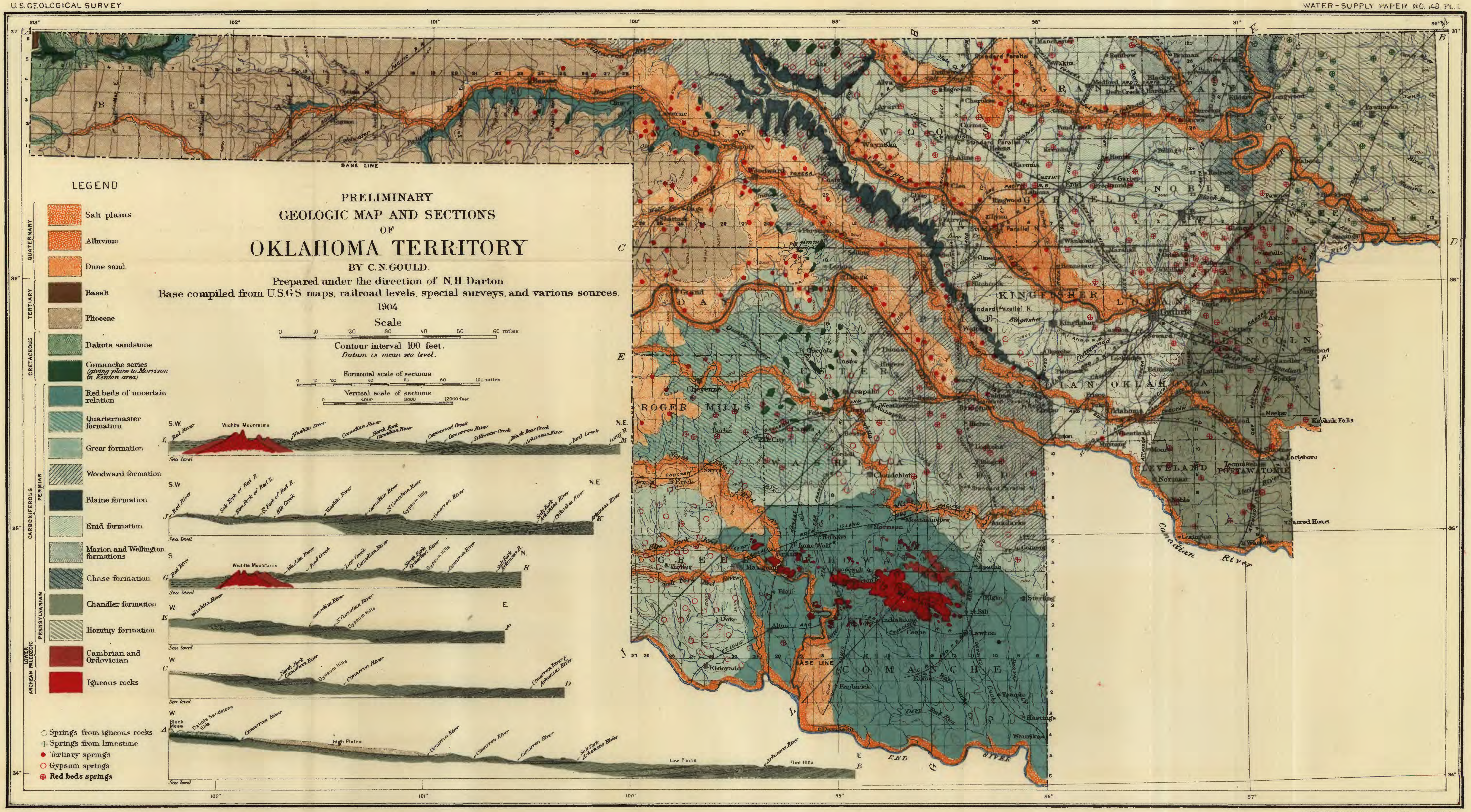
INTRODUCTION.

Location and general description.—Oklahoma is situated in the southern part of the Great Plains, its northern boundary being the thirty-seventh parallel of north latitude. On the west the greater part of the Territory is bounded by the one hundredth meridian, but the northwest corner, Beaver County, 35 miles in width, extends west of this meridian for a distance of 165 miles. The southern and eastern boundaries are irregular, and are sometimes rivers and sometimes parallels or meridians. In places it extends south to the thirty-fourth parallel and east to the ninety-sixth meridian.

The area of the Territory at the present time is 39,030 square miles, about that of Ohio; the population is 365,000, and the assessed value of taxable property $85,000,000. Its resources are chiefly agricultural, although minerals are known to exist in various localities. Oil and gas are present in various parts of the Territory, but Oklahoma's greatest mineral wealth consists of inexhaustible deposits of gypsum and salt, which occur chiefly in the western part of the Territory.

Sources of data.—The work which forms the basis for this report was carried on in the field and office during the years 1900–1903. In 1900 the writer was a member of a field party of the Oklahoma Geological Survey, and in 1901, in connection with Mr. Joseph A. Taff, spent a month making a map of the Wichita Mountains. In 1902 he had charge of the field parties of the Oklahoma Geological Survey, which studied the gypsum deposits in the western part of the Territory; and in 1903 made a reconnaissance in western Oklahoma, southwestern Kansas, southeastern Colorado, northern New Mexico, and the Panhandle of Texas to determine the water conditions along the upper courses of South Canadian, North Canadian, and Cimarron rivers.[a] In addition, many short trips have been made to various

[a] Gould, Chas. N., Reconnaissance in western Oklahoma and adjacent areas: Second Ann. Rept. Reclamation Service, 1904, pp. 423–432.



ANDREW B. GRAHAM CO. LITHOGRAPHERS, WASHINGTON, D.C.

parts of the Territory. Since November, 1902, more than 14,000 blanks and requests for information regarding wells and springs have been sent out and approximately 5,000 replies have been received.

The writer has been very ably assisted by several advanced students in the University of Oklahoma. Mr. Pierce Larkin has had charge of the subject of springs, Mr. Charles A. Long of deep wells, Mr. Charles T. Kirk of rivers. All of these gentlemen and Mr. Chester A. Reeds, who has also assisted in the office the past year, were members of the field party during the season of 1903. Mr. Kirk and Mr. Reeds have drawn the greater part of the maps and figures. Seven of the plates are from photographs made by Dr. A. H. Van Vleet, of the Oklahoma Geological Survey.

The water analysis has been made under the direction of Dr. Edwin DeBarr, professor of chemistry in the University of Oklahoma, largely by his assistants, Mr. R. S. Sherwin and Mr. E. E. Gridley, students in the university; and by Professors Fields and Holter, of the Oklahoma Agricultural and Mechanical College. The gypsums and clays were analyzed by Mr. Sherwin, while the water analyses were compiled by Mr. Gridley.

TOPOGRAPHY.

GENERAL FEATURES.

The topographic features of Oklahoma are due to the fact that it is part of a region which was formerly a plain which was worn down nearly to sea level, then elevated, and again eroded. The surface slopes eastward at an average rate of about 8 feet to the mile. The highest point in the Territory, approximately 4,500 feet, is on Black Mesa, a lava-covered table-land which extends from Colorado into the extreme northwestern corner of Beaver County. The lowest elevation, about 700 feet, is in the southeastern corner of Osage Nation, where Arkansas River flows from Oklahoma into Indian Territory. Cross sections made at various points in Oklahoma are shown in Pl. I.

In general, the rocks of eastern Oklahoma, Kansas, and the Indian Territory dip to the west or southwest, while the country slopes to the east. In most localities the dip is from 10 to 20 feet to the mile. If the surface were level, an outcropping ledge would be 10 to 20 feet below the surface 1 mile to the west of its place of outcrop. Because of this fact the highest rock on a north- or south-facing escarpment is found lower and lower in the valley to the west, until it finally disappears under the bed of a stream, and still farther west may be penetrated in a well many feet underground. In the meantime other ledges outcrop and in turn dip into the valley, disappear beneath the stream bed, and are succeeded by others still higher.

This peculiar combination of slope of surface and dip of rock, together with the erosion of the exposed ledges, gives the marked "stair-step" structure to so much of the Great Plains. Westward the hills rise constantly higher and higher. Such conspicuous forms of relief as the Flint Hills, the Dakota Sandstone Hills, or the Gypsum Hills of Kansas and Oklahoma are simply somewhat exaggerated examples of this phenomenon. These hills are more conspicuous because local conditions of sedimentation or erosion have made them higher than the surrounding region, but there are scores of less-marked escarpments.

The forms of relief of Oklahoma are the result of two factors: First, certain broad structural zones striking in a general northeast-southwest direction, and, second, the alternation of high divides and shallow valleys resulting from stream erosion. Six streams of considerable size cross these structural zones, approximately at right angles, and produce a sort of checkerboard of upland and valley, flat prairie and broken country, which extends north into Kansas and south into Texas. This arrangement, however, can be distinguished in its broader outlines only by one who is thoroughly familiar with the topography of the entire region. The only exception to this general topographic plan is the Wichita Mountain region, where a dome-shaped mass of igneous and lower Paleozoic rocks has been thrust up from below, afterwards surrounded by sedimentary rocks and still later extensively eroded, so that the range appears to be a series of buried mountains with their tops sticking above a vast plain.

The topography of Oklahoma will be discussed with regard to the features due to the structural zones and with reference to valley erosion. On the contour map (Pl. I) the general configuration of the Territory is shown. Contour lines are lines of equal elevation above a certain datum, and the uniform altitudinal space between adjacent contour lines is called the contour interval. On this map the datum is sea level and the contour interval is 100 feet. If a person should follow one of these contour lines he would go neither uphill nor downhill, but on a level. If an area is gently sloping, the lines are far apart; if it is a steep slope, they are crowded together; and if the slope is actually perpendicular the lines will touch. They encircle the hills and recede into the reentrant angles of valleys, indicating both the shape and elevation of the relief forms.

UPLANDS.

With the exception of the Wichita Mountains, there are comparatively few conspicuous relief forms in Oklahoma. In the Osage

Nation, in the northeastern part of the Territory, and the counties bordering Arkansas River the smaller streams have cut canyons into the hard limestone and sandstone, and throughout the central and southwestern part of the Territory are ranges of gypsum hills that rise steeply above the level plain to the east 200 or 300 feet. In the extreme northwestern corner of Beaver County Cimarron River has cut a canyon of considerable size through Cretaceous rocks.

With the exceptions just mentioned, the surface is usually one of low relief. In the central and western part of the Territory there are areas, sometimes thousands of square miles in extent, of practically level plain occupied by prosperous farms, with growing villages and cities.

Following a general classification only, without attempting to outline definite physiographic areas, because they all grade insensibly,

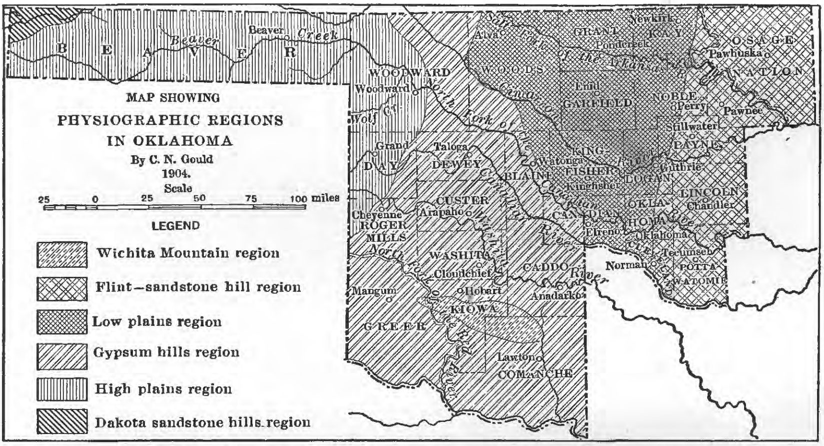
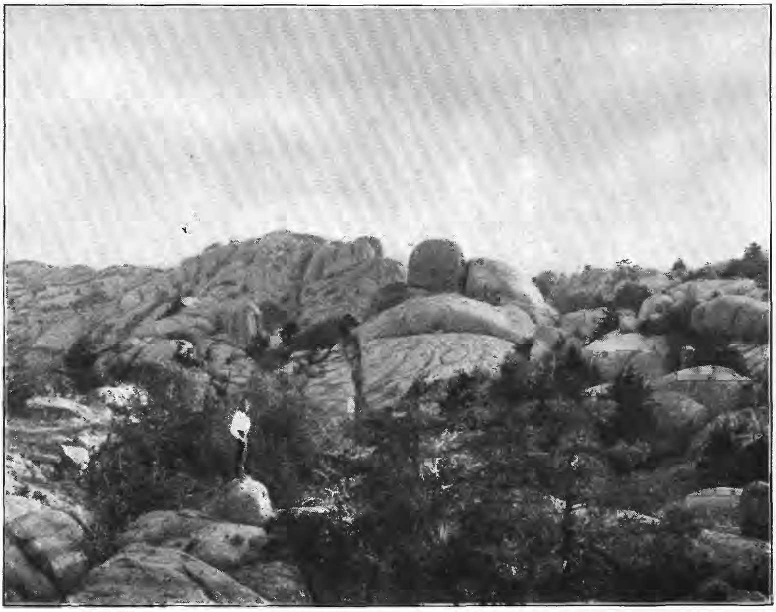


FIG. 1.—Map of Oklahoma, showing physiographic features.

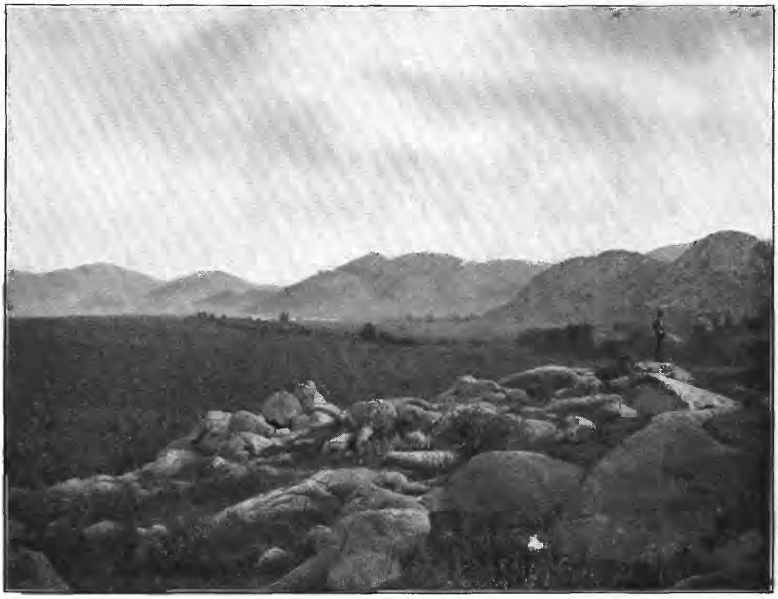
Oklahoma may be divided into the following topographic regions: (1) Wichita Mountain region; (2) Flint-Sandstone Hills region; (3) Low Plains region; (4) Gypsum Hills region; (5) High Plains region, and (6) the Dakota Sandstone region. These regions are shown in fig. 1. It is possible that the third and fourth of these divisions correspond, at least in part, to Professor Hill's Arapahoe and Canadian belts.[a] Doctor Adams has proposed[b] a classification for Kansas physiographic divisions, according to which the northern part of Oklahoma is included under Osage Prairie, Flint Hills Uplands, Great Bend Prairie, Oklahoma Prairie, Red Hills Upland, and High Plains. It has not been found practicable to follow the classification

[a] Hill, R. T., Geography and geology of the Black and Grand prairies, Texas: Twenty-first Ann. Rept. U. S. Geol. Survey, pt. 7, 1901, p. 93.

[b] Adams, G. I., Physiographic divisions of Kansas: Trans. Kansas Acad. Sci., vol. 18, 1903, p. 109.



A. GRANITE WEATHERING ON TOP OF QUANAH MOUNTAIN.



B. DEVILS CANYON MOUNTAIN.

of either Hill or Adams, and for this reason new terms are used. It is, however, not the intention of the writer to propose these names as any but convenient working terms for purpose of discussion.

WICHITA MOUNTAIN REGION.[a]

The Wichita Mountains constitute the westernmost of three domes or uplifts, each of which forms a separate group of mountains. Of these the easternmost, to which the term "Ouachitas" has sometimes been applied, lies in southwestern Arkansas and the southern part of the Choctaw Nation. In the Chickasaw Nation occur the Arbuckle Mountains and in southwestern Oklahoma the Wichita Mountains. Some authorities, however, notably Hill, use the term "Ouachita Mountains" to apply to the entire series of uplifts and designate the easternmost of these as the Massern ranges.[b]

The Wichita Mountains differ from all others in the Territory in that they are composed of igneous rocks, chiefly granite and porphyry. They have been eroded, for the most part, into peaks which vary in height from a few hundred to perhaps 1,200 feet. The main range extends west from near Fort Sill for a distance of about 30 miles, has an average width of 12 miles, and includes among others such peaks as Mount Scott, Mount Sheridan, Mount Baker, Haystack Mountain, Signal Mountain, Saddle Mountain, and Quanah Mountain (Pl. II, *A*). West of this main range to beyond the North Fork of Red River are scattered a number of smaller ranges and peaks, such as Raggedy Mountains, Mount Tepee, Devils Canyon Mountain (Pl. II, *B*), Quartz Mountain, and Headquarters Mountain. From a distance these granite peaks present the regular saw-toothed appearance noticed along the Front Range of the Rockies or in the Sierra Nevadas, with the difference that the Wichita topography is more subdued.

On the north and east for a distance of 30 miles or more is a parallel range of hills composed chiefly of hard massive limestone, and on the east and south are small rounded knobs of similar limestone. These limestone areas are remnants of a series of Paleozoic rocks which once extended as a dome over the igneous rocks, but which have been deeply eroded since the dome was uplifted.

On all sides and between these ranges of granite and limestone the rocks are composed of "red beds" shale and sandstone, with local deposits of conglomerate. In other words, at the time the red beds were being deposited the Wichitas were probably islands in the sea. The numerous creeks which head in these mountains flow either south into Red River or north into the Washita.

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[a] For detailed discussion of the Wichitas see Taff, Joseph A., Prof. Paper U. S. Geol. Survey No. 31, 1904. The writer, as a member of Mr. Taff's party in 1901, assisted in preparing a geologic map of these mountains.

[b] Op. cit., p. 37.

FLINT-SANDSTONE HILLS REGION.

This region includes the Osage and Kaw reservations lying east of Arkansas River, Kay, Noble, Pawnee, Payne, Lincoln, and Pottawatomie counties, and the eastern part of Logan, Oklahoma, and Cleveland counties. It comprises in its northern part the southern extension of the Flint Hills, which stretch from Nebraska across Kansas into Oklahoma. Near the Kansas-Oklahoma line the Flint Hills consist mostly of limestone ledges containing large numbers of flint concretions, interbedded with shales and sandstones, but in the Osage Nation the limestones thin out and most of the ledges disappear before Arkansas River is reached, a few only continuing as far as Cimarron River. South of that stream the rocks are almost entirely red shales and sandstones.

The part of Oklahoma north of the Arkansas is characterized by typical limestone topography—rounded hills and knobs, steep shale slopes with numerous rock terraces, and rather narrow valleys. The principal streams are Bird, Hominy, Salt, Beaver, Turkey, and Buck creeks. The rocks dip gently to the west and southwest, and the stair-step arrangement of the strata, so characteristic of certain parts of Kansas, is well exhibited. West and south of the Arkansas the relief is not so pronounced, as the limestone ledges become thinner and are replaced by sandstones and shales. Streams have cut valleys into the sandstone ledges, and steep but low bluffs are conspicuous. In the western part of the region the topography is characteristically that of the red beds, with few forms of relief except low banks along the streams.

LOW PLAINS REGION.

In the Low Plains region, which includes western Kay, Noble, Logan, Oklahoma, and Cleveland counties, eastern Canadian, Blaine, and Woods counties, and the greater part of Kingfisher, Garfield, and Grant counties, as well as the western part of the Chickasaw Nation, the topography is rolling. Steep bluffs are rare, and high knobs are practically unknown. Rivers of considerable size—Salt Fork, Cimarron, North Canadian, and South Canadian—flow across this region from northwest to southeast and have carved broad and shallow valleys. The high divides are the remnants of the old high table, and, because their slope to the east is so gentle as to be practically unnoticeable, a person may travel across the country for 20 miles along some lines without ascending or descending abruptly 20 feet from the general level. The south bluff of these rivers, for the greater part of their course, is cut up by canyons, while the slope north is generally unbroken and is covered with sand hills (p. 84).

A. UPLAND BASINS.

B. GYPSUM BLUFFS ON NORTH FORK OF RED RIVER.

GYPSUM HILLS REGION.

The Gypsum Hills region includes parts or all of Woods, Woodward, Blaine, Dewey, Day, Canadian, Caddo, Kiowa, Comanche, Greer, Washita, Custer, and Roger Mills counties, in each of which there are exposures of gypsum. In this section the relief is more marked than in the Low Plains region, owing chiefly to the unequal erosion consequent upon the relatively hard ledges of gypsum which outcrop in this part of the territory and to the hard sandstone and dolomite which lie above the gypsum. The relation between these rocks will be explained under the heading "Geology" (pp. 44, 71). The general strike of all the gypsum beds is north and south, the most eastern exposure being just north of El Reno, the county seat of Canadian County, while to the southwest the gypsum ledges extend, through Greer County, into the Panhandle of Texas.

There are two prominent types of gypsum topography in Oklahoma—the wall-canyon type and the round-mound type. The wall-canyon type occurs chiefly in Blaine, Woods, and Woodward counties along the range of gypsum hills designated in this report the Blaine Gypsum Hills, and again in southern Roger Mills and northern Greer counties (Pl. III, *B*). This type of topography is characterized by steep bluffs of red clay capped by massive ledges of gypsum. These bluffs rise steeply above the plain, and numerous streams have cut deep and narrow canyons into them. The second type of gypsum topography is marked by low, white, rounded, gypsum knolls standing out on the plain, or by gentle slopes of gypsum along shallow streams. Such exposures are characteristic of parts of Dewey, Custer, Washita, Caddo, and southern Greer counties.

HIGH PLAINS REGION.

This region includes the most elevated portions of the Territory, and is typically developed in Beaver, Woodward, and northern Day counties, lying west of and at a higher level than the line of gypsum hills. Beaver County, an area 165 miles long and 35 miles wide, lies entirely on the high, level plateau, sloping gradually from a height of about 4,000 feet on the west to a little more than 2,000 on the east. Into this plateau Cimarron and Beaver rivers have cut their channels, usually shallow and broad, while numerous small tributary creeks are now at work dissecting the level upland. Large areas remain, however, which appear to be as level as a floor and on which the only drainage is into playa lakes, or, as they are sometimes called in the West, "buffalo wallows" (Pl. III, *A*).

DAKOTA SANDSTONE REGION.

In the extreme western end of Beaver County, along the Cimarron and the Currumpaw (a head tributary of the Beaver), is a small area which contains topographic features unlike those found elsewhere in Oklahoma, for in this locality the streams have cut canyons into the Dakota sandstone. The Cimarron Canyon has a length of 30 miles or more in Oklahoma and of 60 miles in New Mexico. The hills, as shown on Pls. IV, *B*, and X, *B* are 200 to 500 feet high, and are usually capped by heavy ledges of gray or brown sandstone, which have been carved into fantastic shapes by numerous small creeks.

In the extreme northwestern part of Beaver County these sandstone rocks are covered with 100 feet or more of basaltic lava, forming the eastern end of Black Mesa, a level table-land which extends into Oklahoma from Colorado and New Mexico (fig. 28).

VALLEYS.

All the drainage of Oklahoma flows into Mississippi River, reaching that stream by Arkansas and Red rivers. The Arkansas crosses the northeast portion of Oklahoma, separating the Osage and Kaw reservations from the remainder of the Territory. Red River forms the extreme southwestern boundary of Oklahoma. The chief tributaries of the Arkansas in Oklahoma and the Indian Territory are Salt Fork, Cimarron, North Canadian, and South Canadian rivers, the two latter streams joining before finally reaching the Arkansas in the eastern part of the Territory. The Washita and North Fork of Red River flow into Red River.

The general direction of all these streams is southeasterly—that is, practically at right angles to the strike of the rocks. With the exception of the Washita, they are all typical streams of the plains, each with a relatively broad and shallow valley, containing a broad, sand-choked channel and, except in times of flood, carrying a relatively small amount of water. The character of these valleys is determined largely by the rocks across which they have been cut, being comparatively narrow and deep in the Gypsum Hills or Flint Hills regions and broad and shallow in the more level country in central and western Oklahoma. These valleys will be discussed in regular order beginning on the north. Pl. XVI shows the drainage areas of the various streams.

ARKANSAS VALLEY.

Arkansas River flows in a broad, shallow channel from the point where it debouches from the mountains, in Colorado, to the Flint

A. DAKOTA EROSION NEAR KENTON, OKLA., SHOWING CROSS-BEDDING.

B. EROSION FORMS IN DAKOTA CRETACEOUS.

Hills, at Arkansas City, Kans., a few miles north of the Oklahoma line. From this point to the southeast corner of the Osage Nation it flows in a tortuous channel among limestone hills. The distance is about 83 miles direct, but as traversed by the river it is nearly twice as great. This part of its course is characterized by broad and sweeping oxbow bends, one, for instance, being 9 miles around, while at the nearest point it is not more than 1½ miles across. The valley between the bluffs, which are 150 to 300 feet high, is 1 to 5 miles wide, being narrowest between the Osage country and Kay County.

SALT FORK VALLEY.

The valley of the Salt Fork of the Arkansas, which extends through northern Woods, central Grant, and southern Kay counties, is broad and shallow and is for the most part bordered on the north slope by sand hills and on the south side by canyons cut into steep and uneven slopes. Near the point where this river enters Woods County from Kansas the valley is bordered by the Gypsum Hills, particularly on the south side, while farther downstream it is 2 to 5 miles wide and the hills on either side reach an altitude of 50 to 100 feet above the level of the stream. The tributaries are Medicine Lodge, Mule, Sand, Crooked, Deer, Osage, Buck, Chikaskia, and Bois d'Arc creeks. In eastern Woods County the Salt Fork flows across the northern edge of the Great Salt Plains, where the water acquires saline character, whence the name Salt Fork.

CIMARRON VALLEY.

Cimarron River rises among volcanic peaks in northern New Mexico, flows east through a narrow canyon cut into Dakota sandstone, and enters Oklahoma 4 miles south of the Colorado line, near the town of Kenton. From this point it flows nearly straight east for more than 30 miles in a canyon cut in the sandstone plateau. In this part of its course the valley averages 3 miles in width and the rugged hills, which disappear near the point where the Cimarron flows from Oklahoma into Colorado, are 300 to 400 feet high. From this point to the place where the river cuts through the Gypsum Hills it flows in a broad and shallow valley carved into the level upland. After leaving Oklahoma the Cimarron flows through southeastern Colorado and southwestern Kansas for nearly 100 miles. It enters the Territory again about 15 miles west of the northeast corner of Beaver County, but soon turns northward to pass into Kansas. For the third time it enters Oklahoma, in the north-central part of Woodward County, where it breaks through the Blaine Gypsum Hills. Throughout its entire course in Woodward County, a distance of more than 40 miles, it flows in a canyon cut in the Gypsum Hills. This canyon gradually widens to the east, and near the western line of Woods County these hills recede from the river and swing to the north. On the south side, however, they parallel the river as far as the Glass Mountains in south-central Woods County, forming conspicuous gypsum-capped bluffs, then gradually recede from the Cimarron and approach the South Canadian. East of the Glass Mountains the Cimarron flows across a level country, and the valley is broad and shallow, being only occasionally lined with bluffs, as in the vicinity of Guthrie.

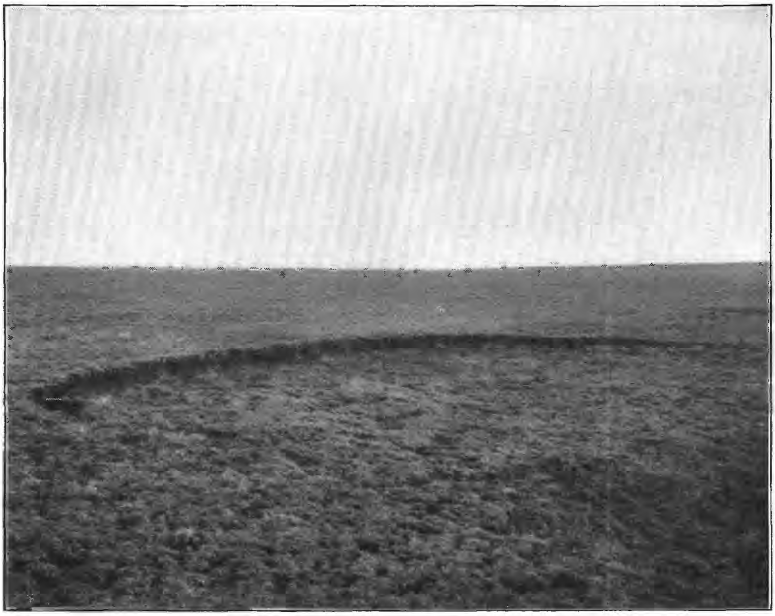
The drainage area of the Cimarron is broader than that of any other Oklahoma stream, and it includes a considerable number of tributary creeks, the chief of which are Buffalo, Eagle Chief, Salt, Turkey, Kingfisher, Cottonwood, Skeleton, and Stillwater. Along its eastern course the river flows into the southern extension of the limestone hills, where the topography consequently is more uneven and bluffs 100 or more feet high are not uncommon.

NORTH CANADIAN VALLEY.

North Canadian River is formed by the junction of Beaver and Wolf creeks at Old Fort Supply, near the center of Woodward County. Wolf Creek rises in the high table-lands of the Panhandle of Texas and flows northeast, in a rather narrow valley bordered by rounded bluffs which rarely exceed 100 feet in height. Beaver Creek, which has cut a valley averaging 3 miles in width and 200 feet in depth throughout its course, rises among volcanic peaks in northeastern New Mexico and flows the entire length of Beaver County. The principal tributaries, all on the south side, are Coldwater, Palo Duro, Clear, and Kiowa creeks. These and other creeks are now dissecting the high plateau, but on account of the arid climate and the firm sod covering have, at the present time, scarcely more than commenced their task (Pl. V, *A*). North Canadian River formed by the union of Wolf and Beaver creeks, flows in a general southeasterly course entirely across the Territory, and its valley is, on the average, 200 feet higher than the Cimarron. The hills on either side are usually low, often not over 100 feet in height, and in many instances the headwaters of streams flowing into the Cimarron approach within less than 2 miles of the North Canadian. Sand hills occur practically all along the north slope, and the south bluff is often cut into red-beds canyons.

SOUTH CANADIAN VALLEY.

With the exception of Arkansas River the South Canadian is the only stream in Oklahoma which takes its rise in the Rocky Moun-



A. PRAIRIE STREAM JUST BEGINNING TO CUT.

B. PIT HOLES ALONG PRAIRIE ARROYO.

tains. In New Mexico and the Panhandle of Texas the drainage area is large, but from the western boundary of Oklahoma to its mouth in the eastern part of the Indian Territory it will not average more than 20 miles in width. In Day and Dewey counties the river swings in a series of broad oxbow bends, and flows in a canyon-like valley about 200 feet deep and 1 to 5 miles wide. In eastern Dewey and Custer counties it flows across the Gypsum Hills region. Below the line of Gypsum Hills it flows in a general southeasterly direction in a valley which averages 4 miles in width and which is bordered by bluffs on either side not exceeding 150 feet in height. In many places, however, the slopes north of the river are covered with sand hills, but on the south side of the stream steep bluffs are common. A few small tributaries, the chief of which are Deer, Commission, and Boggy creeks, flow into the South Canadian in Oklahoma.

WASHITA VALLEY.

As has been stated by Mr. Willis,[a] the Washita resembles an eastern more than a western river, having steep mud banks and heavy timber along most of its course. In its upper part the narrow valley is continued between bluffs of red sandstone 100 to 300 feet high. Where the valley cuts across the Gypsum Hills, in Custer and Washita counties, low, white gypsum bluffs are common. Eastward from the southeastern corner of Washita County the river flows through wide bottom lands in a valley 2 to 5 miles wide, inclosed by hills 100 to 300 feet high. Taken throughout, the Washita has more precipitous bluffs and a greater diversity of topography than any other river in Oklahoma, and at the same time sand hills are practically wanting. Quartermaster, Cavalry, Rainy Mountain, Cobb, and Sugar creeks are the chief tributaries.

RED RIVER VALLEY.

The main branch of Red River forms the southern boundary of Greer and Comanche counties. A number of streams tributary to Red River rise either in Oklahoma or the Panhandle of Texas, the most important of which are the Salt Fork, Elm Fork, North Fork, Cache, and Beaver creeks. North Fork, Salt Fork, and Elm Fork rise in the eastern part of the Panhandle of Texas, flow across the region of Greer Gypsum Hills through canyons in the gypsum-capped red shale bluffs and then out upon the lower plains, where they enter shallow valleys before finally reaching Red River. Cache Creek, which rises in the Wichita Mountains, and Beaver Creek, east

[a] Willis, Bailey, First Ann. Rept. Reclamation Service, U. S. Geol. Survey, 1903, p. 269.

of these mountains, flow south across the red beds plain in broad and shallow valleys.

CONCLUSION.

All of the larger rivers of Oklahoma rise west of the Gypsum Hills region and flow first in broad valleys. In the Gypsum Hills they have cut comparatively deep and narrow canyons, and east of this range of hills the valleys begin to widen again. These streams, with the exception of the Washita, are flanked along the north slope with rows of sand hills, usually 2 to 10 miles in width, while the south bank is almost invariably cut with canyons carved in the red sandstones and shales which make up the greater part of the country rock. In other words, the south bank is a red-shale canyon slope, and the north bank a sand-hill slope.

GEOLOGY.

GENERAL STATEMENT.

The geology of Oklahoma presents certain phases of more than usual interest to the student of stratigraphy. As the conditions of the water supply depend almost wholly upon the character and position of the rocks, it is necessary to outline the geology of the Territory before giving a detailed description of the water supply.

Numerous features of the geology of various parts of Oklahoma are as yet but imperfectly understood, and many of the statements made in this article therefore are offered only tentatively. It is probable that further investigation may cause decided changes in present views of the geology of certain parts of the Territory, especially as to the line of separation between the Pennsylvanian and Permian series of the Carboniferous rocks in the northeastern part of the Territory, the location of certain sand-hill areas, and the lines of outcrops of gypsum deposits in some of the western counties. Certain facts, however, are fairly well established, and it is these, rather than the ones not yet understood, that will be given prominence in the following pages.

The principal formation in the Territory is a widespread deposit of red clay, shale, and sandstone, a large part of which has been classed as Permian in age, and is known as the "red beds." To the east it is underlain by Pennsylvanian rocks and to the west covered by sands and clays of Tertiary and Quaternary ages. In the northeastern part of the Territory are extensive areas of Pennsylvanian rocks, and in the Wichita Mountains rocks of lower Paleozoic age appear. The known outcrops of geologic formations in Oklahoma are indicated on the map (Pl. I), and the following table sets forth their order and age:

Quaternary	Alluvium.	
	Sand hills.	
Tertiary	Lava of Black Mesa.	
Cretaceous	Dakota.	
	Comanche.	
Carboniferous	Permian	Quartermaster.
		Greer.
		Woodward.
		Blaine.
		Enid.
	Pennsylvanian.	
Ordovician	Viola limestone.	
Cambro-Ordovician	Arbuckle limestone.	
Cambrian	Reagan sandstone.	
Early Cambrian or older	Granite.	
	Granite-porphry.	
	Gabbro.	

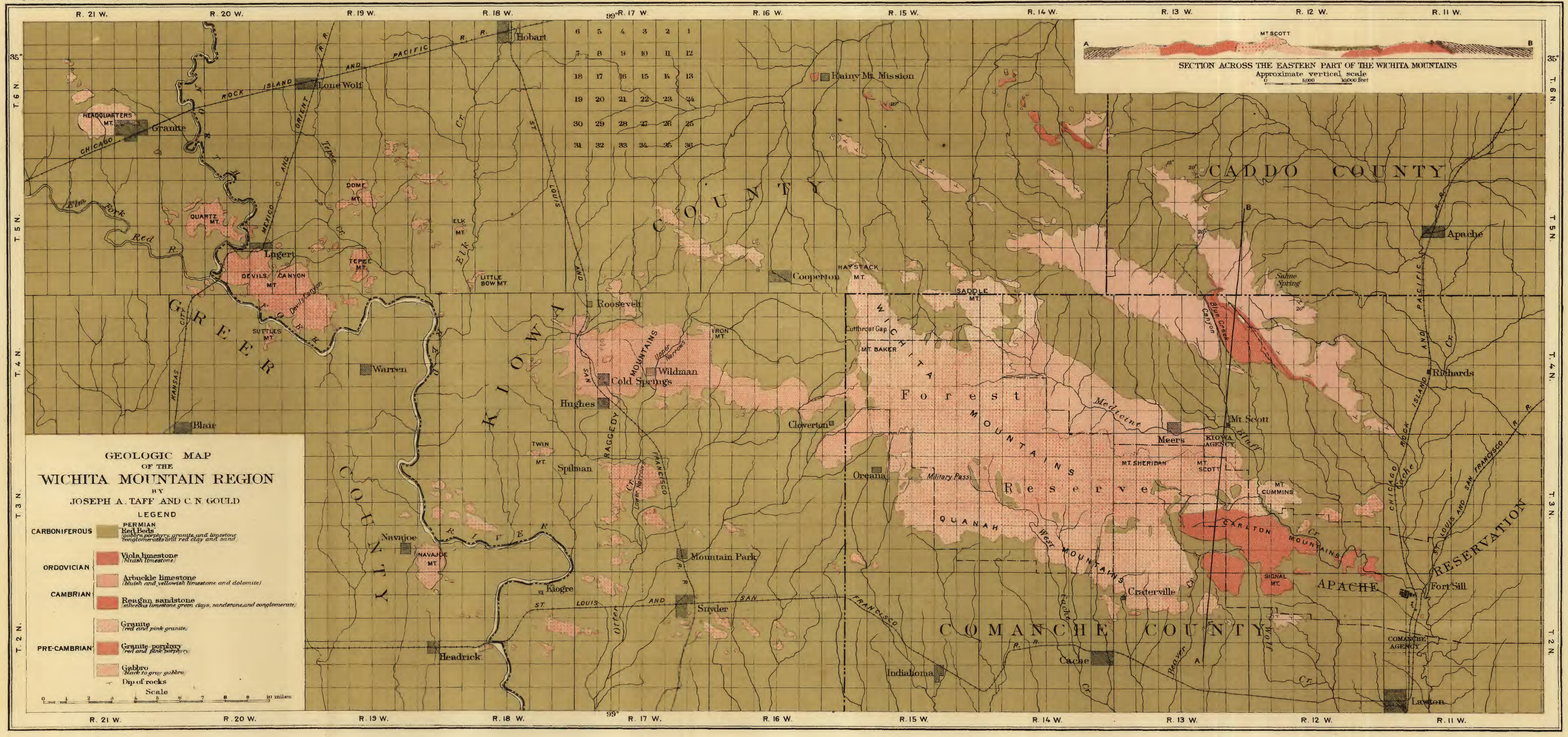
RELATIONS OF THE PRE-CARBONIFEROUS ROCKS.

The oldest rocks in Oklahoma are in the Wichita Mountains, in the southwestern part of the Territory. These mountains are composed chiefly of three classes of igneous rocks, gabbro, granite, and granite-porphyry; and three sedimentary formations of lower Paleozoic age, the Reagan sandstone, Arbuckle limestone, and Viola limestone. Granite greatly predominates, composing probably nine-tenths of all the rocks of the range. In order that the reader may understand the relations of these various rocks to each other and the surrounding "red beds," a short description of the Wichita Mountains is given. The map (Pl. VI) further illustrates the structure of the mountains.

In the Wichita Mountains the rocks do not differ materially from similar formations in the Arbuckle Mountains farther east, and for that reason it appears to be desirable to give the formations the names already used for similar rocks in the Arbuckle region. As these rocks have been named and described by Mr. Joseph A. Taff,[a] to whose publication the reader is referred, only a brief mention will be made of them in this conection.

The extreme length of the Wichita Mountains, from the Carlton mounds on Medicine Bluff Creek near Fort Sill to the last granite hill that disappears under the high prairie 5 miles west of Headquarters Mountain, at Granite, is 65 miles, while the extreme width from Rainy Mountain to the southwestern granite butte on North Fork of Red River, 6 miles southeast of Navajoe, is 30 miles. The Wichita Mountains are not a continuous range throughout this area,

[a] Taff, Joseph A., Preliminary report on the geology of the Arbuckle and Wichita mountains in Indian Territory and Oklahoma: Prof. Paper No. 31, U. S. Geeol. Survey, 1904, pp. 50–81.


GEOLOGIC MAP
OF THE
WICHITA MOUNTAIN REGION
BY
JOSEPH A. TAFF AND C. N. GOULD
LEGEND
CARBONIFEROUS
PERMIAN
Red Beds
(gabbro, porphyry, granite, and limestone conglomerates and red clay and sand)
ORDOVICIAN
Viola limestone
(bluish limestone)
Arbuckle limestone
(bluish and yellowish limestone and dolomite)
CAMBRIAN
Reagan sandstone
(siliceous limestone green clays, sandstone, and conglomerate)
PRE-CAMBRIAN
Granite
(red and pink granite)
Granite-porphyry
(red and pink porphyry)
Gabbro
(black to gray gabbro)
Dip of rocks
Scale
0 1 2 3 4 5 6 7 8 9 10 miles
SECTION ACROSS THE EASTERN PART OF THE WICHITA MOUNTAINS
Approximate vertical scale
0 5,000 10,000 feet
MT SCOTT
A
B
R. 21 W.
R. 20 W.
R. 19 W.
R. 18 W.
R. 17 W.
R. 16 W.
R. 15 W.
R. 14 W.
R. 13 W.
R. 12 W.
R. 11 W.
99°
35°
T. 6 N.
T. 5 N.
T. 4 N.
T. 3 N.
T. 2 N.
GREER
KIOWA COUNTY
CADDO COUNTY
COMANCHE COUNTY
APACHE RESERVATION
WICHITA MOUNTAINS
Forest Reserve
QUANAH MOUNTAINS
West MOUNTAINS
CARLTON MOUNTAINS
Hobart
Lone Wolf
Granite
Lugert
Roosevelt
Cooperton
Rainy Mt. Mission
Apache
Richards
Mt. Scott
Meers
KIOWA AGENCY
Cold Springs
Wildman
Hughes
Cloverton
Oreana
Spilman
Warren
Blair
Navajoe
Mountain Park
Snyder
Kiogre
Headrick
Indiahoma
Cache
Craterville
Fort Sill
Lawton
COMANCHE AGENCY
HEADQUARTERS MT.
QUARTZ MT.
DOME MT.
ELK MT.
TEPEE MT.
DEVILS CANYON MT.
SUTTLES MT.
LITTLE BOW MT.
IRON MT.
HAYSTACK MT.
SADDLE MT.
MT. BAKER
Cutthroat Gap
MT. SHERIDAN
MT. SCOTT
MT. CUMMINS
SIGNAL MT.
NAVAJOE MT.
TWIN MT.
Military Pass
Blue Creek Canyon
Saline Spring
Medicine Bluff
RAGGEDY MOUNTAINS
Red R.
Elm Fork
CHICAGO ROCK ISLAND AND PACIFIC R. R.
ST. LOUIS AND SAN FRANCISCO R. R.
KANSAS CITY MEXICO AND ORIENT R. R.

as they consist chiefly of scattered ranges, peaks, and short chains, the bases of which are buried beneath the surrounding and intervening plains.

The Wichita Mountains may be divided into the following three general groups: (1) The main range; (2) scattered groups and peaks in the western part of the area, and (3) a row of hills which are composed chiefly of limestone and which parallel the main range on the north and east.

The main range of the Wichita Mountains, the width of which averages 10 miles, extends northwest from the vicinity of Fort Sill for about 30 miles to the vicinity of Saddle Mountain and Mount Baker, just east of the headwaters of East Otter Creek. This part of the range is practically continuous throughout and is composed chiefly of rugged peaks of granite, the highest of which, Mounts Scott and Sheridan, each rise about 1,200 feet above the plain. There are two main northwest-southeast ranges, separated by a distinct intermontane valley, 1 to 4 miles wide, extending nearly the entire length of the ranges. The streams draining this valley flow east and south and escape to the plain through gaps in the mountains. East of this main range are a number of outlying peaks and short ranges, some of which attain an altitude of 800 feet or more above the surrounding plain.

West of the main range of the Wichitas, which is divided into two general ridges, are scattered groups, peaks, and low ridges extending a few miles beyond Granite, Greer County, a distance of 40 miles from Mount Baker. The term "Raggedy Mountains" is applied to a group of scattered, roughly outlined ridges and peaks lying along the heads of various branches of Otter Creek. Long Horn Mountain is near the head of Middle Otter Creek; Dome Mountain, Tepee Mountain, Elk Mountain, and others lie near Elk Creek; Devils Canyon Mountain, shown in Pl. II, *B*, is 6 miles long and lies in a bend of the North Fork of Red River; Navajoe, Quartz, and Headquarters mountains are in Greer County west of the North Fork of Red River, which winds in and out among the granite peaks.

Parallel to the Wichitas on the northeast from a point 7 miles north of Fort Sill to Rainy Mountain, a distance of 30 miles to the northwest, is a group of limestone hills, which, like the main range of the Wichitas, consist of irregular low mountains and scattered knobs. The longest range, 16 miles in length, will average 2 miles in width. Near the head of Blue Creek Canyon the range of limestone hills divides into two parts—one part running approximately N. 70° W. and the other N. 40° W. Both ranges finally end toward the northwest in a series of scattered peaks and knobs. These limestone hills, like the granite mountains, are but the tops of buried ranges. The rock comprising the plain around and between the mountains is much younger than the rocks of the mountains—that is, it was deposited at a much later period in the earth's history.

IGNEOUS ROCKS.[a]

GABBRO.

Of the three chief varieties of igneous rocks in the Wichitas the gabbro is probably the oldest. This rock is hard, black, and crystalline, and sometimes is known to the miners as black granite. It frequently has a greenish tint, or again it may be grayish in color, and often weathers into rough, lumpy surfaces. It is in places cut by dikes, composed of diabase, granite, aplite, etc.

As shown on the map (Pl. VI) gabbro outcrops in three separate localities in the Wichita Mountains, two of which are in the main range and the other one west of it. In the main range the most extensive exposure, which covers an area about 2 miles wide and 12 miles long, lies along the north slope of the mountains on both sides of Medicine Bluff Creek, and extends northwest and southeast, paralleling the range from the east end of Mount Scott to the east slope of Saddle Mountain. The second gabbro exposure, about 6 miles long and 1 mile wide, is in the central part of the intermontane valley along the heads of West Cache and Quanah creeks. The gabbro in both these localities does not, as a rule, present conspicuous relief, but weathers into gentle slopes with occasional low ridges and buttes. The third locality in which gabbro is found is in the central part of the Raggedy Mountains, west of the main range. This range is 15 miles long and extends westward from near Mount Baker to a point within 3 miles of North Fork of Red River. Some of the peaks rise to the height of 400 feet above the plain. The average width of the range is something like 3 miles, and across it flow the various branches of Otter Creek. In the western part of the range are numerous dikes and intrusions of other igneous rocks, chiefly granite and quartz.

GRANITE-PORPHYRY.

Granite-porphyry occurs in the eastern part of the main range and in several localities among the limestone hills. This is a hard, massive rock usually with a grayish groundmass in which are embedded numerous large crystals, usually reddish or pinkish, giving a characteristic reddish-gray tint to the rock. The localities in which porphyry occurs are as follows:

In the Fort Sill Military Reservation and between the fort and

[a] For classification of the igneous rocks of the Wichita Mountains see Taff, Joseph A., op. cit., pp. 59–67.

Mount Scott the greater part of the rock is granite-porphyry. Signal Mountain, the Carlton mounds, Medicine Bluff, and a number of unnamed peaks are composed of this rock. This porphyry weathers in small blocks and angular fragments, and the surface of the hills composed of this rock are usually grass covered and easily distinguished from granite hills in which the rock weathers out in large bowlders and which are covered with trees. In the western part of this exposure the porphyry passes gradually into red granite, so that in many places it is virtually impossible to tell where one rock stops and the other begins.

Near the central part of the main ridge of limestone hills, 6 to 8 miles north of Mount Scott, along Blue Creek Canyon, is a second exposure of porphyry covering an area of about 8 square miles. The rock in this region does not differ materially in character from that on the Fort Sill Reservation. On the west the porphyry is cut off from the limestone by a fault and on the east, where it is exposed along the flanks of a limestone ridge, it lies unconformably below the sedimentary rocks.

The third area of porphyritic rocks is in the extreme northern part of the Wichita Mountain region, at the northern extension of the limestone hills. In this vicinity are twelve or more scattered peaks of porphyry. In two instances this porphyry lies unconformably below the Reagan sandstone, a formation of Cambrian age.

GRANITE.

With the exception of the gabbro and granite porphyry just discussed and a relatively few dikes, the igneous rocks of the Wichitas consist of granite, which varies in color from red to gray with light red greatly predominating. It is cut by several series of joint planes and weathers into massive bowlders (Pl. II, *A*, *B*).

The high peaks of the main range, such as Mounts Scott, Sheridan, and Baker, and Saddle Mountain, and others, as well as all the scattered peaks and ranges west of the main range, except the gabbro range previously discussed, are composed of granite. Navajoe, Tepee, Devils Canyon, Little Bow, Quartz, Headquarters, and other peaks and chains in this western group are all granite mountains.

SEDIMENTARY ROCKS.[a]

CAMBRIAN ROCKS.

REAGAN SANDSTONE.

The Reagan sandstone, the oldest sedimentary rock in Oklahoma, in its typical development is composed of coarse-grained, angular

[a] For a more complete description see Taff, Joseph A., op. cit., pp. 67–77.

particles derived from the disintegration of porphyry rocks. There are local ledges of conglomerate interstratified with shaly members, but coarse sandstone makes up the greater part of these rocks. The age of this formation, as indicated by trilobites and other fossils, is Middle Cambrian.

The Reagan formation is exposed on the granite-porphyry, and it is conformably overlain by the Arbuckle limestone at two localities; first, in the limestone hills east of Blue Creek Canyon, and second, along the side of some limestone peaks in the extreme northern part of the mountains. At Blue Creek Canyon the Reagan is exposed for a distance of nearly 4 miles, while farther north the line of outcrop is not more than 2 miles long. In both localities the exposure is but a few hundred feet wide.

CAMBRO-ORDOVICIAN ROCKS.

ARBUCKLE LIMESTONE.

Conformably above the Reagan sandstone is a limestone formation which makes up the greater part of the northern division of the Wichita Mountains. This limestone is hard, compact, and massive, and is at nearly all places much folded and faulted, so that its beds rarely lie level, but have been broken and tilted to various angles, usually steep. The thickness of this formation in the Wichita Mountains is unknown, but in the Arbuckle Mountains it was estimated by Mr. Taff to be 4,000 to 6,000 feet, and there is no reason for supposing that it is less in the Wichitas. In the Arbuckle Mountains the lower 700 feet of this limestone contains fossils of Upper Cambrian age, while from the upper beds Ordovician forms were obtained.

The hills composed chiefly of this limestone extend practically uninterrupted northeast from near Fort Sill for 30 miles or more. From the region of Blue Creek Canyon there are two ranges, both of which finally die out and disappear beneath the plains.

ORDOVICIAN ROCKS.

VIOLA LIMESTONE.

Three small outlying limestone knobs in the vicinity of Rainy Mountain Mission consist of Viola limestone, an Ordovician formation, which in the Arbuckle Mountains occurs approximately 2,000 feet higher in the section than the Arbuckle limestone. In the Wichita Mountain region little lithologic distinction can be made between the limestone comprising these knobs and the limestone which makes up the main range of hills just described. Mr. E. O.

Ulrich, however, who studied the fossils from the entire region, finds that the paleontologic evidence justifies such distinction, and for that reason the rocks composing the three hills near Rainy Mountain are classed as Viola.

CARBONIFEROUS ROCKS.

PENNSYLVANIAN SERIES.

GENERAL RELATIONS.

The oldest rocks on the plains consist of scattered groups of igneous rocks, chiefly granite, forming the hearts of the Ozark, Arbuckle, and Wichita mountains. The greater part of the Ozark and Boston mountains in Missouri and Arkansas consist of sedimentary rocks older than the Coal Measures, chiefly limestones and cherts of the Mississippian ("Lower Carboniferous"). Rocks of the same age are also found in southeastern Kansas and the eastern part of the Cherokee Nation. Westward the rocks belong to successively younger formations.

Resting upon the Mississippian in Indian Territory is a great thickness of rocks of Pennsylvanian age.[a] These rocks occupy the greater part of southern Iowa, western Missouri, eastern Nebraska, and the eastern third of Kansas. Large outcrops are also found in Arkansas and Texas.

Pennsylvanian rocks are exposed over a considerable area in eastern Oklahoma. The line of separation between the Pennsylvanian and the Permian, which make up the greater part of the Territory, has never been sharply drawn. For reasons to be discussed later this line can not be drawn with any degree of accuracy until considerable work has been done in the way of tracing formations in northeastern Oklahoma and until fossils have been collected and identified.[b]

RELATION OF THE PENNSYLVANIAN TO THE PERMIAN.

The problem of the relation of the Pennsylvanian to the Permian of the Great Plains is at best a perplexing one. Perhaps more time has been spent in attempting to solve it than has been devoted to almost any other phase of western geology, and the results have been less satisfactory. In Kansas the rocks of these two epochs have been studied for nearly fifty years, and during the past ten years Willis-

[a] Taff, Joseph A., The southwestern coal fields: Twenty-second Ann. Rept. U. S. Geol. Survey, pt. 3, pp. 367–413; Geology of the McAlester-Lehigh coal fields, Indian Territory; Nineteenth Ann. Rept. U. S. Geol. Survey, pt. 3, pp. 423–593, 1899; Eastern Choctaw coal fields, Indian Territory, Twenty-first Ann. Rept. U. S. Geol. Survey, pt. 2, pp. 255–311, 1900; Coalgate Folio, No. 74, 1901, and Atoka Folio, No. 79, 1902. Drake, N. F., A geological reconnaissance of the coal fields of the Indian Territory: Proc. Am. Philos. Soc., vol. 36, 1898, pp. 326–429.

[b] See footnote, p. 32.

ton,[a] Cragin,[b] Prosser,[c] Hay,[d] Beede,[e] and others have contributed articles which have assisted in the elucidation of this very perplexing question. In Kansas, however, the difficulties are not so great as in Oklahoma, as in Kansas the Pennsylvanian rocks which occur in the eastern third of the State are in a regular, conformable succession, and finally pass conformably into the Permian above. Many of the beds have lithologic characteristics, and fossils are abundant. It is true that the line of separation between the Pennsylvanian and Permian has not been sharply drawn, for such a line depends upon paleontologic rather than upon lithologic data, and in certain strata there is a commingling of Pennsylvanian and Permian forms, but most geologists who have studied the problem have agreed that certain rocks are Pennsylvanian in age and that certain other rocks, several hundred feet higher geologically, belong to the Permian.

In parts of Texas where these rocks are well exposed the line of division between the two series has been fairly well worked out. Certain beds are known to be Pennsylvanian, while certain other higher beds are undoubtedly of Permian age.

In Oklahoma, on the other hand, such conditions do not exist. In the northeastern part of the Territory particularly the stratigraphy is exceedingly perplexing and at the same time fossils are rare. On the geological map (Pl. I) the author has attempted to outline the conditions as they are believed to exist. From this map it will be seen that the greater part of the Osage Nation, which is in the northeast corner of Oklahoma, is underlain by rocks of Pennsylvanian age. In this part of the Territory, as in Kansas to the north, the strike is to the northeast and southwest, and many of the ledges, notably certain limestones, have been traced by Adams[f] and others from Kansas into Oklahoma, some to beyond Arkansas River. The lowest limestone ledge that is known in the Osage Nation (although more detailed study will probably reveal others still lower) is the Drum limestone which has been traced as far south as the vicinity of Bartlesville, in

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[a] Williston, S. W., Science, new series, vol. 5, p. 395; Kansas Univ. Quar., vol. 6, p. 57; Jour. Geol., vol. 6, 1898, p. 342.

[b] Cragin, F. W., Bull. Washburn Col. Nat. Hist., vol. 1, 1885, p. 86; id., vol. 2, 1889, pp. 33, 34; The Permian system of Kansas: Colorado Col. Studies, vol. 6, 1896, pp. 1–48; Observations on the Cimarron series: Am. Geologist, vol. 19, pp. 351–363.

[c] Prosser, Chas. S., The Cimarron series or the Red Beds: Second Ann. Rept. Univ. Geol. Survey Kansas, 1897, pp. 75–95; The Permian and Upper Carboniferous of southern Kansas: Kansas Univ. Quar., vol. 6, 1897, pp. 149–176; Revised classification of the upper Paleozoic formations of Kansas: Jour. Geol., vol. 10, 1902, pp. 703–737.

[d] Hay, Robt., A geological reconnaissance in southwestern Kansas: Bull. U. S. Geol. Survey No. 57, 1890, pp. 20, 27; Eighth Bien. Rept. Kansas State Bd. Agric., pt. 2, 1893, p. 101.

[e] Beede, J. W., Jour. Geol., vol. 9, 1901, p. 339; Am. Geologist, vol. 28, 1901, pp. 46, 47; Advance Bull. First Bien. Rept. Oklahoma Geol. Survey, April, 1902.

[f] Adams, Geo. I., Stratigraphy and paleontology of the Upper Carboniferous rocks of the Kansas section: Bull. U. S. Geol. Survey No. 211, 1903.

the Cherokee Nation, just east of the Oklahoma line. If the direction of the strike of this rock remains constant, however, this ledge should touch the Arkansas not far from the mouth of the Cimarron, and if so, there are probably several hundred feet of Pennsylvanian rocks in Oklahoma below the level of the Drum limestone.

Another ledge of limestone, the Pawhuska, has been traced by Adams from Kansas south through the Osage Nation and across Arkansas River to the vicinity of the Cimarron, near Ingalls, Payne County, Okla.[a] The Pawhuska, however, is stratigraphically 600 feet below the base of the Wreford limestone, which is now considered by Prosser to be the base of the Permian.[b] The Drum limestone is approximately 950 feet below the Pawhuska, so that in the Osage Nation there are at least 1,550 feet of the Pennsylvanian rocks below the base of the Permian.

This part of the problem presents no great difficulty. The point which leads to confusion is the failure to identify many of these prominent ledges in the region south of Arkansas River. Within a belt 50 miles wide on either side of the river the lithologic conditions change rapidly. At the Kansas-Oklahoma-Indian Territory line there are, between the Drum limestone and the Winfield formation, which is the highest prominent limestone ledge in the Permian, no fewer than 16 heavy beds of limestone, varying in thickness from 5 to 40 feet. On passing southward through the western part of the Cherokee Nation and the Osage Nation these limestones become thinner and less conspicuous, while at the same time the intervening shales become thicker and more prominent, often becoming arenaceous, or, indeed, replaced entirely by sandstone, until by the time the Arkansas River is reached the greater part of these limestone formations have totally disappeared, while those that remain have become much thinner, and the rocks consist entirely of alternating layers of sandstone and shale. In the light of our present knowledge it is believed that the Pawhuska limestone extends farther south than any of the others. This limestone was traced by Mr. Pierce Larkin as far south as a point 9 miles south of Chandler, where it seems to disappear and its place is taken by shales and sandstones. At the same time the shales, which have been of a prevailing drab, bluish, or yellowish color, become more and more reddish, until they gradually merge into the typical brick-red shales and clays that make up the greater part of the Oklahoma red beds.

This condition was first pointed out by Dr. George I. Adams, who

[a] Adams, G. I., Bull. U. S. Geol. Survey No. 211, 1903, pp. 61–65. See also Adams, G. I., Carboniferous and Permian age of the red beds of eastern Oklahoma from stratigraphic evidence: Am. Jour. Sci., 4th ser., vol. 12, 1901, p. 383.

[b] Prosser, Chas. S., Revised classification of the upper Paleozoic formations of Kansas: Jour. Geol., vol. 10, 1902, table op. p. 718.

has made a special study of these conditions in Kansas, Oklahoma, and Texas. In speaking of the problem, Doctor Adams says:[a]

It appears that rocks in eastern Oklahoma, which have been referred to the red beds on lithologic grounds, are in part of Upper Carboniferous or Coal Measure age. The sedimentation from the Carboniferous into the Permian is an unbroken sequence. From what is known of the Permian limestones of Kansas, they will be found, when followed southward, to diminish in thickness, and this change will be accompanied by a transition to more sandy beds. This is in accordance with the observations made by Mr. Gould. The age of that portion of the red beds which is in strike with the Permian of Kansas may confidently be expected to be found to be of Permian age. This is in accordance with the evidence already furnished by the vertebrate fossils. Above the Permian limestone in Kansas occur the Wellington shales, which are bluish and greenish gray in color. They are probably represented southwestward by formations which are red. The succeeding formations are typical red beds and have thus far yielded only Permian fossils. Upon the accompanying map the approximate line of transition in color has been drawn with the purpose of showing that it is diagonal to the strike of the Carboniferous and Permian formations.

Doctor Adams found the conditions in northern Texas very similar to those in the Kansas-Oklahoma region. In Young, Archer, Throckmorton, and Baylor counties, Tex., certain beds of limestone of Pennsylvania age thin out northerly and their place is taken by shales and sandstones, which become distinctly red in color. The line of change of color in the rocks cuts diagonally across the strike of the beds, very much as in northeastern Oklahoma. Doctor Adams does not attempt to draw the line between the Pennsylvanian and the Permian in either Oklahoma or Texas.[b]

From this it follows that the line of separation between Pennsylvanian and Permian rocks must be drawn far out in the red beds. If the Wreford limestone be accepted as the base of the Permian in Kansas, the location of the line of separation is a matter of the location of the Wreford in Oklahoma. This ledge is known to outcrop on Beaver Creek in the Kaw Reservation, and has been traced south by Mr. Charles A. Long across the western part of the Osage Nation to a point in the big bend of the Arkansas, about 10 miles west of Ralston and about 8 miles northeast of the mouth of Red Rock Creek, where it is striking southwest. It is probably represented south of the river in one of the ledges of limestone which are known to occur in the eastern part of Noble County, but until it is definitely located the line of separation can only be approximated. For the present, then, it will be drawn roughly through eastern Noble, western Payne, eastern Logan and Oklahoma, and western Cleveland counties, approximately paralleling the Atchison, Topeka and Santa Fe Railroad on the east as far as the vicinity of Oklahoma City, near which

[a] Adams, Geo. I., Op. cit., pp. 385–386.

[b] Adams, Geo. I., Stratigraphic relations of the red beds to the Carboniferous and Permian in northern Texas: Bull. Geol. Soc. America, vol. 14, 1903, pp. 191–200.

place it crosses that line of road and strikes South Canadian River in the western part of the Chickasaw country, west of the Arbuckle Mountains, and, if carried across Red River, will finally reach the region of the western limit of the known Pennsylvanian in Texas.[a]

DESCRIPTION OF PENNSYLVANIAN ROCKS.

If the line of separation between the Pennsylvanian and Permian rocks of Oklahoma be drawn at the line above indicated, there are in eastern Oklahoma about 5,000 square miles of Pennsylvanian rocks. In the southern part of the area these rocks are almost entirely red sandstones and clays; in the northern part they consist of alternating layers of clays, sandstones, and limestones of various colors. The line of separation between the two kinds of Pennsylvanian rocks can never be sharply drawn, for the reason stated above, that while all the rocks are in regular succession they vary in lithologic character along the strike. To express the condition more forcibly, the statement may be made that the rocks of the two sections dovetail into each other; for in the region along Arkansas River there are red shales extending northward into limestone-sandstone regions and beds of limestone extending south into the red-clay-shale country. As stated by Adams, there is an embayment of red sediments extending far to the east among Pennsylvanian strata.

For purposes of description it is proposed to divide the rocks into two districts, the names Hominy and Chandler, by which these districts will be known, being used only as convenient working terms.

Hominy district.—The Hominy district includes the area of outcrop of all the Carboniferous rocks of the Osage and Kaw reservations which lie below the Wreford limestone. The formations exposed in this district include the southern extension into Oklahoma of the Pottawatomie, Douglas, Shawnee, Wabaunsee, Cottonwood,[b] and Neosho[c] formations of the Kansas geologists and have a thickness of over 1,500 feet. In the eastern part of the Osage Nation the rocks are chiefly sandstones and shales, with some massive beds of fossiliferous limestones, while farther west, along the headwaters of Hominy

[a] During the summer of 1904, since the above was written, Mr. Charles T. Kirk, working under the direction of the Oklahoma Geological Survey, traced out the line of outcrop of the Wreford limestone south across Oklahoma. Starting on Little Beaver Creek, in the Kaw Reservation, he followed the ledge across Arkansas River and found that in Payne County the limestone disappeared and its place was taken by a ledge of sandstone to which the name Payne sandstone was applied. This ledge was traced southwest across Cimarron, Deep Fork, and North Canadian rivers, through western Lincoln, eastern Oklahoma, and central Cleveland counties. It crosses South Canadian River near Purcell. In southern Oklahoma the ledge lies some 15 to 20 miles east of the line of Pennsylvanian-Permian contact indicated on Pl. I. For full description see Mr. Kirk's paper in Third Bien. Rept. Okla. Geol. and Nat. Hist. Survey, 1904, pp. 5–14.

[b] Haworth, Erasmus, Univ. Geol. Surv. Kansas, vol. 3, 1898, pp. 91, 94.

[c] Prosser, Chas. N., Classification of the upper Paleozoic rocks of central Kansas: Jour. Geol., vol. 3, 1895, p. 797.

Creek and on Salt and Beaver creeks, the sandstones are rare, and heavy beds of cherty limestone make up the greater part of the rocks. To the south the limestones thin out, and in the vicinity of Arkansas River change into red shales.

The name Hominy is from Hominy Creek, in the southern part of the Osage country, which flows across practically all formations represented in this district.

Chandler district.—The Chandler district includes the area of outcrop of all the strata, chiefly shales and sandstones, from the eastern boundary of the red beds westward to the base of the Permian, near the line of the Atchison, Topeka and Santa Fe Railroad, including part of Pawnee, all of Lincoln and Pottawatomie, and the eastern parts of Noble, Payne, Logan, Oklahoma, and Cleveland counties. It corresponds practically to the southern continuation of the Flint Hills of Kansas and the Osage Nation, which disappear about the line of Arkansas River. Perhaps it would be more correct to say that the rocks of this district are in strike with those of the Flint Hills.

In general, the rocks of this district consist of alternating strata of red and whitish sandstone and red-clay shale. Along the streams the sandstones outcrop as ledges 20 feet or more thick, sometimes forming small waterfalls in some of the streams. To the east of the Santa Fe Railroad the sandstone beds are most abundant, but they are grayish or almost white, though the intervening clay is always red. Business blocks at Perry, Orlando, Mulhall, Guthrie, Edmond, Oklahoma City, Norman, and Noble, along the line of the Santa Fe Railroad, are built of red sandstone. The buildings of the Oklahoma Agricultural and Mechanical College, at Stillwater, and many of the business blocks at Shawnee are constructed of the lighter-colored stone. Practically all of the towns in Lincoln, Payne, and Pottawatomie counties, and those in the eastern parts of Noble, Logan, Oklahoma, and Cleveland counties, contain buildings constructed of either the red or gray sandstone. Through the entire region it is used for the abutments of bridges, for corrals and small buildings, and not infrequently for dwellings.

The sandstone is water bearing. Springs are not uncommon, and water, which is ordinarily soft and suitable for all domestic purposes, is usually found in wells at moderate depths. It is the best water found anywhere in the red beds below the Quartermaster formation.

The region is well wooded. Trees grow along the streams and in many places on the hills. The three eastern counties, especially, are covered with a considerable growth of the more hardy forest trees, notably oak and hickory. Along the line of the Santa Fe

Railroad the uplands are level prairie and the bottom lands are timbered. West of this line the timber becomes less plentiful.

While fossils are not particularly common in the Chandler district, still a number of localities have been found which yield typical Pennsylvanian invertebrates. Near Chandler, the county seat of Lincoln County, for which the district is named, the following forms were found: *Allorisima subcuneata*, *Pinna peracuta*, *Spirifer cameratus*, *Meekella straticostata*, *Productus semireticulatus*, and *Athyris subtilita*.

PERMIAN SERIES.

PERMIAN ROCKS OF KANSAS.

According to the classification of the Kansas geologists, notably Prosser, the line of separation between the Carboniferous and Permian in Kansas has been drawn at the base of the Wreford limestone, a ledge typically exposed near Junction, Kans., on Kansas River.[a] In southern Kansas this ledge outcrops near the summit of the Flint Hills in eastern Cowley County and along Grouse Creek, near Dexter, and, as stated above, is found in Oklahoma along Little Beaver Creek, in the Kaw Reservation, and in the western part of the Osage Nation as far south as Arkansas River. Above the Wreford limestone in southern Kansas and eastern Kay County, Okla., there are at least three heavy beds of limestone with interbedded shales, known as the Florence flint, Fort Riley limestone, and the Winfield formation. Above the Winfield formation limestones become less prominent and clays and shales make up the greater part of the series. These formations above the limestone members constitute the Marion formation of Prosser and the Wellington shales of Cragin.[b] In general, both the Marion and Wellington formations consist of gray, blue, drab, and yellowish shales with a few ledges of impure limestone. The extensive salt beds in central and southern Kansas and the deposits of gypsum in several counties of Kansas and in Kay County, Okla., are found in these rocks. These two formations, however, appear not to be sharply defined, and, inasmuch as both consist of rocks of essentially the same character, a definite line of separation will probably not be drawn between them, and it is not impossible that as a result of more exact knowledge of the conditions both formations will finally be grouped together.

[a] Prosser, Chas. S., Revised classification of the upper Paleozoic formations of Kansas: Jour. Geol., vol. 10, 1902, p. 703.

[b] See articles by Professor Prosser, Jour. Geol., vol. 8, 1895, pp. 764–796; and by Professor Cragin, Colorado Col. Studies, vol. 6, 1896, pp. 8–18.

The southern extension of the Marion and Wellington formations, as well as the southern part of the Flint Hills, reach from Kansas into Oklahoma. The Flint Hills, as stated above, occupy the western part of the Osage Nation, all of the Kaw Reservation, and the eastern part of Kay, Noble, and Pawnee counties. The southern extensions of the Marion and Wellington occur in western Kay County and pass into the Ponca and Otoe reservations, occupying a triangular area between the Flint Hills and the red beds. A glance at the map (Pl. I) will reveal the fact that these formations narrow rapidly in northern Oklahoma and their place is taken by the red beds. Perhaps it is more correct to state that the color of the shales changes to the south, becoming red, while at the same time more of the red sandstone comes in, so that finally the formation changes to typical red beds. On the State line the distance from the Winfield formation, the upper conspicuous limestone member, to the eastern outcrop of the red beds is perhaps 30 miles; on the southern line of Kay County, Okla., it is not more than 15 miles, while farther south the line of separation can not be determined, for the reason that the limestone disappears and its place is taken by red shales and sandstones. In southern Kansas there are three distinct kinds of Permian rocks: First, the heavy limestones in eastern Cowley County and along Walnut River; second, the bluish and gray clays and shales of the Marion and Wellington formations from Walnut River to western Sumner County; and third, the typical red beds consisting of red sandstones and clays extending from this point nearly to the west line of the State. In eastern Oklahoma, on the other hand, only the red beds appear.

Thus it is seen that the red beds extend farther east in Oklahoma than in Kansas, and that the eastern limit of the red beds does not coincide with the line of separation between the Pennsylvanian and Permian. In other words, the red color of the rocks, which has been thought characteristic of only the Permian of the region, in fact transgresses far into the region of the Pennsylvanian rocks. This means, of course, that the line of separation between the rocks of these two epochs must finally be drawn far out in the red beds, and this the writer has attempted to do.[a]

GENERAL RELATIONS OF PERMIAN ROCKS IN OKLAHOMA.

Permian rocks, usually known as the " red beds," occupy the greater part of Oklahoma. This series of rocks is by far the most important in the Territory, inasmuch as it is not only the origin of nearly all the soils, but it also supplies most of the building stone, gypsum,

[a] See footnote, p. 32.

salt, and other economic products, and at the same time furnishes the water supply for the greater part of the Territory. These rocks have been studied for a number of years both in Kansas and Texas, and considerable literature has accumulated upon the subject,[a] but no attempt has ever been made to write a description of the red beds as a whole, nor is such a task contemplated here. All that is attempted is, first, to give only such references as will enable the reader to understand former classification, and afterwards to present a classification, based upon the results of several years field work, that is believed to embody such conditions as exist in Oklahoma.

The geological age of the red beds has long been an open question. The reason for this uncertainty has always been a lack of fossils, for until within the past few years organic remains had been found in but one or two localities in the Oklahoma red beds, and in Kansas none at all. Recently, however, fossils, both vertebrates and invertebrates, all of Permian age, have been discovered in at least five general localities in the red beds of Oklahoma. It seems reasonably certain, however, as shown by Adams,[b] that a large part of the typical red beds rocks in eastern Oklahoma are really Pennsylvanian in age, and, on the other hand, since fossils are not at the present time known to exist in the higher members of the series, the age of that part of the red beds is still open to doubt. And, moreover, until the correlation with the Texas red beds has been more fully worked out and fossils collected and identified throughout the entire region the matter can not be considered as settled. Instead of using any strictly geologic term in speaking of the rocks of the series the writer will employ the name of "red beds," by which the rocks are generally known, to include the rocks of both the Pennsylvanian and Permian ages, it being understood that the rocks above the lower part of the Enid formation are regarded as Permian in age and those below this point as Pennsylvanian.

The red beds area of the southern part of the Great Plains extends for 600 miles or more across Kansas, Oklahoma, Indian Territory, Texas, and New Mexico. The most northern exposure of the beds, so far as known to the writer, is near Arlington, a few miles south of Hutchinson, Reno County, Kans. To the southwest they pass under the Tertiary of the High Plains, or Llano Estacado, and appear in the valleys of the Pecos and Rio Grande in New Mexico.

The eastern border of the outcrop of the red beds in Kansas and Oklahoma is a crescent-shaped line running southeast from near Hutchinson and east of Kingman, Kans., crossing the Kansas-Oklahoma line at Caldwell, then trending southeast near Nardin,

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[a] See under "Classification." [b] Loc. cit.

Tonkawa, and Red Rock, cutting diagonally across the strike of Pennsylvanian limestones and shales through the eastern parts of Payne and Lincoln counties to the western part of the Creek and Seminole nations. Here the line swings to the southwest and continues through the Chickasaw Nation to the vicinity of Davis, Ind. T., passes around the western end of the Arbuckle Mountains, crossing Red River 35 miles west of Gainesville, Tex., and, as stated by Adams, cuts diagonally across the strike of Pennsylvanian rocks in Archer, Young, and Throckmorton counties, Tex.[a] Wherever exposed, the rocks of this series along their eastern border merge into the Pennsylvanian limestones and shales.

The western limit of the red beds in Oklahoma and Kansas is much more irregular. In all instances, so far as observed, the upper line is one of unconformity. The superjacent rocks range from the Lower Cretaceous to those of the latest geologic formations, but by far the greater part of the overlying deposits are of the later Tertiary age. In places the Tertiary deposits extend east along some divide nearly across the red beds area. In other localities they have been almost removed by erosion and the red beds are exposed far to the west of the main body. Along the valleys of the larger streams the red rocks reach many miles westward, although the level uplands are covered by the Tertiary beds. The South Canadian, for instance, has cut through the Tertiary deposits for practically its entire course across the plains, and red beds are everywhere exposed. Other streams, including the Salt Fork, Cimarron, North Canadian, Washita, and Red rise in the Tertiary deposits west of the red beds and flow southeast across these beds and pass into the Pennsylvanian area to the east. It is along the course of these rivers that some of the finest exposures of the red beds may be seen.

CLASSIFICATION.

The red beds in Texas were described by Professor Cummins[b] in 1891. He divided the series into the Wichita beds, the Clear Fork beds, and the Double Mountain beds. In 1902 Professor Hill proposed the term "Brazos series" to apply to the red beds as a whole[c] Professor Cragin has published two papers on the red beds of Kansas and Oklahoma. In his first paper, published in 1896,[d] the red beds were designated the Cimarron series in contradistinction to the Big

[a] Op. cit., p. 196.

[b] Cummins, A. W., Second Ann. Rept. Geol. Survey Texas, 1891, pp. 394–424.

[c] Hill, Robert T., Geology and geography of the Black and Grand prairies, Texas: Twenty-first Ann. Rept. U. S. Geol. Survey, pt. 7, 1901, p. 100.

[d] Cragin, F. W., The Permian system in Kansas: Colorado Col. Studies, vol. 6, 1896, p. 3.

Blue series or lower Permian, and the Permian rocks were divided as follows:

Cimarron series	Kiger division	Big Basin sandstone.
		Hackberry shales.
		Day Creek dolomite.
		Red Bluff sandstone.
		Dog Creek shales.
	Salt Fork division	Cave Creek gypsums.
		Flowerpot shales.
		Cedar Hills sandstones.
		Salt Plain measures.
		Harper sandstone.
Big Blue series	Sumner division	Wellington shales.
		Geuda salt measures.
	Flint Hills division	Chase limestones (Prosser).
		Neosho shales (Prosser).

Professor Cragin afterwards adopted Prosser's name, Marion, instead of Geuda salt measures. In a subsequent paper Professor Cragin modified his classification of the Cimarron as follows:[a]

Kiger	Taloga	Quite variable with locality.
	Day Creek	None.
	Red Bluff	None determined.
Salt Fork	Dog Creek (Stony Hills)	Chapman dolomite.
		Amphitheater dolomite.
	Cave Creek	Shimer gypsum.
		Jenkins clay.
		Medicine Lodge gypsum.
	Glass Mountain	Flowerpot shales.
		Cedar Hills sandstone.
	Kingfisher	Salt Plain.
		Harper.

The writer has spent four seasons in studying the red beds of Oklahoma and finds that there are local conditions which make it desirable to propose a somewhat different classification from any previously suggested. The writer has used the earlier classifications as far as they can be applied, and he has adopted the names which are equivalent to those that he recognizes, but where new classification has become necessary he has given new names to avoid confusion of terms.

The following table shows the relation of Professor Cragin's revised classification to the one used in this report:[b]

[a] Cragin, F. W., Observations on the Cimarron series: Am. Geologist, vol. 19, 1897, pp. 351–363.

[b] See article by the writer in Second Bien. Rept. Oklahoma Geol. and Nat. Hist. Survey, 1902, pp. 42 et seq.

Relations of classifications of Permian rocks.

Cragin's classification.	Classification used in this report.	
Taloga	Quartermaster formation.	
	Greer formation	Mangum dolomite member.
		Collingsworth gypsum member.
		Cedartop gypsum member.
		Haystack gypsum member.
		Kiser gypsum member.
		Chaney gypsum member.
Day Creek	Woodward formation	Day Creek dolomite member.
Red Bluff		Whitehorse sandstone member.
Dog Creek (Stony Hills)		Dog Creek shales member.
Cave Creek	Blaine formation	Shimer gypsum member.
		Medicine Lodge gypsum member.
		Ferguson gypsum member.
Glass Mountain	Enid formation.	
Kingfisher		

The term "formation" is here used in a general sense to designate a larger or smaller sequence of strata, which in one instance corresponds to a formation having a simple and uniform lithologic character, or in another, to a group of such formations. The classification is intentionally elastic, since the precise stratigraphic relations, which could be determined only with accurate base maps and detailed surveys, have not yet been ascertained. The generalized section shown in fig. 2 represents graphically the classification used in this report.

ENID FORMATION.

The Enid formation includes all the rocks of the red beds from the base of the Permian to the lowermost of the gypsum ledges on the eastern slope of the Gypsum Hills. The top of this formation, however, is not a plane, since the gypsum beds, which mark its uppermost limits, are found to be more or less lenticular when traced for long distances. The Enid comprises all of the Harper, Salt Plain, and Cedar Hills members and the greater part of the Flowerpot member of Cragin's first paper and the Kingfisher and Glass Mountain formations of his second paper. It is named from the county seat of Garfield County.

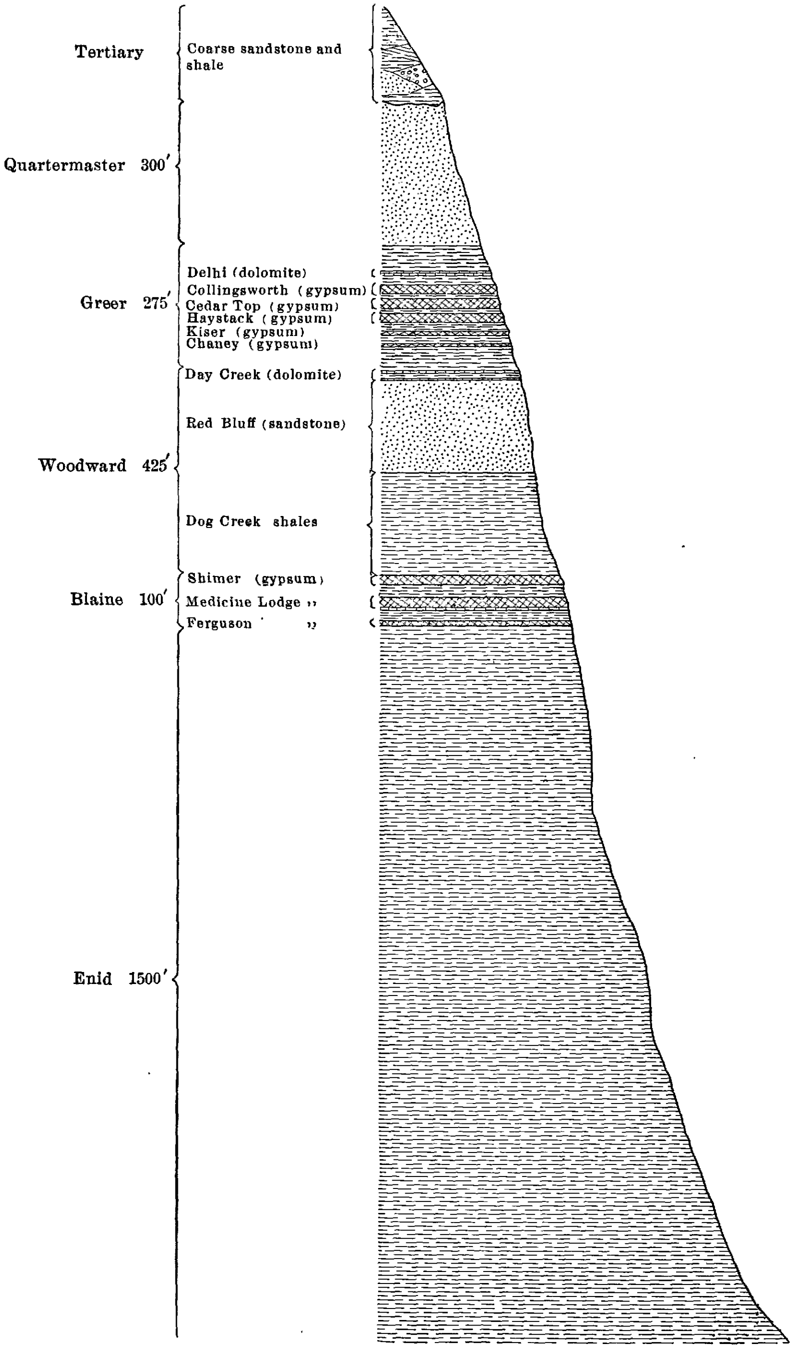


FIG. 2.—Generalized section of the Oklahoma Permian red beds. In the above legend "Delhi" should read Mangum and "Red Bluff" Whitehorse.

The Enid outcrops over a larger area than any other formation of the Permian in Oklahoma and is exposed extensively in adjoining States. In Kansas it outcrops over parts of Sumner, Kingman, Reno, Barber, and Comanche counties and all of Harper County. In Oklahoma it is found in the western parts of Kay, Noble, Payne, Logan, Oklahoma, and Cleveland, parts of Woods, Woodward, Blaine, and Canadian, and all of Kingfisher, Garfield, and Grant counties. It also extends into the Chickasaw Nation.

The Enid formation consists chiefly of brick-red clay shales, with some interbedded ledges of red and whitish sandstone. It occurs in two general areas, which may be distinguished on lithological grounds as follows: An eastern area, in which there are a few inconspicuous ledges of sandstone, and a western area, in which the sandstones are mostly wanting. In the present state of knowledge it is impossible to draw an accurate line of separation between these two areas, and for this reason the strata in them are not defined as separate members.

The eastern area of the Enid formation is triangular and occupies several counties in the central part of the Territory, in which there is little hard rock of any kind. Its eastern boundary is approximately along a line from Blackwell to Norman and its western limit is along a line from Alva to El Reno. It includes eastern Blaine, Canadian, and Woods counties, all of Grant, Garfield, and Kingfisher, and the western parts of Kay, Noble, Logan, Oklahoma, and Cleveland counties.

Throughout this area the soil is red, except where later deposits cover the uplands or among the sand hills north of some of the streams. Red clays and occasional ledges of thin sandstone outcrop along the bluffs of a few streams. These sandstone ledges, however, are of comparatively little economic value, being generally too soft for building purposes. Quarries occur near Nardin, Kingfisher, Hennessey, and Luella. In the general absence of building stone, foundations for houses are usually made of brick, and artificial stone may come into use extensively.

The rocks of the western area of the Enid consist chiefly of red clay shale, some inconspicuous ledges of soft sandstone, and occasional bands of whitish or greenish shales, which vary from 1 inch to several feet in thickness. The upper strata are in places highly gypsiferous, and at some localities brine springs issue from them. No attempt is made to separate the eastern and western areas of the Enid formation, except to state that they are sometimes separable locally a few miles east of the base of the Gypsum Hills.

The Enid formation is in most places strongly impregnated with mineral salts, particularly common salt and gypsum. In many localities the water from the wells is unfit for drinking, and the people are obliged to use cistern water.

In the western area, along the base of the Gypsum Hills, salt measures are prominent. The Little Salt Plain, in northern Woodward County, near the Kansas line, and Big Salt Plain, in the northeastern part of the same county, are both located in the Cimarron channel, while the Salt Creek Plain, in north-central Blaine County, is on a tributary of the same river. At the Salt Creek Plain some of the most typical saline springs in the Territory may be seen. In several canyons at the head of Salt Creek are exposures of a grayish-red, mottled, saliferous sandstone. This sandstone is often distinctly cross-bedded, and appears to have been tilted; from it issue numerous springs of strong brine. So far as known, this sandstone is not found elsewhere in the region, and it seems to be a local phase of the clay-shale formation. It is possible, however, that these sandstones are not themselves salt bearing, but are merely porous strata through which brines from some deep-seated source reach the surface. The water from the springs issuing from the various canyons forms rills, which, in turn, unite to form the headwaters of Salt Creek.

Above the level of the Salt Plains and below the gypsum ledges there intervene 150 or 200 feet of red clay shale, which is interspersed with bands of whitish, greenish, and bluish clay and local thin ledges of gypsum.

The following analyses of shales from the slope of the Gypsum Hills indicate their chemical constitution:

Analysis of clay from Stucks Canyon, at the head of Salt Creek, 4 miles west of Ferguson, Blaine County, Okla.

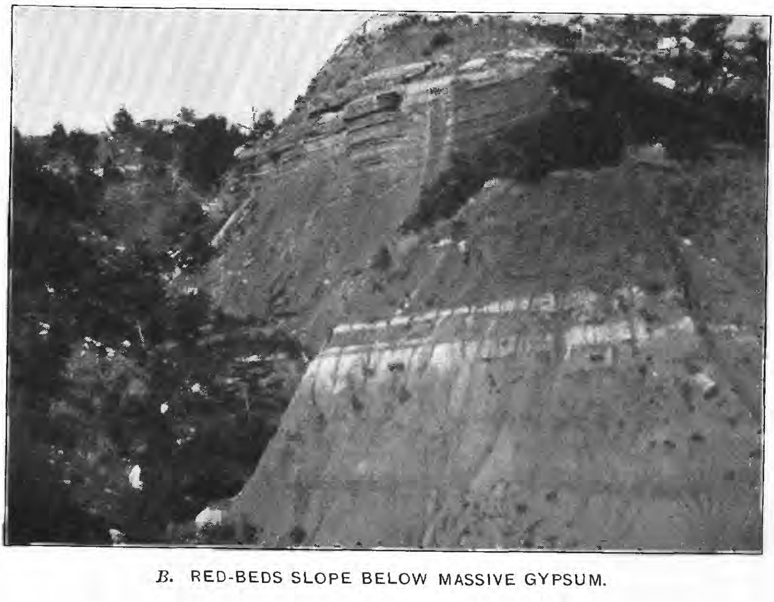
	Per cent.
Silica	64.17
Calcium oxide	1.34
Iron oxide	8.10
Aluminum oxide	14.80
Magnesium sulphate	5.57
Magnesium carbonate	.27
Water	6.54
Total	100.79

Analysis of so-called copper ore from Henquenets Canyon, on Salt Creek, 4 miles east of Ferguson, Blaine County, Okla.

	Per cent.
Silica and insoluble silicates	67.43
Iron oxide	16.95
Calcium carbonate	1.85
Magnesium carbonate	5.41
Sodium chloride	4.99
Water	3.40
Total	100.03

The material analyzed was a concretion-like piece of green clay or shale. It is thought by some to be copper ore, on account of its color,

A. TYPICAL RED-BEDS EROSION.



B. RED-BEDS SLOPE BELOW MASSIVE GYPSUM.

but it contains no copper, and the green color is due to some form of iron, probably a mixture of ferrous and ferric oxides.

Analysis of gypsiferous green clay from slope of the Gypsum Hills, near Mount Heman, eastern Woodward County, Okla.

	Per cent.
Calcium sulphate	58.06
Calcium carbonate	5.35
Magnesium carbonate	3.49
Water	15.38
Oxides of iron and aluminum	3.27
Silica and insoluble residue	13.58
Total	99.13

The very soft material of which this shale is composed renders it particularly susceptible to the action of weathering and the entire thickness is characterized by such marked erosion forms as are shown on Pl. VII, *B*. Wherever the cap of gypsum has been removed over any considerable area, or for any great length of time, these shales have been worn away. Perhaps the most common erosion form is that of cones of red clay cut by deep and uneven gullies—regular badlands structure. Not infrequently rows of these cones are arranged palisade-like along the summit of a fast-disappearing ridge into which gullies are eating their way (Pl. VII, *A*.) In the Glass Mountains, for instance, the slope of the bluffs below the gypsum ledges is much cut by erosion. The action of the water has produced a great variety of unusual forms; small buttes and buttresses, cones and minarets, pinnacles and peaks, shoulders and ridges, domes, towers, chimneys, gullies, ravines, and all sorts of fantastic shapes have been carved by erosion from the blood-red shales along the slope of the bluffs.

The face of the bluffs is frequently covered with fragments of gypsum, either in the form of plates of transparent selenite (Pl. VIII, *B*) or in the form of concretionary masses (Pl. VIII, *A*). The selenite is usually found in seams running diagonally through the clay, and the crystals weather out and reflect the sun from thousands of points, making the slopes appear to be covered with glass, whence the name Glass Mountains.

An analysis of two specimens of the transparent selenite and one of the concretionary masses is given below.

Analysis of a thin ledge of satin spar from the canyon 4 miles west of Ferguson, Blaine County, Okla.

	Per cent.
Calcium sulphate	78.87
Water	20.94
Insoluble residue	.18
Total	99.99

Analysis of selenite flakes from Mount Heman, eastern Woodward County, Okla.

	Per cent.
Calcium sulphate	76.76
Magnesium carbonate	.84
Water	19.80
Iron and aluminum oxides	1.45
Insoluble residue	.95
Total	99.80

Analysis of crystalline gypsum concretions from Henquenets Canyon, 4 miles west of Ferguson, Okla.

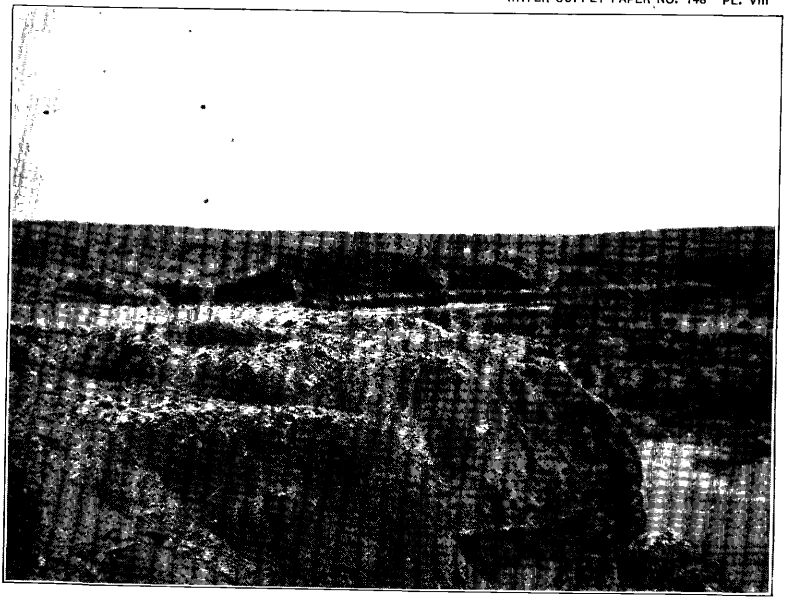
	Per cent.
Calcium sulphate	75.20
Magnesium carbonate	1.58
Water	17.32
Oxides of iron and aluminum	2.52
Insoluble residue	4.54
Total	100.89

The thickness of the Enid formation is unknown, but it is probably not less than 1,200 feet, and may reach 1,500 feet. The well at Fort Reno, a section of which is shown in Pl. XXII, was started at about the same level as the top of this formation and reached a depth of 1,370 feet, the drill stopping in red clay. It is possible, however, that this well passed through the Permian rocks into red beds of Pennsylvanian age beneath. At Spencer, 12 miles east of Oklahoma City, a well passed out of the red beds at a depth of 1,550 feet. The greater part of this thickness, however, was in Pennsylvanian rocks.

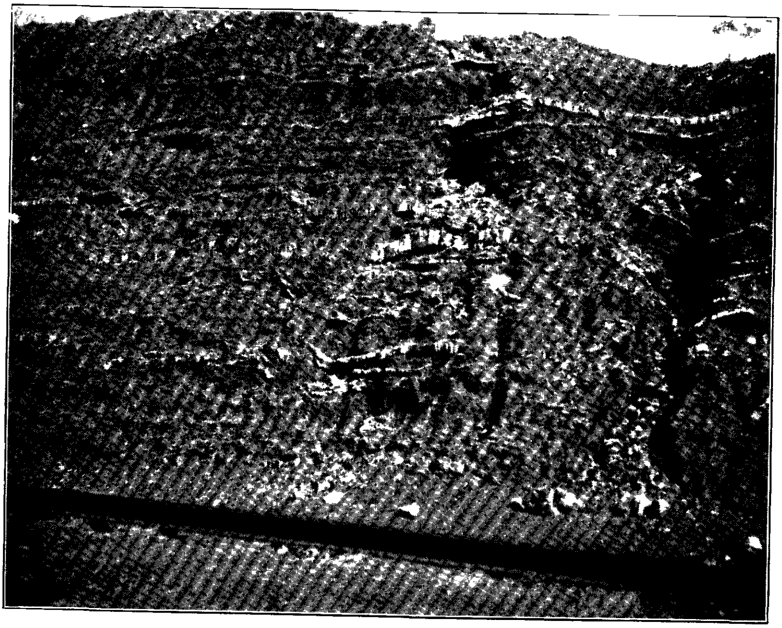
BLAINE FORMATION.

The Blaine formation consists of red shales with interbedded strata of gypsum and thin ledges of dolomite. It includes the portion of Professor Cragin's Flowerpot formation above the base of the Ferguson gypsum and all of his Cave Creek formation. It is named from Blaine County, Okla., where it is typically developed.

The characteristic which justifies its recognition as a formation is the abundance of gypsum contained in it, and its extent and limits are defined accordingly. The bottom of the lowest massive gypsum bed—the Ferguson gypsum member—is the base of the formation throughout its occurrence northwest from Darlington, Canadian County. Where it disappears the shales of the Enid continue up to the base of the Medicine Lodge gypsum member, which necessarily becomes the basal member of the formation. The top is the Shimer gypsum member. Where the gypsum members run out, as they all do north of Darlington, the Blaine can not be distinguished readily



A. GYPSUM CONCRETIONS COVERING THE SLOPES OF RED CLAY, GLASS MOUNTAINS.



B. SELENITE AND SATIN SPAR IN RED CLAY.

from the Enid below and the Woodward above, and this local division of the red beds can not well be traced. The Blaine formation gives rise to an escarpment known as the Gypsum Hills, extending from Darlington northwestward between North Canadian and Cimarron rivers, through the corner of Kingfisher County, across Blaine County into Woods County. At the Glass Mountains the escarpment approaches closely the Cimarron, which it parallels northwesterly to the Kansas boundary. Beyond Cimarron River the gypsum beds are exposed in the northwestern corner of Woods and pass into Barber County, Kans., where they trend north and northwest and finally disappear under the Tertiary sands north of Medicine River, 30 miles northwest of Medicine Lodge.

From the east the Gypsum Hills appear as a wall crowned with a

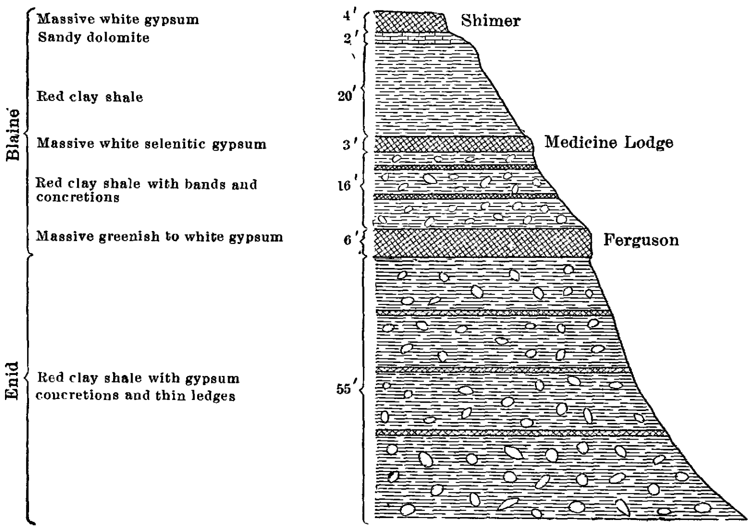


FIG. 3.—Section 2 miles east of Altona, Okla.

white band, but the sky line is not continuous, as numerous breaks occur where the gypsum ledge has been dissolved by water and carried away. The general appearance is rather that of an uneven row of flat-topped buttes or mesas of various sizes than a single hill with a continuous escarpment. To these buttes the name "Mansard Mounds" has been given by one writer, in fancied resemblance to a mansard roof.[a] Not infrequently a few bold points stand out at a distance east of the main range, and these outliers being more conspicuous have sometimes received distinct names, as Glass Mountains, Mount Heman, Cedar Hill, and Henquenets Butte. Particular names have been given to certain parts of the range, as Stony Hills, in Blaine County, east of Watonga, and Chatauqua Mountains for

[a] Hay, Robert, Bull. U. S. Geol. Survey No. 57, 1890, p. 22.

the same range farther north, extending to the Glass Mountains. The name Marcy Range has been proposed for the entire section of hills. These names, however, probably will never supersede the much-used term, "Gyp Hills."

The Blaine formation consists of three ledges of massive gypsum interstratified with red shale and an occasional local ledge of more or less arenaceous and argillaceous dolomite, which usually occur at the base of the heavy gypsum. Only the gypsum members will be described in this report. The shales which make up the greater part of the red beds have not been differentiated and the dolomites

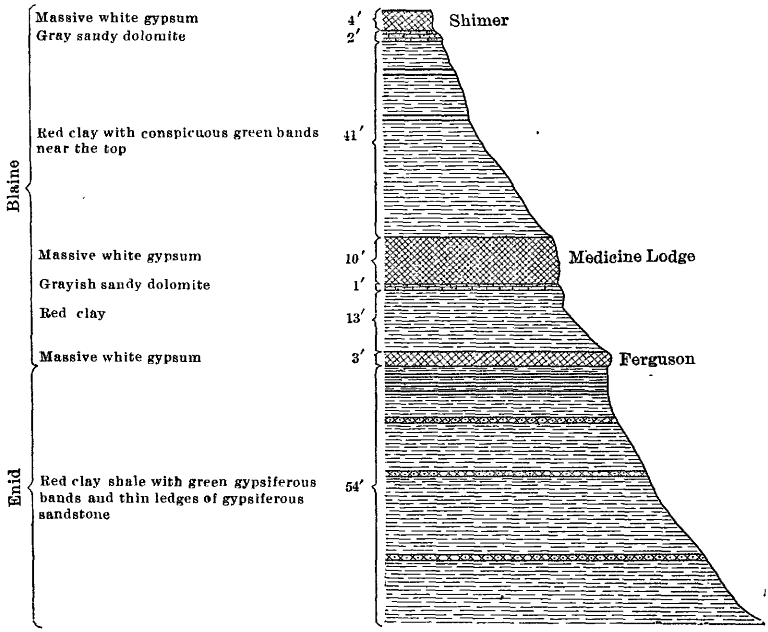


FIG. 4.—Section near Watonga, Okla., in sec. 32, T. 16 N., R. 10 W.

are too local to deserve formation rank. The gypsum members of the Blaine are briefly described below.

Ferguson gypsum member.—The Ferguson gypsum member is the lowermost of the thick gypsum beds in the red beds of this region. It varies in color from almost pure white to a dirty brown, according to the purity of the mineral. It outcrops usually a little more than half way up the slope of the escarpment formed by the formation, but is rarely conspicuous. In Canadian, Kingfisher, and southern Blaine counties it is the thickest of the three gypsum members, but it thins out to the north and disappears in the region of the Glass Mountains, north of which only the two upper gypsum ledges appear. The name is derived from the town of Ferguson, Blaine County, in the hills southwest of which the ledge is typically exposed. The following is an analysis of this ledge:

Analysis of gypsum from 4 miles west of Ferguson, Okla.

	Per cent.
Calcium sulphate	80.09
Water	19.82
Insoluble residue	.65
Total	100.56

On Pl. IX, *A*, the Ferguson is the lowermost of the gypsum members, scarcely distinguishable as a white line halfway up the slope. Its relation to the other gypsum members is shown in fig. 5.

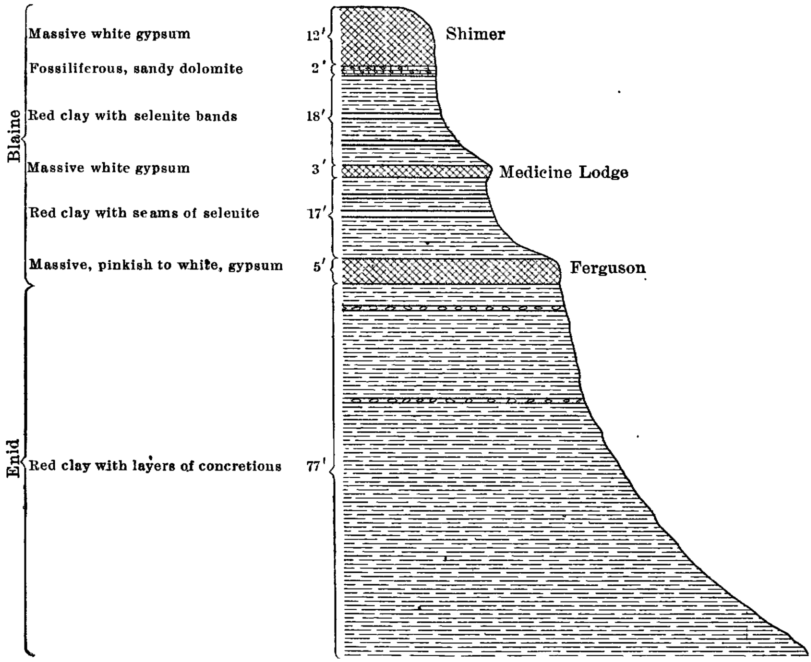


FIG. 5.—Cedar Hill section in SW. ¼ sec. 18, T. 16 N., R. 10 W.

Medicine Lodge gypsum member.—The Medicine Lodge gypsum is the most conspicuous gypsum deposit in the red beds. It extends uninterruptedly from near the head of Medicine River, in Kansas, to Canadian County, Okla., and is in most places the ledge which forms the cap of the Gypsum Hills. Perhaps no better description of this ledge can be given than that of Professor Cragin, who first described it in Kansas, as follows:[a]

In minor parts, the Medicine Lodge gypsum is nearly pure white; in others it is suffused with leaden-gray or dusky-brown shades; most commonly it is

[a] Cragin, F. W., The Permian system in Kansas: Colorado Col. Studies, vol. 6, 1896, p. 32.

grayish white mottled with feebly defined dark spots. The latter are generally the expression of a tendency that existed in the gypsum to form crystals under the original conditions of a precipitation, as is shown by the occurrence of spots in every gradation from ill-defined spot-like segregations to well-formed crystals of selenite. Some of the crystals are of the common rhomboidal pattern, others are of the stellar type.

In the region around the head of Salt Creek and its tributary, Bitter Creek, in Blaine County, Okla., the Medicine Lodge gypsum,

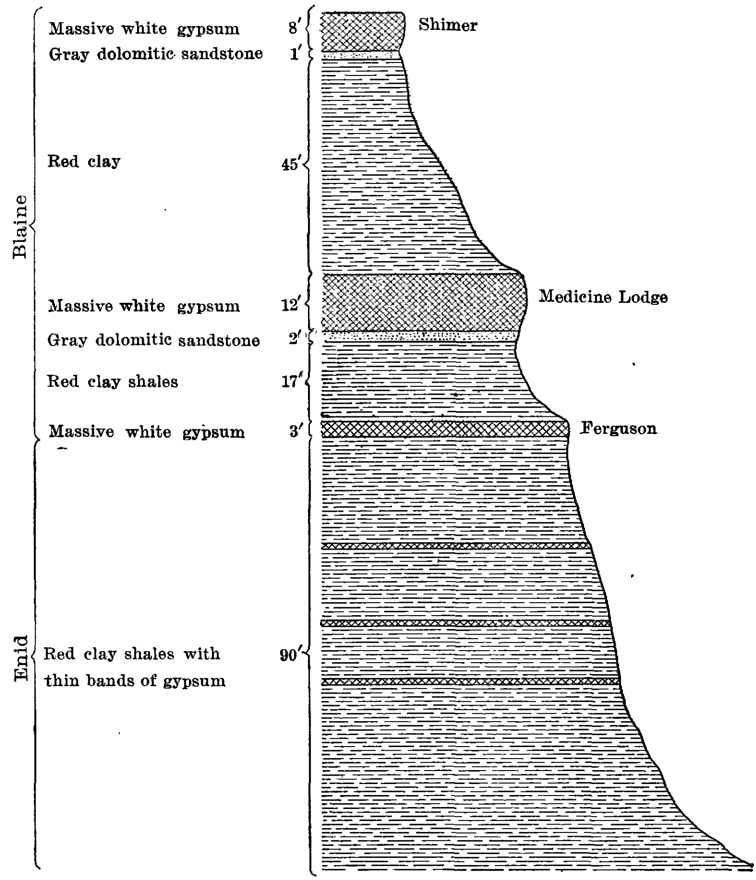
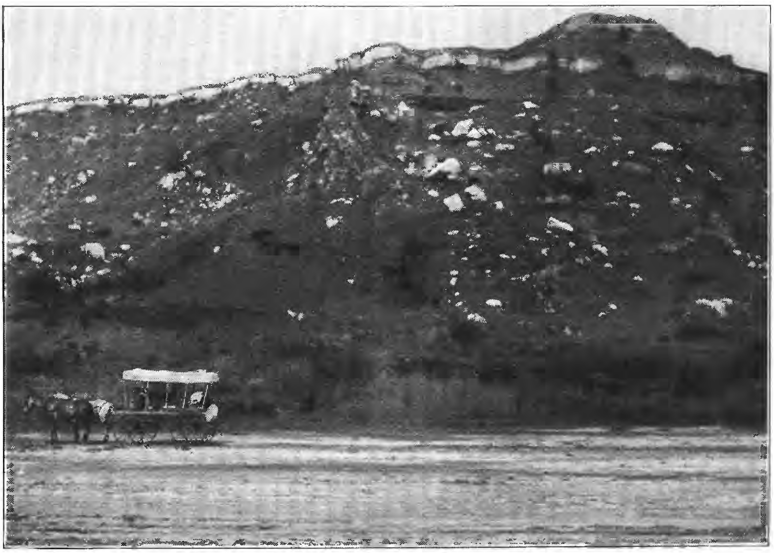


FIG. 6.—Hitchcock section 4 miles south of Hitchcock, Okla., along Rock Island Railroad.

the middle of the three ledges, has a peculiar form. The middle part of the ledge, usually 8 to 10 feet thick, is much harder than the rest of the bed or any other ledge of gypsum known in the Territory. As seen from below, this part of the ledge is pure white, as shown on Pl. IX, *B*. It breaks with an even fracture, so that it may often be distinguished a mile away. On closer examination it is found to be very hard and very fine grained, usually pure white, but with an occasional bluish

A. CEDAR HILL, EAST OF WATONGA, OKLA.

Showing Ferguson gypsum on the slope and Medicine Lodge gypsum as a cap.



B. ANHYDRITE MEMBER OF THE MEDICINE LODGE GYPSUM.

Salt plain in foreground.

or reddish tint. It takes a good polish and has the general appearance of marble, and is known locally as the Salt Creek marble. And sometimes it is difficult to persuade farmers who own a part of the ledge that the rock is not valuable for building stone or for ornamental purposes. A chemical analysis reveals the fact that the rock approaches an anhydrite—that is, it has a very small per cent of water of crystallization. Ordinary gypsum contains from 20 to 21 per cent of water, while in the rock from this ledge the amount of water is sometimes as low as 2 per cent.

The area covered by the anhydrite is about 10 miles long and 1 mile or more wide. No adequate explanation of this peculiarity of structure has ever been forthcoming. It is probably because of this relatively harder ledge, which resists erosion, that the marked topographic forms mentioned above are due.

The following analyses show the relatively small amount of water in this rock:

Analyses of "marble" gypsum from the middle part of the Medicine Lodge member.

	Per cent.	Per cent.
Calcium sulphate	94.83	92.73
Magnesium sulphate	1.93	------
Magnesium carbonate		3.15
Water	2.74	3.15
Insoluble residue		.33
Total	99.50	99.36

Analysis of "red marble" gypsum from the middle part of the Medicine Lodge member.

	Per cent.
Calcium sulphate	84.00
Calcium carbonate	3.41
Magnesium carbonate	2.13
Water	5.38
Oxides of iron and aluminum	.78
Insoluble residue	1.69
Total	97.39

The analyses given below indicate the composition of the gypsum from the lower, middle, and upper parts of the Medicine Lodge:

Analyses of gypsums from the lower (1), and middle (2 and 3) parts of the middle ledge of the Medicine Lodge member.

	Per cent.	Per cent.	Per cent.
Calcium sulphate	79.66	94.94	80.82
Water	20.22	4.95	20.89
Insoluble residue	.46	.67	.35
Total	100.34	100.56	102.06

No. 1 is very hard, being almost an anhydrite, and is left in large bowlders when the softer parts are worn away. No. 2 is softer and sometimes fills the place usually occupied by No. 1.

Analyses of gypsums from the upper part of the Medicine Lodge member.

	1. Per cent.	2. Per cent.	3. Per cent.
Calcium sulphate	78.41	78.23	89.30
Magnesium carbonate	2.03	.98	1.44
Oxides of iron and alumium	1.38	------	------
Water	18.23	20.75	9.33
Insoluble residue	.41	.34	.16
Total	100.46	100.30	100.23

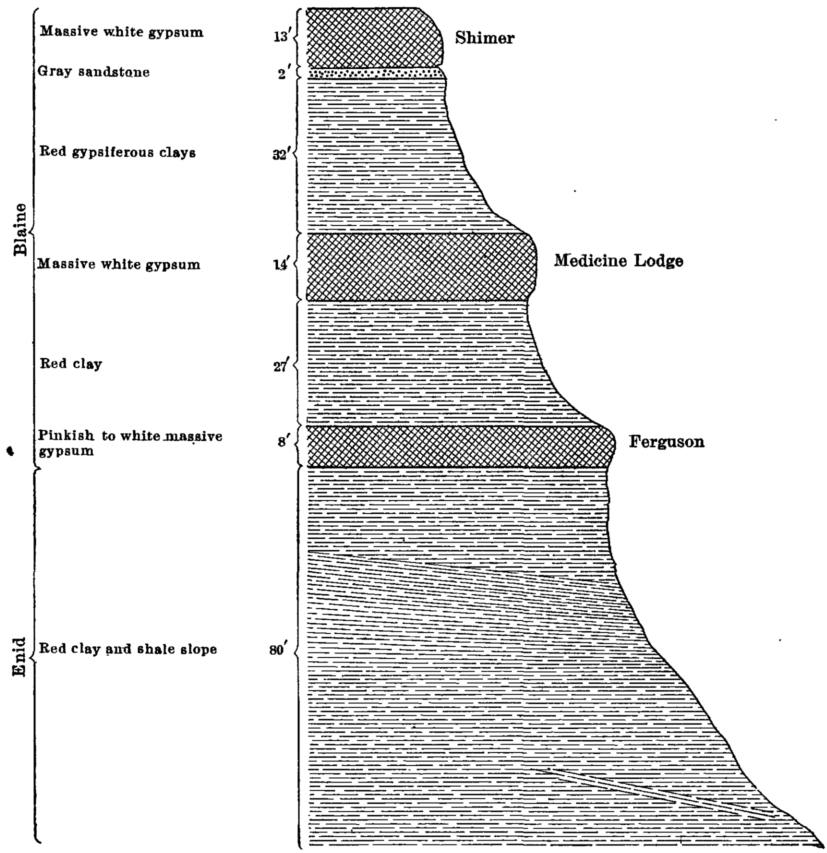


FIG. 7.—Bitter Creek section, 6 miles southwest of Ferguson, Okla., on West Branch of Bitter Creek.

Nos. 1 and 2 are the rocks that make up the greater part of the ledge and are used for plaster. No. 3 is harder material, approaching anhydrite, sometimes found in lumps or masses, and is not used for plaster.

The name Medicine Lodge is that of the county seat of Barber County, Kans., and was proposed by Professor Cragin in 1896.

Shimer gypsum member.—A third gypsum ledge. to which Professor Cragin gave the name Shimer gypsum, from a township in Barber County, Kans., where the rock was first studied, is the uppermost member of the Blaine formation. It is typically exposed either as the highest gypsum outcrop somewhat back from the brow of the hills, or as the cap rock of occasional bluffs and buttes overlooking

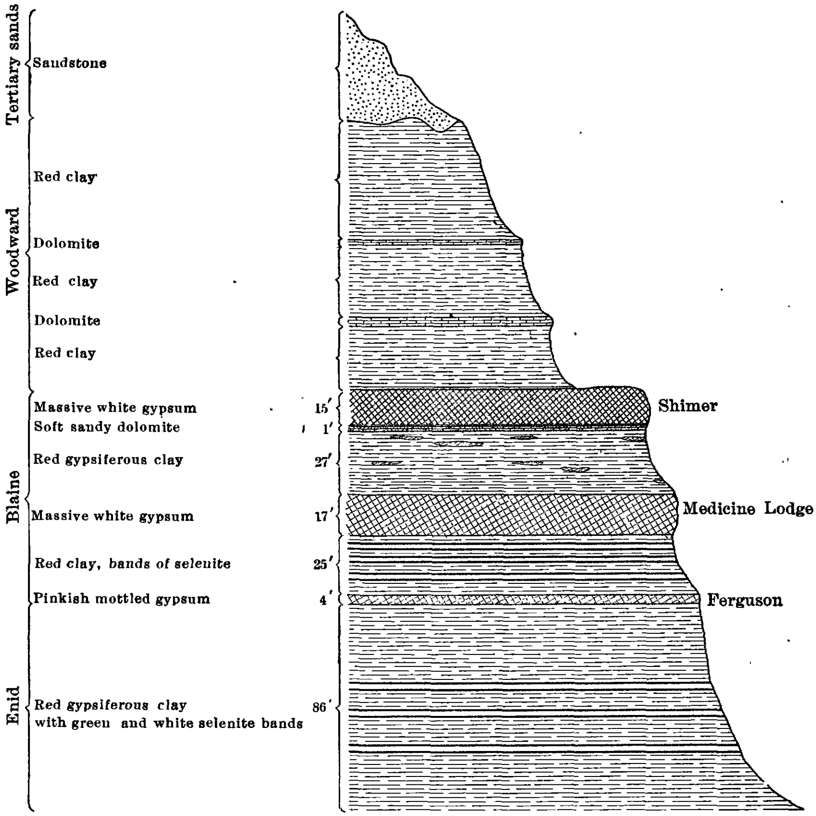


FIG. 8.—The Rubey section, in South Canyon, head of Salt Creek, at the Rubey stucco-plaster mill, Ferguson, Okla.

the slopes below. It is the upper white ledge shown in Pls. IX, *B*, and XXI, *A*. The description of the Medicine Lodge gypsum quoted above from Professor Cragin will in most places apply equally well to the Shimer, but the thickness of the upper ledge is not so great as that of the Medicine Lodge. Its areal extent and physical characters are about the same, except that so far as known there is no anhydrite in the Shimer.

The following analyses, made from specimens obtained from the

Shimer member of the Blaine formation in the canyons 4 miles west of Ferguson, indicate the constituents of this rock:

Analyses of gypsum from the lower (1), middle (2), and upper (3) parts of the Shimer member.

	1. Per cent.	2. Per cent.	3. Per cent.
Calcium sulphate	78.22	80.16	79.07
Water	21.22	20.00	21.00
Insoluble residue	.87	.86	.39
Total	100.31	101.02	100.46

In some localities the shale member which separates the Medicine Lodge from the Shimer thins out and the two massive gypsum ledges are practically continuous. Caves are not uncommon below the various ledges. A generalized section of one of these caves is shown in fig. 9.

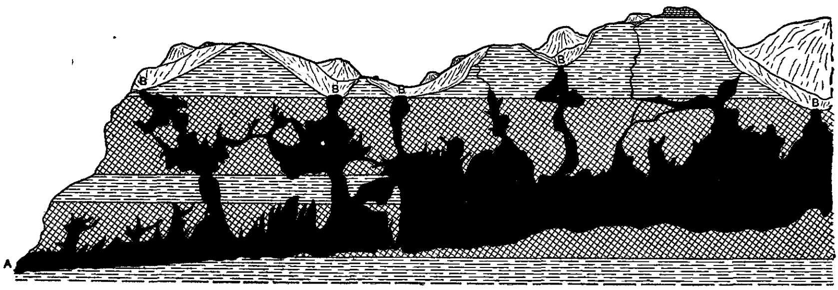


FIG. 9.—Section of gypsum cave.

The thickness of the Blaine formation varies considerably with the locality, but it averages about 75 feet.

WOODWARD FORMATION.

Above the Blaine is approximately 300 feet of rocks, consisting chiefly of shales, sandstones, and dolomites, and distinguished from the formations above and below by the prominence of dolomites and the absence of gypsum. The formation includes all the rocks between the two conspicuous gypsum horizons, the Blaine and the Greer, and in general it may be divided into three members—the Dog Creek, the Whitehorse and the Day Creek—which were all recognized and named by Professor Cragin from localities in Kansas, except that his term Red Bluff was preoccupied, and for it the name Whitehorse has been substituted. For the formation as a whole, from the top of the Shimer gypsum to the base of the Chaney gypsum, the name Woodward is proposed, from the county in Oklahoma where the strata are well represented.

Dog Creek shales member.—The Dog Creek member is composed mainly of clays, containing occasional thin ledges of magnesian limestone, which in places grade into a fair quality of dolomite.

The ledges, however, are usually thin and rarely sufficiently conspicuous to be worthy of more than passing notice. Professor Cragin's original description of this member is as follows:[a]

The Dog Creek * * * consists of some 30 feet, or locally of a less or greater thickness, of dull-red argillaceous shales, with laminæ in the basal

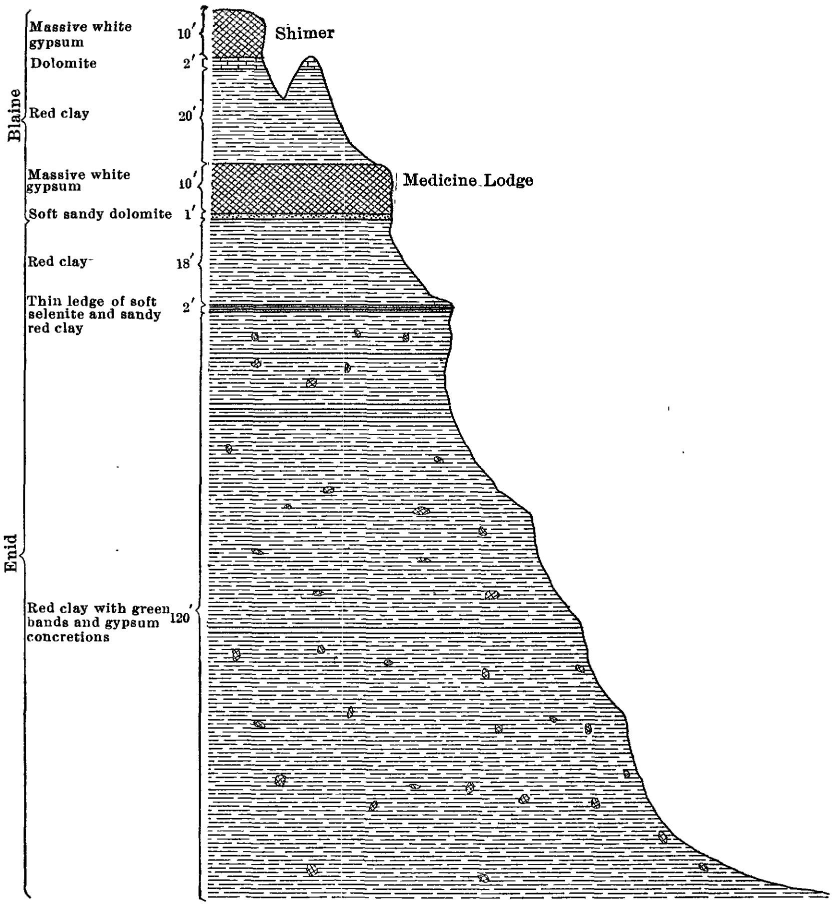


FIG. 10.—Roscoe section, 1 mile south and 1½ miles west of Roscoe, Okla.

part and one or two ledges of unevenly lithified dolomite in the upper. The color of these shales resembles that which prevails in most of the divisions below rather than of the terranes above the Dog Creek.

In his second paper he modifies his description in this way:

In central Oklahoma it is a great dolomite formation, laminated dolomite occupying a considerable part of the thickness.[b]

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[a] Op. cit., p. 39.

[b] Cragin, F. W., Observations on the Cimarron series: Am. Geologist, vol. 19, 1897, p. 358.

In his second paper he suggests that the name Dog Creek be changed to Stony Hills. The writer agrees that the name Dog Creek is, perhaps, not the best that could be used, but in view of the fact that the dolomites which make up the Stony Hills in eastern Blaine county belong to the Blaine formation and do not belong to the Dog Creek, there seems to be no good reason for using the name Stony Hills to designate this member.

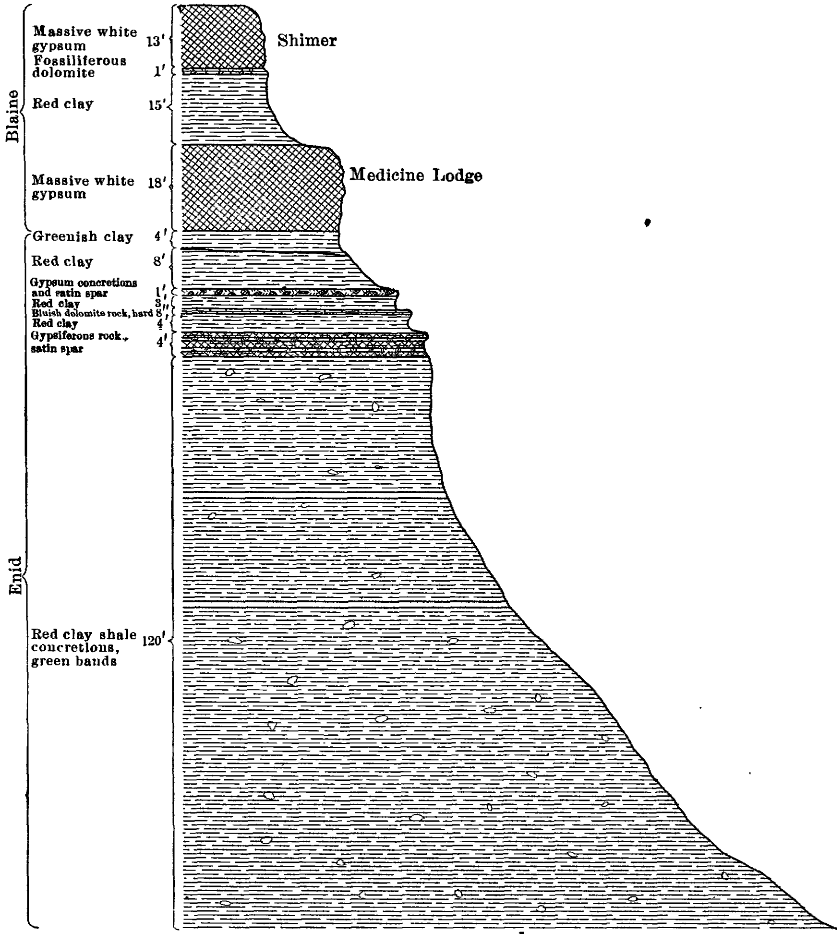

FIG. 11.—Glass Mountain section, on northwest side of the mountain.

Studies made during the last three years have demonstrated that in many parts of Oklahoma the thickness of the Dog Creek is much greater than that given by Professor Cragin. Near Quinlan, in eastern Woodward County, the aneroid readings indicate 225 feet as the thickness of these beds, measured from the top of the underlying gypsums of the Blaine formation to the sandstones of the next higher formation of this member, the Whitehorse, and in a number of localities 150 and 175 feet were recorded. Exposures are common along the top of the Gypsum Hills from Canadian County to the Kansas line and beyond.

Whitehorse sandstone member.—The Whitehorse sandstone was also described (under the name Red Bluff sandstone) by Professor Cragin in his first paper, as follows:[a]

This formation consists of some 175 or 200 feet of light-red sandstones and shales. * * * Viewed as a whole it is very irregularly stratified, being in

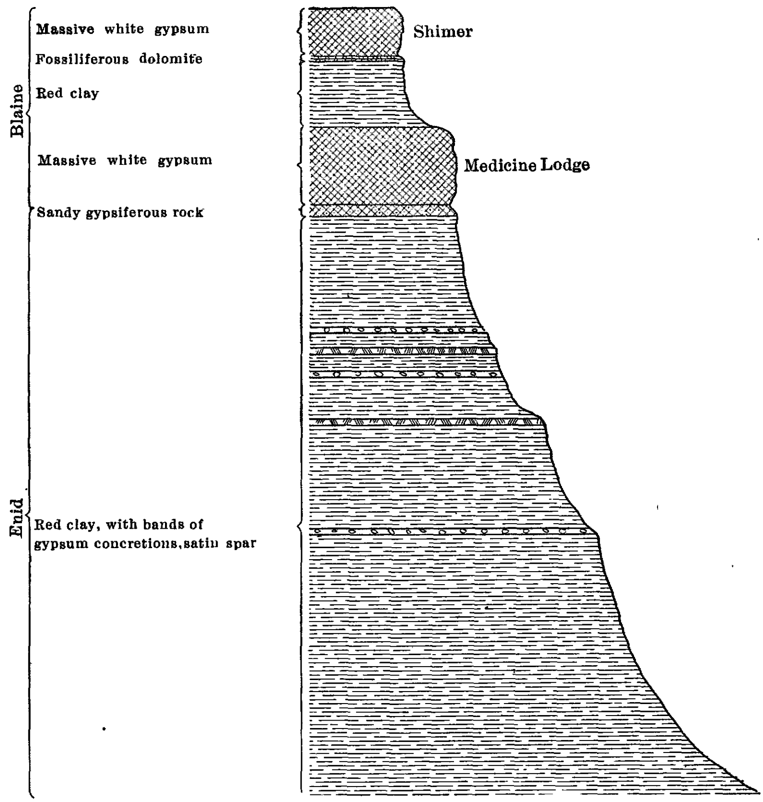

FIG. 12.—Granton section; gypsum-capped butte 1 mile east of Granton, Okla.

some cases considerably inclined, in others curved, and this oblique and irregular bedding, being on a much larger scale than that of the ordinary cross beddings, at first glance gives the impression of dips, anticlines, synclines, etc., that have been produced by lateral pressure, the dips, however, being in various directions. * * * The Red Bluff beds exhibit the most intense coloration of any of the rocks of the series. When the outcrops are wet with recent rains their vividness of color is still greater, and the contrasts of their almost vermilion redness with other colors of the landscape is most striking.

[a] Cragin, F. W., The Permian system in Kansas: Colorado Col. Studies, vol. 6, 1896, p. 40.

Spots and streaks of bluish or greenish gray sometimes occur in these rocks, but not to nearly so great an extent as in the lower beds. The sandstones of the Red Bluffs are generally too friable for building stone, but in some instances selected portions have proved hard enough for such use and are fairly durable.

In Oklahoma the Whitehorse member often weathers into conspicuous buttes and mesas. For instance, in eastern Woodward and

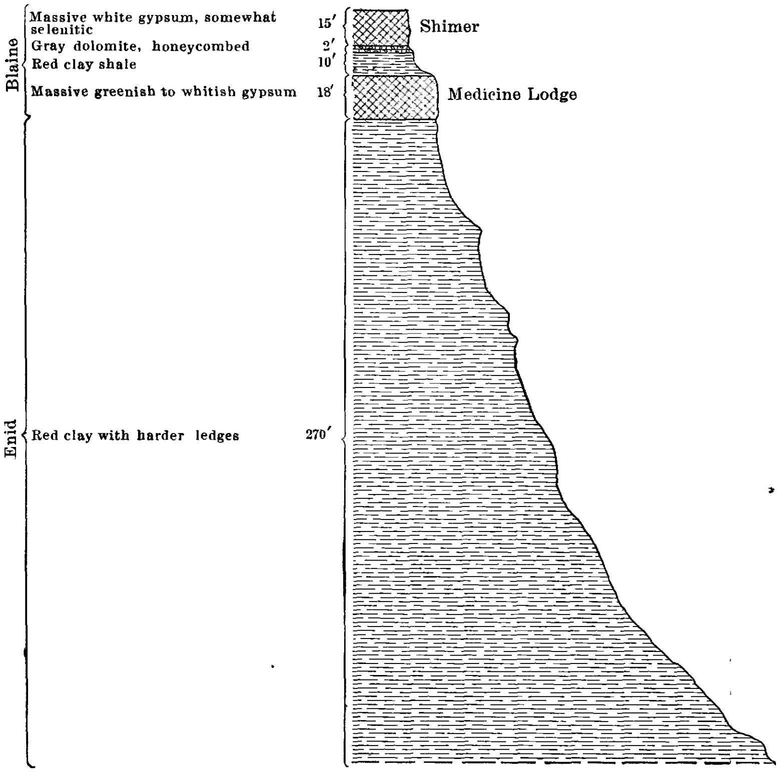

FIG. 13.—Section of hill west of the mouth of Greaver Creek.

western Woods counties a row of these buttes, which rise 100 to 200 feet above the surrounding country, extends from the vicinity of Whitehorse Springs, whence the name, southwest across the Cimarron, to the high divides beyond. To some of these buttes characteristic names have been given, as Lone Butte, Potato Hill, Watersign Hill, Wild Cat Butte, and the like. The noted Red Hill, between Watonga and Geary in southern Blaine County, is composed chiefly of the Whitehorse formation. South of South Canadian River this sand-

A. EROSION FORMS IN CADDO COUNTY BUTTES.

B. DAKOTA SANDSTONE HILLS.

stone thickens and on weathering often forms conspicuous bluffs, such as the famous Caddo County Buttes, southwest of Bridgeport, shown on Pl. X, *A*. The Whitehorse sandstone is exposed along the Washita from near Chickasha, Ind. T., westward, and in the vicinity of Anadarko it forms bold bluffs both north and south of the river, and extends as far west as Mountain View. Ledges which probably belong to the same general horizon outcrop north of the Wichita Mountains in the vicinity of Hobart and Harrison, and it is not impossible that further studies may demonstrate that the same beds extend under the upper gypsums across Greer County.

Day Creek dolomite.—Resting upon the upper part of the Whitehorse sandstone in Kansas and Oklahoma is a conspicuous ledge of hard, white dolomite, first described by Professor Cragin from exposures in southern Kansas, as follows:[a]

> Upon the latest of the Red Bluff rests a persistent stratum of dolomite varying in thickness from less than a foot to 5 feet or more. * * * It is a true dolomite, containing with the carbonate of lime an equal or even greater percentage of carbonate of magnesia. * * * Though not of great thickness, it is an important member of the upper Permian of southern Kansas and northern Oklahoma, owing to its persistence, which makes it a convenient horizon of reference. * * * The stone is nearly white in fresh fracture, weathering gray, and often has streaked and gnarly grain resembling that of fossil wood. * * * Its cherty hardness and fracture are not due to the presence of silica, as one is tempted to infer, but are characters belonging to it as a dolomite. It is a durable building stone.

In his second paper on the Permian rocks, in describing a typical Oklahoma locality Professor Cragin says:

> The brow of the Red Hills near Watonga, Okla., is capped with the Day Creek dolomite, which here presents itself as a compact stratum of gray, somewhat pinkish or reddish tinged cherty-hard rock, little different from the typical ledge that skirts the flanks of Mount Lookout in Clark County, Kans. The stratum here has a thickness of 3 feet.

The line of outcrop of the Day Creek in Oklahoma is not continuous; nevertheless, it is found in numerous localities, and on account of its distinctive lithological appearance it is always easily recognized. It is displayed on many of the hills of Woodward County, not only north of the Cimarron, but also between the Cimarron and the North Canadian and south of the latter stream. In Blaine County it forms the caps of a number of the prominent hills, notably the Red Hills betweeen Geary and Watonga. South of South Canadian River in Caddo County the dolomite covers the Whitehorse buttes southwest

[a] Op. cit., p. 44.

of Bridgeport and outcrops southwestward as far as the headwaters of Cobb Creek and on the west side of that creek past Colony. In the vicinity of Mountain View, in the valley of Washita River, a ledge of dolomite appears at the same general level as that occupied

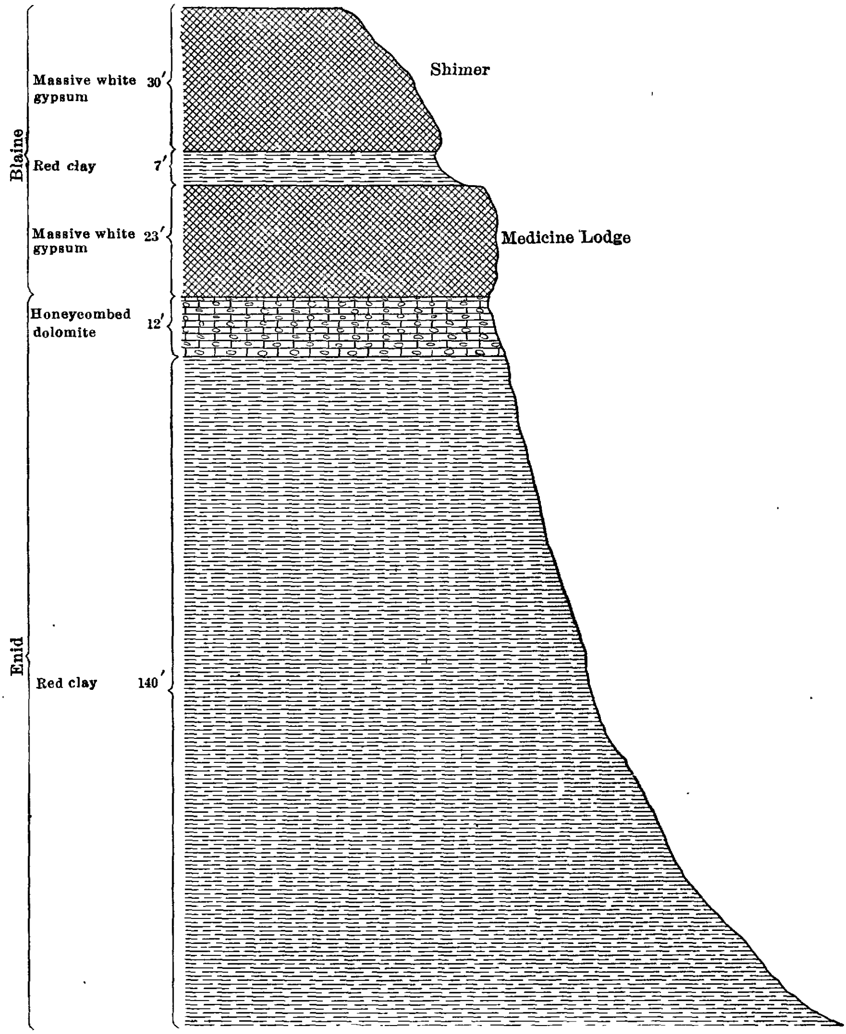

FIG. 14.—Section on Main Creek one-half mile northeast of Bat Cave.

by Day Creek, and another dolomite ledge in the hills north of Harrison may provisionally be referred to this horizon.

The composition of this material in Oklahoma may be understood by reference to the following analysis:

Analysis of dolomite from the summit of the Red Hills 6 miles northwest of Geary, Okla.

	Per cent.
Calcium carbonate	42.47
Magnesium carbonate	52.86
Water	1.82
Oxides of iron and aluminum	1.35
Silica and insoluble residue	1.82
Total	99.88

GREER FORMATION.

Above the Woodward formation are red clays, shales, and sandstones, and intercalated beds of gypsum and magnesium limestone or dolomite 150 to 300 feet thick. Gypsum is the characteristic deposit of this formation, as it is of the Blaine. This formation, for which the name Greer is proposed, from the county in southwestern Oklahoma, in which it is well exhibited, is exposed over a very irregular area. For the purposes of discussion it may be grouped according to two general areas, an eastern and a western. The eastern area extends from the southern part of Woodward County southeast through Dewey, Custer, Washita, Caddo, and Comanche counties into the Chickasaw Nation. The western area extends over Washita County, touches the extreme southeastern part of Roger Mills County, and crosses Greer County to Collingsworth, Tex. The rocks of these two areas are overlain by the same formation.

The rocks of the eastern area of the Greer formation strike northwest and southeast just west of the outcrops of the Woodward formation. They are chiefly red clay shale, interstratified at several horizons with red sandstone and gypsums, which are, however, very irregularly bedded and can rarely be traced as continuous or definite ledges. Nevertheless, the thickest ledges of gypsum known in the red beds are found in this area. Thus 5 miles northwest of Weatherford a ledge 60 feet thick was measured, as shown in fig. 18; in the vicinity of Cloud Chief beds 50 feet thick are not uncommon (see fig. 19); and in a well near Seger, Washita County, a ledge 115 feet thick is reported. But these beds are not constant, thickening rapidly or disappearing without apparent regularity. Along a single bluff one may see the beds change from gypsum to sandstone within a distance of a few rods, and a quarter of a mile farther the sandstone again merges into gypsum. So variable is the stratification of all the rocks of the Greer formation in this region that no attempt is made to divide it into members. A section would usually not answer for a point half a mile away.

The most northern outcrop of this formation, so far as known, is in the southeastern part of Woodward County, Okla., a few miles south of Richmond. It is possible that these strata represent the

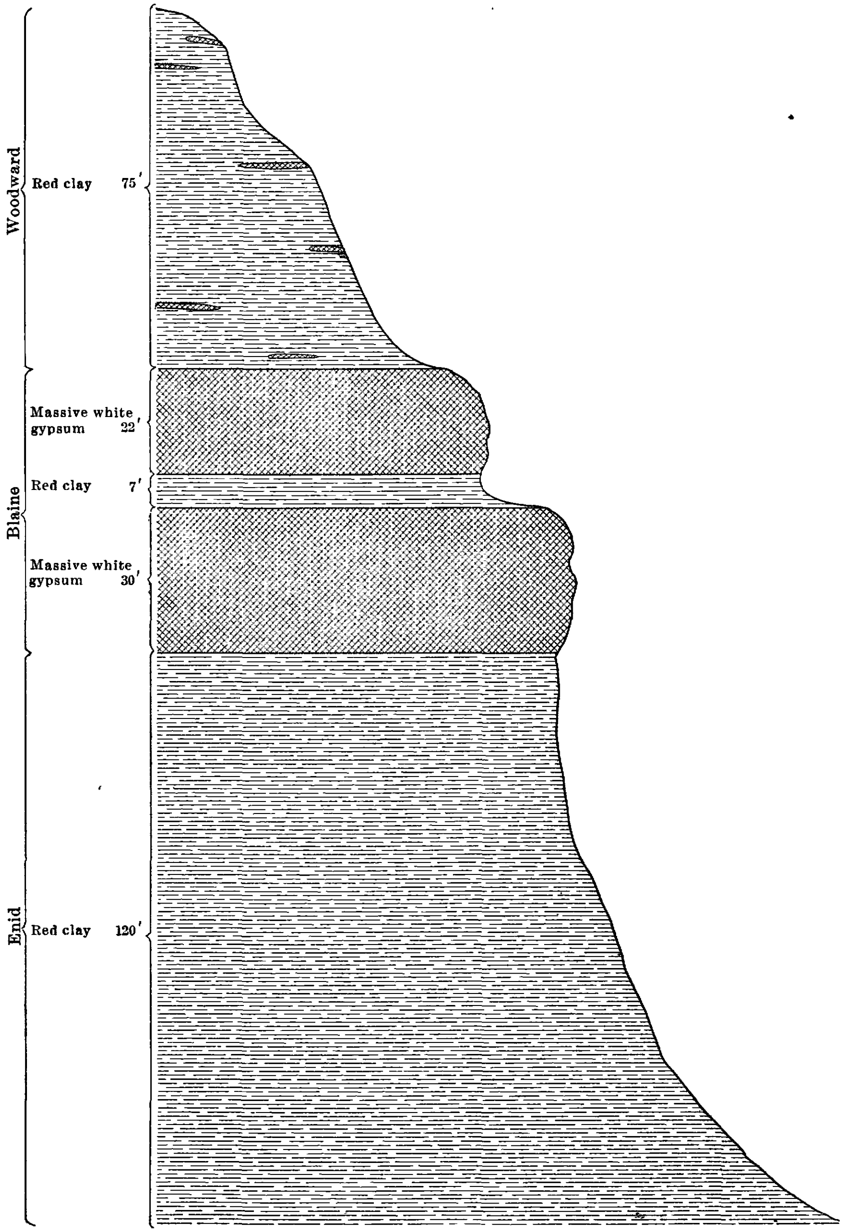

FIG. 15.—Section on Sand Creek, 5 miles northwest of Quinlan, Okla.

southern continuance of Professor Cragin's Hackberry shales and Big Basin sandstone, but further study in the field is necessary to substantiate this point. A few miles south of Richmond, Woodward County, on the divide between the North Canadian and South Canadian, a thin bed of gypsum appears, interstratified between shales and sandstones. This ledge, which is 1 to 3 feet thick, continues south, appears as a cap to the high bluffs along the South Canadian

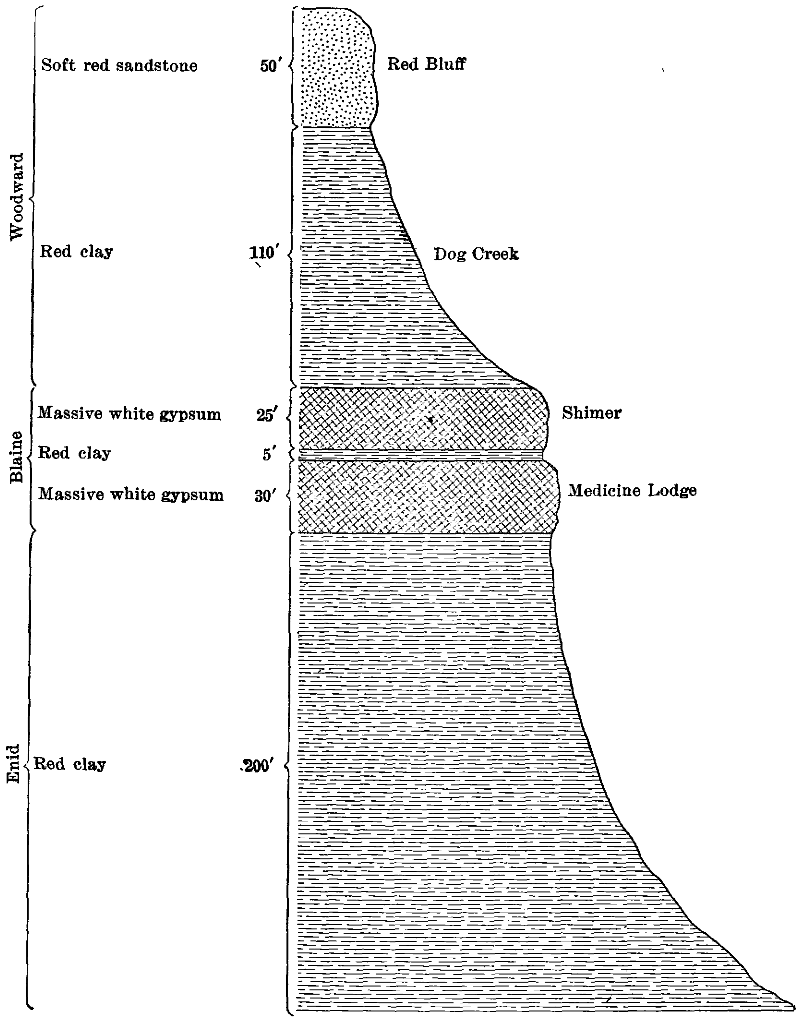

FIG. 16.—Section on butte at mouth of Doe Creek, Woodward County, Okla. In the above legend "Red Bluff" should read Whitehorse.

north and west of Taloga, and outcrops on both sides of this river as far as the vicinity of Stone, Day County. The ledge thickens to the south, and at Weatherford, Custer County, one of the beds is more than 60 feet thick. Pl. XI shows the entrance to a cave at this place, and fig. 18 a section of the hill. The various exposures, averaging perhaps 10 feet in thickness, appear along the various branches of Barnitz Creek and the Washita River in Custer County and as far west as Roger Mills County. In eastern Washita County, in the vicinity of Seger, in the region between Cloud Chief and Weatherford, the gypsum members seem to find their extreme development, there being several heavy ledges, and one, as stated above, that has a reported thickness of 115 feet. Fig. 19 gives section of a butte on the Washita River near Cloud Chief.

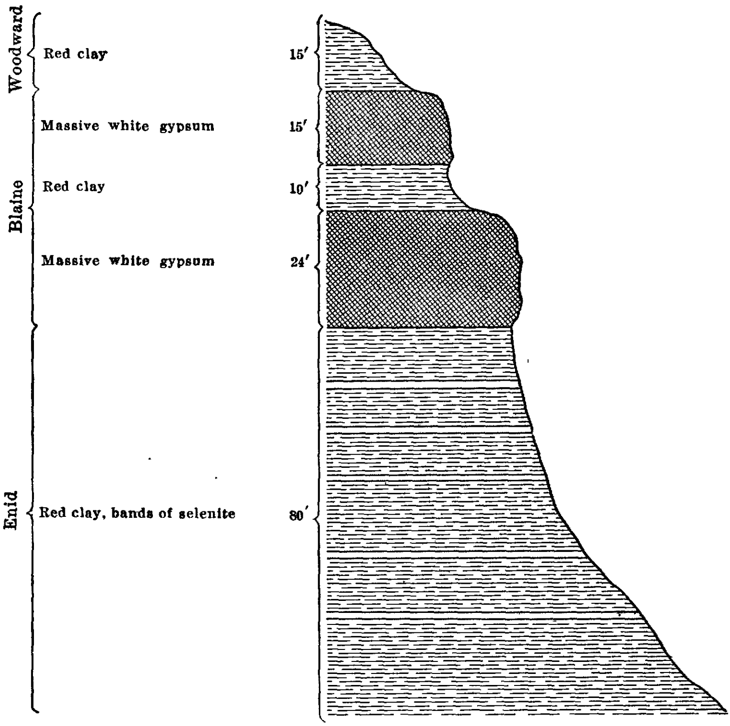

FIG. 17.—Section of high bluff at southeast corner of the Salt Plain.

Following the strike to the southeast outcrops of gypsum occur on the hills north of Washita River, between that river and Cobb Creek, almost to Fort Cobb. South of that river the gypsum forms the top of conspicuous bluffs opposite Fort Cobb, and on the hills to the south and east. Exposures of gypsum continue on the divide between the waters of the Washita and those of Red River as far as the vicinity of the Keechi Hills in southwestern Caddo County, along Little Washita River (see fig. 20), and between these hills and Apache. The same beds probably extend to the region of Marlow, Ind. T.

ENTRANCE TO GYPSUM CAVE NEAR WEATHERFORD, OKLA.

The character of the gypsum in the eastern part of the outcrop of the Greer formation may be better understood by the following analyses of material taken from this region, No. 1 being from the cave 5 miles northwest of Weatherford, No. 2 from ledge 4 miles west

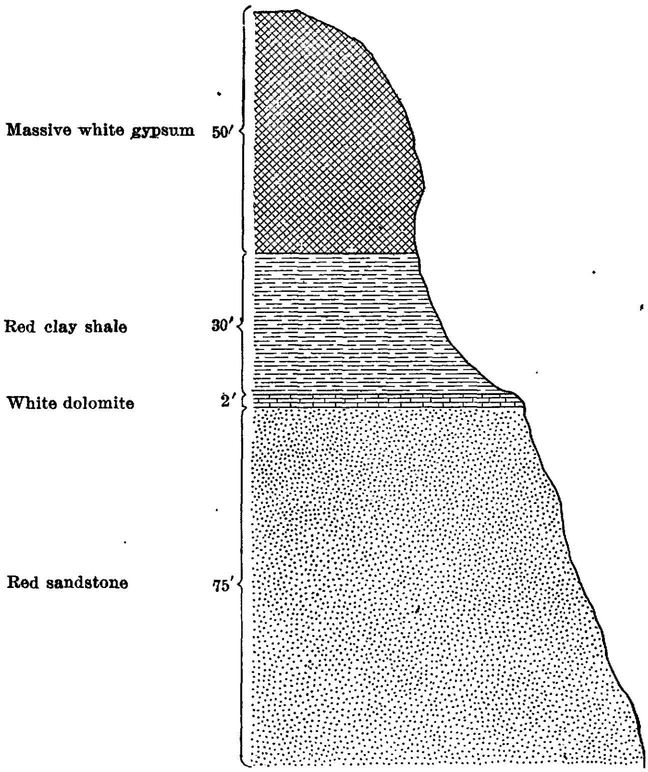

FIG. 18.—Section of bluff 5 miles northwest of Weatherford, Okla.

of Weatherford, No. 3 from 5 miles west of Weatherford (near ledge of sandstone), and No. 4 from 5 miles southwest of Cement, Okla.:

Analyses of gypsum from near Weatherford and Cement, Okla.

	1. Per cent.	2. Per cent.	3. Per cent.	4. Per cent.
Calcium sulphate	75.57	77.38	27.25	74.45
Calcium carbonate	1.11	------	46.73	4.25
Magnesium sulphate	-----	.83	------	-----
Magnesium carbonate	.40	------	1.42	.84
Water	20.22	20.78	17.36	18.61
Oxides of iron and aluminum	.45	.67	8.30	.61
Silica and insoluble residue	1.66	.41	1.22	1.02
Total	99.41	100.07	102.28	99.78

In the western area of the Greer formation the rocks differ in several particulars from those in the eastern area just described. Instead of being unevenly stratified the rocks are deposited in regular layers. Sandstones are practically absent, or at least inconspicuous, and the sequence consists of layers of gypsum and magnesian limestone or dolomite interstratified among gypsiferous clays.

The rocks of this area appear to connect with those of the eastern area in southwestern Washita County, although throughout the region between Cloud Chief and the southwestern part of the county across the valleys of the various branches of Elk Creek, the gypsums ordi-

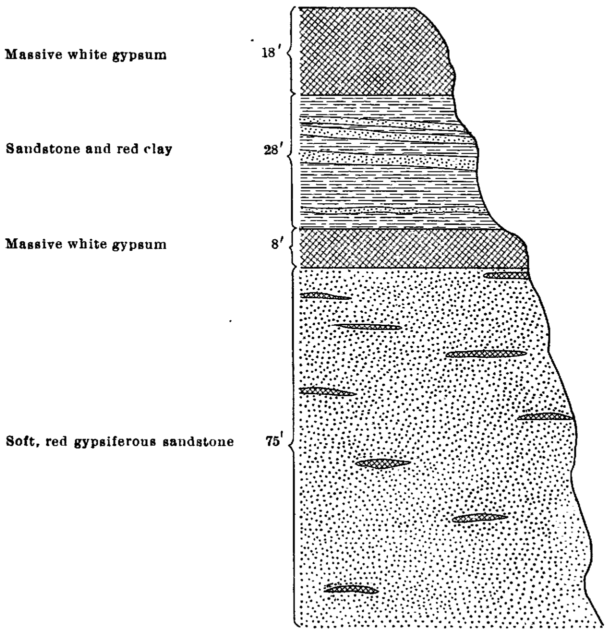

FIG. 19.—Section of butte 5 miles southwest of Cloud Chief, Okla.

narily do not appear. However, at several points along the line of strike, ledges 10 feet or more in thickness may be seen in canyons or along stream beds. Just before reaching the North Fork of Red River, and just north of the corner of Roger Mills, Washita, and Kiowa counties, regular ledges appear, and along the north side of the North Fork for 10 miles or more they form an escarpment 125 to 175 feet high, as shown in Pl. III, *B*, and fig. 21. This is, perhaps, the finest exposure in Oklahoma, the gypsum members, here appearing in four separate ledges, having a thickness of 75 feet. The river cuts through the formation west of these bluffs, and the gypsums again appear at Haystack Butte in Greer County about 20 miles northwest of Granite. The rocks of the Greer form conspicuous bluffs on both sides of Haystack Creek and on Elm Fork of Red River and its tributaries as far as Collingsworth County, Tex. The gypsums which occur in such abundance in southern Greer County in the vicinity of Duke and Eldorado also belong to the Greer formation.

The rocks of the western area of the Greer consist of red clay shales, heavy gypsum members, and a ledge of dolomite or magnesian limestone. At the base of the formation is an unknown thickness of red gypsiferous and saliferous shales and sandstones. These shales contain occasional local ledges of gypsum a foot or two thick,

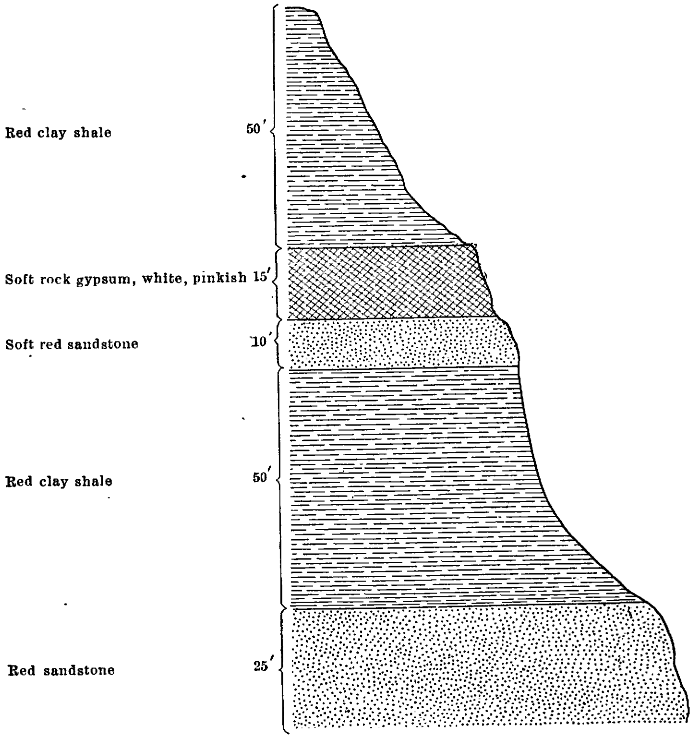

FIG. 20.—Little Washita River section, taken west of Frisco Railroad crossing.

and beds of white and greenish shales are not uncommon. In the region of the heavy gypsum formations there are several salt plains fed by springs that issue from below the gypsums, or in one instance, from shales between the gypsums. These shales between the gypsum beds do not differ materially from those at the base of the formation, nor from those between the gypsum ledges of the Blaine formation. Immediately beneath the heavy gypsum beds there is often a foot or two of bluish or greenish clay or shales. Figs. 22, 23, and 24 show characteristic sections taken in this region.

There are five prominent ledges of the Greer formation outcropping in this region, the three upper ones being thickest and most conspicuous. In general, neither of the two lower members is more than 4 feet thick, and because of their position near the foot of the bluff they are frequently inconspicuous. The various members are described below.

Chaney gypsum member.—This gypsum is well exposed along the south side of Elm Fork from Mangum northwest to the Texas line.

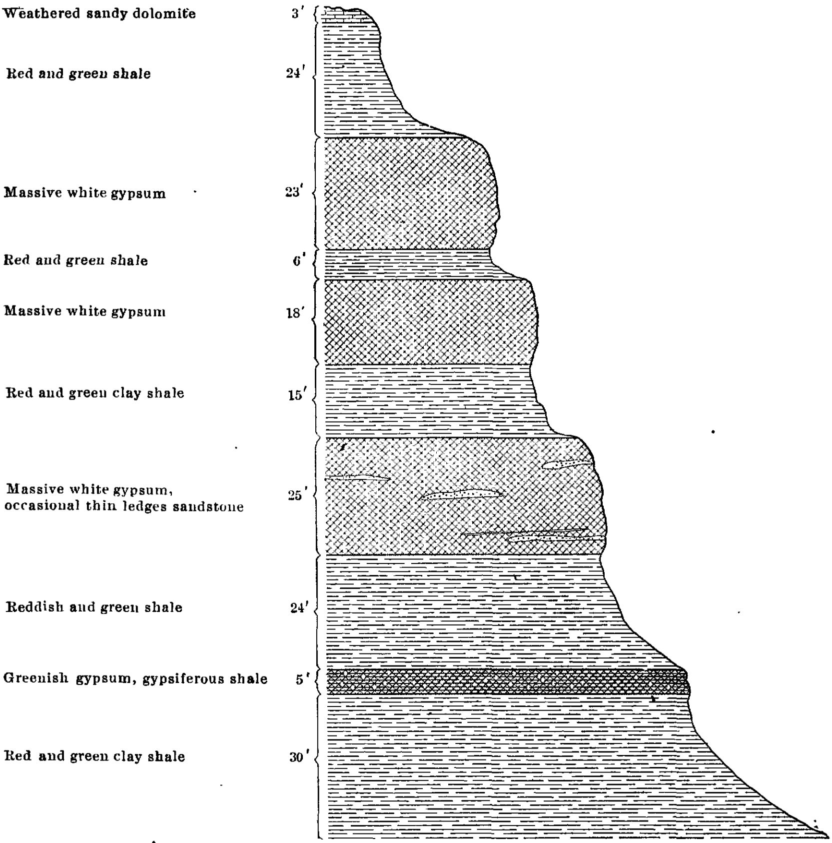

FIG. 21.—Section of bluff at the Salt Plain, on North Fork of Red River, 5 miles south of Carter, Okla.

It is also seen on Haystack Creek, but on North Fork, in Roger Mills County, it loses its characteristic structure and becomes simply a gypsiferous band in the red clay. On Elm Fork at the mouth of Hackberry Creek and also at the Kiser and Chaney salt plains near the Texas line, it is a hard massive stratum 3 to 5 feet thick, usually white, but sometimes gray or bluish. It is often distinctly stratified or apparently cross-bedded, or it may be that the lines of stratification are wanting. The formation derives its name from the Chaney Salt Plain on Elm Fork of Red River, 4 miles east of the Texas line.

Kiser gypsum member.—This member is exposed throughout the western area of the Greer formation. It is rarely white and in this

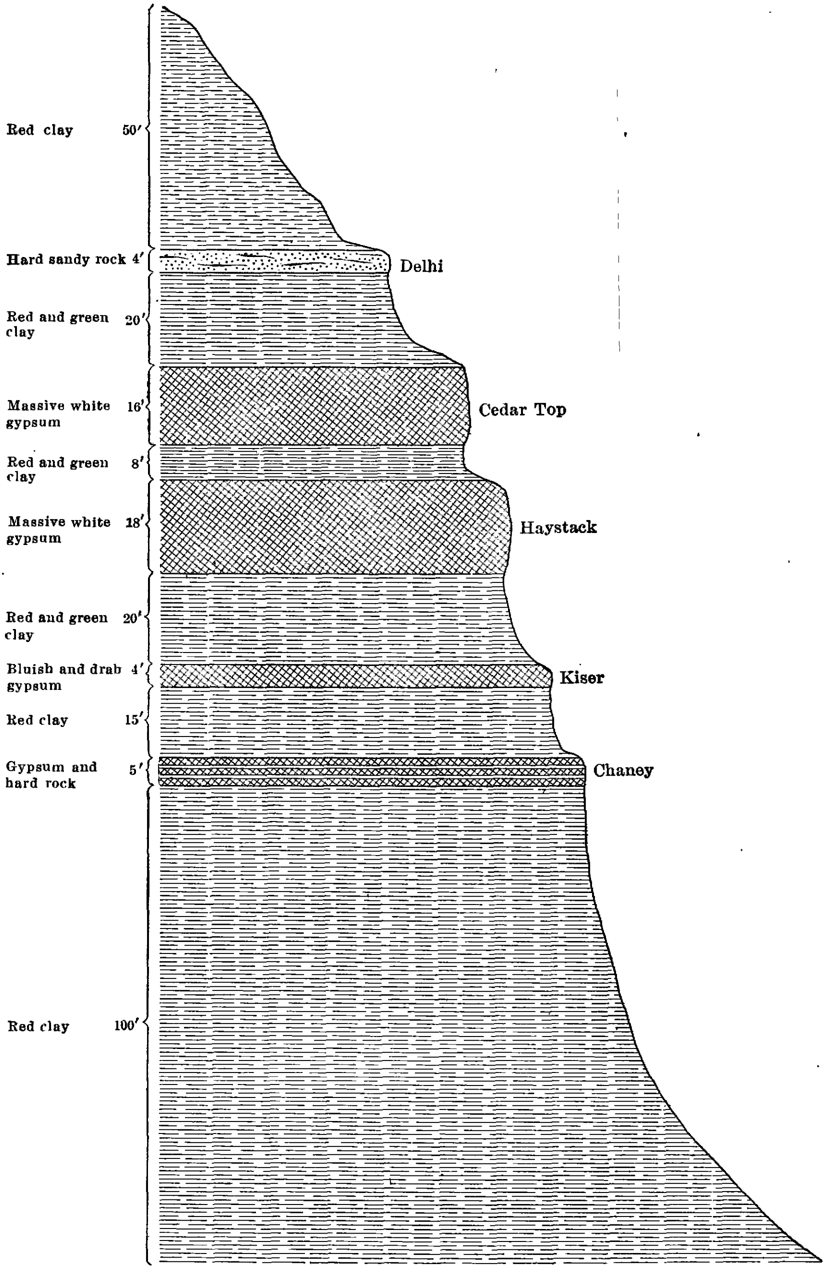

FIG. 22.—Haystack section, 6 miles south of Delhi, Okla. In above legend "Delhi" should read Mangum.

regard differs from all other ledges of the Greer. It varies from a decidedly bluish or greenish tint to drab or gray. On the North

Fork it is composed of greenish gypsum and gypsiferous shales, becoming hard locally, and on Haystack Creek of bluish and drab gypsum, grading into gypsiferous rock and clay. On Elm Fork, at both the Kiser and Chaney salt plains, it is composed of soft, bluish to greenish, selenitic gypsum, and at the mouth of Hackberry, 10 miles down Elm Fork, it is a bluish stratified gypsum. These occurrences

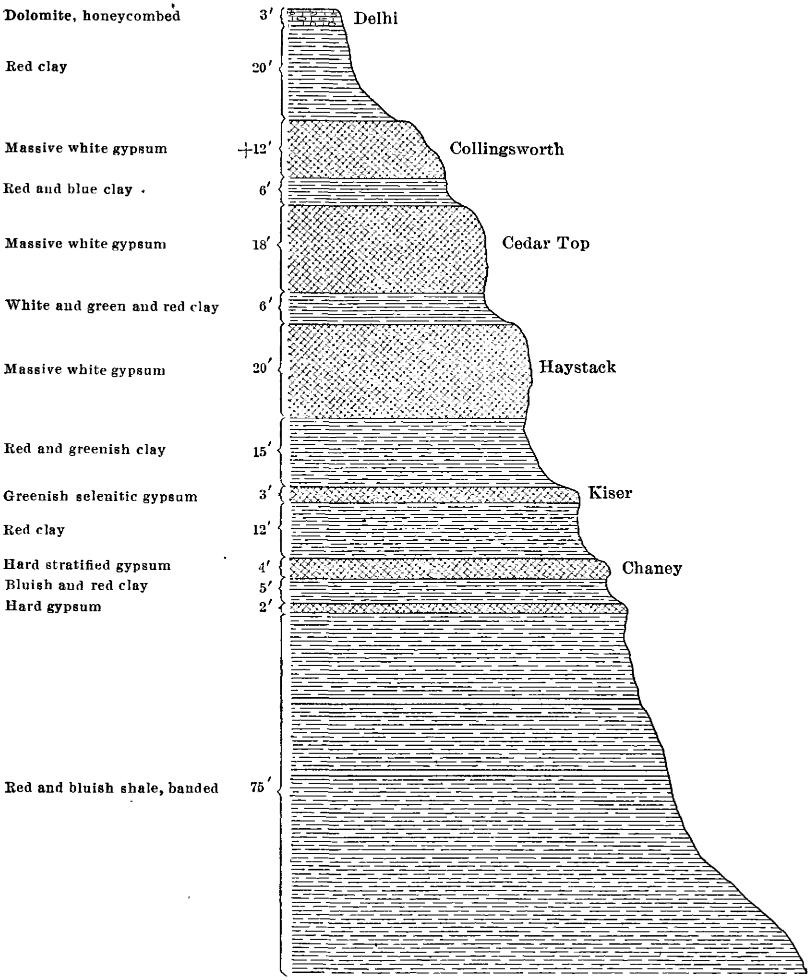

FIG. 23.—Section at Salton, Greer County, Okla. In above legend "Delhi" should read Mangum.

show that while the general character is fairly constant, the stratum varies considerably in local sections. The softness of the rock renders it particularly susceptible to weathering, and it is frequently inconspicuous. Its thickness varies from 1 to 3 feet. The name is from the Kiser Salt Plain on Elm Fork, Greer County, where the ledge is well exposed.

Haystack gypsum member.—The upper part of the Greer formation consists of three layers of massive gypsum and one of dolomite, interstratified between beds of red clay shale. The lowermost of the three thicker layers, the third gypsum member from the bottom of the formation, consists of the typically massive gypsum, almost pure white or occasionally grayish in places, with a few thin bands of gypsiferous sandstone. This ledge is often cut by joints which separate the rocks into rectangular blocks. These blocks frequently weather out and roll down the slope and in places render it conspicuously white for miles. The Haystack varies locally from 18 to 25

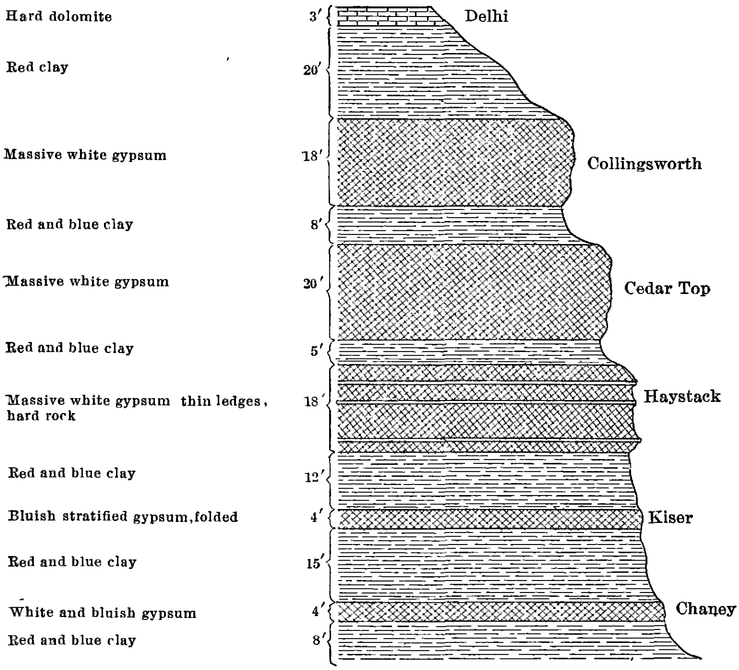

FIG. 24.—Section at mouth of Hackberry Creek, Greer County, Okla. In above legend "Delhi" should read Mangum.

feet in thickness, and so far as known is the thickest gypsum member in the western area of Greer. It is exposed along all the bluffs on North Fork and Elm Fork and is particularly conspicuous on Haystack Creek and in the vicinity of Haystack Butte, whence the name.

Cedartop gypsum member.—The Cedartop is a massive white gypsum, very similar in appearance to the Haystack. It has a constant thickness of 18 to 20 feet throughout the region of outcrop. It is very conspicuous on North Fork, Haystack, and Elm Fork, and forms the caps of a number of buttes and bluffs throughout the region. It is called "Cedartop," from a prominent butte on the North Fork of Red River, in the extreme southeastern corner of Roger Mills County.

This rock forms the upper ledge of this butte, and may be seen from a great distance up and down the river and even from Headquarters Mountain at Granite, 15 miles away. It is shown in Pl. III, *B*.

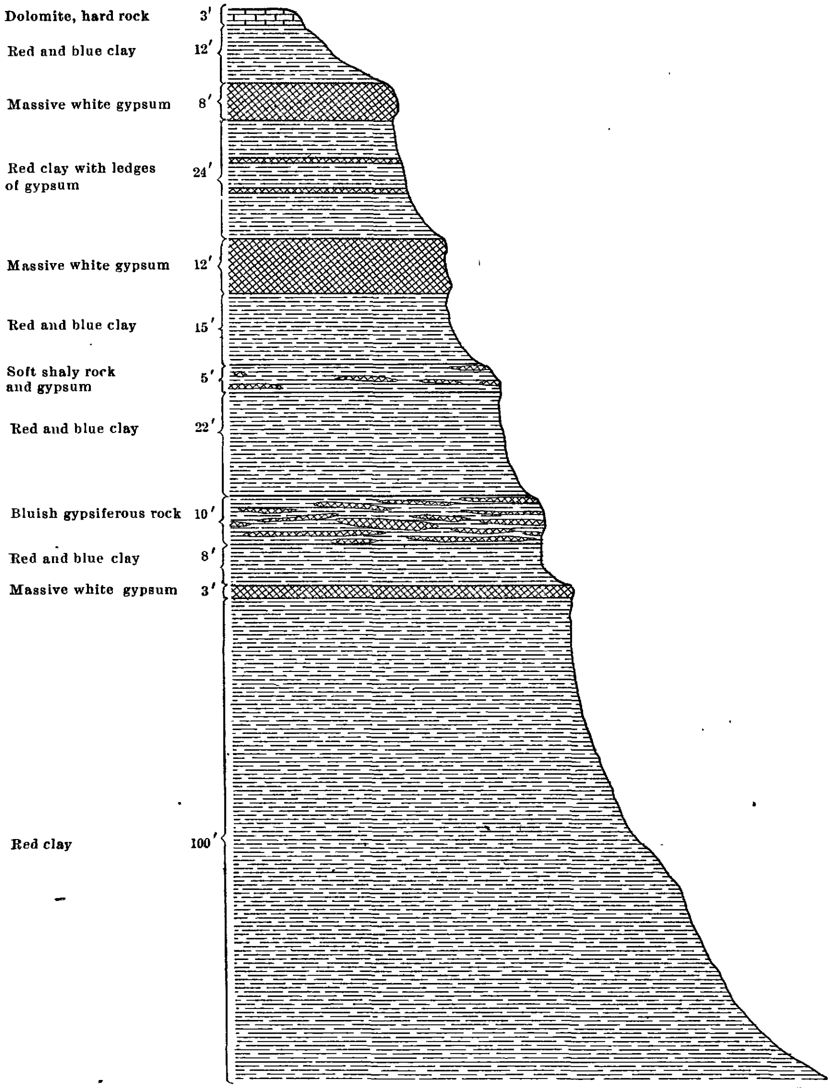

FIG. 25.—Section 10 miles south of Mangum, Okla., in bluffs between Salt Fork and Horse Branch.

Collingsworth gypsum member.—This is the upper gypsum ledge of the Greer formation, and it does not differ materially in lithological appearance from the Haystack or Cedartop. Like them, it is massive and white throughout, and like them, also, it is cut by a series of master joints into rectangular blocks. Where exposed, the thickness varies from 18 to 20 feet, being approximately that of the Cedartop and not so great as the Haystack. As it is the upper gypsum member it has often been eroded, and for that reason does not always appear in a section. Near the heads of the various creeks, however, it is the prominent ledge, and it is also exposed on a number of the conspicuous bluffs, as along North Fork. It is named from Collingsworth County, Tex., just west of Greer County, Okla., where the gypsum is well exposed.

Mangum dolomite member.—Above the Collingsworth and separated from it by about 20 feet of red clay shale is a very persistent 3-foot bed of more or less dolomitic limestone. In places it is true dolomite; while at others it contains only a small per cent of magnesia and is a magnesian limestone. The character of the rock

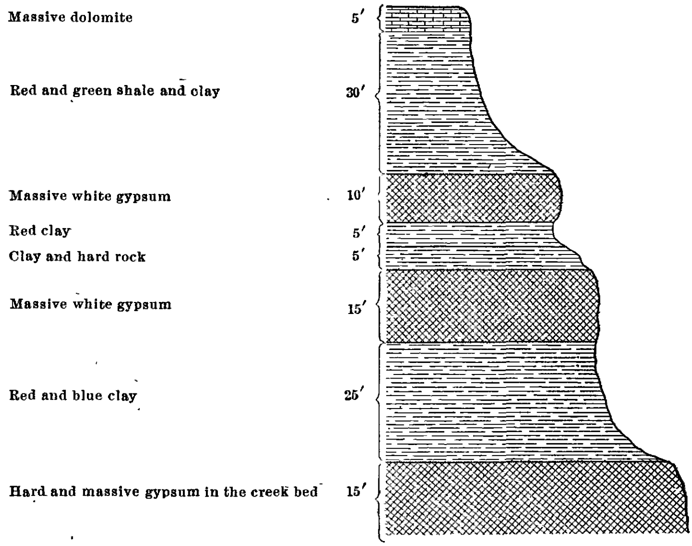

FIG. 26.—Section on Boggy Creek, 9 miles northeast of Eldorado, Okla.

varies considerably. In places it is arenaceous and soft, in other localities cavernous or honeycombed. Often, however, it is firm and solid and forms an excellent building stone. Its color is white, drab, or sometimes yellowish. The underlying clays have often been eroded and the rock frequently covers slopes at a considerable distance below its original position. While the thickness averages 3 feet, it varies from 1 foot to 5 feet. This member is exposed on the hills north of North Fork, in Roger Mills County, and on practically all the divides of Elm Fork and Haystack, Bull, and Fish creeks in Greer County. The name of Magnum is that of the county seat of Greer County, near which the dolomite is well exposed.

Figs. 21 to 26, inclusive, showing sections taken in Roger Mills and Greer counties, indicate the stratification in that region.

QUARTERMASTER FORMATION.

Above the Greer are 300 feet or more of soft, red sandstones, and arenaceous clays and shales, to which the name Quartermaster has been applied. So far as known this is the highest formation of the red beds in Oklahoma.

In the lower part of the formation the rocks are chiefly shales, typically red, but sometimes containing greenish bands and layers. The shales become more arenaceous above, and in places form a strong, consolidated sandstone, which is rather thin bedded and prone to break into small rectangular blocks, and weather queerly into long and narrow buttresses or rounded, conical, or nipple-shaped mounds from 10 to 50 feet or more high. These mounds may be solitary, but in some areas hundreds of them occur in a single quarter-section. The sandstone is further characterized by the marked and very peculiar dip of the rocks in certain directions. The strata often dip at angles of from 20° to 40° to all points of the compass, even in a small area. These dips often produce escarpments that have the appearance of those formed by regularly bedded dipping strata. The most plausible explanation of this phenomenon is that the erratic dipping is caused by the undermining of deep-seated rocks, probably some of the various gypsum members of the Greer.

In this sandstone, particularly in its upper part, there are many springs of soft water, which usually issue as seeps at the head of deep canyons or beneath bluffs of red sandstone. While few of them have large flows, many are large enough to supply farmhouses, or, in some cases, to furnish stock water for ranches. Wells in these sandstones frequently yield good water at moderate depths. In fact, with the exception of the eastern area of the Enid, the Quartermaster is the only red-beds formation in which any large amount of good water is found.

Except where covered by younger rocks, the Quartermaster outcrops over practically all of Day and Roger Mills counties, and is also extensively developed in the western part of Dewey, Custer, and Washita counties. To the south and east it is underlain by the Greer, while to the west and north it disappears beneath the sands of the Tertiary. Streams tributary to the South Canadian, Washita, and the North Fork of Red River in the region form canyons in this rock and are fed by springs issuing from it. The name is from Quartermaster Creek, which flows from Day County through the extreme northwestern corner of Roger Mills County and empties into Washita River in Washita County. Along this creek both the lower shales and the sandstones higher up in the formation are well exposed. The peculiarities of structure and weathering are also well exemplified along this stream. In the present state of our knowledge it is not deemed advisable to attempt to subdivide the Quartermaster formation.

RED BEDS OF UNCERTAIN RELATIONSHIP.

There are in Oklahoma two areas of red beds which are not certainly known to belong to any of the five formations heretofore described. In this report the names Lawton and Laverne will be used to designate these two areas, the term being used in a geographic sense.

Lawton area.—One of the areas referred to includes the country surrounding the Wichita Mountains on all sides, occupying practically all of Comanche and Kiowa counties, besides eastern Greer, southern Washita, and southwestern Caddo counties. The deposits of the Greer formation surround the Wichita Mountains, at a distance of from 20 to 30 miles, on all sides except on the south. (See Pl. I.) It is between these Greer outcrops and the mountains that the rocks referred to occur. They consist chiefly of red clay shales, with a few ledges of sandstone and dolomite, and in that regard correspond to the Woodward. Like the Woodward, also, these beds appear to underlie the Greer. Until the correlation of the rocks with the Texas beds south of Red River has been worked out, however, the exact relation of the red beds of this area must remain a matter of doubt.

Laverne area.—The second area in Oklahoma in which the relations of the red beds are still obscure is a narrow strip along the south side of Beaver Creek in Woodward and Beaver counties. The beds are composed chiefly of shale, with an occasional ledge of sandstone or gypsum. These beds are in strike with the outcrops of the eastern area of the Greer formation farther south in the Territory, the intervening country being covered with Tertiary deposits. (See Pl. I.) In lithologic character the rocks are also very similar to the Greer formation. Until the stratigraphy of the region is thoroughly worked out, however, the question of their correlation must remain open.[a]

Conglomerate.—At the bases of all of the Wichita Mountains, whether composed of igneous rock or limestone, are considerable deposits of conglomerate, evidently derived from the rocks of which the mountains are composed—that is, at the base of the limestone hills the conglomerate is made up of limestone bowlders, at the foot of porphyry knobs the conglomerate is made up of porphyry, while

[a] There are also exposures of red beds below Dakota and Tertiary rocks on the upper Cimarron River, in the northwestern corner of Beaver County, and extending up that stream into New Mexico. These beds may or may not be the same in age as those along the south side of Beaver Creek in the eastern part of the county. It is in these red beds near Kenton that the copper mines, which at various times have been worked with more or less success, are located.

granite or gabbro peaks produce granite or gabbro conglomerate. Near the base of the mountains this conglomerate is composed of rather large stones, sometimes as large as a peck measure. On leaving the mountains the stones become smaller and more rare, and at the same time the shales in which they are embedded become more reddish in color until at a distance of a few miles from the mountains the conglomerate has changed into typical red beds. In some places red shales approach the very base of the peaks and may occasionally be seen lying unconformably on granite, porphyry, or limestone rocks. Regarding the age of this conglomerate Mr. Joseph A. Taff wrote me under date of January 23, 1904, as follows:

It is my interpretation that the conglomerates at the base of the Wichita Mountains are composed of near-shore deposits of the red beds and therefore are of the same age, supposedly Permian. Of course, you understand that there are considerable surfacial deposits of gravel and sand, especially in the south side of the mountains, along the valleys of West Cache Creek, which would be classed as Recent.

GYPSUM IN THE RED BEDS.

In 1902 the Oklahoma Geological Survey made an estimate of the amount of available gypsum in the Territory. The following method was employed: A ledge of gypsum a foot thick and a mile square was used as a basis, the specific gravity of the gypsum was estimated at 2.32, and the weight of a cubic foot of water at 62.5 pounds. From this it was estimated that a ledge of gypsum of the thickness given above would weigh 2,021,184 tons.

In estimating the amount care has been taken to include only available material. Throughout a large portion of the region the deposits are often covered to considerable depths by overlying shales and clays, which make up the greater part of the hill. The ledges, however, outcrop again on the other side of the hill, perhaps a mile distant. In other regions the ledges outcrop along an escarpment and disappear entirely beneath the higher hill to the west. In still other localities the ledges do not appear on the surface, but their presence is attested by numerous sink holes and by ledges encountered in shallow wells, while, on the other hand, in many places the ledges are exposed over considerable areas, and not infrequently a ledge 20 to 50 feet thick will be uncovered for half a mile or more, so that the entire thickness might be removed without being compelled to strip any material from above the ledge.

West of this region of gypsum outcrops this rock occurs beneath the surface, being encountered in deep wells at various depths, increasing to the west. In a well at Childress, Tex., about 20 miles from the southwest corner of Oklahoma, gypsum beds were found at a depth of more than 1,000 feet, and there seems to be no doubt that the ledges which outcrop in the various localities in Oklahoma extend westward for considerable distances, passing deeper and deeper beneath the surface. It is entirely useless even to conjecture upon the extent of these deposits, for nothing but an extended system of deep borings will ever solve the problem. These deep-seated ledges have not been taken into account in making up the results. No deposits have been considered in these calculations that are more than 100 feet beneath the surface, and in general the ledges discussed are less than 50 feet deep, with the greater part exposed upon the surface.

In arriving at results the plan has been to estimate the number of square miles occupied by gypsum and the approximate combined thickness of the ledges. In both calculations care was constantly taken to make conservative estimates. The number of square miles was multiplied by the thickness in feet and this by 2,000,000. This product is considered the number of tons of gypsum in a given area.

Classified by counties the approximate amount of gypsum in Oklahoma is as follows:

	Tons.
Canadian County	50, 000, 000
Kingfisher County	50, 000, 000
Blaine County	2, 500, 000, 000
Woods County	14, 000, 000, 000
Woodward County	24, 000, 000, 000
Comanche County	200, 000, 000
Caddo County	3, 000, 000, 000
Washita County	20, 000, 000, 000
Custer County	6, 000, 000, 000
Dewey County	1, 000, 000, 000
Day County	500, 000, 000
Roger Mills County	1, 000, 000, 000
Greer County	53, 000, 000, 000
Total	125, 300, 000, 000

At the present there are eight mills in Oklahoma where gypsum is manufactured into plaster.

PALEONTOLOGY OF THE RED BEDS.

The scarcity of fossils in the Kansas-Oklahoma red beds has been a matter of comment ever since these rocks have been studied. In Kansas, particularly, Hay, Cragin, Prosser, Beede, Williston, and others have at various times searched carefully over the counties in which these rocks are exposed, but without avail. So far as known not a single fossil has ever been found in the Kansas red beds.

In Oklahoma, fortunately, the results have been more satisfactory. Not that fossils are abundant, for they are in fact very rare, yet enough forms have been found at various horizons to assist the geologist in the classification of the rocks. Four years ago the geologic age of the red beds was not certainly known, for at that time fossils had been found in but one locality, and these for the purpose of correlation were far from satisfactory. Of the five localities west of the provisional base of the Permian from which fossils have been obtained in Oklahoma two only have yielded invertebrates, in two other localities vertebrates alone have been found, and from the fifth locality vertebrates, invertebrates, and plants have been secured. A brief description of these localities and the fossils obtained from each will be given.

On the farm of W. T. McCann, 5 miles southeast of Nardin, Kay County, a number of fossils were found in a ledge of sandstone which lies just at the base of the red beds. A vertebrate, identified as *Eryops megacephalus* by Dr. S. W. Williston, a small crustacean, *Estheria minuta*, and some fossil leaves comprise the collection.

Dr. E. C. Case has identified the following forms obtained near Orlando, Logan County:[a]

PISCES.

Diacranodus (Pleuracanthus) ampressus (?) Cope.
Sagenodus (?) sp.

BATRACHIA.

Diplocaulus magnicornis (?) Cope.
limbatus (?) Cope.
salamandroides Cope.
Trimerorhachis sp. Cope.
leptorhynchus sp. nov.
Cricotus sp. Cope.
Cricotillus brachydens g. et sp. nov.
Eryops megacephalus Cope.
Crossotelos annulatus g. et sp. nov.

REPTILIA.

Noasaurus sp. Cope.
Embolophorus (?) sp. Cope.
Pariotichus ordinatus Cope.
sp. Cope.
Pleuristion brachycoelous g. et sp. nov.

A number of vertebrates have recently been discovered 5 miles east of Pond Creek, Grant County. These bones have not been identified, but from superficial examination they appear very similar to the specimens from Nardin or Orlando.

In a ledge of soft, sandy dolomite which underlies the Medicine Lodge gypsum near Ferguson, Okla., a number of invertebrates have been found, among which Dr. J. W. Beede finds the following forms:

Pleurophorus subcuneatus Meek.
Schizodus (?) like S. Wheeleri.

[a] Case, E. C., On some vertebrate fossils from the Permian of Oklahoma: Second Biennial Rept. Oklahoma Geol. Surv., 1902, pp. 62, 68.

Near Whitehorse Spring, 16 miles west of Alva, a considerable number of invertebrates were obtained. Doctor Beede identified the following genera:[a] *Naticopsis*, *Pleurotomaria*, *Pleurophorus*, *Lima*, *Sedgwickia*, *Aviculopecten*, *Bakewelia*, *Conocardium*, and *Dielasma*. The last four genera are represented by new species.

AGE OF THE RED BEDS.

Regarding the age of the red beds, Doctor Williston identifies *Eryops megacephalus*, from Nardin, as a Permian amphibian, described by Cope, from Texas. Of the Orlando fossils he says:[b] "Altogether these fossils unmistakably point to the Permian." Doctor Case points out the close resemblance of these fossils to similar forms from the Permian of northern Texas, Ireland, and Bohemia.[c]

Doctor Beede, in the paper referred to, in speaking of the Whitehorse invertebrates, says:

> On the whole, these fossils show an advance over the fossils of the Permian below. Some of the species still persist, as we should expect from the fact that there is no unconformity between these various formations. On the other hand, there is a new species of *Dielasma* belonging to a group new to the American Permian. * * * Taking all this into consideration, there can be little doubt that the age of these beds is Permian.

Of these localities Orlando, Nardin, and Pond Creek are in the Enid formation; Gypsum Hills locality in the Blaine, and the Whitehorse locality in the Whitehorse sandstone, the middle member of the Woodward formation. So far as known no fossils have been found in the Greer and Quartermaster formations of Oklahoma, but there is no reason for supposing that these beds differ greatly in age from those immediately subjacent.[d]

CRETACEOUS ROCKS.

Wherever the red beds are covered by other rocks there is always a distinct line of unconformity, showing that erosion has taken place before the later rocks were deposited. As far as known there is no evidence of Triassic or Jurassic rocks in Oklahoma and the formations next higher than the red beds in the geological scale are Cretaceous rocks, which are exposed in many parts of western Oklahoma, but almost invariably in local and scattered areas. The Cretaceous rocks belong to either the Comanche or the Dakota series.

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[a] Beede, J. W., Advance Bulletin of the Second Annual Report of the Oklahoma Geological Survey, April, 1902.

[b] Letter of November 24, 1900.

[c] Op. cit., p. 62.

[d] Since the above was written fossils found in the Quartermaster sandstone in Collingworth County, Tex., have been identified by Doctor Beede, who finds that they are very similar to those from Whitehorse and of Permian age.

COMANCHE SERIES (LOWER CRETACEOUS).

In general the Comanche or Lower Cretaceous rocks in Oklahoma consist of limestone and shales. In many of the western counties these deposits are found on hillsides and are known locally as "shell rock," because they are composed largely of fossil shells belonging chiefly to some member of the oyster family.

Outcrops of the Comanche series are known to occur in the following counties: Woodward, Dewey, Custer, Day, Washita, Roger Mills, and Beaver. In every instance these rocks lie on the eroded surface of the old red beds floor, and in many instances apparently upon the flank of a former pre-Cretaceous red beds hill.

The most eastern point to which the Comanche deposits formerly reached can not be ascertained, because these deposits have been largely eroded since they were laid down. It seems probable, however, that the same deposits are but the remnant of a much larger area of the Comanche beds.

The Oklahoma Cretaceous beds form a connecting link between larger areas of Comanche series in Texas and Kansas. In the former State the Lower Cretaceous beds occur in large areas. In Kansas there are extensive outcrops of Comanche deposits near Belvidere, Kiowa County, and in Clarke, Comanche, and other counties, the thickness in places reaching 200 feet or more. Near Salina, in the central part of the State, the Mentor beds are also of Lower Cretaceous age. It is not the intention of the writer to discuss the age of these beds further than to say that it seems probable that they belong to the Washita or upper member of the Lower Cretaceous. This statement is substantiated by the fact that in the extreme northwestern part of Beaver County a series of clays containing typical Cretaceous fossils, *Gryphæa*, *Exogyra*, *Ammonites*, etc., are found lying conformably below the Dakota sandstone.

UPPER CRETACEOUS.

DAKOTA SANDSTONE.

As far as known the outcrops of the Dakota in Oklahoma occur only in the extreme western part of the Territory, along canyons cut by the Cimarron and the headwaters of Beaver Creek. Typical exposures occur near Kenton, Okla., within a few miles of the New Mexico line, and for 60 miles farther up the Cimarron, as far as the vicinity of Folsom, N. Mex. The section shown in fig. 28 was made on the Black Mesa, 2 miles north of Cimarron River, at Kenton, Okla. The Dakota in that region consists of alternating ledges of shale and sandstones, a form of structure which is characteristic of the Dakota in central Kansas and Nebraska, where it is typically exposed. Typical Dakota hills in Oklahoma are shown in Pls. IV, *A*, *B*; X, *B*; and XVII, *A*, *B*. A few imperfectly preserved dicotyledons belonging to the genera *Populus*, *Salix*, *Ficus*, and *Platanus* were found in the sandstone rocks near Mineral, Okla. These genera are common forms in central Kansas, where dicotyledon leaves are abundant. The writer does not desire to express an opinion as to whether or not the Morrison may be found in the region of Kenton.

TERTIARY ROCKS.[a]

Lying unconformably upon the surface of the red beds and Cretaceous over a large part of western Oklahoma is an extensive deposit of Tertiary rocks, the exact age of which has never been determined with accuracy. Paleontological evidence is rare, but, following the usual classification of beds of apparently the same age in western Kansas and Nebraska, there seems no valid reason for not considering them Miocene or Pliocene. In Nebraska Darton distinguishes the Arikaree and Ogallala formations, the former being Miocene and the latter doubtfully Pliocene in age.[b] In Kansas the geologists have not differentiated the strata, and in the light of our present knowledge it seems impossible to do so in Oklahoma, and for this reason this formation will be referred to as Miocene or simply as Tertiary.

With the exceptions of the alluvium and sand hills the Tertiary is the uppermost formation in Oklahoma. The red beds underlie it, except that between the red beds and the Tertiary occur sometimes Comanche Cretaceous members, but in nearly every instance the latter are but inconspicuous beds sandwiched in between the other formations.

In general the later Tertiary occupies the uplands of the western half of Oklahoma, almost always occurring on the high divides be-

[a] For discussions of Tertiary deposits for various parts of the Great Plains the reader is referred to the following publications:

Hay, Robert, Water resources of a portion of the Great Plains: Sixteenth Ann. Rept. U. S. Geol. Survey, pt. 2, 1895, pp. 535 et seq.

Gilbert, G. K., The underground waters of the Arkansas Valley in eastern Colorado: Seventeenth Ann. Rept. U. S. Geol. Survey, pt. 2, 1896, pp. 557 et seq.

Haworth, E., Physical properties of the Tertiary: Univ. Geol. Survey Kansas, vol. 2, 1897, pp. 247–284. Underground waters of southwestern Kansas: Water Sup. and Irr. Paper No. 6, 1897.

Johnson, Willard D., The high plains and their utilization: Twenty-first Ann. Rept. U. S. Geol. Survey, pt. 4, 1901, pp. 601–741. Continued in Twenty-second Ann. Rept. U. S. Geol. Survey, pt. 4, 1902, pp. 631–669.

Darton, Nelson Horatio, A preliminary report of the geology and water resources of Nebraska west of the one hundred and third meridian: Nineteenth Ann. Rept. U. S. Geol. Survey, pt. 4, 1899, pp. 719–785. Preliminary report on the geology and underground water resources of the central Great Plains: Prof. Paper U. S. Geol. Survey No. 32, 1905.

[b] Op. cit., pp. 732 et seq.

tween the streams. It comprises mostly all of Beaver County, and in Day and Woodward counties it occupies the extensive level prairies between Cimarron and South Canadian rivers. The high divide between the North Fork of Red River and the Washita in western Roger Mills County is Tertiary also. In the central part of the Territory Tertiary deposits occupy the greater part of the uplands, and in places are known to extend nearly as far as the eastern tier of counties. Pls. V and XIII exhibit characteristic Tertiary topography.

Physical properties.[a]—The Tertiary consists for the most part of clay, sand, and gravel. These materials are in no regular stratigraphic succession, as shown in fig. 27. In places the entire thickness of the formation is clay; again sand and gravel predominate, and often deposits of different character will be interbedded.

The clay is usually white or pinkish, and sometimes forms steep banks or cliffs along the bluffs or around the heads of canyons. To the harder ledges the name "mortar beds" has been applied by the

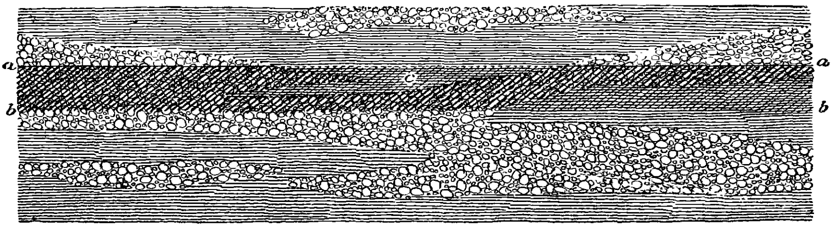


FIG. 27.—Tertiary structure, showing formation of mortar beds.

Kansas geologists. Outcrops of this formation are shown in Pls. XII, XIII, and XIV, *B*.

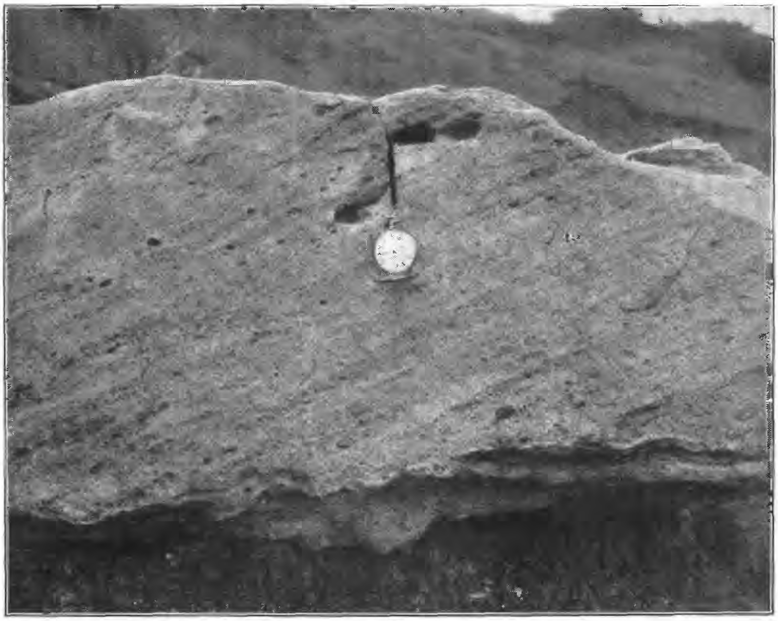
The sand is of various degrees of fineness, and is composed for the most part of quartz, although other minerals are present. The grains, when examined under the microscope, are usually rounded, indicating the action of water.

"Tertiary pebbles" is the term usually applied by geologists to the smooth, rounded, waterworn pebbles scattered abundantly over the slopes and points throughout western Oklahoma and Kansas. These pebbles have been washed out of the Tertiary deposits, of which they often constitute a moderately large proportion. They are frequently cemented together and form a hard conglomerate rock known as Tertiary grit, which on exposure forms conspicuous ledges. (See Pl. XIV, *A*.) A good example may be seen near the head of Bents Canyon, on the trail from Woodward to the Big Salt Plain.

The pebbles are of all sizes, from coarse sand to stones several inches in diameter. Quartz is the principal mineral, granite, feldspar, and other minerals also being present.

[a] See article by E. Haworth, Second Ann. Rept. Kansas Univ. Geol. Survey, pp. 247–284.

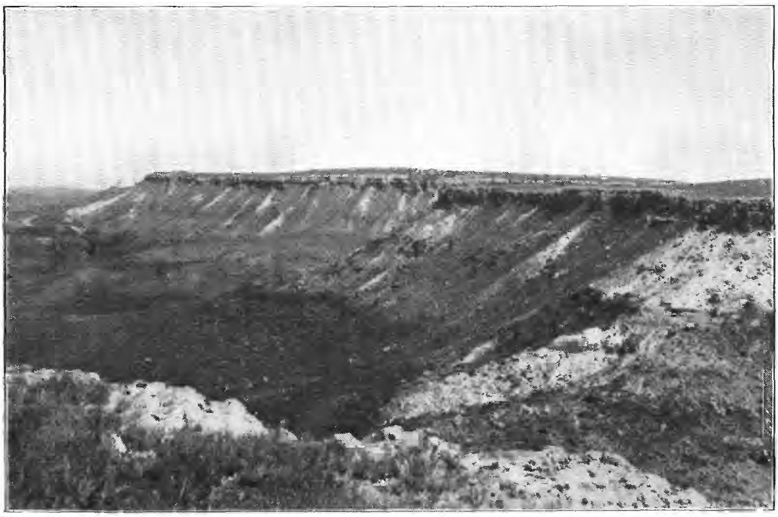
A



B

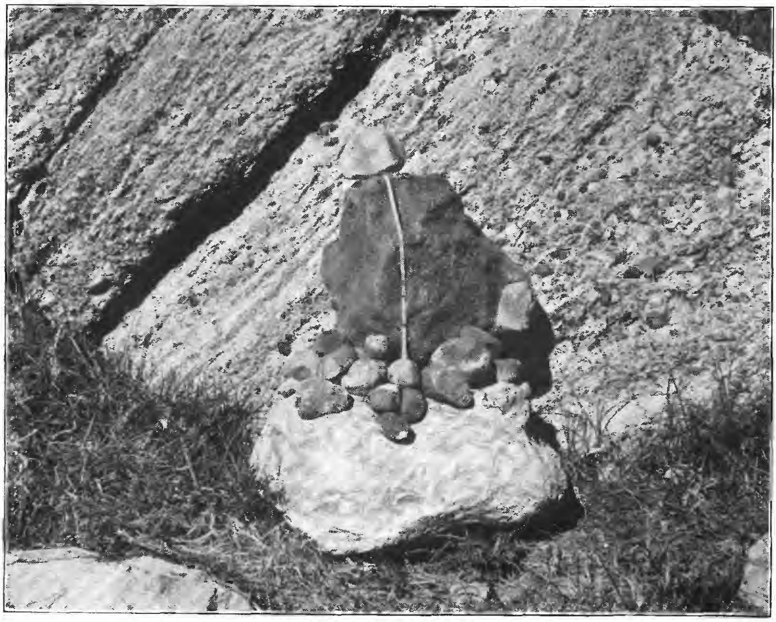
CROSS-BEDDING IN MORTAR BEDS.

A

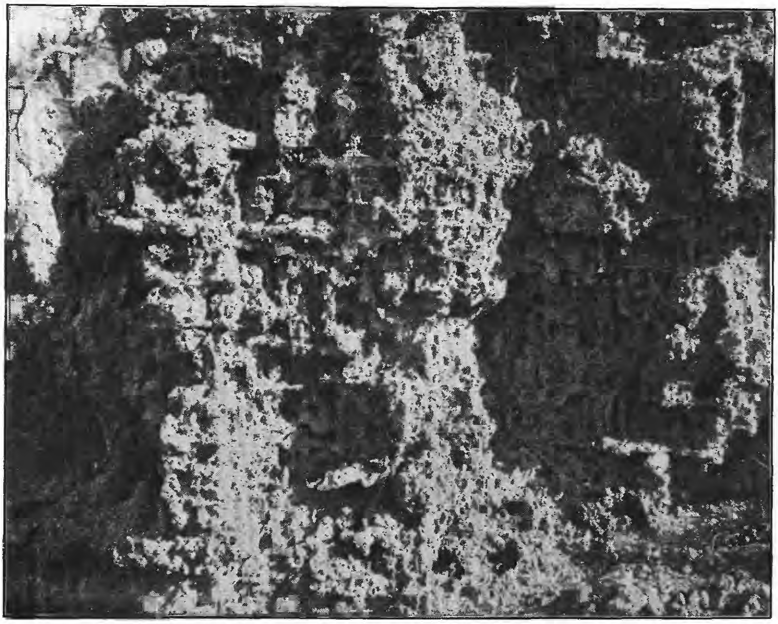


B

MORTAR-BED TOPOGRAPHY.



A. TERTIARY PEBBLES IN PLACE.



B. MORTAR-BED STRUCTURE.

In the grits and conglomerates the cementing material usually is calcium carbonate. A drop of acid placed upon almost any of the material taken from a depth of a few feet below the surface will cause it to effervesce rapidly. In addition to the materials named above there are also in the Tertiary rocks small amounts of other substances, of which the most important are silt, black sand, and volcanic ash, but they need not be discussed in this connection.

Origin.—The Tertiary is not only the latest important deposit in point of time, but it is also the only fresh water formation in Oklahoma (except, perhaps, some Pleistocene). The Pennsylvanian, Permian, and Cretaceous are sea deposits and contain marine fossils, but the fossils of the Tertiary are chiefly bones of land animals, mastodons, rhinoceroses, camels, etc., and fresh-water shells. There has been considerable difference of opinion among geologists regarding the mode of deposition of the Tertiary, but there has never been any doubt as to the fact that the Rocky Mountains alone could have supplied the vast amount of material that has been spread out over the western part of the plains.

Extent and thickness.—It is probable that the Tertiary deposits at one time covered the entire western part of Oklahoma. The valleys of the present streams have been carved in these deposits, and in many parts of the Territory all traces of the Tertiary are gone, except scattered quartz pebbles.

The thickness of the formation varies with the locality, being greatest on the high divides. Throughout a large part of western Oklahoma its thickness averages 100 feet or more, while in a few localities distant from the streams it may reach as much as 300 feet. On the other hand, in a great many places there is but a thin blanket of the deposit over the red beds.

LAVA OF BLACK MESA.

Black Mesa extends from Colorado and New Mexico into the extreme northwest corner of Oklahoma (see fig. 28). The height of the table-land above the valley of Cimarron River is approximately 500 feet, the upper 125 of which is conposed of a black, firm, basaltic lava, which lies unconformably upon beds of typical Tertiary, both the pebbles and marl being exposed along the slope of the mesa. The Tertiary in turn lies unconformably on the Dakota sandstone. The area in Oklahoma covered by this lava is 6 square miles The age of the lava flow is not ascertained beyond the fact that it was later than the Tertiary deposits, but doubtless the flow occurred when the many volcanic peaks in northeastern New Mexico were formed.

QUATERNARY SYSTEM.

SAND HILLS.

In Oklahoma there are two general regions in which sand hills

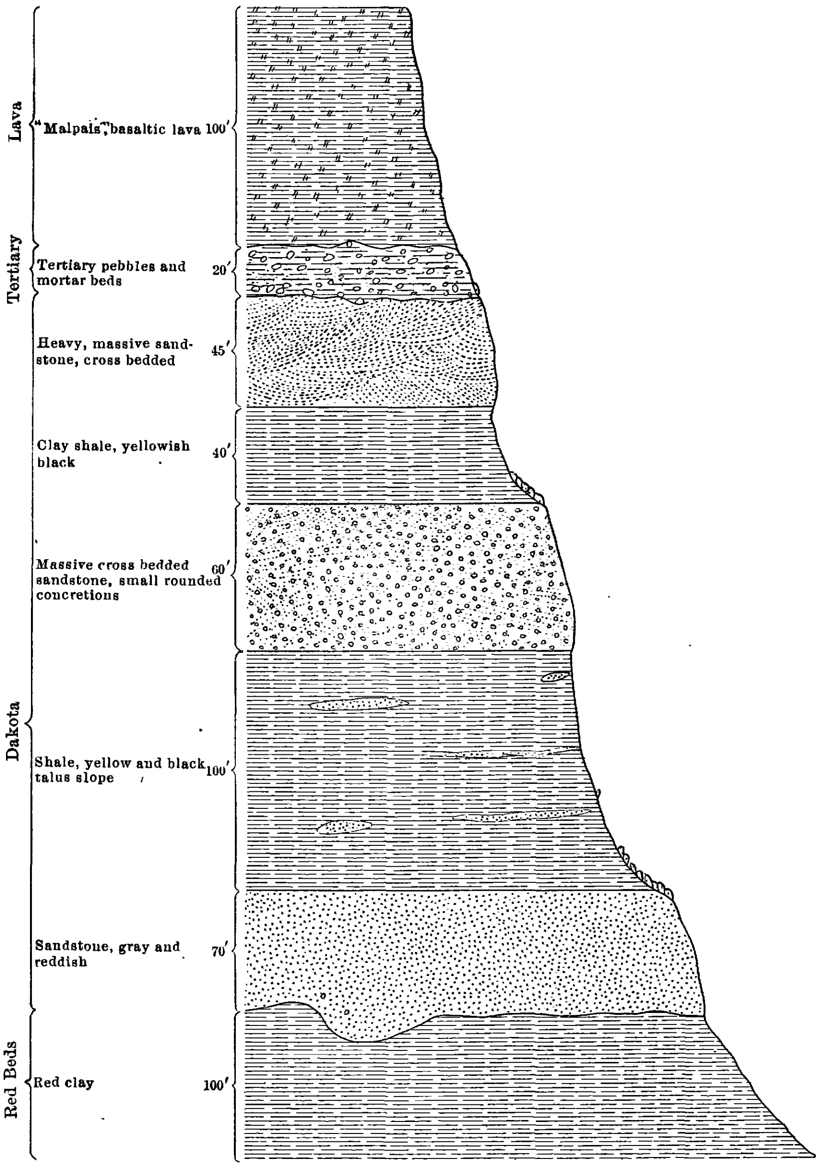


FIG. 28.—Section of Black Mesa, 2 miles north of Kenton, Okla.

occur—the first being located in the eastern tier of counties and the second in the central and western part of the Territory. The sand hills of the two regions differ somewhat in origin, but all are due to the wind.

In the eastern region the sand hills are extensively developed in parts of Pottawatomie, Lincoln, and Payne counties, as well as in the eastern part of the counties immediately adjacent on the west. The greater part of this region is underlain by Pennsylvanian rocks of the Chandler district, which consists largely of ledges of soft sand rock interbedded between arenaceous shales. It is to this sand rock that we must look for the origin of the sand hills. The agents of weathering—rain, frost, temperature, wind, etc.—break down the sand rock, leaving loose unconsolidated sand grains. The modifying force is the wind. Inasmuch, however, as this is mainly a timbered country, wind action is made much less violent than in localities farther west, and so the sand hills are usually not so pronounced as in other parts of the Territory.

The sand hills of the western region are mainly the resultant of two factors—gravity and wind. Practically all of the sand is derived from the Tertiary deposits, which, as has been stated, probably once covered nearly the entire central and western part of Oklahoma. Along the streams, particularly along the southern slopes, this blanket of Tertiary beds has been largely removed by erosion; but on the divides, and on the north slopes of the streams as well, it has remained in many places. As the Tertiary deposits consist largely of clay, sand, and pebbles, and the clay is washed away more rapidly than the coarser materials, much unconsolidated sand remains in many areas. Some of this sand finds its way to the various streams and eventually chokes their channels. During times of drought strong south winds blow this sand out of the channel onto the flood plain to the north. Some persons believe that all sand hills along the streams are composed of sand blown from the stream, but the facts observed do not justify so sweeping an assumption. In many parts of the Territory there are sand-hill regions 15 or more miles wide, extending north from the stream, and on top of some of these sand hills pebbles as large as a walnut, weighing several ounces, have been found. The writer is not yet ready to admit that the wind can carry a pebble of this size and deposit it on a sand hill.

The theory of river sand being untenable in many cases, another origin must be sought. To the writer it appears most probable that the sand which forms the greater part of these sand hills is obtained directly in place from the disintegration of Tertiary rocks and that the wind is but the modifying factor. The sand hills are mainly north of the streams, and the force of gravity is also constantly at work, producing a slow but constant creeping of the sand streamward; but, on the other hand, the prevailing winds being from the south tend to counteract the creeping motion, and so it may be assumed that the material composing the hills remains practically stationary.

Another interesting feature is the zonal arrangement of the sand hills. Every stream in the Territory, except Washita River, which is unlike all other streams of the Plains, has a row of sand hills along its north bank. Salt Fork, Cimarron, North Canadian, South Canadian, and Red rivers are all bordered with sand hills on the north side, while the south bank of these streams is usually a canyon-cut slope composed of the red clays and shales of the red beds. This subject will be discussed on pages 121, 122.

ALLUVIUM.

The flood plain, or "bottom land," of the rivers of Oklahoma is made up largely of alluvium, or, as it is often known, valley wash, derived largely from the uplands. For the most part this alluvium is composed of material derived from the disintegration of two kinds of rocks, red beds clays, and Tertiary sands and clays. In places the bottom lands have the bright vermilion hue of a red beds slope, or, again, the flood plain is made up almost entirely of white sand; but in the majority of cases the alluvium is a dark-colored chocolate loam and forms an extremely fertile soil. The extent of the alluvial deposits varies greatly along different streams. Their width is from 2 to 4 miles along such rivers as Salt Fork, Cimarron, North Canadian, South Canadian, Washita, and Red, and perhaps less than a mile along the secondary streams. The depth of the material as shown in wells varies from 2 to 30 feet.

WATER SUPPLY.

GENERAL CONDITIONS.

The water of Oklahoma varies from the purest of spring water from granite rocks or sand hills to water so thoroughly impregnated with mineral salts as to be totally unfit for domestic use. The quantity of the water is in most localities ample for all ordinary purposes, there being few sections in the Territory in which a supply may not be obtained in wells of moderate depth.

In order to study intelligently the problem of water supply in a region with so many and varied kinds of water as Oklahoma it becomes necessary to subdivide the Territory into districts, each of which furnishes water of a certain more or less uniform quality. In Oklahoma it has been found that no better general system of classification may be adopted than the one already given under the heading

"Topography," for the topographic features and character of water both depend primarily on the rocks. The topographic divisions are as follows: Wichita Mountain region, Flint-Sandstone Hills region, Low Plains region, Gypsum Hills region, High Plains region, and Dakota Sandstone region. The general outline of these various regions is given on pages 13–18, and illustrated on fig. 1 (p. 14).

Another factor which should be mentioned before taking up the various regions in detail is the kinds of rocks in which water occurs. Leaving out of account the Wichita Mountain region and the Osage nation, practically all the water in Oklahoma comes from either red beds or Tertiary deposits. In the Tertiary areas the water is almost uniformly sweet, pure, and wholesome; in the red beds, on the other hand, it is often unfit for use. The red beds are practically everywhere present at the surface, except in the western part of the Territory, where they are covered by Tertiary deposits. It will be remembered that Tertiary rocks cover nearly all of Beaver County, as well as large areas in other western counties, and occur as rows of sand hills covering the red beds along the north side of practically all the large streams nearly to the eastern part of the Territory. The water in these Tertiary sand hills is good; it follows that well-defined zones or belts of good water extend far east into the general area of red beds.

The water in the alluvial deposits along the streams is usually both abundant and of good quality. As the alluvium is composed largely of sand, clay, and loam derived from red beds and Tertiary rocks, and the amount of sand usually is sufficient to make it porous, the entire flood plain of nearly all the streams is saturated with water. Even in those areas of the red beds where good water can not be obtained from the red clays of the uplands, it is not unusual to find an abundant supply of pure water along the river bottoms, and not infrequently a small creek or even a prairie sand draw will contain a deposit of alluvium from which a considerable supply of water may be obtained. Medford, Enid, and Weatherford may be cited as examples of cities that obtain water under such conditions.

WICHITA MOUNTAIN REGION.

In the Wichita Mountains numerous springs issue from granite and porphyry rocks and furnish an abundant supply of water of good quality. Such creeks as Medicine Bluff, Blue Beaver, West Cache, Oak, Otter, and Rainy Mountain are fed at least in part by springs from igneous rocks.

In the limestone hills north of the main range springs issue from the Arbuckle limestone, and Blue, Chanler, East Cache, Rainy Mountain, and other creeks are fed in part by them. Few wells have been put down as far as either igneous or limestone rocks, but in many mining shafts water is encountered in such quantities as to interfere seriously with the progress of the work, indicating the presence of considerable quantities of ground water.

In the red beds country surrounding the mountains, water is usually found, but in many places neither the quantity nor the quality is satisfactory.

FLINT-SANDSTONE HILLS REGION.

This region includes the Osage and Kaw reservations north of Arkansas River, all the counties along the eastern boundary of the Territory and the eastern part of Kay, Noble, Logan, Oklahoma, and Cleveland counties. In other words, it comprises practically all the territory east of the main line of the Atchison, Topeka and Santa Fe Railway. It is 150 miles long, north and south, with an average width of 50 miles, and has an area of approximately 7,500 square miles.

This region corresponds closely to the outcrop of the Pennsylvanian series as represented in eastern Oklahoma. In the western part of the Osage Nation is the southern end of the Flint Hills, the rocks of which consist chiefly of limestones and shales, while farther east in the same reservations sandstones and shales predominate. South of Arkansas River limestones are rare, sandstones and shales predominating. In this part of the region, particularly in parts of Lincoln and Pottawatomie counties, there are considerable areas of sand hills, the material of which is disintegrated sand derived from the rocks in place.

In general, this district is the best-watered part of the Territory. There are several reasons for this condition: First, the rainfall is from 35 to 40 inches, being greater than in the regions farther west; second, the rocks consist largely of porous sandstone which is an excellent water carrier; third, there is a smaller amount of mineral salts in the rocks of this region than in those farther west. Springs are not uncommon. In the Osage Nation, as well as in the counties south of Arkansas River, a number of springs issue from above the shale beds, beneath either limestone or sandstone ledges. Wells have been put down on practically every quarter section and the greater part of them furnish good water at moderate depths.

LOW PLAINS REGION.

This region has been outlined on page 16. It extends practically from the main line of the Atchison, Topeka and Santa Fe Railway west to the Gypsum Hills. Geologically it includes the Enid division of the red beds, the rocks consisting chiefly of red clays and shales, with a few thin interbedded beds of red sandstone. North of each of the rivers which cross this region—Salt Fork, Cimarron, and North and South Canadian—is a strip of sandhills country from 2 to 15 or more miles wide.

Water from the red beds usually contains mineral salts, which in many places render it unsatisfactory for use. In Oklahoma water that is unpleasant to the taste is often called "gyp water." As the popular phrase has it, "Gyp water tastes sleek and greasy and leaves an aftertaste in the mouth." Much of the water, however, does not contain any great percentage of calcium sulphate. The most common salts are sodium chloride, sodium sulphate, calcium carbonate, magnesium sulphate, sodium carbonate, magnesium carbonate, calcium chloride, and sodium borate, in the order named. Sometimes nearly all these salts are found in the water of a single well, while in other instances but one or two may appear.

In this part of Oklahoma springs are rather rare in the red beds, and the greater part of the water for domestic use is obtained from wells. Often a farmer is obliged to sink half a dozen wells in order to find one in which the water is both sufficient in quantity and suitable in quality for general use. In certain parts of the region, notably part of Woods County, the water is often so salty as to be unfit for drinking.

Among the sandhills north of the rivers the conditions are different. Here water is both abundant and pure. Springs which issue along bluffs and wells obtain a good supply of excellent water at moderate depths.

GYPSUM HILLS REGION.

The Gypsum Hills region includes parts of Woods, Blaine, Caddo, and Comanche counties, and all counties west of these except Beaver and parts of Woodward and Roger Mills. The rocks consist of the Woodward formation, the Greer gypsum, and the Quartermaster formation. It will be remembered that the Whitehorse, the middle member of the Woodward formation, and the Quartermaster are both composed of sandstone. With these exceptions the remainder of the rocks here consist of beds of gypsum interstratified between red shales. It is the gypsum that gives the mineral character to the water. In both the Blaine and Greer gypsum hills the water of many springs is so strongly impregnated with calcium sulphate as to be undrinkable. Salt springs are not uncommon, six of the seven known salt plains in Oklahoma being at the base of the Gypsum Hills.

In wells in the Gypsum Hills water is usually reached at a moderate depth, ranging all the way from 10 to 150 feet. It usually resembles the water from the springs in the same region and contains relatively large amounts of gypsum.

Water from the Whitehorse sandstone is usually pure and wholesome. Springs are not uncommon in this member and wells usually obtain a good supply at reasonable depths.

In the Quartermaster formation where the water is usually good the rocks consist largely of fine-grained red shaly sandstone. A very peculiar class of springs, best described by the term "seep springs," is found here, and that character is due to the nature of the rock. Usually these seep springs issue from the head of small canyons carved in the red sandstone, and bold springs are rarely found in this region. Seeps, however, are common and one not infrequently comes upon a basin which has been hollowed out in the soft sandstone and is kept full by this kind of flow. Wells in the Quartermaster usually obtain a sufficient supply of water at moderate depths. Among the sand hills areas north of the various streams springs and wells are common.

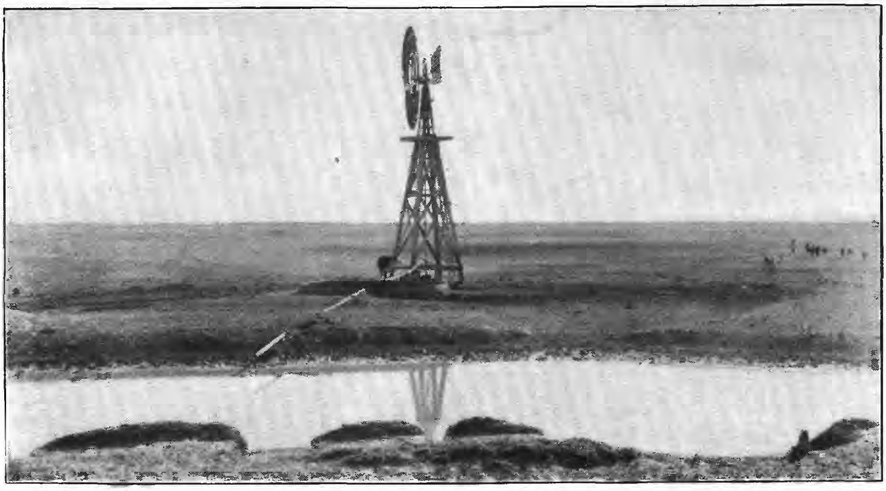
HIGH PLAINS REGION.

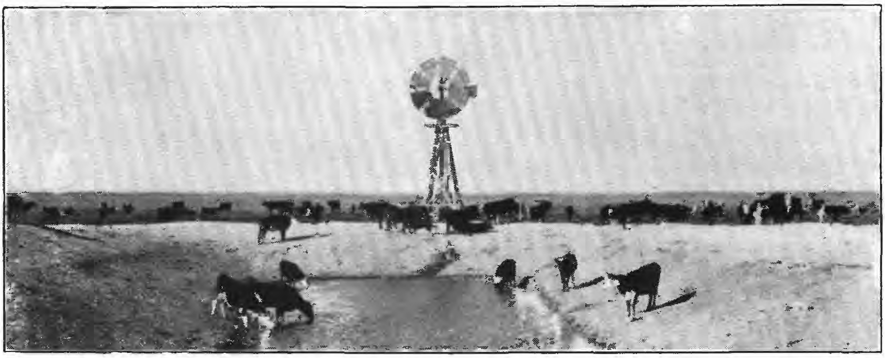
The Tertiary plains of Beaver, Woodward, Day, and Rogers Mills counties only are included here, although in fact the sand hills north of the various streams in the Territory belong to this division both by reason of the quality of the water and the character of the rock. In the High Plains good water is obtained almost uniformly. The Tertiary rock consists chiefly of sand, clay, and gravel, and as the sand and gravel beds almost invariably contain water, wells sunk to these beds usually secure an abundant supply. In the counties mentioned above the wells are usually deep, often as much as 300 feet or more, and windmills are used almost exclusively to bring water to the surface, but the supply is certain. In Pl. XV are shown typical High Plains windmills.

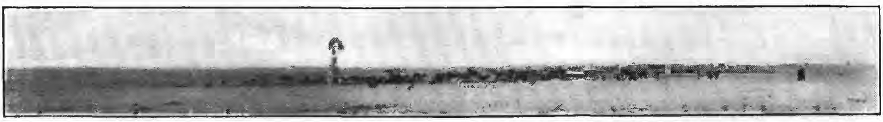
In many places where a stream has cut through the Tertiary into the subjacent red beds exposing an unconformity, a spring issues, the water of which is sweet and pure like the well water on the high plains. Some of the best water in Oklahoma comes from the Tertiary springs. Many a ranch and farmhouse and even some towns, as for instance Cleo and Grand, have been located with reference to some Tertiary spring.

DAKOTA SANDSTONE REGION.

In Kansas and Nebraska the Dakota sandstone is famous for its springs, but in the Dakota sandstone of western Beaver County springs are scarce, and so far as noticed by the writer the conditions in other parts of Oklahoma and New Mexico where these rocks are







HIGH PLAINS WINDMILLS.

exposed are similar to those in Beaver County. However, springs in the Dakota beds are not unknown and the water that is found is of good quality. Few wells have been put down in that region and consequently data for wells in the Dakota in Oklahoma are not available.

STREAMS.

None of the important rivers of Oklahoma rise in the Territory. Two out of the seven—the Arkansas and South Canadian—rise in the Rocky Mountains, and the others have their headwaters on the High Plains of Texas, New Mexico, Colorado, or Kansas, and flow across Oklahoma in a general southeast course. The Salt Fork and Cimarron empty into the Arkansas in northeastern Oklahoma; the North and South Canadian unite before joining the Arkansas in the eastern part of Indian Territory, and the Washita joins the Red River at the southern line of the Indian Territory. The map (Pl. XVI) shows the drainage areas of the rivers which flow across Oklahoma.

ARKANSAS RIVER.

Arkansas River flows southeast across the northeast corner of Oklahoma, separating the Kaw and Osage nations from the remainder of the Territory. For almost its entire course in Oklahoma it winds through a rather deep and narrow valley among the Flint Hills, where it is characterized by sweeping curves and bends. In many places it flows at the foot of steep limestone bluffs, while the whole region is cut into a series of hills and hollows by a number of small creeks tributary to it. It is estimated that during the past few years the supply of water in the Arkansas has decreased, owing to the fact that so much is taken out for irrigation purposes near the head of the river. In central Kansas there seems little doubt that the visible supply is less than in former years. Much of the water in this stream in Oklahoma comes from tributaries, such as Little Arkansas, Ninnescah, Walnut, and Grouse, that empty below Hutchinson, Kans. In Kansas, where the river flows in a broad valley in the prairie, it has a considerable underflow, but in crossing the Flint Hills this underflow is forced to the surface, and for that reason the channel rarely runs dry. Analyses Nos. 111, 112, 113, and 114 are from waters of the Arkansas or the smaller tributaries.

SALT FORK.

Salt Fork of the Arkansas rises in southern Comanche County, Kans., west of the line of Gypsum Hills, enters Oklahoma in northwestern Woods County, and flows through southern Grant and Kay counties before joining Arkansas River. Its total length is approximately 150 miles, 115 miles of this distance being in Oklahoma.

Salt Fork receives a number of tributaries, most of which are fed by springs from the Tertiary. The greater part of these enter from the north, and two of them—Medicine and Chikaskia rivers—carry as much water as does the Salt Fork above the mouth of the Medicine. Besides the two large tributaries just mentioned the following creeks enter from the north: Mule, Sand, Crooked, Roundpond, Cottonwood, and Bois d'Arc, and from the south Coldwater, Clay, and Sand creeks. These creeks are for the most part typical prairie streams, with shallow valleys, low banks, and sand-filled channels, and for a part of the year at least they are dry.

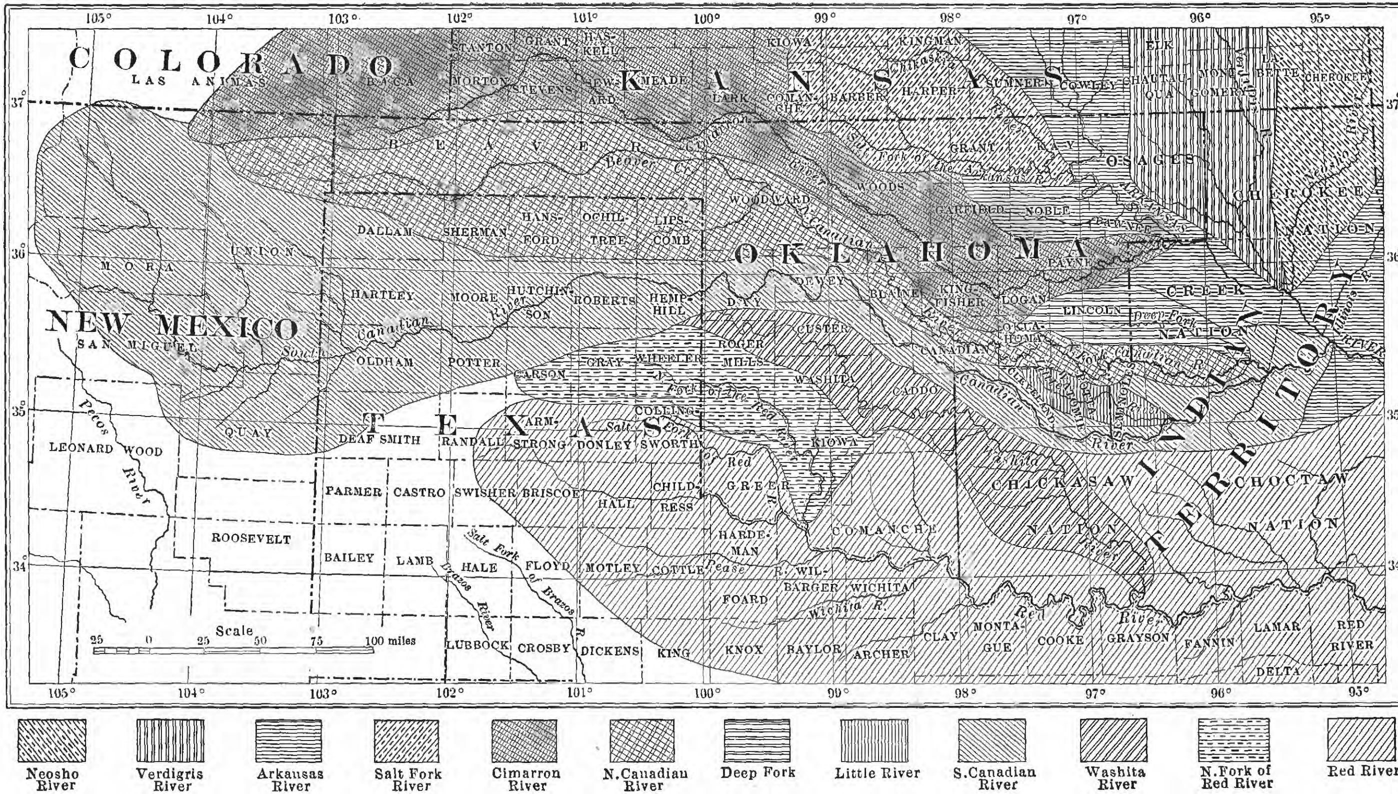
In eastern Woods County the Salt Fork flows across the northern end of the Great Salt Plain, which has an area of approximately 60 square miles. It is 10 miles long and 6 miles wide, irregularly oval in shape, level as a floor, and, except after a rain, as white as a snow field. The water of the river mingles with the saline water of the plain and takes on a distinctly salty taste; so much so that at certain times of the year stock will not drink it.

Analysis No. 86 is of water taken above the Woods County Salt Plain; Nos. 87 and 88 from below the plain, and Nos. 89 and 90 from small streams tributary to the Salt Fork.

CIMARRON RIVER.

The Cimarron rises among the volcanic peaks of northeastern New Mexico and carries a small volume of water into Oklahoma. In New Mexico and for 30 miles into Oklahoma the river flows in a canyon cut through Dakota sandstone rocks into the subjacent red beds. From the sandstone issue springs which supply a number of intermittent creeks, Travessier, Carriso, Carrisoso, Tequesquite, and others which flow for at least part of the year. The channel of the Cimarron in this part of its course is not more than 20 feet wide and is confined often by mud banks. In flowing out of the canyon onto the Tertiary plain, 30 miles east of the New Mexico line, the character of the stream begins to change; the channel widens and fills with sand, the banks become low, and from this point to its mouth at ordinary stages of the river the water wanders about over sandy beds.

At irregular intervals along this river water sinks in the sand and passes beneath the surface for a number of miles. For instance, from the old post-office of Metcalf, Okla., to Point of Rocks, Kans., a distance of 25 miles, the channel of the Cimarron is often dry, but at Point of Rocks the water comes to the surface at Wagon Bed Springs, a famous camp on the old Santa Fe trail, and the channel is usually full for a number of miles. It gradually sinks again,



MAP SHOWING DRAINAGE AREAS OF STREAMS CROSSING OKLAHOMA.

however, before reaching Oklahoma the second time, so that above the mouth of Crooked Creek the channel is often dry. This creek, however, is perennial, and below its mouth the river carries water for many miles.

Until it flows across the Salt Plains in northern Woodward County the water of the Cimarron is pure and sweet, being derived largely from Tertiary springs, but from this point it contains so much salt that stock will scarcely drink it. Salt springs flowing from the base of the Gypsum Hills give rise to the Little Salt Plains near the Kansas line and the Great Salt Plains, shown in Pl. XX, 10 miles farther downstream.

The drainage basin of the Cimarron is more regular in outline than that of any other Oklahoma stream, averaging 40 miles or more in width across the Territory, and the stream flows approximately equidistant from either divide. The valley is from 100 to 300 feet lower than the valley of North Canadian River, which parallels the Cimarron on the south. Excluding a number of short streams in the Gypsum Hills, the principal creeks that enter the Cimarron from the north are Eaglechief, Indian, Turkey, and Skeleton, and those from the south are Salt, Kingfisher, and Cottonwood. These creeks, which will average 30 or more miles in length, enter the river at an acute angle, have a well-developed radiate drainage, and are in every way normal tributary streams, a fact rather unusual among the smaller creeks of Oklahoma.

In central Oklahoma the channel of the Cimarron is from a quarter to a half mile wide, with low sandy banks and a relatively small amount of water. For a part of each year the river runs dry, but, like all other streams of the plains, it is subject to sudden and rapid rises, at which times the river will often remain bank-full for several days. The sand partakes of the nature of quicksand, and after a rise it is unsafe to attempt to cross the river. Farther east the river enters the sandstone-bluff country and the channel is often narrowed, but the characteristic sandy condition prevails to its mouth. Water analyses Nos. 91 and 92 are from the Cimarron above the Salt Plains, Nos. 93, 94, 95, 96, 97, 98, and 99 from below the Salt Plains, and Nos. 100, 101, 102, 103, 104, 105, 106, 107, 108, 109, and 110 are from tributaries of the Cimarron.

NORTH CANADIAN RIVER.

Beaver Creek and Wolf Creek unite at old Fort Supply, in central Woodward County, to form the North Canadian. Wolf Creek rises in the northern part of the Panhandle of Texas and flows northeast into Oklahoma, while Beaver Creek heads in northeastern New Mexico and flows east the entire length of Beaver County before reaching

Woodward. Both these creeks are fed largely by Tertiary springs, and for that reason are practically perennial streams, and both are subject to rapid rises occasioned by local storms. The North Canadian has no large tributaries. With the exception of Indian and Persimmon creeks, in Woodward County, neither of which exceed 20 miles in length, there are few tributaries more than 10 miles long.

Throughout its entire course, a distance of approximately 200 miles, the width of the drainage basin of the river does not average more than 15 miles, and in places the distance from the bed of the North Canadian across the divide to the waters of the Cimarron is not more than a mile. This is the case at Oklahoma City and a few miles east of Elreno.

The North Canadian has perhaps the best water of any of the larger streams in Oklahoma, owing chiefly to two causes—first, the river is fed largely by Tertiary springs; and, second, it does not flow through regions of salt springs. The waters of Salt Fork, Cimarron, and Red rivers are salty, and the South Canadian and Washita waters are derived largely from the red beds, and consequently contain both gypsum and salt. The water of the North Canadian, on the other hand, is usually soft and of a good quality. There is more timber along the banks of this stream, the flood plain is more uniform, and in general it appears more like an eastern river than any of the others just mentioned, except the Washita. Water analyses Nos. 115, 116, 117, 118, 119, 120, and 121 are of water from the North Canadian, and Nos. 122, 123, 124, 125, 126, 127, 128, and 129 from its tributaries.

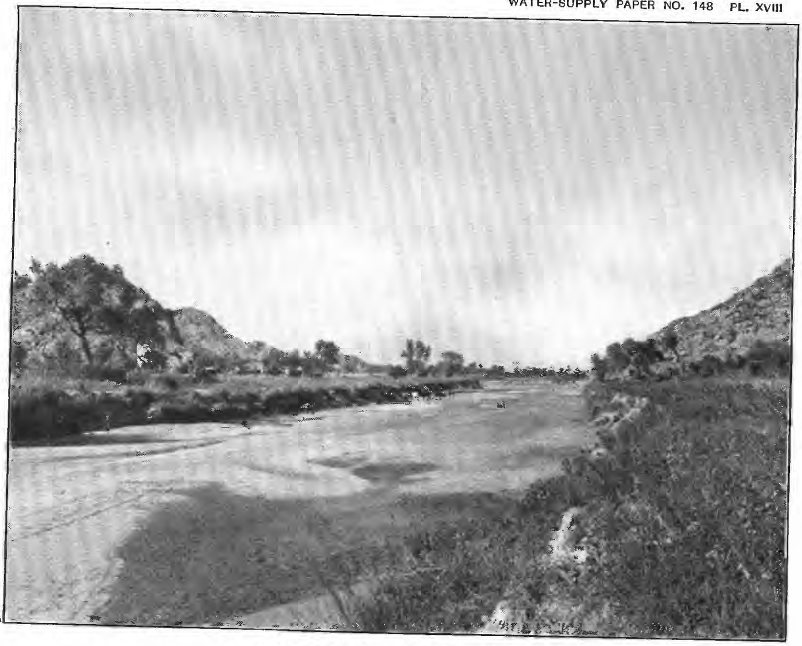
SOUTH CANADIAN RIVER.

The headwaters of the South Canadian flow from the snow-covered peaks of the high ranges of the Rocky Mountains in northern New Mexico. A characteristic view along its upper course is shown in Pl. XVIII, *B*. In that territory the South Canadian drains approximately 30,000 square miles, having a drainage area of 150 by 200 miles in the northeastern part of the Territory; but in the Panhandle of Texas this basin narrows, funnel shaped, until by the time the river flows into Oklahoma, in Day County, the distance between the divides north and south of the river does not exceed 25 miles. From the Texas line to the mouth of the river, a distance of about 300 miles, the width of the drainage basin does not average more than 20 miles, while in places it is less than 10 miles. The channel of the river is sand choked, and throughout Oklahoma averages half a mile in width, the banks being low and sandy. Its channel is constantly shifting, and oxbow bends and cut-offs are common.

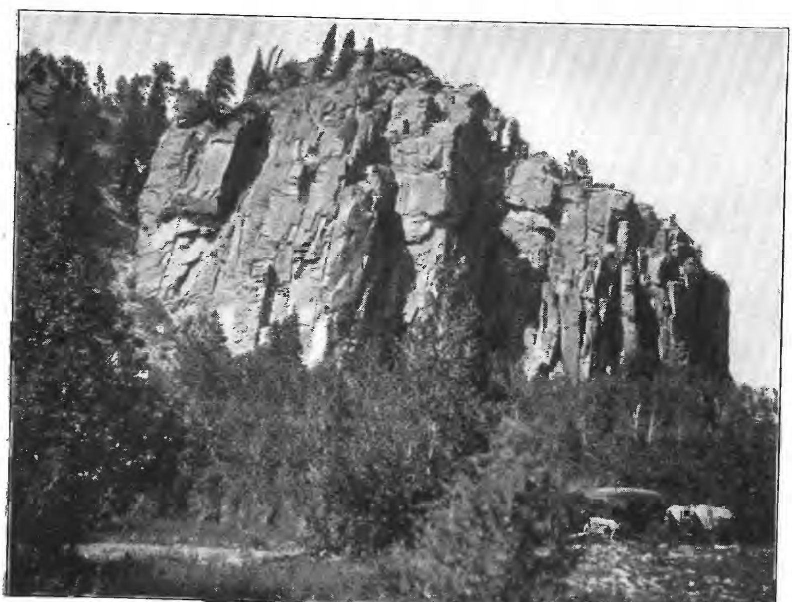
The South Canadian is the most uncertain and treacherous of all Oklahoma streams, and, with the exception of Arkansas River, the

A. BLUFF OF DAKOTA SANDSTONE.

B. RED BEDS DAKOTA UNCONFORMITY.



A. DAM SITE AT QUARTZ MOUNTAIN.



B. SCENE ALONG THE UPPER COURSE OF SOUTH CANADIAN RIVER.

largest. Its water supply is derived from several sources—partly from rainfall and springs in the mountains, partly from small tributary streams fed by Tertiary springs, and partly, of course, from local storms. This river, perhaps more than any other on the plains, is subject to sudden and rapid rises. The channel may be dry from bank to bank, when suddenly, without warning, a wall of foaming water several feet high, carrying all sorts of débris, will rush downward at great speed, filling the channel bank-full. For several days it will be full, when the water will gradually recede and the channel be dry again. The possible explanation of the phenomenon may be found in the fact that there is a large drainage area at the head of the river, but that it narrows rapidly downstream. A heavy storm on almost any one of the head tributaries of the river would cause it to rise, and the water flowing into the main channel, the sand of which is already saturated, would cause a sudden rise all along the river. It must be admitted that this explanation is at best far from satisfactory, and until the data from a number of gaging stations along this river have been obtained and the results studied it is improbable that we shall be able to determine all the causes that lead to this very interesting phenomenon.

Water analyses Nos. 130, 131, 132, and 133 show the character of the water from various points of South Canadian River.

WASHITA RIVER.

The Washita is an anomaly among streams of the plains. It alone has steep mud banks, comparatively little sand in the channel, and heavy timber on the bottom lands. To account for these facts it is necessary to consider briefly the nature of the region drained by the Washita. It alone of all the rivers of Oklahoma flows for practically its entire course through red beds rocks. In its upper part only does the river drain other formations, notably areas of Tertiary.

Rising in the eastern part of the Panhandle of Texas it flows across Roger Mills, Custer, Washita, and Caddo counties before entering Indian Territory. These counties are included in the Gypsum Hills region, and consequently the water of the Washita contains an appreciable percentage of mineral salts. The red clays and shales along the river bank are easily disintegrated, making the Washita the muddiest stream of Oklahoma. It enters Indian Territory and, after flowing for more than 100 miles across the red beds, passes through a gorge which it has cut through the lower Paleozoic rocks of the Arbuckle Mountains.

RED RIVER.

Red River, which forms the extreme southern boundary of Oklahoma, resembles the Cimarron or South Canadian in having a broad and sandy channel and an intermittent flow. The name of the river is derived from the color of the water, and the red color is derived from the red beds across which the river runs.

In Oklahoma there are several northern tributaries to the Red, the chief of which are Salt Fork, North Fork, and Cache Creek. Of these North Fork and Salt Fork take their rise on the high plains among Tertiary rocks and flow southeast across the Gypsum Hills before joining the Red. Elm Creek, which is tributary to the North Fork, drains a region of salt springs. This combination of salt, gypsum, and other mineral salts makes the water rather impure. The valley of the North Fork is shown in Pl. III, *B*.

Red River is subject to sudden and rapid rises, as are the Cimarron and South Canadian. The stockmen living near the river speak of a "7-foot rise" and a "10-foot rise" as a not uncommon occurrence. This river, however, rarely runs dry, as do those farther north. Besides the Arkansas the Red is the only Oklahoma stream that empties directly into the Mississippi.

STREAM MEASUREMENTS.

There are few data regarding the discharge of Oklahoma streams, for only within the past two years have gaging stations been established in Oklahoma. During the year 1903 stations were maintained on the following streams: Salt Fork, at Alva and Tonkawa; Cimarron, at Waynoka; North Canadian, at Elreno and Woodward; Washita, at Anadarko and Chickasha, Ind. T.; North Fork of Red River, at Granite; and Otter Creek, at Mountain Park. These stations, with two exceptions, were established in 1903, and as yet the records are in an incomplete state, but they will be found in Progress Report of Stream Measurements for the year 1903.[a]

SPRINGS.

Springs can best be classified with regard to the character of the water. Following this plan the springs of Oklahoma naturally are divided into three groups—fresh-water springs, salt springs, and sulphur springs. Under the first are grouped all the springs of the Territory except those in which the water is either noticeably salty or contains an appreciable amount of sulphur. The term "fresh water," as used in this connection, does not necessarily imply the absence of mineral salts, for the water from many of the springs described is hard, containing often a large percentage of lime, gypsum, or other mineral salt. These fresh-water springs are found in all parts of Oklahoma and form a great proportion of the whole number. Salt

[a] Water-Sup. and Irr. Paper No. 99, U. S. Geol. Survey, 1904, pp. 244 et seq.

springs, on the other hand, are found in but few localities and usually under peculiar stratigraphic conditions. Sulphur springs are even more rare, occurring only in the Wichita Mountain region.

FRESH-WATER SPRINGS.

In the Wichita Mountains there are two principal kinds of springs—those from the crystalline rocks and those from the limestone. In eastern Oklahoma there are limestone springs and sandstone springs, and in the low plains there are red beds springs. Besides these there are gypsum springs, Tertiary springs, and river terrace, or alluvial springs. These will be discussed in the order given. Pl. I gives the location of such springs in Oklahoma as are at the present time known to exist.

WICHITA MOUNTAIN SPRINGS.

The Wichita Mountain region, as a whole, is well watered. A number of bold springs flow either directly from fissures in the porphyry or granite or issue along dikes, or, perhaps, at the point of contact between igneous and sedimentary rocks. Blue Beaver Springs, Talahina Springs at Cutthroat Gap, springs near Saddle Mountain, Mount Scott, and Mount Sheridan that feed Medicine Bluff Creek, and numerous springs that supply Otter, Cache, and other creeks that flow south through the mountains are of this character. In addition to these there are great numbers of relatively weak springs that issue from small fissures in granite or gabbro rocks and flow during wet weather.

The water from these springs from the crystalline rocks is notably fresh and pure, in the main the purest water of the Territory, chemical analysis revealing a very small percentage of solid residue.

LIMESTONE SPRINGS.

Under this heading will be described not only the springs issuing from the Arbuckle limestone hills in the Wichita Mountains, but also those that flow from the conglomerate that surrounds these hills, and the limestone springs in eastern Oklahoma, chiefly north of Arkansas River.

The springs flowing from the conglomerate hills north of the main range of the Wichita Mountains are probably the largest of any in the whole region. The distribution of the conglomerate is very irregular; it fills the old valleys and in some places extends beyond, covering tracts of country several miles in area to a depth of sometimes as much as 60 feet. The formation is very porous and most of the rain which falls on it is absorbed, so that the supply of underground water during wet seasons is large, and springs often flow as much as a cubic foot of water a second. The areal extent of the formation is so limited, however, that after a few months of drought the flow from the springs either decreases materially or may even cease entirely. None of the springs are badly choked with sand, so their flow is not retarded in this way.

Most of the limestone springs of the region do not differ greatly in this respect from the conglomerate springs. They are often as strong as the former, and like them they usually go dry or run very low during dry seasons, particularly in the later summer months. The hills from which these springs get their supply of water consist of tilted ledges standing almost on edge, which naturally form a good reservoir, but these hills are so limited in size that where the water is free to escape it soon leaves the rock dry. Where banks of sand and alluvium surround the base of these hills the water is retarded in its escape, and under this condition there is a constant flow without much fluctuation. Next to the alluvial springs, which will be discussed below (p. 99), the limestone springs are more widely distributed throughout the region than any others.

The water from both conglomerate and limestone springs contains a certain amount of mineral salts, chiefly calcium carbonate, but none in quantities that render it objectionable. These springs are among the most important in the Territory.

Limestone springs in eastern Oklahoma are confined to the Osage Nation and Kay and Pawnee counties, where they occur along many of the creeks. They usually come from a ledge of limestone which immediately overlies a stratum of clay or shale, although sometimes they may be found flowing from a porous rock lying above a more impervious limestone, the largest springs of the region appearing under the latter conditions. The springs of this part of the Territory are neither large nor very numerous, the flow being limited by the impervious character of the rock as well as by the fact that the water-bearing beds are not of sufficient extent to supply a strong stream of water.

The springs which flow from the harder ledges of limestone generally are unimportant, being mere seeps, often too weak to be utilized even for watering stock. Farmers owning such seeps sometimes dig cisterns in the clay just under the point where the water appears, and by so doing manage to secure a supply of water for domestic purposes. Some of the ledges of limestone are more porous than others, and these porous or shattered ledges furnish an abundance of spring water where the overlying strata permit percolation. A condition of this kind in eastern Kay County yields several good springs, one particularly on Deer Creek, northeast of Newkirk, which issues just over a ledge of compact limestone. This is the largest spring of this character known, and its flow averages about 0.5 second-foot.

SANDSTONE SPRINGS.

In eastern Oklahoma the whole region from Payne County southward is crossed by a number of alternating ledges of sandstone and clay, and in many places where a draw or creek cuts one of these strata a spring is found. In the northern counties the flow is usually free and uninterrupted, but farther to the south there is often a superficial covering of sand, derived from disintegration of rocks in place, through which the water flows, and eventually reaches the underflow in the sand-choked bed of some stream without appearing at the surface. In the southern counties, where this condition often occurs, there are fewest springs, but to offset this plenty of well water can be obtained at a short distance beneath the surface. In wet weather springs often appear for a few weeks in places where this blanket of sand on a hillside is not deep enough to carry off the flow of the buried spring in addition to the extra rain water which is moving down the slope, but the stream supplied by such a spring usually sinks before it goes far. The flow from most of the springs of this region is very limited. This is due to probably two principal reasons: First, the country is so cut up by small streams that the area of water tables is limited; and second, the rate of flow through sandstone is so slow that no large quantities of water can be delivered at the spring under the slight hydrostatic pressure in such small areas. Many small hills often have a half-dozen springs on their slopes. The upper ledge of sandstone usually furnishes the main flow, although a hill which contains a number of alternating strata often has seeps coming from all the sandstone formations. Few, if any, of the springs of this country will flow over 0.5 second-foot; but as a whole the region is well watered.

RED BEDS SPRINGS.

Most of the red rocks of the Low Plains region belong to the Enid formation and consist of shales and clays, with occasional ledges of sandstone. While springs occur in all the rocks, they are by no means abundant, the unbroken topography not being suitable for their development and the rock not being sufficiently permeable. The clay, however, is often a kind of joint clay and the water passes through its seams to a limited extent in veins. Where springs occur in the shale and clay of this part of the red beds they often are large. Two causes may be assigned for this. In the first place, the water beds, although with a small capacity for holding water, are of wide extent.

In the second place, the clay of the region yields readily to the action of running water, and when once a small vein is cut it soon becomes enlarged and joins with others in its vicinity, thus producing a bold spring.

The quality of the water of these springs is variable, some of them yielding soft and palatable water, while others are heavily charged with sulphur and gypsum. The conditions which bring about these different characteristics are local. Bois d'Arc Springs, in Kay County, are charged with gypsum, while not far from these are Willow Springs, the water of which is almost soft. Timberlake Springs, in Woods County, on the western border of the plains, flow soft water, while a number of springs not far east of them contain gypsum. The springs flowing from the sandstone of the region resemble those coming from the same kind of formations in the eastern part of the Territory, except that they are never choked with sand.

GYPSUM SPRINGS.

In the Gypsum Hills region, in the western part of the Territory, are numbers of springs in which the water is strongly impregnated with calcium sulphate, which are consequently known as "gypsum springs," or more popularly as "gyp springs." The greater part of the springs of this kind issue from directly beneath heavy ledges of gypsum, and in many cases are due to underground streams. The Gypsum Hills country is full of sink holes and caves, most of which contain underground streams. Such caves and sink holes as are shown in Pl. XI and fig. 9 are abundant.

Gypsum springs such as those just described are particularly common in Blaine, Woodward, Washita, and Greer counties, where the Gypsum Hills have their most conspicuous development. Some of them are strong, flowing as much as 5 second-feet.

TERTIARY SPRINGS.

Springs occur in the sand hills north of the rivers from the western line of the Territory as far east as the eastern limit of the Low Plains, as well as in the High Plains region of Beaver, Woodward, and Day counties. In the western part of the High Plains region they flow out near the rivers on both sides of the stream, but farther eastward they appear chiefly along the divides of the rivers. Before reaching the Gypsum Hills, the Sand Hills formation, from which they flow, disappears along the south sides of the rivers, but continues, usually in the form of a heavy row of wind-blown sand hills, on the north sides. These hills, as well as the springs flowing from them, extend eastward across the Low Plains country and gradually grow smaller, finally disappearing in the eastern part of the Territory.

A

B

TERTIARY SPRINGS AND CONTIGUOUS TOPOGRAPHY.

The springs in these hills as far west as the High Plains almost always issue along the lines of unconformities between the Tertiary deposit above and the red beds beneath, usually where a creek has cut through the sand into the red clay and shale below, thus exposing the water plane, as shown in fig. 29. In some places the water flows out along a bank for a distance of several hundred yards, as in the case of Cleo Springs in Woods County; in other cases it issues as a single bold stream—for instance, in Bents Canyon in northern Woodward County. In many cases these springs boil up from the sand, and are often called boiling springs. Springs of this kind are, in fact, artesian in character, and will often raise the water to a height of several feet if confined. In Pl. XIX Tertiary springs and characteristic contiguous topography are shown.

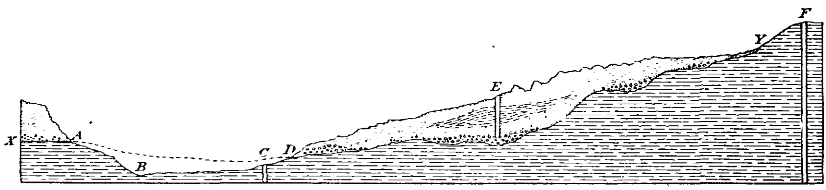


FIG. 29.—Ideal section of Tertiary springs. *A, D,* Tertiary springs; *C, F,* wells in red beds; *E,* well in Tertiary.

It can be said almost without exception that all Tertiary springs yield relatively strong flows. The material from which the water comes and through which it circulates is so coarse that the flow is less impeded than in the case of any other class of springs of the Territory, unless, indeed, it be the springs flowing from the conglomerate in the Wichita Mountains. An immense amount of water is allowed to go to waste every year by not utilizing these springs. In some instances the owners are using them for irrigation purposes, but as a general rule little attention is paid to their economic value. The city of Alva uses water from a Tertiary spring. It is carried by gravity through pipes a distance of 2 miles to a cistern and is then distributed to the different pipe lines of the city by pumps. The supply is more than adequate. None of the Tertiary springs have been known to go dry during the droughts which are common to the region in which they occur. They sometimes diminish in flow, but this is rarely ever the case. The water of the Tertiary springs is almost without exception soft and palatable.

ALLUVIAL SPRINGS.

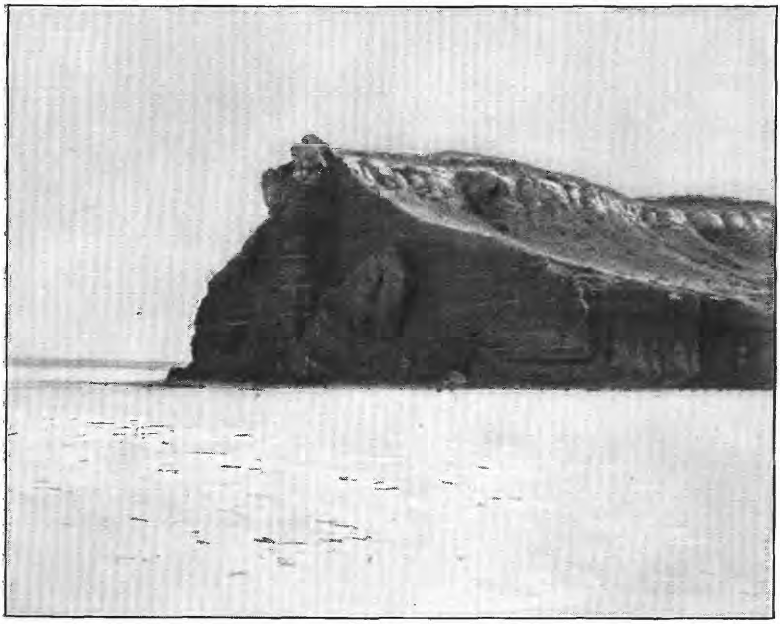
Springs of this kind occur along the rivers in all parts of the Territory, but are most common in the Wichita Mountains and along Arkansas River. The alluvial springs of the Wichita Mountains are found along the banks of every stream of the region, issuing just above the surface of the water or flowing out onto the low bottom lands. Nearly every piece of low land has at least one spring flowing from it. They are rarely strong. The flow usually comes from the base of the deposit and trickles out for several rods along the bank, or else it issues from a single outlet. These springs furnish a large amount of water to the creeks, and altogether they probably do more than their share toward supplying the running water of the region. On account of their number and distribution they are probably of more economic value than the other springs of the mountains, but at the same time are less conspicuous.

Along Arkansas River in Oklahoma these springs from terrace deposits usually are large, although in many cases they do not flow out in a bold stream, but hundreds of small seeps come out along a bank for several hundred yards and the aggregate is a large stream of water. In the Wichita Mountain region these springs appear near the present creek beds, but along Arkansas River they usually flow from terrace deposits which are now many feet above the river channel. These deposits are rarely over half a mile wide and seldom more than 30 feet deep. The springs flowing from them seldom go dry and are rarely ever affected by drought.

SALT SPRINGS AND PLAINS.

Wells and springs, the water of which contains an appreciable amount of common salt (sodium chloride), are found not only throughout the red beds, but also in the Pennsylvanian rocks, and in certain regions the water from the springs is of such noteworthy salinity as to warrant the popular phrase "salt spring" or "salt plain." Leaving out of account the regions in eastern Oklahoma in which the water is but slightly salty, it is proposed to describe the localities, particularly in the western part of the Territory, in which salt springs and salt plains are common.

There are two salt plains in Woodward and Greer counties and one each in Woods, Blaine, and Roger Mills counties. These plains have a wide geographical distribution and vary greatly both in size and amount of flow. While all the salt springs come from Permian red beds, they do not issue from the same geologic horizon. The Woods County plain is located a little more than halfway up the Enid formation of the red beds, the Woodward and Blaine county plains are supplied by springs that issue near the top of the Enid, not far below heavy gypsum members of the Blaine formation, and the Roger Mills and Greer county plains are found either near the base of the Greer formation, or, in some instances, springs are known to issue between gypsum ledges which are members of the Greer.



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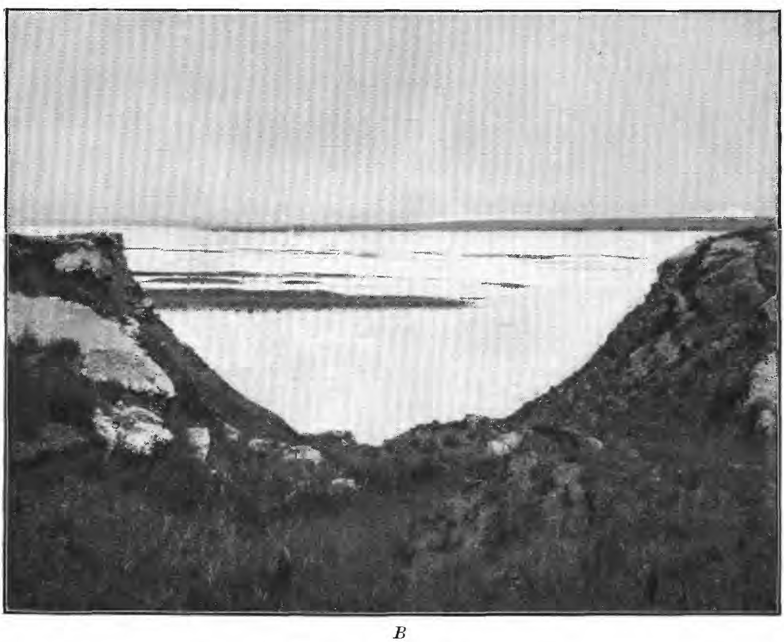


B

SALT PLAINS ON THE CIMARRON.

WOODS COUNTY PLAIN.

This is the largest of all the Oklahoma Salt Plains and also the only one that contains no large salt springs. It is located just south of the Salt Fork of the Arkansas in the eastern part of Woods County, about 35 miles from the nearest point of the gypsum hills, and includes an area of approximately 60 square miles, extending about 10 miles north and south and 6 miles east and west. The plain is as level as a floor, and on ordinary occasions as white as a snow field, from the incrustation of salt crystals which cover it. It is absolutely barren of vegetation, with only here and there a scattered bit of driftwood to break the monotony.

The origin of the salt on this plain is somewhat obscure. About the margin of the plain are a few weak salt springs, but they rarely furnish sufficient water to form a running stream. On digging a hole a few feet deep in any part of the plain, however, salt water begins to run in, and in ten minutes the hole will fill up to a point within 6 inches of the top. The plain is composed of loose reddish-brown sand and clay, which is apparently everywhere saturated with salt water. The surface evaporation of this water gives rise to the white salt incrustations which render the surface of the plain white, except after a rain which has dissolved the salt crystals. To the writer the only plausible explanation of the origin of the salt water is to suppose that it comes from a large number of small springs which issue from the red beds at the bottom of the plain. There is no way of estimating the amount of flow from this plain, but total volume of water is many second-feet.

WOODWARD COUNTY PLAINS.

In Woodward County there are two salt plains, both located in the valley of the Cimarron and fed by springs which issue from red shales 50 to 100 feet below the Medicine Lodge gypsum. Locally these plains are known as Big Salt Plain and Little Salt Plain, the latter being just south of the Kansas line, where the Cimarron River first breaks through the line of gypsum hills.

The Big Salt Plain is located 12 to 20 miles farther down the Cimarron, extending for 8 miles or more along the river. In width it varies from half a mile to 2 miles. On the south bank the bluffs of red shale and sandstone capped with gypsum rise directly from the edge of the plain to a height of 100 feet or more, as shown in Pl. XX. North of the plain these hills are not so steep and are at a distance of half a mile or more from the plain, but even here the sinuous white line of gypsum may be traced along the tops of the bluffs as far as the eye can reach. In other words, the plain lies in a broad canyon of the Cimarron, inclosed on both sides by gypsum-capped red shale hills.

The plain is flat, except for a few meandering channels which in wet weather contain small streams of water, but are ordinarily dry. After a rain sometimes a stream of considerable volume flows down the channel across the plain, but during the summer months nearly all the water either evaporates or sinks into the sand. In places where a small stream still runs down the channel the water is often so salty that a thin crust of crystal white salt, resembling a sheet of ice, forms on the surface of the stream. The entire plain is covered with a thin incrustation of snow-white crystals, which in most places does not exceed an eighth of an inch in thickness, but which reflects the sunlight like a snow field.

In a large cove among the gypsum-covered red hills on the south side of the plains proper are a number of salt springs, which boil up from the flat surface of the plain. The water is crystal clear, and it sometimes requires more than ocular proof to convince one that it contains nearly 50 per cent of salt. There are scores, perhaps hundreds, of these springs on an area of but a few acres, some of which flow streams as large as a man's arm; others are much weaker. In all cases the presence of a spring is marked by a conspicuous white incrustation of salt, which forms around the spring and along the sides of the little stream that flows from it. Particles of grass or weeds blown into these springs or streams soon become covered with white salt crystals, forming strings of them which are often an inch or more in diameter and look like rock candy. In places the incrustations around the springs are so thick that the salt may be scraped up and hauled away. Beds of rock salt are reported from this plain, but have never been seen by the writer. The combined flow of the various springs which feed the plain will approximate perhaps 2 or 3 second-feet.

BLAINE COUNTY PLAIN.

Besides the two plains of the Cimarron, just described, the Salt Creek plain, in northern Blaine County, is also fed by springs which issue from below the gypsum ledges, and, like the others, it is located in a canyon at the foot of the Blaine Gypsum Hills. This plain is much smaller than the Big Salt Plain just described; its width is not more than a quarter of a mile in the widest place, and for the greater part of its course is not more than 100 yards, with a length of perhaps 3 miles.

The region of Salt Creek is one of the most picturesque spots in Oklahoma. The upland is covered with jack oak and the capping of Tertiary sands breaks off abruptly into precipitous cliffs and canyons

A SALT SPRING ISSUING FROM BENEATH GYPSUM LEDGE.

B. LOG AND EARTH DAM ON UPPER CIMARRON RIVER.

200 or more feet deep, the slopes of which are composed of the brick-red shales of the upper part of the Enid formation, capped by massive white gypsum ledges of the Blaine formation. (See Pls. VII, *B*, and IX.) Numerous narrow canyons with cedar-covered slopes radiate outward from the head of Salt Creek, a tributary of the Cimarron. In the head of the main Salt Creek canyon are the springs which supply the plains. A ledge of red and blue mottled cross-bedded sandstone outcrops along the heads of several branches of the main canyon, and from it issue the springs, the waters of which form a small creek. Along the bottom of the canyon salt incrustations, formed by evaporation, cover a narrow strip of 100 yards or more of the sandy level. A mile below the springs the canyon widens, the creek leaves the wall of hills and enters the flat country, the salt plain spreads out to become in one place as much as a quarter of a mile wide. A mile or so farther downstream it is joined by creeks which do not carry salt water, and it soon loses its individuality.

From the standpoint of economic importance the Salt Creek plain bids fair to exceed all others in the Territory, as it is nearer to the coal fields of the Indian Territory, as well as near to market. A number of primitive salt plants have at times been located along the edge of the plain. The methods employed in securing the salt are extremely simple. A well is dug in the sand of the plain and the water pumped by hand into vats and evaporated by boiling. Fuel, chiefly cedar and oak, was formerly obtained from the canyons near by. It is stated that three buckets of brine will make one bucket of salt. The capacity of one of these plants is approximately 2,000 pounds per day. The salt is hauled in wagons to supply local trade, and the demand is said to have exceeded the supply for a number of years.

The Oklahoma Salt Company has erected a plant with a capacity of 450 barrels per twenty-four hours at Ferguson, Okla., the nearest railroad point to the plain. The brine is obtained from open and drilled wells and is carried $2\frac{1}{8}$ miles in a $2\frac{1}{2}$-inch wrought-iron pipe. Steam will be employed to operate rakes, elevators, conveyors, etc. Pans are of cement 12 by 150 feet and 20 inches deep.

ROGER MILLS COUNTY PLAIN.

In the extreme southern part of Roger Mills County, on secs. 10, 11, 14, and 15, T. 8 N., R. 22 W., is a salt plain occupying an area of about 40 acres. This plain, which is about half a mile distant from the North Fork of Red River, is located near the base of the Greer Gypsum Hills, which in this region are well exposed. In places springs of salt water issue directly from beneath gypsum ledges, as shown in Pl. XXI, *A*, while in other instances the water boils up in the form of bold springs from the level surface of the plain. There are in all 20 or more springs, the waters of which unite to form a stream estimated to flow at least 1 second-foot, although, in view of the fact that a great part of the water sinks into the sand, it is probable that this amount represents but a part of the actual flow. Salt has been manufactured at this plain for many years. The water is said to contain a considerable proportion of gypsum, but not so much as to render it unfit for use.

GREER COUNTY SALT PLAINS.

The two Greer County salt plains are located in small canyons which have been carved in Gypsum Hills, south of Elm Fork of Red River, about 5 miles east of the Texas line. From the names of the owners these plants are known locally as the Chaney Salt Plain and the Kiser Salt Plain. Neither covers an area of more than an acre or two. Both are fed by springs that issue from the red shales below heavy ledges of Greer gypsum. Springs boil up from the level sand floor, and the water flows out of the canyon to mingle with the water of the river. A flourishing local industry has been carried on at these plains for twenty years or more, and some years as much as 600,000 pounds of salt have been manufactured at each one. Since the timber, which formerly grew in the canyons, has been exhausted solar evaporation has been largely employed to produce salt. The average combined flow from the springs is estimated at 1 second-foot from each plain. In a number of canyons emptying into Elm Fork in this region there are salt springs, but no others have sufficient strength of flow to warrant the establishment of salt plants.

Salt has been manufactured at various times on all of the salt plains of Oklahoma except the large plain in Woods County, which, as stated above, contains no springs of any size. Until the present time, however, primitive methods only have been employed, and no considerable amount of capital has been invested. It goes without saying that salt springs of this character will ultimately develop into properties of much value. Ten or more second-feet of saturated brine will not always remain unutilized.

SULPHUR SPRINGS.

All the springs in Oklahoma which may be denominated sulphur springs are located in the vicinity of the Wichita Mountains. In all there are a score or more, the greater part of which are mere seeps, located usually among the limestone hills which lie north of the granite peaks of the Wichitas. The three which are hereafter described are probably the strongest of the lot.

GRANITE SULPHUR SPRING.

This spring is located in the northwest part of the town of Granite, Greer County, Okla., in a cove south of Headquarters Mountain, the westernmost of the high peaks of the Wichita Range. The water issues from deposits of clay and gravel close to the granite rocks at the foot of the mountain. The water is comparatively pure except for a small quantity of sulphides. The spring has quite a reputation and its water is used for medicinal purposes.

RAINY MOUNTAIN SULPHUR SPRING.

Standing out on the plain in the eastern part of Kiowa County are three limestone knobs, the extreme northwestern outliers of the range of limestone hills referred to above. From a small ravine at the base of one of these hills there issues a sulphur spring which from its location near Rainy Mountain is known as the Rainy Mountain Sulphur Spring. It is situated in sec. 33, T. 7 N., R. 15 W. Not only sulphur, but salt as well is found in the water of this spring.

APACHE SULPHUR SPRING.

This spring is about 10 miles southwest of Apache, Comanche County, Okla., in sec. 32, T. 5 N., R. 12 W., near the foot of one of the limestone hills that make up the range lying north of the Wichitas. The flow of the spring is small; the source of the water is probably in the limestone rock.

DEEP WELLS.

GENERAL CONDITIONS.

Within the past few years a number of deep wells have been put down in various parts of Oklahoma. These wells have been bored for water, gas, oil, and other products.

Because of the fact that shallow wells do not always furnish a sufficient amount of water, efforts have been made in various places to find deep-seated waters, and in many instances they have been successful. So far it has been found that if a depth of 400 feet is reached without securing the desired amount and quality of water there is little use in going farther. The reason for this is that the greater part of Oklahoma is underlaid with red shales, which usually contain a large percentage of salt, gypsum, or other mineral salts. So far as known, except along the eastern edge of the outcrops of the formation, the drill has never penetrated to the base of these red shales, and so their thickness is unknown.

In this discussion only those wells that have reached a depth of 400 feet or more will be considered. Any classification of deep wells that might be made must be largely an arbitrary one, but perhaps the classification based upon the purpose for which the well was drilled will more fully meet the conditions in Oklahoma than any other, and for this reason the deep wells of the Territory will be described under the two heads "Water wells" and "Oil and gas wells."

WATER WELLS.

Fort Reno well.—In 1893 a well 1,370 feet deep was drilled at Fort Reno, Canadian County, for the purpose of securing a supply of water for the post. The well, however, failed to secure enough good water for the purpose intended and was abandoned. A small amount of salt water was encountered at about 400 feet and fresh water at 441 feet. This is the only well in the Territory in which fresh water is found below 400 feet. The rock passed through consisted mainly of red shale. The section is given in Pl. XXII, *A*.

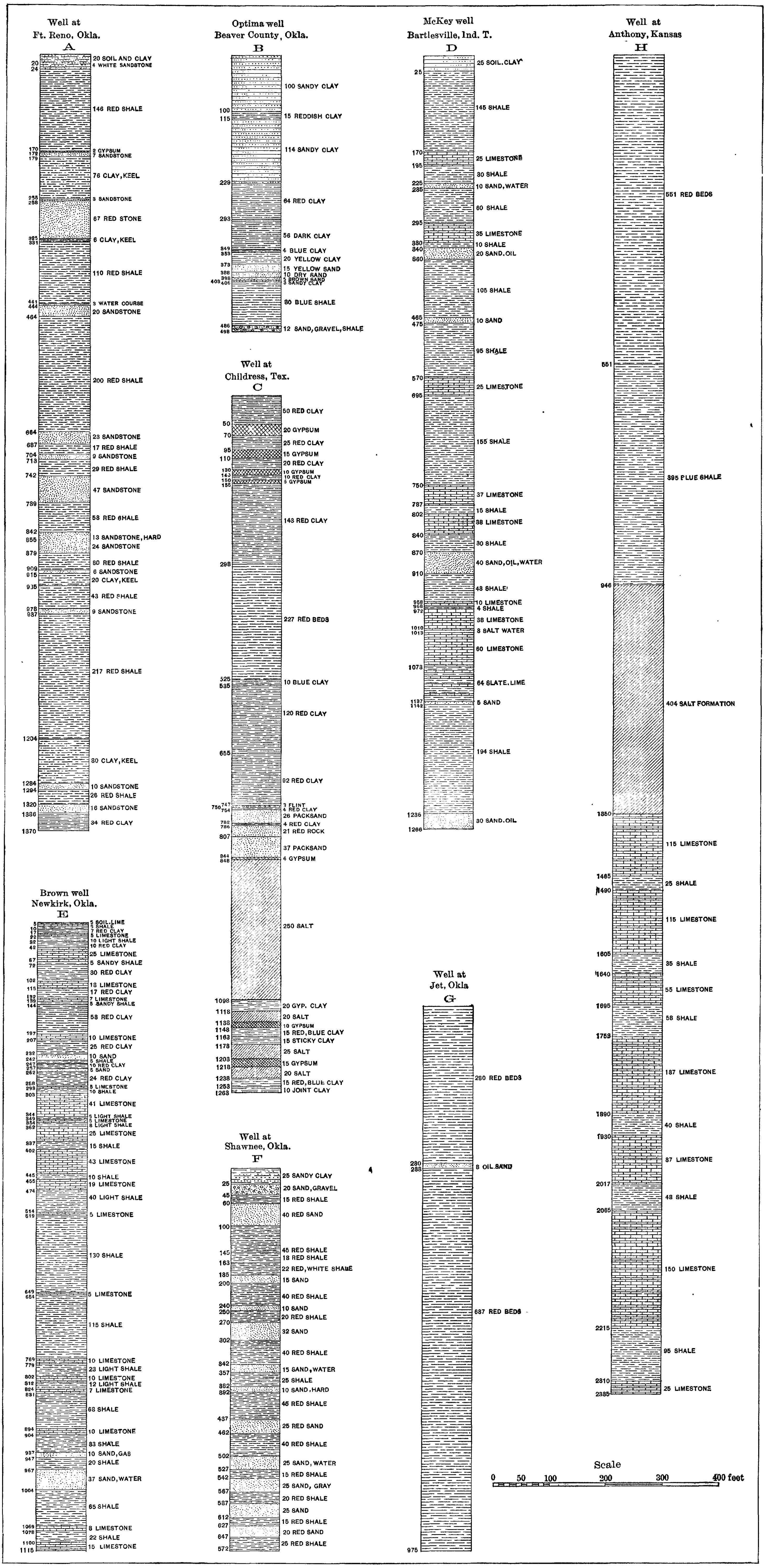
Kingfisher well.—At Kingfisher an attempt was made to secure deep-seated water, and at a depth of 600 feet a great flow of strong salt water was encountered, the water rising to within 8 feet of the top.

Optima well.—At Optima, in north-central Beaver County, a well was drilled to a depth of 498 feet without obtaining water, a rather rare occurrence on the high plains. The strata passed through seem to be all Tertiary deposits, and the depth indicates the thickness which these deposits attain. The log given in Pl. XXII, *B*, shows the rocks passed through.

Childress, Tex., well.—The Fort Worth and Denver Railroad Company had a well put down at Childress, Tex., 15 miles southwest of the southwest corner of Oklahoma, in an effort to secure water for engines and shops. The water found was impregnated with salt and gypsum, and therefore unfit for use. The rocks passed through were red shale, clays, thin sandstones, and gypsum and salt beds. These formations being soft caved badly, and the well was abandoned. The log of the Childress well is given in Pl. XXII, *C*.

OIL AND GAS WELLS.

Wells in the Osage Nation.—Along the eastern line of the Osage Nation, from the Creek country to Kansas, a number of wells have been sunk for the purpose of securing oil. In a number of these both oil and gas have been found, the former product running as high as 200 barrels per day and the latter product several million cubic feet per day. The wells pass through shales, limestones, and sandstones of Pennsylvanian age. Salt water is frequently encountered at



WELL SECTIONS.

a depth of 1,400 feet. A log of one of these wells, near Bartlesville, is given in Pl. XXII, *D*.

Cleveland well.—At Cleveland, Pawnee County, a well was drilled to a depth of 520 feet through comparatively thin ledges of red and blue shales and sandstone with two limestone members. Salt water was found at 220 feet and rose to within 40 feet of the surface.

Newkirk well.—At Newkirk, Kay County, in the northern part of the Territory, several wells have been drilled for oil and gas. These wells start on top of the Flint Hills, and consequently pass through a larger amount of limestone than any other wells in Oklahoma. A small amount of oil was encountered in all the wells, but not enough to pay for the cost of drilling. Salt water was found at various depths, in one instance rising to within a few feet of the mouth of the well. The log is given in Pl. XXII, *E*.

Shawnee well.—The log of the Shawnee well, given in Pl. XXII, *F*, illustrates the conditions along the eastern edge of the red beds, where alternating strata of shales and sandstones make up the entire formation. If the well had been continued a few hundred feet deeper, there is no doubt that the drill would have passed through the red beds into the subjacent members.

Jet well.—The Saline Oil and Mining Company has put a well down 975 feet at Jet, Woods County, in the hopes of securing oil and gas from the red beds. The well passed through red and blue shales all the way, with the exception of about 8 feet of sand at 280 feet, which are reported to have yielded one to three barrels a day. Soft water was reported at 180 feet. The log is shown in Pl. XXII, *G*.

Anthony, Kans., well.—This well was drilled 12 miles north of the Oklahoma line. A study of the log (Pl. XXII, *H*) will assist in understanding the conditions in the northern part of the Territory. At this point the red beds are 551 feet thick, below which are 395 feet of blue shales and 404 feet of salt beds. Limestone, notably that of the Flint Hills, was encountered at 1,350 feet.[a]

CONCLUSIONS.

From the above facts and known conditions the following conclusions regarding the underground conditions in Oklahoma may be drawn: (1) In general, water may be obtained in fair quantities between the depths of 200 and 400 feet, but such water often contains a high percentage of soluble salts, which sometimes render the water unfit for use. (2) Water below 400 feet is almost invariably too

[a] Since the above was written a well at Spencer, 12 miles east of Oklahoma City, has been put down to a depth of 2,050 feet. The red beds were penetrated at 1,550 feet, below which gray to brown shales and sandstones were encountered.

salty for any purposes except for the manufacture of salt. (3) Drilling wells to any considerable depth in the red beds is difficult, because of the unstable and treacherous character of the formations.

ARTESIAN WATER.

There is little hope for artesian water in Oklahoma. The Dakota sandstone, the great artesian water-bearing formation of the plains, outcrops only in the extreme western part of the Territory. Tertiary rocks carry large quantities of water, but, so far as known, the structural conditions are not suitable for an artesian flow. The red beds are water bearing, but in the main sparingly so, and, besides, they all dip westward or toward the higher lands.

Flows of artesian water depend upon several conditions, among which the two most important are (1) a porous stratum of rock contained between impervious strata; and (2) an exposure of this porous stratum at the surface at a higher elevation than the mouth of the well. It has been thought that in Oklahoma these conditions might be furnished by the red beds, which extend westward far up the flanks of the Rocky Mountains, but the rocks have not been found to yield flows. As to prospects in the subjacent rocks, the difficulty is that the drill has rarely penetrated the red beds in Oklahoma. In one or two instances wells which started in the red beds have reached the blue and gray clays and shales below, but in these instances the wells were located near the eastern margin of the red beds. Salt water only was found in these wells and in no instance did it reach the surface. The relations and capabilities of the formations underlying the red beds in central and western Oklahoma remain to be settled.

There are a few local instances of flowing wells in Oklahoma, but none of economic importance. At Guthrie a well in the red beds flows over the surface. Near Beaver City an artesian well is reported from the Tertiary.

In many parts of Oklahoma are wells that are semiartesian in character; that is, the water rises in the well often nearly to the top, but does not flow out. At Newkirk, in a well which was drilled 1,680 feet for gas or oil, salt water was encountered which rose practically to the surface. In the vicinity of Norman there is a water-bearing stratum at a depth of about 250 feet below the surface, and in a number of wells which have reached this stratum the water rises from 150 to 175 feet, standing within 75 to 100 feet of the surface. This fact may be readily explained by remembering that the rocks at Norman dip west 10 to 20 feet per mile, while the surface slopes to the east. The sandstone in which the water is found at a depth of 250 feet comes to the surface some miles east of Norman, and at a level lower than the mouth of the well. Under this condition the water rises to the level of the intake area, which is 75 to 100 feet below the level of the mouth of the well.

WATER CONDITIONS, BY COUNTIES.

In the following pages will be discussed briefly the general conditions of water supply in each of the 27 counties (counting the Osage Nation as one). The order is as follows: First, a brief mention of the rocks and the principal drainage features; second, a statement of the character of the wells and springs; and third (pp. 156, 173), a list of 10 wells from the county. These well records, more than 250 in all, have been selected from about 3,000 records now on file in the office, and are believed to represent fairly well the water conditions of the various counties.

OSAGE NATION.

Rocks and drainage.—The Osage Nation, which includes all of Oklahoma lying north and east of Arkansas River, is approximately 50 miles square. Tributary to the Arkansas in the Osage Nation are Beaver, Salt, and Gray Horse creeks. The greater part of the Nation is drained by Verdigris River, through Hominy, Bird, Buck, and Sand creeks. In the eastern part of the reservation the rocks are chiefly shales and sandstones, with an occasional ledge of massive limestones, while farther west to the Arkansas River the limestone ledges are more frequent. In this reservation the Flint Hills reach their highest development in Oklahoma, although they are here not so conspicuous as in Kansas. South of the river the limestone ledges begin to thin out and disappear.

Water supply.—In general, this area is not yet extensively under cultivation and consequently comparatively few wells have been put down. The Osage Indians are the most primitive of all the tribes in Oklahoma. Many yet retain their tribal customs and manners of dress, and are usually known as "blanket Indians." During the last few years, however, many of the Osages have taken allotments, and the greater part of the land along the various streams has been leased to enterprising white men who are cultivating farms, often of considerable size. This is particularly the case along the valleys of Arkansas River and such minor streams as Beaver, Salt, Hominy, and Sand creeks. Except in rare instances, however, the uplands are not cultivated, and for that reason no comprehensive statements may be made regarding wells on them; but in such wells as have been put down near farmhouses and on ranches in the valleys an abundant supply of water has usually been found. There is no reason to doubt that on the uplands a satisfactory supply of water can be obtained. As is usual in a limestone country, the water often is hard, but usually is not unfit for use. In the eastern part of the Osage country, as stated above, the rocks are chiefly sandstone and shales, and in this region the wells furnish a good supply of soft water.

Throughout the greater part of the Osage Nation are many springs of considerable size. In the eastern part of the reservation these springs flow out from under sandstone ledges, usually above shale rocks, and the water of such springs is soft. Many Indian cabins and even many farms and ranches of considerable size have been located with reference to some spring. The water in Buck, Sand, Bird, and Hominy creeks, which rise in the Flint Hills and flow east across the reservation, emptying into Verdigris River, usually comes from springs that are for the most part perennial. In the western part of the Osage Nation are also many large springs, usually issuing from under limestone ledges, and the water is consequently hard. Such creeks as Little Beaver, Big Beaver, Salt, Gray Horse, and others are fed by springs from the Flint Hills. Some of these springs are of considerable size—for instance, Big Spring, on Little Beaver Creek, 6 miles south of Maple City, Kans., has long been known as a camping place and resort. On the hill above this spring are located the famous Timbered Mounds, which are, in fact, nothing but ancient flint quarries from which Indians obtained the material for their implements.

But few wells have been reported from the Osage Nation, and because of the insufficient data no records are given.

KAY COUNTY.

Rocks and drainage.—This is the northeastern county of Oklahoma. It is limited on the east by Arkansas River and on the north by the Kansas boundary. The county is approximately 30 miles square, and is one of the most fertile in the Territory. With the exception of the portion along Arkansas River in the eastern part of the county, the topography is in general very even.

The Salt Fork of the Arkansas flows through the southern tier of townships and empties into Arkansas River in the Ponca Reservation a few miles south of the Kay County line. Tributary to the Salt Fork in Kay County are Chikaskia River, Bois d'Arc Creek, and Deer Creek, and tributary to the Chikaskia are Duck and Gypsum creeks. All of these streams have carved shallow channels in the level upland, rendering the surface in many places slightly rolling, but in only few localities are there bluffs of any considerable height.

In the eastern part of the county from the Kansas line south to Ponca City are the limestone rocks, which form the southern part of the Flint Hills. From the level of the river to the top of the hill near Newkirk there are 6 or 8 heavy ledges of limestone varying in thickness from 5 to 30 feet.

West of the limestone country there is an area comprising the greater part of the county, in which the rocks consist of grayish or bluish shales with a few ledges of thin limestone. This area, which extends about as far southwest as Deer Creek, is the southern extension of the Marion and Wellington formations of Kansas, which in that State outcrop over several counties and extend from the top of the Flint Hills westward to the line of the red beds or Cretaceous rocks. In Oklahoma, however, these formations have but a limited areal extent, being confined to Kay County. In both Kansas and Oklahoma the shales contain extensive deposits of gypsum and salt, and one of the Oklahoma gypsum mills is located in this county.

In the southwestern part of the county, including the township west of Deer Creek and most of the regions south of the Salt Fork of Arkansas River, are typical red shales and sandstones of the red beds. Along several of the streams, particularly along the north slope of the Salt Fork, there are areas covered with Quaternary sand hills.

Water supply.—Wells have been sunk on nearly every quarter section in Kay County, with depths varying from 20 to 80 feet, and usually yield an abundant supply of water. In central and northern Kay County, in the gypsum region west of the limestone hills, the supply of water is abundant, but rather inferior in quality, being usually too hard for domestic use. In the red beds region, in the southwestern part of the county, the water usually contains more or less gypsum, although there are a number of wells which obtain water from a bed of sandstone. In these wells the water is almost uniformly soft. The best water in Kay County is found in the sand hills region, north of the Salt Fork, where the wells are usually shallow, not exceeding 20 to 30 feet in depth. In the bluffs along Arkansas River in the eastern part of the county are numerous springs, and, as is usual in a limestone region, the water from these springs is hard, though in most places not sufficiently so to render it unfit for use. There are also a number of springs of good soft water among the sand hills, particularly along the north bank of Salt Fork west of Tonkawa. Analyses Nos. 41, 42, and 43 are of water from wells, and Nos. 138 and 139 are of water from springs in Kay County.

Well records.—Of 104 wells reported from Kay County, 35 furnish soft water, 55 hard water, and 14 salty water. The average depth of the 104 wells reported was 61 feet. The list on page 162 includes records of 10 wells taken from various parts of the county, and is believed to be representative of the water conditions.

NOBLE COUNTY.

Rocks and drainage.—Noble County lies directly south of Kay County. In describing this county there will be included the Otoe and the southern half of the Ponca reservations. Arkansas River flows for 20 miles or more along the northeastern boundary of the county, forming a double oxbow bend. Across the county from west to east flow Red Rock and Black Bear creeks, both of which rise in Garfield County and empty into Arkansas River.

The rocks in the northeastern part of Noble County are largely shales and limestones, but in this region many of the ledges of limestone, which form the main part of the Flint Hills in the Osage country, finally disappear and give place to shales and sandstones. The greater part of the rocks of this county, however, particularly in the vicinity of Perry and westward, consist of typical red beds clays and sandstones. It would perhaps be correct to say that the transition from the Flint Hills and the Pennsylvanian rocks to the typical red beds takes place largely in this county. The sandstones throughout the greater part of Noble County are normally gray or brown, while the shales are almost always brick red. Along the western line, however, even the sandstones become red, and so continue to the western part of the Territory.

Water supply.—The water in the eastern part of Noble County, particularly in the region now occupied by the Otoe and Ponca reservations, is not particularly abundant. Wherever wells have been put down, however, a sufficient supply of water for domestic and stock use has usually been obtained. In the southern part of the county sandstone beds are abundant, and in most localities wells yield plenty of good water. In the western part the water often contains mineral salts, chiefly gypsum or salt, but there are comparatively few wells in which water is not suitable for house use. There are also springs of considerable importance in Noble County, and a number of the small creeks which are fed by them flow the year round. Analyses Nos. 52, 53, 54, 55, and 56 are of water from wells in Noble County.

Well records.—Of 29 wells reported from Noble County, 16 contained soft water, 9 hard water, and 4 salty water. The average depth was 52 feet. A list of wells from all parts of the county is given on page 166.

PAWNEE COUNTY.

Rocks and drainage.—The shape of Pawnee County, which lies immediately east of Noble, is that of a right angle triangle, of which Arkansas River on the northeastern side is the hypotenuse. The eastern end of the county extends farther east than any other part of Oklahoma except the Osage Nation. Cimarron River empties into the Arkansas in the extreme southeastern part of the county. Black Bear Creek enters from Noble County and flows southeast to join Arkansas River. A number of small creeks tributary to the Arkansas, Cimarron, and Black Bear have cut the surface into a series of valleys and ridges, and in parts of the county the surface is uneven, high hills and steep slopes being common.

The rocks are mostly shales, sandstones, and limestones and do not differ materially from those of Osage Nation, just across the river. In Pawnee and Noble counties the Flint Hills finally lose their identity and become merged with the red beds and heavy ledges of sandstone.

Water supply.—As would be expected in a region with the geologic structure of Pawnee County, water is abundant and there is no part of the county where it is not good. Wells which usually obtain a permanent supply at moderate depths are found on practically every quarter section. In a few instances the water from the wells is salty, but such cases are rare.

Springs which usually issue from beneath ledges of limestone are common in Pawnee County, and from under several of these ledges there is almost constant seep for a distance for sometimes several miles. In other localities bold springs are common. Analyses Nos. 64, 65, 66, 67, 68, and 69 are of water from wells and No. 142 is of water from a spring in Pawnee County.

Well records.—Of 151 wells reported from Pawnee County, 94 furnish soft water, 50 hard water, 6 salty water, and 1 sulphur water. The average depth is 57 feet. The records on page 166 were taken from all parts of the county.

PAYNE COUNTY.

Rocks and drainage.—The Cimarron flows through the southern part of Payne County and across the northwest corner of the Creek country before joining Arkansas River. The largest tributary of the Cimarron in Payne County is Stillwater Creek. The smaller creeks cutting across sandstone ledges have produced the rough surface characteristic of so much of eastern Oklahoma.

The rocks of Payne County are chiefly shales and sandstones, with a few interbedded limestone layers which have persisted from the Flint Hills region. The color of the rocks in the western part of the county is normally red, although some of the sandstones are brown or gray. Farther east they are all of a lighter color, but the shales continue to be red nearly to the eastern line of the county.

Water supply.—The general conditions of water supply in Payne County do not differ materially from those in Pawnee and Noble counties. Wells are numerous and furnish plenty of water, usually of good quality. In the western part of the county, however, where the rocks are typical red beds a considerable amount of hard water is encountered, and some wells even contain salt water. Springs are found in practically all parts of the county. Most of them, however, are nothing but small seeps, which issue from under limestone or sandstone ledges. Analyses 70, 71, 72, 73, 74, and 75 are of water from wells in Payne County.

Well records.—Of 140 wells reported from Payne County, 78 furnish soft water, 56 hard water, and 6 salty water. The average depth of the 140 wells reported is 55 feet. Records 202–211, on page 166, are from this county.

LINCOLN COUNTY.

Rocks and drainage.—Deep Fork of the Canadian flows east across the center of Lincoln County. The north line of the county approaches nearly to the Cimmaron, while part of the south boundary is North Canadian River. This stream arrangement causes two east-west divides, which pass across the county, and small tributary creeks flowing into the Cimarron, Deep Fork, or North Canadian have cut into these divides and increased by erosion the asperity of surface features. The rocks of Lincoln County are largely sandstones and shales; the shales are usually red, the beds of sandstones being often brown or gray.

Water supply.—Wells in this county obtain abundant supplies of water at depths ranging from 25 to 150 feet. Sandstone is the source of the water in the greater part of them, and most of them supply soft water. The springs of Lincoln County do not differ from those in counties farther north, where similar rocks are found. From under sandstone ledges numerous seep springs issue and in certain localities bold perennial springs are common. Over a considerable part of the county the soil is loose and sandy, and much water which under other conditions might come to the surface in the form of springs escapes in underflow. In many places where a spring reaches the surface the water soon again sinks into the sand. Analysis No. 140 is of water from a spring in Lincoln County.

Well records.—Of 58 wells reported from Lincoln County, 40 furnish soft water, 16 hard water, 1 salty water, and 1 sulphur water. The average depth of the 58 wells is 84 feet. The 10 well records on page 164 indicate the water conditions in this county.

POTTAWATOMIE COUNTY.

Rocks and drainage.—This is the southeastern county of the Territory. The North Canadian flows through the northern part, the South Canadian forms its southern boundary, and Little River flows from west to east across the central part of the county. Numerous small tributaries to these larger streams have cut into the upland, forming low, rolling hills.

The rocks are similar to those in counties north, being chiefly sandstones and shales, normally red in color. The sandstone is loosely consolidated, and the cementing material, chiefly calcium carbonate, having been dissolved, the sand grains fall apart and form loose sand, which is blown by the wind into sand hills. This county, as well as Lincoln and Payne, lies entirely within the Sandstone Hills region of Oklahoma.

Water supply.—Wells have been put down in all parts of this county, and the water obtained from them is usually of a good quality, although in certain sections it contains gypsum and other mineral salts. In this county springs occur chiefly under three conditions—in creek bottoms, where water removes the sand down to the underlying shale; on hillsides, where the covering sand mantle is too thin to carry all the water that flows down the hill, and as seep springs, which in wet weather occur in shale beds. Analyses Nos. 76, 77, and 78 are of water from wells in Pottawatomie County.

Well records.—Of 76 wells reported from Pottawatomie County, 37 furnish soft water, 37 hard water, and 2 salty water. The average depth is 70 feet. On page 168 is the record of 10 representative wells, selected from practically all parts of the county.

CLEVELAND COUNTY.

Rocks and drainage.—South Canadian River bounds this county on the south and west; Little River, a tributary of the latter stream, rises in the county and flows east into Pottawatomie County. The eastern part of the county lies in the Sandstone Hills region and the northwestern part in the Low Plains region. The eastern part of the county is somewhat broken, as the streams that flow into Little River and South Canadian have cut rather deep valleys into the sandstones that comprise the greater part of the rocks. The divide between Little River and Canadian is generally level.

The rocks consist for the most part of red beds in which sandstone members are common in the eastern part of the county, although even here red shales make up a great part of the rocks. West of the Atchison, Topeka and Santa Fe Railway there is relatively little sandstone, and red shale makes up the greater part of the rocks. Along the north slope of the South Canadian there are areas of sand hills, probably composed of remnants of Tertiary sands.

Water supply.—In the eastern part of Cleveland County much of the water is found in sandstone, and is consequently soft. On the level divide between the rivers the water is, in general, not so good, being impregnated in many places with mineral salts, although even here many of the red beds wells furnish pure, soft water. In the sand-hills region north of the South Canadian the water is always good. Springs are not abundant in this county; in the eastern part there are a few springs issuing from under ledges of sandstone, in which the flow, while never very strong, is constant. In the sand-hills region are a number of springs that flow the year round. Analyses Nos. 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, and 24 are of water from wells in Cleveland County.

Well records.—Of 82 wells reported from this county, 40 furnish soft water, 33 hard water, 7 salty water, and 2 iron water. The average depth of the 82 wells was 88 feet. Records of wells in Cleveland County are given on page 158.

OKLAHOMA COUNTY.

Rocks and drainage.—The drainage of Oklahoma County is rather complex. North Canadian River flows east through it, making a large bend to the north in the eastern part of the county, but its drainage area is limited, and the four corners of the county drain into four different streams. Deep Fork of the Canadian drains the northeast part and Little River the southeast corner. South Canadian drains the southwest corner, and Chisholm Creek, a tributary of the Cimarron, heads in the northwest corner.

Oklahoma County, like Cleveland County, lies partly in the Sandstone Hills region and partly in the Low Plains region; consequently, the rocks of the eastern part of the county consist largely of red sandstones, while farther west sandstones become less abundant, and shales and clays make up practically all the rocks. The eastern part of the county is more broken than the western. The headwaters of Deep Fork have cut canyons into the sandstones, giving to the country the dissected surface so characteristic of eastern Oklahoma, while farther west there are comparatively few forms of relief.

Water supply.—Wells in this county find water at reasonable depths. In the Sandstone Hills region the water is often soft, but farther west hard water predominates. Along the North Canadian, wells in the alluvial flood plain have good water. Oklahoma County has comparatively few springs. Of these the greater part flow from the sandstone beds in the eastern part of the county, generally near one of the divides, and issuing at the head of a canyon which has been cut through the sandstone into the clay and shale below. Especially is this condition true along the canyons which empty into Deep Fork. Red beds springs occur, however, along both Chisholm and Cottonwood creeks. So far as known, there are no Tertiary springs in this county. Analyses Nos. 57, 58, 59, 60, 61, 62, and 63 are of water obtained from wells in Oklahoma County.

Well records.—Of 36 wells reported from Oklahoma County, 25 furnish soft water, 10 hard water, and 1 salty water. The average depth is 60 feet. The 10 well records given on page 166 are believed to represent typical conditions in this county.

LOGAN COUNTY.

Rocks and drainage.—With the exception of the southeastern part of the county, the water of which flows into Deep Fork, all of Logan County is drained by the Cimarron, which flows east across the county. Skeleton Creek from the north and Cottonwood Creek from the south are the chief tributaries of this river. The surface is rather broken, particularly in the southern and eastern parts of the county.

Sandstone beds interstratified with red shales make up the greater part of the rocks of Logan County; but, as in the counties north and south of Logan, the sandstone members become thinner as the western part of the county is reached. North of the Cimarron there are belts of sand hills.

Water supply.—The wells of Logan County are in a general way similar to those in Payne and Oklahoma counties. In the sandstone country the wells produce soft water, while farther west the rocks contain more mineral salts. At Guthrie there is an artesian well which probably is supplied from a local head. There is no reason for supposing that other wells of this character will be encountered.

Springs are scattered quite generally over Logan County, but are most numerous in the sandstone region in the eastern and northeastern parts. Many of the streams which flow into Deep Fork from the southeastern part of the county are fed by springs, and they are also abundant near Mulhall, in the northeastern part. Tertiary springs are reported from Sandy Creek, in the southwestern part of the county, and from the sand hill region north of the Cimarron. Analyses Nos. 49, 50, and 51 were from wells, No. 141 from a spring, and No. 154 from a pond in Logan County.

Well records.—Of 35 wells reported from Logan County, 16 furnish soft water, 19 hard water, and the average depth is 78 feet. On page 164 are given the records of wells in various parts of Logan County.

CANADIAN COUNTY.

Rocks and drainage.—Both North Canadian and South Canadian rivers flow southeast across Canadian County, and into both of these rivers empty a number of short tributary creeks. The southwestern part of the county drains into the Washita, and the northeastern part into the Cimarron. Nearly all the county lies in the low plains region of Oklahoma.

The rocks are chiefly red shales and clays, with occasional thin-bedded sandstones. They belong to the Permian red beds. In the northwestern part of the county occur the southern end of the Blaine Gypsum Hills in Oklahoma. In Canadian County, however, the beds of gypsum are not massive, rarely being more than 3 feet thick. North of both rivers there are deposits of Tertiary sands, these deposits being more abundant in the northwestern part of the county, north of North Canadian River and west of the Chicago, Rock Island and Pacific Railroad.

Water supply.—Water is obtained at moderate depths in practically all parts of Canadian County, and, as would be expected in a region composed largely of red shales, the water is often hard, containing a large percentage of mineral salts. Among the sand hills north of the larger streams and in the alluvial flood plain along the rivers, however, the water is usually soft and pure.

There are springs of both hard and soft water in most parts of Canadian County, particularly in the Gypsum Hills region. Soft-water springs come from under sandstone beds in the eastern part of the county and from Tertiary sand hills north of the streams. Caddo Spring, at the Cheyenne Indian school, 4 miles north of Darlington, is the most noted Tertiary spring in Canadian County.

Well records.—Of 21 wells reported from Canadian County, 11 furnish soft water, 9 hard water, and 1 salty water. The average depth is 61 feet. The water conditions of the county are set forth in the list of wells on page 158.

KINGFISHER COUNTY.

Rocks and drainage.—The entire drainage of Kingfisher County is into the Cimarron, which flows from its northwest to its southeast corner. Turkey Creek from the north and Salt, Copper, Kingfisher, and Walnut creeks from the south rise in other counties and cross Kingfisher before emptying into the Cimarron.

The rocks are typical red beds. Few sandstones are found, and the rocks consist largely of soft red shales. In the extreme southwestern part of the county are the Blaine Gypsum Hills, composed of masses of white gypsum. North of and parallel to Cimarron River is a row of Tertiary sand hills from 3 to 10 miles wide. The county is all in the Low Plains region of Oklahoma.

Water supply.—The greater part of the water of Kingfisher County comes from the red beds and contains a considerable percentage of mineral salts, chiefly calcium sulphate. Wells are found in all parts of the county, and it is rare that an abundant supply of water is not found at a reasonable depth. Among the sand hills north of the Cimarron wells are usually shallow and yield soft water.

The best springs of Kingfisher County are found in the sand hills region north of the Cimarron. These springs are larger than those in Logan, the next county east, and being sand springs, consequently furnish soft water. Both in the flat region south of the Cimarron and among the Gypsum Hills in the extreme southwestern part of the county there are a few hard-water springs. Analyses Nos. 44, 45, 46, and 47 are of water from wells in Kingfisher County.

Well records.—Of 38 wells reported from Kingfisher County, 23 furnish soft water, 13 hard water, and 2 salty water, and the average depth is 36 feet. The 10 well records given on page 162 represent the conditions in Kingfisher County.

GARFIELD COUNTY.

Rocks and drainage.—Garfield County drains in three directions—south into the Cimarron, north into Salt Fork, and east into the Red Rock and Black Bear creeks, tributaries of the Arkansas. It has no large river. The surface of the greater part of the county is flat, monotonous prairie, while along the large creeks the bluffs are low and inconspicuous.

Red beds make up the greater part of the rocks of the county, and of the red beds red shales and clays constitute the greater proportion. A few beds of sandstone, however, outcrop in the eastern part of the county, but they are so infrequent as to give scarcely noteworthy relief. The southwestern fourth of the county contains more or less conspicuous deposits of sand, approaching, in localities, sand-hill conditions. Most of the shallow creek bottoms, and some portions of the uplands, are covered with a blanket of Tertiary sand.

Water supply.—Water in the red beds of Garfield County is abundant; it varies from that which is pure and soft to water so full of gypsum and other salts as to be unfit for use. Wells are found everywhere, and water is encountered at reasonable depths. In the sand-hills region good water is abundant, and in many parts of the county upland wells or those along prairie streams yield soft water.

Springs, which are most abundant in the sand-hills region in the central and southwestern parts of the county, supply good water, usually in considerable quantities. The water from many of these springs, however, soon sinks again into the sand, and in some instances reappears farther downstream as another spring. In the red beds region springs are found, but in general these springs rarely furnish sufficient water for domestic use. Strong red beds springs are, however, not unknown, and in some of them the water is of good quality. Water analysis No. 38 is from a well in Garfield County.

Well records.—Of 104 wells reported from Garfield County, 41 furnish soft water, 46 hard water, 15 salty water, 1 sulphur water, and 1 iron water. The average depth is 42 feet. Typical water conditions are shown by the well records on page 160.

GRANT COUNTY.

Rocks and drainage.—This county lies west of Kay, its north line touching Kansas, and is entirely within the Low Plains region of Oklahoma. The drainage is all into the Salt Fork of the Arkansas, which flows east across the southern part of the county. The chief tributaries in the county are Deer, Cottonwood, Pond, and Sand creeks, all of which enter Salt Fork from the north. The surface is smooth or rolling, very few conspicuous relief forms being found.

The rocks consist chiefly of red beds and Tertiary deposits. The red beds, which belong to the Enid formation and constitute the bed rock throughout the county, consist largely of sandstones and clays, of which the latter form the major part. Few ledges of sandstone hard enough for building purposes are found in Grant County. Sand hills are found along the Salt Fork, principally on the north side of the streams, in an east-west belt from 5 to 15 miles in width. A considerable portion of the upland is covered also with sand and loam of Tertiary or Quaternary age.

Water supply.—Wells may be found on nearly every quarter section in Grant County, and in most cases the water is both abundant and wholesome. Among the sand hills this is almost universally true. In a number of cases where the rocks are chiefly red beds, wells put down in the sand and gravel deposits along some prairie creek have plenty of good water. As an example of this fact may be given the city well at Medford. After trying in vain to secure good water in the red beds under the city a well was dug in the bed of a small stream a mile distant and an abundant supply was obtained. There are wells in which the water contains gypsum, salt, soda, magnesia, or some other such substance, but in the majority of them such is not the case.

Springs, which are abundant in most parts of the county, issue usually from sand deposits, and almost without exception furnish soft water. The streams north of the Salt Fork are fed in a large part by bold, perennial Tertiary springs. There are also springs in the red beds in Grant County, but like those of this formation in adjoining counties, they are usually unimportant. Analyses Nos. 39 and 40 are of water from wells and 152 and 153 of water from ponds in Grant County.

Well records.—Of 54 wells reported from this county, 27 furnish soft water, 18 hard water, and 9 salty water. The average depth of the wells recorded is 33 feet. The well records on page 162 show the characteristic water conditions in the county.

WOODS COUNTY.

Rocks and drainage.—With the exception of the southwestern and northwestern parts, which are included in the Gypsum Hills region, Woods County lies within the Low Plains region of Oklahoma. Three of the larger streams of the Territory flow across the county—the Salt Fork, which flows across the northern part; the Cimarron, which crosses the county south of the center, and the North Canadian, which touches the extreme southwest corner. Sand, Mule, and Medicine creeks from the north and Clay Creek from the south are the chief tributaries of the Salt Fork, which receives the drainage of perhaps one-third of the county. Of the smaller streams emptying into the Cimarron, Eagle Chief and Indian flow from the north, and Cottonwood, Skull, Barney, Greaver, Main, and West creeks, all of which take their rise among the Gypsum Hills, from the south. The Cimarron and its tributaries drain more than half of Woods County. North Canadian River, in the southwestern part, receives the drainage of but a small area, perhaps not to exceed two townships in all, no creeks emptying into it in this county.

The rocks of the county consist largely of red beds clays and Tertiary sand. The Blaine Gypsum Hills, which it will be remembered are a part of the Permian red beds, extend parallel to and south of the Cimarron across the southwestern part of the county, and appear again in the northwestern part, near the Kansas line. In the Gypsum Hills the rocks consist chiefly of red shales with interbedded deposits of massive white gypsum and dolomite. With the exception of the formations in the Gypsum Hills, the rocks of the red beds do not differ materially from those farther east, being composed chiefly of red shales, with a few inconspicuous sandstone members. The sand hills, also, are like those already discussed, the only difference being that toward the western part of the Territory the Tertiary deposits are more pronounced and the sand-hills districts more conspicuous.

The alternation of surface deposits of sand hills and red beds gives rise to a peculiar zonal distribution of formations noticeable in many parts of western Oklahoma, but nowhere better exemplified than in Woods County. It may be illustrated as follows: In passing from the Kansas line to the southwestern part of the county one will cross successively a number of these various lithologic zones. On the Kansas line is found the typical red shales; a few miles south, north of the Salt Fork, one enters the sand-hills region, a strip of country here about 10 miles wide, that continues south to the river. South of the Salt Fork the red beds again appear and continue for 20 miles or more across the divide between the waters of the Salt Fork and the Cimarron, until finally the sand hills north of the latter stream begin to appear. This belt of sand hills is 10 to 15 miles across. Then comes the red beds slope south of the Cimarron, including the Gypsum Hills, while on top of these hills and still farther southwest lie the sand hills on the north slope of the North Canadian.

Water supply.—The water conditions follow closely the lithologic conditions in this as in other Oklahoma counties. In red beds areas the water is abundant, but often hard; in the sand hills it is both abundant and soft, and in the region around the Great Salt Plain, in the eastern part of the county, water from wells is often salty, while among the Gypsum Hills and in some other parts of the county gyp-

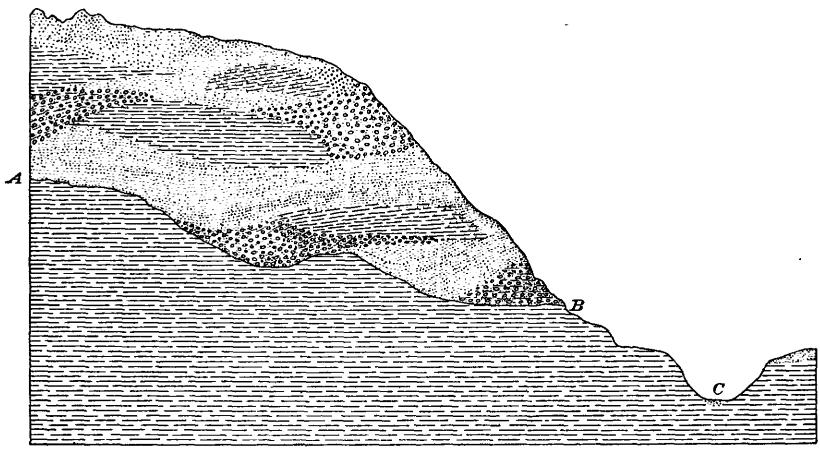


FIG 30.—Section at Cleo Springs, Okla. *A–B*, red beds–Tertiary unconformity; *B*, spring; *C*, bed of Eagle Chief Creek.

sum water is found, often of such a character as to render it unfit for use. The water is about equally divided between hard and soft.

Woods County has an abundance of springs, most of which are located in regions of Tertiary rocks. North of the Salt Fork there are scores, perhaps hundreds, of strong perennial springs, and among the sand hills north of the Cimarron they are equally abundant. Cleo Springs (see fig. 30), near the mouth of Eagle Chief Creek, and Elm Springs, from which the city of Alva obtains its water supply, may be cited as examples of Tertiary springs. There are springs in the red beds in Woods County, and some of them have a considerable reputation. In the vicinity of the Salt Plains there are a number of salt springs, although none of them are of size comparable with the salt springs in Woodward, Blaine, or Greer counties. Clay Creek is fed largely by springs, Timberlake Springs were famous long before the country was open to settlement, Whitehorse Springs supply the whole township with water, and among the Gypsum Hills are a number of perennial springs. Analyses Nos. 79, 80, 81, 82, 83, and 84 are of water from wells, and Nos. 143, 144, 145, 146, 147, 148, and 149 are of water from springs in Woods County.

Well records.—Of 304 wells reported from Woods County, 148 furnish soft water, 138 hard water, 15 salty water, and 3 sulphur water. The average depth of the 304 wells reported is 46 feet. The well records on page 170 show the water conditions in various parts of this county.

BLAINE COUNTY.

Rocks and drainage.—Cimarron, North Canadian, and South Canadian rivers flow southeast across Blaine County. The Cimarron touches the northeast corner, the South Canadian flows for 15 miles through the southwest corner, while the North Canadian enters at the northwest corner and flows diagonally across to the southeast corner. While the Cimarron flows but such a short distance through the county, it receives nearly half of the drainage. This is due to the fact that the valley of the Cimarron in Oklahoma is from 200 to 300 feet lower than the valley of the North Canadian. Several creeks of considerable size, of which Salt Creek is the largest, rise among the Gypsum Hills and flow northeast into the Cimarron. The North Canadian receives a few short tributary creeks, most of which enter from the south, and drains a strip of country about 20 miles wide. An area of perhaps 150 square miles in the southwestern part of the county is drained by the South Canadian.

The rocks of Blaine County consist of Permian red beds and Tertiary and Pleistocene sands and alluvium. The northeastern part of the county is included in the Low Plains region, and the remainder of the county in the Gypsum Hills region. The Blaine Gypsum Hills, which are parallel to and 10 to 15 miles south of the North Canadian, rise like a wall 200 to 300 feet above the level prairie to the east. Red shales make up not only this flat prairie country, but also the greater part of the slope of the Gypsum Hills, while on top of these hills and between the bluffs and the North Canadian lie extensive sand hills. Southwest of this river red beds again appear, the rocks consisting largely of the Whitehorse and Day Creek members of the Woodward formation. On Red Hill, 8 miles northwest of Geary, is one of the best exposures of Day Creek dolomite in the Territory. Sand hills occur again along the north slope of the South Canadian, and beyond that stream red beds are again found.

Water supply.—The water of Blaine County varies with the locality. In the sand-hills region it is good. East of the Gypsum Hills, in the red shale country, the water from wellsc ontains a comparatively large percentage of mineral salts, chiefly gypsum. South of the North Canadian, also, the water is often not suitable for use. North of both Canadian rivers, in the sand-hills country, wells usually encounter good soft water at moderate depths.

Springs are common among the Gypsum Hills, issuing generally from above shales and beneath gypsum ledges, but in such a case the water is often so strongly impregnated with gypsum as to be unfit for use. In the bottom of one of the deep canyons among these hills, 4 miles west of Ferguson, are a number of springs of strong salt water. The waters of these springs unite and form a plain, which extends for several miles along Salt Creek. There is enough salt water going to waste in this region alone to make sufficient salt to supply several States. The best soft-water springs in Blaine County are found among the sand hills north of the streams, and these springs as in other counties in which sand hills are found, are generally strong and flow the year round. As an example of the use to which a Tertiary sand-hills spring may be put may be cited the case of the Rubey Stucco-Plaster Company, at Ferguson, Okla. The cement mill is located in a canyon at the base of the Gypsum Hills and good water was not available. A pipe was laid from a spring located on a hill at an elevation of 200 feet above the plant and $2\frac{1}{2}$ miles distant, and an ample supply of water was obtained for boiler and domestic use. Analyses Nos. 3, 4, and 5 are of water from wells in the red beds at Geary, Blaine County, and Nos. 150 and 151 are of water from salt springs at the head of Salt Creek, 4 miles west of Ferguson, Blaine County.

Well records.—Of 108 wells reported from Blaine County, 63 furnish soft water, 39 hard water, 6 salty water, and the average depth is 60 feet. The 10 records on page 156 were taken from all parts of the county and represent the general water conditions.

CADDO COUNTY.

Rocks and drainage.—Washita River flows east across the central part of this county, while the South Canadian touches the northeast corner, and Cache Creek, a tributary of the Red River, drains several townships in the southern part. The chief tributaries to the Washita in this county are Sugar and Cobb creeks, both of which enter from the north.

Red beds constitute the greater part of the rocks of Caddo County, and, as in other parts of the Territory, sandstones and clay shales make up the greater part of the red beds. In Caddo County, however, the sandstone greatly predominates. The Whitehorse member of the Woodward formation thickens in this region, giving rise to a series of fine-grained red or grayish sandstones, often weathering into conspicuous buttes, which are typically exposed on the high divide between the Washita and South Canadian southwest of Bridgeport. (See Pl. X, *A*.) In the southern and western parts of the county the deposits of Greer gypsum outcrop in conspicuous ledges on hilltops. So far as known there are no extensive deposits of Tertiary sand in Caddo County. It is true that there are sand hills, but they are composed largely of sand of disintegration from the Whitehorse. In the southwestern part of the county there are hills composed of Arbuckle limestone, the northern extension of the Wichita uplift.

Water supply.—The water in Caddo County is generally good. Wells in the sandstone usually secure soft water, although in certain parts of the county, notably on the divide between the Canadian and the Washita, the depth to water is often as much as 200 feet, but the water when found is almost uniformly pure and wholesome. In the gypsum region hard water predominates. Springs are not uncommon in Caddo County, although over considerable areas strong springs are rare. The water which percolates through the fine-grained sandstone comes out as seeps along the side of a hill or in the head of a narrow canyon. In the limestone hills are a number of strong springs which issue from limestone rocks. Analysis No. 6 is of water from a well at the Anadarko brickyard.

Well records.—Of 75 wells reported from Caddo County, 62 furnish soft water and 13 hard water. The average depth is 88 feet. The 10 well records on page 156 show the character of the water in the various parts of the county.

COMANCHE COUNTY.

Rocks and drainage.—With the exception of small areas in the northwestern and northeastern corner, which drain into the Washita, Comanche County is drained by Red River. Beaver, Cache, Deep Red, and other creeks are the principal tributaries.

The main range of the Wichita Mountains lies in the northwestern part of Comanche County. These mountains consist largely of igneous rocks—gabbro, porphyry, and granite. North of the main range is a row of limestone hills containing rocks of Cambrian and Ordovician age. The rocks over the remaining portion of the county are chiefly red bed and shales, except along the north bank of Red River, where there is a district covered with sand hills.

Water supply.—Comanche County is well watered. Wells which have been put down in the red beds encounter water, usually of good quality, at moderate depths. Springs are found in most parts of the county. Those in the red beds are usually weak and uncertain, often being nothing but seep springs. Among the granite and limestone mountains, however, springs are abundant, and the perennial streams issuing from these mountains are fed by the springs. The springs among the limestone rocks contain a considerable amount of calcium carbonate, while the granite springs yield very pure water. Analyses Nos. 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, and 36 are of water from wells; Nos. 136 and 137 of water from springs, and Nos. 134 and 135 are of water from creeks in Comanche County.

Well records.—Of 25 wells reported from Comanche County 18 furnish soft water, 7 hard water, and the average depth is 32 feet. Typical water conditions are given in the 10 well records on page 158.

KIOWA COUNTY.

Rocks and drainage.—The North Fork of Red River forms the western line of Kiowa County, and the Washita flows through the northeast corner. The drainage of the greater part of the county is carried by Elk and Otter creeks, which flow south into North Fork, and Rainy Mountain Creek, which flows northeast into the Washita. The rocks consist chiefly of red beds and granite, the latter rock forming the western extension of the Wichita Mountains. The red beds consist largely of typical red clay shale, which, in localities near the mountains, grades off into conglomerate. In the northern part of the county are a few ledges of dolomite and sandstone, and along North Fork are localities in which sand hills are found.

Water supply.—Water is obtained from wells in practically all parts of the county. Its quality varies, being usually better south of the mountains than north. Springs are found among the mountains, and the water there obtained is pure and sweet; Otter Creek is fed largely by springs of this kind. Red beds springs are also known, but as a rule the amount of flow from springs of this kind is not great. Analysis No. 48 is of water from a well at Snyder.

Well records.—Of 35 wells reported from Kiowa County, 21 furnish soft water, 12 hard water, and 2 salty water. The average depth is 29 feet. The water conditions in various parts of the county are shown by well records on page 164.

GREER COUNTY.

Rocks and drainage.—Greer, the southwestern county in Oklahoma, lies southwest of the North Fork of Red River, and all the drainage is into one of the four branches of the Red—North Fork, Elm Fork, Salt Fork, or South Fork. The surface is generally level with the exception of canyons in the Gypsum Hills along parts of Elm Fork and Salt Fork. The extreme western extension of the Wichita Mountains lies west of North Fork of Red River, in the northeastern part of the county.

The rocks are mostly red beds, with red shale predominating. A very considerable part of the county is underlain with gypsum, which in places outcrops along the sides of various streams. Sand hills occur along some parts of both the North Fork and the South Fork.

Water supply.—As Greer County has more gypsum than any other two counties in the Territory, one would expect to find hard water. Wells frequently encounter beds of gypsum at depths ranging from 20 to 100 feet, and in such cases the water often found just beneath the gypsum partakes of the quality of that mineral. The springs of Greer County issue usually from beneath gypsum ledges along bluffs, although prairie springs are not unknown. In the western part of the county, within 5 miles of the Texas line, there are two salt plains, each formed from salt springs which issue from the bottoms of canyons carved into the Gypsum Hills south of Elm Fork. For a number of years salt has been manufactured on both these plains. Sand-hills springs are found near some of the streams and at Granite there is a sulphur spring. In general, the water of Greer County is abundant in quantity but rather undesirable in quality.

Well records.—Of 152 wells reported from Greer County, 26 furnish soft water, 109 hard water, and 16 salty water. The average depth is 70 feet. The well records on page 162 show the varying character of the water of this county.

WASHITA COUNTY.

Rocks and drainage.—Washita River flows southeast through the eastern part of the county and receives more than three-fourths of its drainage. The southwestern corner is drained by Elk Creek, a northern tributary of North Fork of Red River. In the eastern part on both sides of the Washita there are considerable ledges of gypsum, while farther west sandstone of the Quartermaster formation prevails. On the divide between Elk Creek and the Washita, in the western part of the county, there are sand hills. Red beds constitute practically all the rocks of the county.

Water supply.—In the eastern part of Washita County wells often pass through gypsum and obtain a supply of hard water directly beneath a bed of it. One such deposit, penetrated in a well near Seger, is reported to be 115 feet thick, the thickest so far known in the Territory. In the western part of the county good water is obtained from the Quartermaster, although the supply is sometimes limited.

Springs in Washita County are principally of two kinds—gypsum springs and sandstone springs. In the eastern part of the county the water from gypsum springs is not always good; water from the sandstone springs in almost every instance is soft and wholesome, although occasionally limited in amount. Many of the gypsum springs issue as bold streams from beneath heavy ledges, while the sandstone springs usually occur as seeps from the fine-grained sandstone along the heads of prairie canyons.

Well records.—Of 60 wells reported from Washita County, 43 furnish soft water, 13 hard water, and 4 salty water. The average depth is 66 feet. The well records on page 168 show the water conditions in this county.

CUSTER COUNTY.

Rocks and drainage.—The greater part of the drainage of Custer County enters Washita River, which flows southeast across the county. South Canadian River, however, crosses the northeast corner and Deer Creek, a tributary of that stream, drains the eastern part. Beaver, Barnitz, Turkey, Quartermaster, and other creeks are tributary to the Washita. The surface is rolling, the streams having cut rather deep valleys into the upland.

The rocks are chiefly of red-beds shales and clays. In the western part of the county the Quartermaster formation is well developed, and in the eastern and central parts are considerable deposits of gypsum. Small areas of Comanche Cretaceous rocks are found in Custer County, but are of no importance as far as the water supply is concerned. Sand hills are rare in Custer County.

Water supply.—The character of the water is such as would be expected in a region of red-beds shales and gypsums, generally containing mineral salts in greater or less amounts. Wells usually obtain an abundance of water, however, and there is very little of it that may not be used. Springs are also found, but not in large numbers. In the Quartermaster sandstone, in the western part of the county, springs typical of that formation occur—weak seep springs which issue usually from the head of a small canyon that has been cut into the soft sandstone. The water from these springs is uniformly good.

Well records.—Of 125 wells reported from Custer County 44 furnish soft water, 80 hard water, and 1 salty water. The average depth is 74 feet. Typical conditions are shown by the well records given on page 158.

DEWEY COUNTY.

Rocks and drainage.—The South Canadian flows east through this county in a series of oxbow bends, while the North Canadian crosses the northeast corner. Perhaps three-fourths of the drainage empties into the South Canadian, although the creeks tributary to this stream are usually short and unimportant.

The rocks are largely red beds. Sand hills occur north of the

South Canadian. Among the red beds sandstone is rare, the greater part of the rock consisting of red shales interspersed with beds of white gypsum.

Water supply.—Wells are common in Dewey County, and the water, which varies much in quality, is usually plentiful. Springs are found chiefly among the sand hills, where the water is both abundant and pure, although red beds springs which furnish hard water are not unknown. Analysis No. 37 is of water from a well in Dewey County.

Well records.—Of 123 wells reported from Dewey County, 21 furnish soft water and 102 hard water. The average depth is 93 feet. The 10 records on page 160 indicate the varying conditions of the water of this county.

ROGER MILLS COUNTY.

Rocks and drainage.—The North Fork of Red River forms the southern boundary of this county, and the Washita flows across its northeastern corner. A number of short creeks emptying into these rivers drain the entire county. Except a part of the divide between the Washita and North Canadian rivers, in the western part of the county where Tertiary sand hills are found, the rocks consist largely of red beds which cover practically the entire county. The greater part of these belong to the upper Quartermaster formation of the Permian and consist of fine-grained sandstone and shales. In the extreme southern part of the county, along the North Fork of Red River, gypsum ledges are exposed along a bluff nearly 200 feet high and 10 miles long, one of the finest exposures known in the Territory.

Water supply.—With the exception of the southeastern part of the county, in which gypsum water is found, soft water predominates throughout Roger Mills County. Wells in the Quartermaster formation usually secure good water, although in limited amounts, while in the sand hills water is both abundant and wholesome. Springs which occur in the Quartermaster are usually rather weak seep springs, but often furnish sufficient water to supply a farm with domestic and stock water. In the southern part of the county are a number of salt springs, while in the western part Tertiary springs are not unknown, and some of them furnish large amounts of water.

Well records.—Of 47 wells reported from Roger Mills County, 27 furnish soft water and 20 hard water. The average depth is 60 feet. Characteristic water conditions are shown in the 10 records on page 168.

DAY COUNTY.

Rocks and drainage.—The South Canadian has cut a broad canyon through this county, swinging from north to south in a series of oxbow bends, and across the southwestern corner flows the Washita, here but a small creek. The drainage is into these two rivers.

Red clay and sandstones of Permian age, which form the bed rock, and considerable deposits of Tertiary sand and clays on the uplands, particularly in the region north of South Canadian River, constitute the rocks of Day County. The valley of the South Canadian has cut its way through this upper sand and clay formation into the red-beds clays and sandstones below. North of the Canadian, as well as in the region between this river and the Washita, in the southwestern part of the county, are large areas of sand hills, while in the southeastern part there are extensive deposits of gypsum among the red beds.

Water supply.—In the sand hills soft water is found in all the wells, and as the area covered by these hills is larger than that occupied by the red beds, it follows that in this county the water is usually good. Springs are found in both the sand-hills and the red-beds areas, the former being usually strong and furnishing good water, while the red beds springs are usually weak and the character of the water often unsatisfactory.

Well records.—Of 28 wells reported from Day County 21 furnish soft water and 7 hard water. The average depth is 84 feet. Typical records of the wells of this county are given on page 160.

WOODWARD COUNTY.

Rocks and drainage.—Woodward County is drained by Cimarron and North Canadian rivers. The former stream enters the northwest corner from Beaver County, flows southeast for 10 miles, passes into Kansas, and after flowing a distance of 25 miles in that State, again flows into Woodward County and continues in a southeast course for 40 miles or more before reaching Woods County. North Canadian River is formed by the junction of Beaver and Wolf creeks, which unite at old Fort Supply, near the center of the county, Beaver Creek flowing southeast and Wolf Creek northeast to form this junction. The chief streams flowing into the Cimarron in Woodward County are Doe, Chimney, Sand, Long, Traders, and Buffalo creeks from the south, and Anderson, Indian, Whitehorse, and Redhorse creeks from the north, all of which rise in the Gypsum Hills. Neither North Canadian River nor Beaver Creek have any tributaries of importance emptying from the north in Woodward County for the reason that the north slope of these streams is covered with sand hills; Kiowa, Otter, Clear, Indian, and Persimmon creeks are southern tributaries to these streams, while Wolf Creek has a number of smaller creeks emptying from both north and south.

In Woodward County red beds are exposed along the streams, while Tertiary sand covers the uplands. Along the Cimarron and its tributary creeks beds of gypsum outcrop, and the entire valley in Woodward County is but a broad canyon cut into the Gypsum Hills. Along the North Canadian and Beaver Creek red beds are exposed, especially on the south side of the stream, but on Wolf Creek the red beds are mostly hidden and only Tertiary rocks are found. All the divides in Woodward County, as well as the north slope of the North Canadian and Beaver Creek, are covered with sand hills or consist of level upland capped by Tertiary rocks.

Water supply.—Along the Cimarron and south of North Canadian River the water is usually obtained from red beds, and in consequence is usually not good. The water from the red clay is sometimes good, but more frequently it carries so much mineral salts as to be unsuitable for house use, but on the uplands and the north slope of the North Canadian wells put down in the Tertiary formations secure an abundance of good water. On some of the uplands the wells are 200 feet deep or more, but the average depth of the wells of this kind is perhaps not more than 75 feet.

Springs occur both in the red beds and Tertiary formations. Among the Gypsum Hills along the Cimarron springs issue sometimes from beneath heavy ledges of gypsum in which the water contains large amounts of calcium sulphate in solution. In the northern part of the county there are two regions of salt springs, the largest of which includes a plain 8 miles long and 2 miles wide, from which flows a stream carrying approximately 2 second feet. The Tertiary springs of Woodward County are among the finest in the Territory. The Moscow Springs on the North Canadian have long been famous, and the Bent Canyon Springs, 20 miles north of Woodward, form a veritable oasis. Old Fort Supply was supplied with water carried in pipes from a Tertiary spring 3 miles distant, and Woodward, the county seat, obtains its water supply from Tertiary rocks. Analysis No. 85 is of water from a well in Woodward County.

Well records.—Of 53 wells reported from Woodward County, 37 furnish soft water, 15 hard water, and 1 salt water. The average depth is 56 feet. The well records on page 170 show the typical water conditions in this county.

BEAVER COUNTY.

Rocks and drainage.—Beaver County (formerly known as "No Man's Land" or the "Neutral Strip") extends from the one hundredth to the one hundred and third meridian, a distance of 165 miles west of the main part of Oklahoma. Its width is 35 miles. It is a typical part of the high plains, apparently flat and level as a floor, but in reality sloping from an altitude of over 4,500 feet at the New Mexico line to about 2,000 feet in the eastern part of the county.

Across this county Cimarron River and Beaver Creek flow from west to east. The Cimarron flows across the northwestern part of the county for 50 miles, then goes on a long excursion through Colorado and Kansas and returns to Beaver County 25 miles west of the eastern line of the county. Except for a distance of 15 miles where the stream bends south into the Panhandle of Texas, Beaver Creek flows across Beaver County from end to end. Both of the streams have carved valleys averaging 150 feet in depth and 3 miles in width, and tributary creeks are now at work dissecting the high table, but at the present time have scarcely more than commenced their task. Such creeks as Duckpond, Clear, Palo Duro, Coldwater, and others emptying into Beaver Creek from the south have their rise in Tertiary springs and are practically perennial streams.

With the exception of small areas of red beds along the south bank of the larger streams and some outcrops of Cretaceous rocks, particularly in the extreme western part of the county, practically all the surface rocks of Beaver County consist of formations of Tertiary age, which form a deposit sometimes as much as 400 feet thick above the subjacent red beds. Along the streams these Tertiary rocks have been weathered away and form sand hills, but on the uplands the surface is hard and firm.

Water supply.—Beaver County has good water. Wells on the upland rarely fail to obtain an ample supply of pure, wholesome water, although the depth of the well, often from 100 to 250 feet, renders the water difficult to draw; accordingly windmills are in almost universal use, both on ranches and near farm houses. There are a few places along the south side of Beaver and Cimarron where water is obtained in the red beds, but this is uncommon.

Springs are found in Beaver County usually issuing from Tertiary rocks, and as is the usual case the water from these springs is always good. Beaver Creek and its tributaries, perennial streams, are fed by springs from the Tertiary.

In the Dakota sandstone region, in the western part of the county, there are both wells and springs which furnish soft water, although the Dakota in this region does not supply as much water as in Kansas and Nebraska. Analyses Nos. 1 and 2 are of water from wells in Beaver County.

Well records.—Of 29 wells reported from Beaver County 19 furnish soft water and 10 hard water. The average depth is 110 feet. The varying character of the water conditions is shown by the 10 well records on page 156.

IRRIGATION.

GENERAL STATEMENT.

Irrigation in Oklahoma has met with considerable indifference, or even open opposition, on the part of many of the people. The western part of the Territory, in which irrigation is most needed, has been settled mainly during the last five years, and in that time the rainfall has been greater than the average, and the crops have been abundant. There is a general impression that an acknowledgment that irrigation is needed will be detrimental to the interests of the Territory, and for this reason in many places the matter has usually met with a cold reception. During the last few months, however, public opinion has in a large measure undergone a change, and communities that formerly scouted the idea are now asking how such operations may be brought about.

In Oklahoma water for irrigation may be obtained from rivers, from reservoirs, from springs, and from wells. These various sources will be discussed in the order named.

IRRIGATION FROM RIVERS.

As has been stated in another part of this report, seven rivers flow southeast across Oklahoma, but for the greater part of the year many of these streams carry comparatively little water. Most of them also have sandy banks, and for that reason ditches leading across the bottom lands would lose much of their water by seepage or would soon become sand choked. In a number of places where dams have been thrown across small streams and the channel diverted into ditches it is necessary to remove the silt from the ditch every few months or to construct a new one, but in other cases where there is no sand to obstruct the ditch it remains open from year to year.

It must be remembered also that while the normal flow of Oklahoma streams is not great, they are all subject to sudden and rapid rises. The South Canadian, Red, and Cimarron rivers, in particular, often rise 10 feet or more in an hour and remain bank-full for several days, when the water gradually subsides and the channel may be practically dry for weeks. These sudden rises are often sufficient to tear out any dams such as have heretofore been constructed. On account of the broad and shallow valleys, the depth to bed rock, and the scarcity of building material, masonry dams are practically unknown, and those constructed have been of piling, plank, logs, loose rock, earth, brush, etc. (See Pl. XXI, *B*.)

Along Cimarron River and Beaver Creek, both of which are sand-filled, and often sand-choked, irrigation has been carried on for a number of years. These streams have both been carved out of the level Tertiary upland, and both have in many places cut entirely through this surface formation into the subjacent red beds. Along Beaver Creek the red beds occur almost continuously on the south bank of the stream as far west as the mouth of Palo Duro Creek, while on the north side of the creek there are sand hills which extend 5 to 10 miles from the river. In other words, in eastern Beaver County are exhibited the phenomena so often observed along the rivers farther east, viz, a strip of sand hills north of the stream and a row of red beds canyons south of it. The amount of water in Beaver Creek varies greatly at different points and at different times of the year, so that any estimates as to amount of flow, unless based on data collected through a series of years, would be misleading. Such tributaries as Kiowa, Coldwater, and Palo Duro carry nearly as much water as the main stream at the point where they join Beaver Creek.

There are numerous small irrigation plants all along the streams of Beaver County, where rude dams of logs, earth, or loose rock have been built across the creeks and the water diverted from the channel and carried out over the bottoms to irrigate small fields and gardens. In times of flood these frail structures are washed out and often not rebuilt for several months. One of the better class of stone dams was washed out during the flood in May, 1903, and had not been rebuilt the following August. It is safe to estimate that at least one dam is present every 5 miles along Beaver and its larger tributaries as far west as Guymon. It is the universal testimony of persons living along the stream that the water taken out for irrigation does not sensibly diminish the flow, and the explanation given is that springs come in all along the bed of the stream. It is very probable, however, that this is due largely to the fact that much of the water seeps back into the channel and the stream is thereby replenished.

The character of Cimarron River in Beaver County does not differ from that of Beaver Creek. Both these streams have cut channels into Tertiary rocks, and in places into the red beds below, and both are fed at least in part by Tertiary springs.

The most successful irrigation plant in this region is just across the Kansas line near Englewood, Clark County, Kans., but the water comes from the Cimarron, in Oklahoma. The following description of this plant is taken from the report of Mr. W. G. Russell: [a]

The principal irrigation development in this part of the country has been carried on by C. D. Perry, of Englewood, Kans. About fourteen years ago he constructed a ditch from the Cimarron River to irrigate his lands in Kansas.

[a] Russell, W. G., First Ann. Rept. Recl. Service, U. S. Geol. Survey, 1903, p. 271.

He built a sheet pile dam across the channel, consisting of 2-inch piling driven to a depth of about 12 feet in the sand. The tops were held in line by two walings fastened with three-eighth inch bolts through the piling and both strips. This ditch was 8½ miles long and had a capacity of about 14 second-feet. It was not well built and was difficult to maintain. The total cost was nearly $10,000. The floods tore out a considerable portion of the dam, filled the channel with sand, and made a new channel, passing around the remains of the dam.

A new ditch was built by Mr. Perry, with head-gates lower down the stream. Instead of a dam for diverting the water, he constructed a wooden stave pipe, 30 inches in diameter, sunk in the sand, extending from the headworks diagonally upstream. This was 900 feet long and was planned to extend a mile or more. The underside of the pipe had perforations through galvanized sheet iron, intended to admit the water. The pipe was partly washed out before it was tested and the remaining portion filled with sand. Water was obtained, however, through a ditch heading at a brush dam below the pipe. The ditch now in operation is 7 miles long and cost nearly $3,000, including the wooden stave pipe. It is successful and discharges at the lower end into the old ditch. Experiments for obtaining the so-called "underflow" could probably be made at this locality with good chances for success.

Between Englewood, Kans., and Kenton, Okla., are a number of small plants where water is taken from the river by means of dams of stone, earth, or logs, and west of Kenton practically all the water is taken from the Cimarron and its tributary creeks and used for irrigation. Pl. XXI, *B*, shows a log-and-earth dam on the upper Cimarron.

Along Wolf Creek, in Woodward County, and certain branches of Washita and Red rivers small irrigation plants have been erected from time to time, but the same conditions exist as in Beaver County, and the temporary dams are usually washed out by every flood, and no great importance can be attached to these irrigation systems.

One fact regarding irrigation from Oklahoma rivers remains to be mentioned, namely, the character of the water. Cimarron, Salt Fork, and North Fork of Red River drain regions of salt springs which render the water too salty to be of any use for irrigating purposes. Salt Fork crosses the Great Salt Plain in eastern Woods County, and below that point its waters contain a considerable percentage of salt. Cimarron River flows through two salt plains in northern Woodward County and receives the drainage of the Blaine County salt plain. The salt plains of Roger Mills and Greer counties are drained by North Fork of Red River, and the water of that stream below the mouth of Elm Fork is very salty. Besides the cases mentioned, the water of the other Oklahoma streams is suitable for irrigation.

IRRIGATION FROM RESERVOIRS.

The greatest difficulty in the construction of large reservoirs in Oklahoma is that so few available sites exist. All of the larger streams of the Territory flow for practically all their course through broad and shallow sand-filled channels. There are a comparatively few localities where streams flow through narrow gorges and masonry dams might be constructed. Of these localities the most satisfactory that have so far been examined are located in the Wichita Mountains. In October, 1903, the writer, in company with Mr. Bailey Willis, of the United States Geological Survey, visited the most available of the sites in these mountains. The following descriptions are from Mr. Willis's report:

MEDICINE BLUFF SITE.[a]

In sec. 7, T. 3 N., R. 12 W., the valley of Medicine Bluff Creek is an extensive bottom land, approximately from 1 to 1½ miles wide 60 feet above the stream level. The stream itself has moderate fall. Near the south line of the section the valley narrows to a canyon 75 feet deep and 400 feet wide between steep walls. Beneath the wider valley the rock is rather impervious red shale and sandstone; in the canyon it is granite, more or less jointed, but forming a fairly solid mass, suitable for the foundations of the dam. The stream in the canyon runs on bed rock.

The drainage area tributary to this site is estimated from the map at about 90 square miles. The waters from the reservoir might be conveyed a distance of 10 miles down the valley to Fort Sill and thence over the prairie lands in the vicinity of Lawton. The height of the dam site above Lawton is 200 feet, and the water would be available upon the highest prairies of the neighborhood.

The value of this reservoir site is limited by the small area tributary to it. Medicine Bluff has the reputation of being a comparatively constant stream for the region; but from field observation, without measurement, it would appear probable that the greater part of its flow throughout the year could be stored without utilizing the entire capacity of the reservoir site.

The waters from Medicine Bluff Creek flow largely from granite slopes and so far as they are derived from other rocks are not contaminated by gypsum or alkali.

LOWER NARROWS OF OTTER CREEK.[b]

In sec. 9, T. 3 N., R. 17 W., several branches of Otter Creek assemble in a usually flat valley, and the combined stream enters a canyon about 200 feet wide and approximately 100 feet deep, with nearly vertical walls. The conditions are the same as those already described on Medicine Bluff, except that the valley above the canyon is much broader and shallower and the canyon is narrower. It is estimated from the map that the drainage area of Otter Creek tributary to this reservoir site is about 125 square miles. Surveys have been made by the Otter Creek Irrigation Company on the basis of a dam 60 feet in height, constructed to throw the water over the lowest point into the divide on the southeast, and according to Mr. Mark Roberts, the originator of the plan, the area included within the contour at a level of the top of the 60-foot dam is 6,000 acres, and the average depth of water in the reservoir would be about 20 feet. Aneroid readings appear to agree fairly well with Mr.

[a] First Ann. Rept. Recl. Service, U. S. Geol. Survey, 1903, p. 267.

[b] Op. cit., p. 268.

Roberts's statements of the position of the outline of the reservoir, at least along the route by which it was crossed.

The area to be irrigated by the water which may be thus stored lies south of Mountain Park, on the lower course of Otter Creek and along Red River. The area of agricultural lands available is probably more than can be supplied by the drainage basin, which it is proposed to utilize, and the capacity of the reservoir also is probably sufficient to hold the water that can be stored from that basin.

The waters of Otter Creek flow in part from hills of igneous rock, but in greater part from areas of red beds. They do not, however, contain any notable quantity of gypsum or alkali.

QUARTZ MOUNTAIN SITE.[a]

North Fork of Red River is joined in T. 5 N., R. 20 W., by a very considerable stream known as "Elm Fork," the waters of which contain a large amount of gypsum and probably of other salts. Any irrigation plan contemplating the use of the waters of North Fork of Red River should exclude those of Elm Fork on this account. Above its junction with Elm Fork, North Fork of Red River flows from a valley in the red beds across a small area of granite in the east end of Quartz Mountain. The narrowest point of the short canyon which is thus formed in the eastern part of sec. 22, T. 5 N., R. 20 W., and the wider valley above the canyon occupies sections 14 and 15. The canyon has a minimum width at water level of 500 feet. The depth to granite in the bottom land is indeterminate. Fence posts are sunk in red and green clays of the red beds just below the narrowest part, and it may be inferred that the granite is not near the surface, even at the dam site; but the shales and sandstones of the red beds would probably afford an equally substantial foundation. It was stated that even when the river bed is otherwise dry there is always a pool of water next to the granite at the dam site, and this would seem to indicate that the underflow was brought to the surface by ledges of rock. About 200 yards west of the canyon there is a depression in the granite ridge 80 feet above the river, and this would limit the depth of the reservoir unless a supplementary dam were placed in that gap. The gap is narrow and could be easily controlled by closing it with the dam or by utilizing it as waste way. A dam 80 feet high would back the water up the valley of Red River for many miles, and would constitute a reservoir of very large proportions. The foundations and walls at the dam site appear to be adequate for any such construction.

The drainage basin of Red River tributary to this site is roughly estimated at 3,000 square miles. The quality of water, even in the autumn season, is good, although slightly saline to the taste. The water from this site could most easily be conducted across Elm Fork and southwestward into Greer County. The Otter Creek Irrigation Company proposes, however, to divert at least the flood waters to a canal extending east from the above-described dam site to Tepee Creek, and thence across to Elk Creek, by a deep cut in the divide, to the basin of Otter Creek. Surveys for this purpose were contemplated late in October.[b]

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[a] Op. cit., p. 268.

[b] Since the above was written Mr. Gerard H. Matthes and other engineers of the Reclamation Service have pursued extensive investigations on the Wichita Mountain reservoir sites. The results of their work will be found in Second Ann. Rept. Recl. Service, U. S. Geol. Survey, 1904, pp. 412, 423.

Pl. XVIII, A, shows the location of the dam site at Quartz Mountain.

CIMARRON RIVER SITE.

On the Cimarron River, in northeastern Beaver County, Mr. W. G. Russell describes a reservoir site as follows:[a]

A suggested opportunity for construction of storage works has been pointed out in sec. 32, T. 5 N., R. 6 E. of the Cimarron meridian. The river at this point passes a bluff 30 feet or more high. To the south the overflowed bottom is about one-half mile wide, and to the north the ground rises gradually for a quarter of a mile before gaining the height of the south bluff. A dam 30 feet above the river would measure about one-half mile in length, and one-fourth mile additional would be required to complete it on the north slope. The bottom lands increase in width above the dam site, and the fall of the river being approximately 8 feet to the mile, it is estimated that a reservoir could be created about 3.5 miles long by 1 mile wide, having a capacity in round numbers of 35,000 acre-feet. A survey has not been made, but these figures are given from inspection of the ground. It is believed that the flow of the Cimarron River is sufficient to fill this reservoir. Below it are lands situated on both sides of the river. It is claimed that there is an impervious clay lying only a few feet below the bed of the river upon which a dam could be formed. A structure placed at this point must be built presumably of earth, as there is little rock in sight. On the tops of the bluffs, about 300 feet above the river, are fragments of a porous limestone, which may be used in concrete or for revetment on the slopes.

The construction of a dam across the Cimarron, in Beaver County, is a difficult undertaking, and one which must be given careful consideration. Little can be known without expensive surveys and borings to ascertain the character of the foundations and the proper material to be used in the structure.

UTILIZATION OF STORM WATERS.

In addition to the sites mentioned, all of which are located on rivers, there are in western Oklahoma hundreds of places where small dams might be thrown across small watercourses, draws, or arroyos, forming a reservoir for the storing of storm waters. In many instances, such reservoirs could be so located as to irrigate many acres of fertile land now too dry to yield satisfactory crops.

Some of the difficulties are, first, relatively small amounts of rainfall; second, the great evaporation, and third, sandy character of the soil. The rainfall of Beaver County varies from 20 inches in the eastern part to less than 10 inches near the New Mexico line. The greater part of this precipitation usually falls during a few heavy downpours, amounting often to cloud-bursts, while for months at a times almost no rain will fall. A difficulty, of course, is that after a heavy rain, any but the most strongly constructed dams will be washed out.

There are few data available as to the amount of evaporation in the

[a] Op. cit., p. 271.

region under discussion, but it amounts to at least 6 feet per year in the western portion of the Territory. As stated by Johnson and others, there are large areas where there is practically no run-off, the drainage flowing down shallow draws into playa lakes. Areas of many square miles are as flat and level as a floor, and the water that falls remains on the surface of the ground until it is evaporated.

In a region of this kind, with high summer temperature and almost constant wind, it would be expected that a large proportion of water collected in reservoirs would soon be evaporated. Lakes on the Plains usually go dry during the summer, and the same conditions obtain in artificial reservoirs, except that these can be made of sufficient depth to provide a surplus of water beyond the evaporation.

Much of the soil in this region is sandy, particularly along the streams where reservoirs must usually be constructed. In the sand-hill districts there is practically no run-off; the water is either evaporated or soaks into the soil, and it goes without saying that it is useless to locate a reservoir in such a locality.

Notwithstanding the objections cited in the preceding paragraphs, however, there are plenty of places in central and western Oklahoma where a reservoir a few acres in extent might be profitably constructed which would afford useful water storage. The writer does not venture an opinion as to whether such projects would be profitable. The problem is one, however, that should be carefully investigated.

IRRIGATION FROM SPRINGS.

At best, irrigation from springs can be but local, on account of the relatively small amount of water supplied from even the strongest. Of the various classes of springs in Oklahoma, the water from red beds and Tertiary springs only is used for purposes of irrigation; in by far the greater number of instances a Tertiary spring is so used. As has been stated in another part of this report, the supply from these springs is practically inexhaustible, the amount from a single one often approximating several second-feet. The quality of the water leaves little to be desired, being usually pure, sweet, and free from mineral salts. The chief difficulties in the way of irrigation from these springs are those of location. Tertiary springs issue almost invaribly along the line of unconformity between the red beds below and the Tertiary above, as shown in figs. 29 and 30, and usually in a canyon or along a bluff where the country below is so rough and broken that in most cases the water can not be utilized. In a number of instances, however, the water from one of these springs is led out over a garden or orchard. The table given herewith (p. 140) sets forth the location of areas irrigated from springs so far as ascertained by the writer.

Water from Tertiary springs is utilized in another way, namely, as a source of city supply. At Alva the water from Elm Spring, 3 miles away, is carried in a pipe by gravity to the north part of the city, and then forced by a pump into the water mains and carried to all sections of the city. Old Fort Supply obtains its water from a Tertiary spring 3 miles away across Beaver Creek, the water being carried in a 6-inch main. Woodward, Grand, Beaver, and other county seats in the western part of the Territory are supplied either from Tertiary wells or Tertiary springs.

Irrigation from springs in Oklahoma.

Name of owner.	Township.	Range.	Section.	Irrigation section.	Kind.	Acres.	Crops irrigated.
John Cornvine	25	1 W.	13	SW.	Tertiary		
W. E. Miller	24	16 W.	2	NE.	do		
Jacob Eckart	22	21 W.	4	NE.	do	3	Garden.
A. L. McPherson	23	21 W.	14		do		
S. A. Pollock	23	21 W.	4		do	5	
J. E. Fitzlin	28	14 W.	8	NE.	do	10	Garden and orchard.
A. C. Grimes	28	14 W.	35	SW.	do	3	Garden.
L. F. La Brue	27	9 W.	9	NW.	do	12	Produce and orchard.
Wm. Crow	27	8 W.	20	SW.	do	1	Garden.
M. L. Bodenheimer	25	10 W.	9	SE.	Red bed	3	Orchard.
Levi Manning	22	10 W.	15	NE.	Tertiary	12	Garden and orchard.
F. M. Matthews	27	9 W.	33	NE.	do	9	
M. L. Guffey	27	9 W.	4	SW.	do		
Adam Walck, sr	17	4 W.	6	NE.	Red bed		
C. N. Jett	25	9 W.	2	NW.	do	6	Orchard.
Do	25	10 W.	36	NE.	do	12	Garden.

IRRIGATION FROM WELLS.

In a great part of western Oklahoma there is sufficient underground water, if it were brought to the surface, to irrigate considerable areas. The difficulty here is that no cheap method has yet been devised whereby sufficient underground water may be elevated from considerable depths to be of practicable importance. Windmills seem to furnish the simplest solution of the problem, and considerable literature has already accumulated on the subject.[a] Pl. XV gives types of Oklahoma windmills.

In western Oklahoma a great part of the water lies at depths of 100

[a] For a discussion of the relation of windmills to water supply the reader is referred to the following numbers of the Water-Supply and Irrigation Papers of the U. S. Geological Survey:

No. 1. Pumping water for irrigation, Herbert M. Wilson, 1896.
No. 8. Windmills for irrigation, C. E. Murphy, 1897.
No. 14. New tests of certain pumps and water lifts used in irrigation, O. P. Hood, 1898.
No. 20. Experiments with windmills, T. O. Perry, 1899.
No. 29. Wells and windmills in Nebraska, E. H. Barbour, 1899.
Nos. 41 and 42. The windmill, its efficiency and economic use, E. C. Murphy, 1901.

to 400 feet, and windmills have so far proved inadequate to the task of lifting sufficient quantities of water for irrigation purposes. Farms and ranches are supplied by windmills, and in certain parts of Oklahoma to-day lone windmills are the only signs of civilization, but in most cases all efforts to secure a greater supply of water than is necessary for stock and domestic purposes has proved a failure. The problem is one that deserves attention and which may in time yield practical results.

CLIMATE.

Eastern Oklahoma lies in the humid, western Oklahoma in the semiarid, and extreme western Beaver County in the arid belt of the

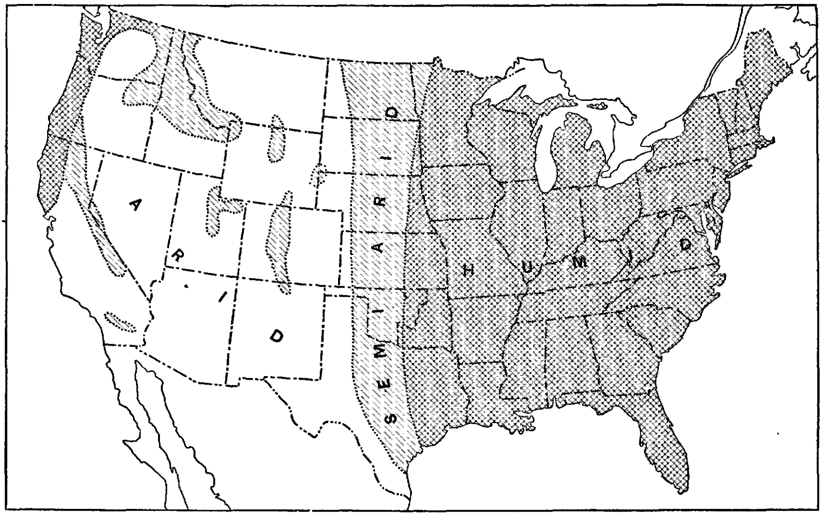

FIG. 31.—Map showing the arid, semiarid, and humid regions of the United States.

United States, as these belts are usually demarked (see fig. 31). In the Osage Nation and the eastern tier of counties the annual precipitation for the last ten years has averaged about 35 inches. In central Oklahoma during the same time the average has been 30 inches, along the western line, exclusive of Beaver County, 25 inches, and in the western part of this county the annual rainfall has not exceeded 15 inches (see fig. 32).

In the eastern part of the Territory the rainfall is not only more abundant, but it is also more evenly distributed. As a general thing rain falls during every month, but on the average there are more than 175 clear days in the year, while days with 0.1 inch precipitation will not average more than 70 each year. On the high plains the precipitation is neither regular nor abundant. For months at a time there may be practically no rainfall, when, again, during a heavy storm, often amounting to a cloud-burst, a level plain will be covered with several inches of water.

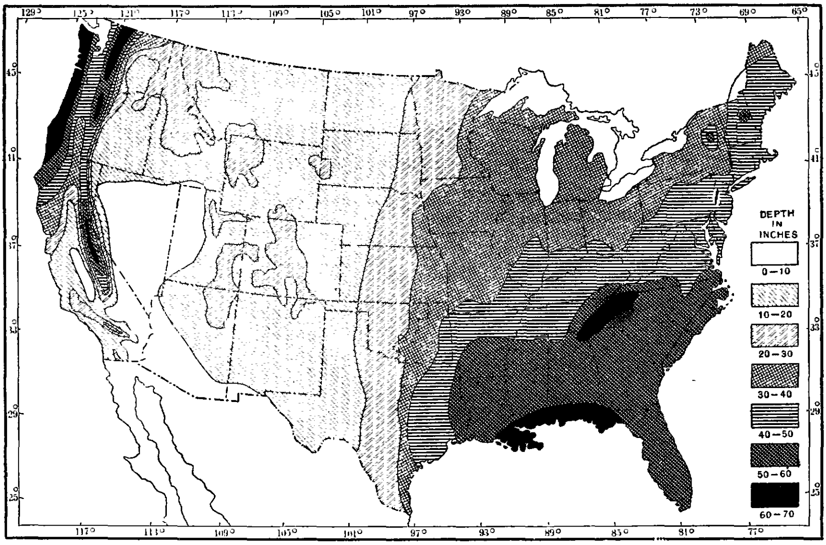

FIG. 32.—Map showing the mean annual rainfall of the United States.

The mean annual temperature for ten years has been 59°, varying from 55° in Beaver County to 62° in Comanche. The winters are mild and the heat of the summers tempered by almost constant breezes.

WATER ANALYSES.

METHOD.

The calcium oxide, magnesium oxide, sulphuric anhydride, chlorine, and solid residue are determined in the usual way, using Cheever and Smith, Sutton, Cairns, and Mason as guides. The carbon dioxide is not estimated, but is calculated by differences.

In general, in this report, the metals in their combination with the acids are taken in the following order: Calcium, magnesium, sodium.

In their combination with the metals the acids are taken in order as follows: Sulphuric acid, hydrochloric acid, carbonic acid.

These combinations are only hypothetical, yet they can not fail to give a better idea of the constituents of the water, and it is merely for this purpose that such combinations have been made.

DEFINITION OF TERMS.

That the general reader may more readily understand the analyses given below, the following definitions and explanations of terms are given:

Grains per gallon.—The number of grains per United States gallon are determined from the parts per million on the basis that " 1 United

States gallon of pure water at 60° F., weighed in air at 60° F. at atmospheric pressure of 30 inches of mercury, weighs 58,334.946 grams."[a]

Common names.—Calcium sulphate is gypsum, and in its dried form is commonly known as plaster of Paris; calcium carbonate is limestone; magnesium sulphate is Epsom salt; sodium sulphate is Glauber's salt; sodium chloride is common salt; sodium bicarbonate is common baking soda. All the remaining salts occurring in the analyses have no common names.

COMPARISON OF RED-BEDS WELLS.

To show the great variations in the supply and quality of waters from the red beds, even in the same locality, eight wells within a radius of two blocks in the city of Norman, Okla., have been taken as an example.

Comparative table showing variation of red-beds waters.

[Parts per million.]

Sample No.	How put down.	Kind of rock.	Total depth.	Depth to water.	Depth of water	Variation of water depth at different times of year.	Amount of water.
			Feet.	*Feet.*	*Feet.*		
7	Dug	Red beds	28	12	16	None	Not easily lowered
8	do	do	30	25	5	Very slight	Do.
9	Drilled	do	50	14	36	None	Do.
10	do	do	20	16	4	Very slight	Quite easily lowered.
11	Dug	do	23	14½	8½	Considerable	Not easily lowered.
12	do	do	25	21	4	do	Do.
13	do	do	23	21	2	do	Quite easily lowered.
14	do	do	24	21	3	do	Do.

Sample No.	Calcium oxide.	Magnesium oxide.	Sulphuric anhydride.	Chlorine.	Total residue.	Normal hardness.	Carbon dioxide.
7	115.0	9.0	271.0	160.0	945.0	58.5	146.0
8	122.0	60.0	256.0	60.5	621.0	53.3	121.8
9	242.0	220.0	1,129.0	1,185.0	4,365.0	1.3	147.0
10	152.0	139.0	709.0	750.0	2,980.0	3.9	None.
11	53.0	43.0	68.0	33.0	572.0	9.6	124.0
12	174.0	96.0	236.0	104.0	1,099.0	14.3	146.0
13	137.0	96.0	58.0	89.5	856.0	11.7	170.0
14	137.0	63.0	50.0	54.5	641.0	14.3	130.0

[a] Mason's Examination of Water, 2d ed., 1901, p. 93.

The wells selected are Nos. 7 to 14, inclusive, in the general report of analyses.

Sample No. 7 is a dug well, 28 feet in depth. In this the depth of water is 16 feet. No. 8, less than a block from No. 7, is 30 feet in depth and has but 5 feet of water. The supply of water in both is practically constant the year around and is not easily lowered by excessive use. In calcium oxide, sulphuric anhydride, normal hardness, and carbon dioxide Nos. 7 and 8 differ but slightly. However, in magnesium oxide No. 7 is very low and No. 8 is comparatively high, while No. 7 greatly exceeds No. 8 in chlorine and total solid residue. These differences are remarkable because the geologic and sanitary surroundings of the wells are apparently the same.

Nos. 10 and 11 also make an interesting comparison. No. 10 is 20 feet deep, varies but slightly in water depth at different times of the year and is easily lowered by excessive use. No. 11, distant from No. 10 by but a little more than the width of a street, is 23 feet deep, contains 8½ feet of water, varies considerably in water depth at different times of the year, and is not easily lowered by excessive use. With a difference of but 3 feet in depth, and so close together, the difference in the amount of water constituents is worthy of notice. In No. 10 the calcium oxide, magnesium oxide, and solid residue are about five times that of No. 11, while the sulphuric anhydride is about ten times and the chlorine twenty-five times as much. The normal hardness of each is small, but that of No. 11 is more than twice that of No. 10, which has no carbon dioxide as carbonates, while No. 11 has a fairly large amount. It might be noted here that No. 11 runs lower in nearly all the tests than any other water taken for comparison.

In the same block with No. 11 are wells Nos. 12, 13, and 14, occurring in the order given. The width of the two lots separates wells No. 11 and No. 12. The depths of these wells are practically the same, yet in No. 12 the solid constituents greatly exceed in amount those of No. 11, running especially high, comparatively, in calcium oxide, sulphuric anhydride, chlorine, and solid residue. Wells Nos. 12 and 13 are separated by about the width of one lot and differ by but 2 feet in depth. In No. 13 the calcium oxide, chlorine, solid residue, and normal hardness are but slightly less than in No. 12; the magnesium oxide is the same in both; the carbon dioxide in No. 13 is higher than in No. 12; but the most noticeable difference is that of the sulphuric anhydride, which in No. 13 is but about one-fourth of that in No. 12. No. 14 differs but little from Nos. 11 and 13.

All of the wells so far compared have been between 20 and 30 feet in depth. It may therefore be of interest to include one deeper well. For this comparison No. 9 will answer the purpose. Both No. 9 and

No. 10 are on the same lot, about 40 feet apart. No. 9 is a drilled well 50 feet in depth and contains 36 feet of water. It might be well to note in this connection that good water was struck at 14 feet and at a depth of 40 feet salt water was encountered. This lower stream of water has rendered the well altogether unsuitable for drinking purposes. In this water the calcium and magnesium oxides are considerably higher than in any other of the waters taken for comparison, while the sulphuric anhydride, chlorine, and solid residue are excessively high.

All other deep-well waters from this section of the country which have been analyzed have, like No. 9, run exceedingly high in sulphuric anhydride, chlorine, and solid residue. These deep-well waters also vary greatly, although perhaps not so noticeably as the waters from the shallower wells.

The wells used in the above comparison may be considered as typical of all the wells having their origin in the red beds. For general domestic purposes the shallow wells are the more satisfactory, although few of these contain water which can be classed as really good. In short, the red beds make a poor and unreliable source of water supply.

Analyses of Oklahoma well waters.

[Grains per United States gallon.]

Number.	Location.	Calcium oxide (CaO).	Magnesium oxide (MgO).	Sulphuric anhydride (SO_3).	Chlorine (Cl).	Total solid residue.	Carbon dioxide (CO_2).	Supposed combination of constituents. Calcium sulphate ($CaSO_4$).	Calcium chloride ($CaCl_2$).	Calcium carbonate ($CaCO_3$).	Magnesium sulphate ($MgSO_4$).	Magnesium chloride ($MgCl_2$).	Magnesium carbonate ($MgCO_3$).	Sodium sulphate (Na_2SO_4).	Sodium chloride (NaCl).	Sodium carbonate (Na_2CO_3).	Sodium bicarbonate ($NaHCO_3$).
	Beaver County:																
1	Beaver, lot 14, block 106	72.7	17.8	139.4	313.5	799.9	27.2	176.6			52.9			1.2	517.3		51.9
2	Guyman, on city square	4.2	.7	4.6	.6	17.9	4.7	7.8	1.0	.8			1.5				6.7
	Blaine County:																
3	Geary, at Geary Mill and Elevator Co.'s mill	5.9	2.6	11.3	2.5	31.6	4.9	14.4			4.2	2.2			1.5		9.6
4	Do	4.2	5.6	17.7	6.8	62.3	12.9	10.2			16.7			.96	11.2		23.1
5	Ferguson, in south canyon, at head of Salt Creek	206.2	92.1	163.7	8,610.0	(a)	(a)	278.2	181.2			161.8			13,840.6		(a)
	Caddo County:																
6	Anadarko, south of brickyard	11.0	1.4	17.9	1.4	58.2	11.7	26.8			4.2			3.0	1.97		22.3
	Cleveland County:																
7	Norman, lot 8, block 10, Larsh's addition	6.71	.5	15.8	9.3	55.1	8.5	16.4			1.6			9.2	15.4	20.5	
8	Norman, lot 18, block 11, Larsh's addition	7.1	3.5	14.9	3.5	36.2	1.2	17.3			7.2	2.6			2.7	2.95	
9	Norman, lot 19, block 12, Larsh's addition	14.1	12.8	65.8	70.8	254.7	8.6	34.3			38.2			35.9	114.1	20.7	
10	Do	8.9	8.1	41.4	43.8	173.9	.0	21.6			24.2			22.4	72.2		
11	Norman, lot 13, Larsh's addition	3.1	2.5	3.97	1.9	33.4	7.4	6.8		.6			5.2		3.2	10.3	
12	Norman, lot 4, Elmwood addition	10.0	5.7	13.8	6.1	64.1	8.5	23.4		.9			11.7		10.0	4.8	
13	Norman, lot 6, Elmwood addition	8.0	5.6	3.4	5.2	49.9	9.9	5.7	8.2	2.7			11.7			6.4	
14	Norman, lot 10, Elmwood addition	8.0	3.7	2.9	3.2	37.4	7.6	4.95	4.97	6.1			7.6			1.1	
15	Norman, new city well	1.7	1.4	54.5	3.4	(a)	29.6	4.0			4.4			87.3	5.6		5.7

16	Norman, SE. ¼ sec. 32, T. 9 N., R. 2 W.	2.7	1.8	9.7	5.4	31.5	3.5	6.7	......	......	5.4	......	......	3.8	8.9	......	6.7
17	Norman, old city well	1.7	1.5	54.5	3.4	114.2	29.6	4.0	......	......	4.3	......	......	87.5	5.6	7.1	......
18	Norman, at oil mill	3.9	4.3	92.7	8.8	183.2	2.96	9.5	......	......	12.7	......	......	139.4	14.4	7.1	......
19	Norman, SE. ¼ sec. 19, T. 9 N., R. 2 W.	2.7	3.3	28 0	12.6	71.0	2.8	6.8	......	......	11.7	......	......	30.97	13.3	6.7	......
20	Norman, SW. ¼ sec. 24, T. 9 N., R. 3 W.	5.3	3.1	96.4	2.5	173.0	.0	12.9	......	......	9.2	......	......	146.4	4.1	......	......
21	Norman, NW. ¼ sec. 31, T. 9 N., R. 2 W.	4.8	3.4	81.1	4.7	149.4	.0	11.8	......	......	10.1	......	......	119.2	7.8	......	......
22	Norman, on university campus	4.0	2.7	89.2	3.2	161.7	.0	9.8	......	......	7.99	......	......	138.3	5.3	......	......
23	Box, NE. ¼ sec. 25, T. 6 N., R. 1 E	.3	1.1	3.0	.6	6.8	.9	.7	......	......	3.3	......	......	.6	.96	2.2	......
24	Noble, lot 9, block 29	6.2	4.2	3.6	3.7	30.97	9.3	6.1	5.9	1.7	......	......	8.8	......	......	9.6	......
	Comanche County:																
25	Madden, sec. 20, T. 2 S., R. 19 W.	22.4	3.7	18.3	37.2	128.2	11.6	31.1	19.0	......	......	8.8	......	......	30.6	27.8	......
26	Madden, sec. 19, T. 2 S., R. 19 W.	60.9	8.9	65.6	94.5	338.3	20.4	111.6	29.5	......	......	20.9	......	......	89.6	42.2	......
27	Madden, sec. 20, T. 2 S., R. 19 W.	14.1	3.9	7.0	15.3	73.4	11.3	11.9	4.1	......	......	10.8	......	......	9.5	27.3	......
28	Lawton, SW. ¼ sec. 29, T. 2 N., R. 11 W.	7.6	2.5	5.6	.9	23.9	6.2	9.5	1.5	5.2	......	......	5.2	......	......	......	1.9
29	Lawton, NW. ¼ sec. 29, T. 2 N., R. 11 W., Indian school	6.1	1.3	3.7	1.6	32.4	12.1	6.2	2.4	4.0	......	......	2.8	......	......	......	16.9
30	Lawton, SW. ¼ sec. 20, T. 2 N., R. 11 W.	4.2	1.7	4.9	3.7	32.4	9.6	8.3	1.6	......	......	2.6	......	......	1.3	......	18.4
31	Fort Sill, at Rock Island depot	9.0	1.6	9.98	1.3	30.2	5.7	16.95	2.1	1.9	......	......	3.4	......	......	......	5.96
32	Lawton, N. ½ sec. 14, T. 2 N., R. 12 W.	3.2	1.7	8.9	21.2	54.5	2.5	7.7	......	......	2.0	......	......	......	35.0	......	4.9
33	Lawton, lot 3, block 5, Beal addition	5.8	2.0	3.3	1.1	26.4	9.8	5.7	1.7	4.6	......	......	4.3	......	......	......	10.1
34	Lawton, lot 3, block 6	8.0	.7	3.0	3.4	27.1	8.2	5.1	5.4	5.7	......	......	1.8	......	......	......	9.1
35	Lawton, lot 16, block 4	4.4	.9	3.5	8.8	42.7	11.8	5.95	3.9	. .	......	2.5	......	......	8.7	......	22.6
36	Lawton, lot 1, block 13	5.2	2.6	5.6	5.9	40.3	11.3	9.5	2.6	......	......	4.5	......	......	3.0	......	23.97
	Dewey County:																
37	Taloga, 13 miles east and 1 mile south.	6.3	.4	.1	1.2	17.96	4.9	11.2	......	......	.2	.7	......	......	1.1	1.5	......
	Garfield County:																
38	Enid, test well for city supply	6.7	2.6	2.8	3.2	24.4	7.3	4.8	5.1	3.8	......	......	5.4	......	......	......	5.4
	Grant County:																
39	Pond Creek, 1 mile east	6.5	5.6	4.0	34.7	88.1	8.3	......	......	11.7	6.1	5.5	4.9	......	50.4	5.9	......
40	Pond Creek, at Rock Island depot	6.0	3.97	12.4	25.7	89.5	6.8	......	......	10.7	6.3	......	3.97	14.5	42.4	6.7	......
	Kay County:																
41	Newkirk, lot 19, block 4	10.0	3.6	4.2	13.3	41.6	10.2	7.1	15.4	......	......	4.6	3.4	......	......	20.2	......
42	Newkirk, block 50	5.3	3.3	3.7	3.2	27.4	7.3	6.2	4.9	.4	......	......	6.9	......	......	8.6	......
43	Newkirk, NE. ¼ sec. 6, T. 28 N., R. 2 E.	10.9	3.7	14.6	.4	47.3	6.4	24.9	.5	.6	......	......	7.8	......	......	5.0	......

[a] Not determined.

Analyses of Oklahoma well waters—Continued.

Number.	Location.	Calcium oxide (CaO).	Magnesium oxide (MgO).	Sulphuric anhydride (SO_3).	Chlorine (Cl).	Total solid residue.	Carbon dioxide (CO_2).	Supposed combination of constituents. Calcium sulphate ($CaSO_4$).	Calcium chloride ($CaCl_2$).	Calcium carbonate ($CaCO_3$).	Magnesium sulphate ($MgSO_4$).	Magnesium chloride ($MgCl_2$).	Magnesium carbonate ($MgCO_3$).	Sodium sulphate (Na_2SO_4).	Sodium chloride (NaCl).	Sodium carbonate (Na_2CO_3).	Sodium bicarbonate ($NaHCO_3$).
	Kingfisher County:																
44	Omega	10.0	3.4	16.2	39.4	114.2	8.3			17.8	8.8		1.0	18.3	64.9	2.1	
45	Kingfisher	9.0	5.1	11.6	10.2	68.6	8.98			16.2	10.3		3.6	2.4	16.3	1.0	
46	Kingfisher, 6 miles east and 2½ miles south	1.6	3.8	12.7	4.7	50.2	7.6			13.4	5.6		3.6	15.9	7.7	1.3	
47	Downs	3.9	1.3	.8	2.3	26.3	4.4			6.9	.4		2.6	1.1	3.5	7.7	
	Kiowa County:																
48	Secs. 11 and 12, T. 2 N., R. 17 W	14.1	2.97	11.7	35.2	94.6	7.7	19.9	11.6			7.0			47.1	18.8	
	Logan County:																
49	Guthrie, city park	67.0	18.4	116.3	590.4	1,200.0	39.2	162.9			20.7	18.9			943.0		74.9
50	Guthrie, city water supply	9.5	4.9	5.8	4.7	45.3	15.8	9.9	4.9			.1	10.1				20.2
51	Langston	6.1	5.1	1.98	10.5	44.3	6.3			10.9	2.98	6.8	2.7		9.0	3.1	
	Noble County:																
52	Billings, sec. 14, T. 23 N., R. 3 W	5.7	3.3	50.5	67.7	238.8	.0	13.9			9.9			63.3	111.8		
53	Billings, SE. ¼ sec. 29, T. 24 N., R. 2 W	3.3	4.8	7.5	18.8	69.0	11.6	7.9			4.3	7.98			21.3		22.1
54	Redrock	Trace.	.0	8.4	.6	28.3	5.1							14.8	.96	12.4	
55	Redrock, NE. ¼ sec. 25, T. 23 N., R. 2 E	4.3	.0	3.7	1.2	26.5	3.3	6.2	4.9	1.3						6.5	
56	Perry, NW. ¼ sec. 22, T. 21 N., R. 1 W	74.6	16.4	160.0	104.5	458.2	.6	181.3			46.9			37.4	172.4	1.5	
	Oklahoma County:																
57	Choctaw City, lot 8, block 28	2.4	1.8	3.0	1.2	17.3	2.5	5.2	.9			.9	2.9			2.4	
58	Sweeney, SW. ¼ sec. 23, T. 12 N., R. 1 E	1.6	.6	.3	1.4	9.6	1.7	.5	2.1	.95			1.3			1.4	
59	Oklahoma City, NE. ¼ sec. 4, T. 12 N., R. 4 W	25.6	6.8	53.8	1.8	132.8	6.2	62.1			20.3			7.1	2.9	14.9	

60	Oklahoma City, sec. 9, T. 12 N., R. 4 W.	4.8	1.5	1.9	2.3	21.9	3.1	3.2	3.6	2.9			3.2			.4	
61	Do	6.5	3.7	8.2	2.5	38.2	6.5	13.9	1.6			1.98	5.8			7.3	
62	Oklahoma City, sec. 33, T. 12 N., R. 3 W.	7.9	.4	1.2	.4	21.9	5.8	1.98	.5	17.2			.9				
63	Do	8.1	3.97	6.4	9.9	44.7	6.0	9.8	7.3			7.1	2.0			11.9	
	Pawnee County:																
64	Blackburn, sec. 1, T. 21 N., R. 6 E	6.2	3.0	4.6	.7	21.4	5.7	7.9	1.1	4.4			6.3			1.1	
65	Blackburn, NW. ¼ sec. 30, T. 22 N., R. 7 E	4.96	2.9	3.5	1.2	21.6	5.2	5.95	1.95	2.8			6.1			1.9	
66	Blackburn, sec. 10, T. 22 N., R. 7 E	1.6	1.1	3.8	56.6	120.7	1.2	3.96			2.2	.6			93.3	2.8	
67	Pawnee, SE. ¼ sec. 36, R. 4 E	20.7	15.8	63.5	9.1	170.4	9.3	49.5			47.2			6.3	22.0	17.7	
68	Jennings, 1½ miles west	3.6	1.3	1.6	1.2	29.5	2.6	2.8	1.9	2.6			2.8				
69	Valley, NE. ¼ sec. 14, T. 21 N., R. 6 E	8.6	2.8	8.2	60.9	135.6	6.0	13.9	5.7			6.6			144.6	14.5	
	Payne County:																
70	Cushing, NW. ¼ sec. 5, T. 16 N., R. 5 E	6.4	.0	13.7	4.1	28.0	.8	11.5						8.9	6.7	1.8	
71	Stillwater, 1 mile north	2.7	1.1	.5	1.5	26.3	2.9			4.8	.7		1.5		2.4	12.1	
72	Perkins, NE. ¼ sec. 14, T. 17 N., R. 2 E	9.6	8.5	6.7	31.5	85.5	6.2	11.5	9.7			19.96			17.3		21.8
73	Stillwater	3.4	.9	.2	.7	11.9	3.2	.4	1.1	4.8			1.95			.2	
74	Stillwater, 11 miles southwest	2.2	.9	.0	1.2	10.3	2.7		1.9	2.3			1.95			1.7	
75	Stillwater, NW. ¼ sec. 8, T. 20 N., R. 2 E.	6.3	3.4	4.6	2.5	33.1	5.4	7.7	3.8	2.1			7.2			1.7	
	Pottawatomie County:																
76	Tecumseh, lot 12, block 33	3.3	.0	2.6	.7	8.5	1.5	4.4	1.1	1.6						1.7	
77	Pink, NW. ¼ sec. 17, T. 9 N., R. 2 E	4.2	1.0	8.2	.9	15.1	.6	10.2			3.0			.3	1.5	1.6	
78	Tecumseh, NW. ¼ sec. 18, T. 8 N., R. 4 E.	.2	.6	7.5	.8	19.5	1.1	.3			1.6			10.8	1.3	2.5	
	Woods County:																
79	Alva, lots 13 and 14, block 16	42.9	28.8	118.7	4.5	278.6	40.4	104.3			82.2			6.8	7.4		77.2
80	Alva, lot 1, block 1, Ament's addition	43.9	22.1	115.2	2.2	250.8	31.8	106.7			68.9			10.7	3.6		60.8
81	Ringwood	8.1	3.1	3.1	3.7	23.9	6.3	5.2	5.8	5.5			6.6				.9
82	Cleo, 9 miles east and 6½ miles north	6.3	1.2	2.9	8.2	34.5	5.7			11.3	1.8		1.3	2.6	13.5	1.5	
83	Cleo, town well	7.6	.8	.5	3.8	21.6	5.0	.9	1.9	11.4		1.9			1.8	.8	
84	Leslie	7.3	5.1	11.1	7.3	53.1	6.3			13.0	13.7		1.1	3.5	12.0	1.3	
	Woodward County:																
85	Woodward	25.6	3.7	28.5	18.9	98.4	5.8	58.4	11.1			6.4			12.4	13.9	

Analyses of Oklahoma stream waters.

[Grains per United States gallon.]

Number.	Stream.	Location.	Calcium oxide (CaO).	Magnesium oxide (MgO).	Sulphuric anhydride (SO_3).	Chlorine (Cl).	Total solid residue.	Carbon dioxide (CO_2).	Supposed combination of constituents.									
									Calcium sulphate ($CaSO_4$).	Calcium chloride ($CaCl_2$).	Calcium carbonate ($CaCO_3$).	Magnesium sulphate ($MgSO_4$).	Magnesium chloride ($MgCl_2$).	Magnesium carbonate ($MgCO_3$).	Sodium sulphate (Na_2SO_4).	Sodium chloride (NaCl).	Sodium carbonate (Na_2CO_3).	Sodium bicarbonate ($NaHCO_3$).
86	Salt Fork, above Salt Plains.	Alva	22.2	5.1	35.7	6.5	95.3	2.1	53.9			5.9	5.4			4.8	5.1	
87	Salt Fork, below Salt Plains.	Pond Creek, ½ mile east	7.9	3.2	24.96	178.5	347.8	2.7	19.3			8.5			12.9	294.5	6.6	
88		At ford south of Ponca School.	17.4	3.8	22.3	286.7	516.2	.6	38.15		1.5	1.1	8.2			463.3	.5	
89	Tributaries of Salt Fork.	Chikaskia River, west of Ponca City.	4.8	1.8	4.0	1.8	20.5	3.7	.4		8.3	5.3			.5	2.9	.4	
90		Deer Creek, west of Tonkawa.	6.7	2.7	5.3	9.6	33.7	.9	8.9	3.7	1.98		6.4			4.3	1.3	
91	Cimarron River, above Woodward County Salt Plains.	At head of Col. C. D. Perry's ditch.	7.0	3.4	10.1	43.8	103.6	7.7	17.0			.2	5.8			65.9		14.7
92		Kenton	7.6	4.3	36.5	3.97	97.7	15.9	18.4			12.9			30.3	6.5		29.6
93	Cimarron River, below Woodward County Salt Plains.	Waynoka, 4 miles southwest.	8.9	1.1	12.4	232.8	420.6	4.7	21.0	.4			1.8			371.6	11.2	
94		Kingfisher, 8 miles north	24.0	9.7	34.2	355.9	664.5	2.6	68.2	.1			22.9			559.1	6.2	
95		Langston, 3 miles east	14.3	5.6	21.7	205.3	385.6	3.5	23.9		7.9	10.7	4.8			332.8	.5	
96		Guthrie, 2 miles north	18.1	6.7	13.8	245.7	463.1	3.0	23.4	16.7			11.7			375.1	6.5	
97		Perkins, 2½ miles southeast	14.23	4.9	17.7	216.9	397.3	3.9	30.1	3.6			13.5			336.8	9.3	
98		Perkins, at crossing south of town.	8.3	1.2	7.5	34.7	74.7	1.9	12.7	6.2			2.7			47.3	4.5	
99		Cleo, at ford south of town	16.4	2.7	24.4	236.3	435.9	2.3	32.9		5.1	7.6	.4			389.3	.6	
100	Tributaries of Cimarron.	Cottonwood Creek, north of Guthrie.	12.4	5.1	17.4	3.4	61.6	14.3	29.6	.5			4.2	6.9				20.4
101		Stillwater Creek, ½ mile south of Stillwater.	8.2	4.5	8.6	4.2	55.1	9.4	14.6	4.4			1.9	7.7			13.1	

102		Boomer Creek, ¼ mile east of Stillwater.	7.9	2.97	3.5	1.1	35.6	7.4	5.95	1.6	8.3	......	......	7.1	......	......	......	......
103		Council Creek, 3½ miles northwest of Ingalls.	1.9	1.8	.2	.7	13.9	3.5	.3	1.1	2.2	......	......	3.7	......	......	1.5	......
104		Little Stillwater Creek, 6 miles east of Stillwater.	3.9	1.6	.0	.8	23.2	6.1	......	1.2	5.9	......	......	3.3	......	......	5.8	......
105		Salt Creek, 10 miles northeast of Ingalls.	3.2	2.3	0.0	0.8	15.1	5.3	......	1.2	4.6	......	......	4.8	......	......	1.9	......
106	Tributaries of Cimarron.	Wild Horse Creek, 11 miles southwest of Stillwater.	3.97	3.6	0.0	1.8	32.2	6.9	......	2.8	4.5	......	......	7.5	......	......	0.97	......
107		Stillwater Creek, ½ mile south of Stillwater.	1.5	0.9	1.1	0.2	10.0	1.8	1.8	0.4	1.0	......	......	1.8	......	......	0.95	......
108		Dog Creek, Waynoka	7.2	3.6	7.5	2.1	35.9	5.5	12.8	3.3	0.5	......	......	7.6	......	......	3.7	......
109		Salt Creek, ½ mile below Salt Spring, Ferguson.	198.5	87.3	192.3	7,930.0	(a)	(a)	327.0	126.3	......	......	153.4	......	......	12,824.2	......	(a)
110		Cottonwood Creek, ½ mile north of Guthrie.	3.1	1.2	3.5	2.5	17.4	2.7	5.95	1.3	......	......	2.0	......	......	0.5	6.5	......
111		Ponca City, 2 miles east	6.5	0.4	3.2	7.6	29.8	3.9	0.8	......	8.8	1.1	......	......	3.5	12.5	0.3	......
112		Black Bear Creek, 2 miles northwest of Stillwater.	6.5	3.0	2.1	3.2	34.8	6.4	......	......	11.6	3.2	2.5	2.6	......	2.2	8.2	......
113	Arkansas River and tributaries.	Red Rock Creek, at Otoe School.	3.5	0.9	1.2	1.5	14.6	2.98	1.3	......	5.4	0.6	1.6	......	......	0.4	1.3	......
114		Black Bear Creek, north of Stillwater.	6.1	1.6	0.6	1.4	29.1	5.5	1.1	2.2	8.1	......	......	3.4	......	......	0.5	......
115		Beaver Creek, sec. 9, T. 4 N., R. 22 E.	7.2	5.6	13.3	38.7	99.3	7.3	18.3	......	......	4.4	7.2	......	......	56.1	......	13.0
116		Paladuro Creek, NE. ¼ sec. 23, T. 1, R. 18.	6.5	1.0	8.3	10.4	42.0	5.8	14.1	1.5	......	......	1.7	......	......	13.7	......	11.0
117		Cold Water Creek, Hardesty, Okla.	7.5	1.9	12.6	8.6	50.3	4.9	18.1	......	......	2.9	1.7	......	......	12.4	......	9.4
118	North Canadian and tributaries.	North Canadian, at Cantonment.	7.5	2.3	9.6	19.5	65.2	4.1	5.7	......	9.3	7.0	......	......	2.8	32.3	1.5	......
119		North Canadian, 4 miles northwest of Watonga.	5.5	3.9	10.3	19.5	67.7	2.8	4.8	......	6.4	11.2	0.4	......	......	31.7	1.0	......
120		North Canadian, 2 miles north of El Reno.	6.9	4.6	11.8	14.0	58.0	3.3	16.9	......	......	2.8	6.3	......	......	16.3	8.0	......
121		North Canadian, at Sweeney	6.2	3.2	3.9	6.3	36.3	5.8	6.6	6.8	......	......	3.3	2.3	......	......	10.98	......
122		Branch of Deer Creek, NE. ¼ sec 4, T. 12 N., R. 4 W.	16.5	4.3	30.2	1.4	83.4	5.5	39.95	......	......	9.97	1.9	0.4	......	......	12.7	......

[a] Not determined.

Analyses of Oklahoma stream waters—Continued.

Number.	Stream.	Location.	Calcium oxide (CaO).	Magnesium oxide (MgO).	Sulphuric anhydride (SO_3).	Chlorine (Cl).	Total solid residue.	Carbon dioxide (CO_2).	Supposed combination of constituents. Calcium sulphate ($CaSO_4$).	Calcium chloride ($CaCl_2$).	Calcium carbonate ($CaCO_3$).	Magnesium sulphate ($MgSO_4$).	Magnesium chloride ($MgCl_2$).	Magnesium carbonate ($MgCO_3$).	Sodium sulphate (Na_2SO_4).	Sodium chloride (NaCl).	Sodium carbonate (Na_2CO_3).	Sodium bicarbonate ($NaHCO_3$).
123	North Canadian and tributaries.	North Canadian, 1 mile south of Oklahoma City.	10.2	3.8	9.7	10.5	48.2	4.8	16.5	6.6	......	......	6.7	......	......	3.1	11.7	......
124		North Canadian, at Shawnee	4.1	0.0	4.1	(a)	(a)	4.4	7.0	......	2.1	......	......	......	......	......	......	6.6
125		Clear Creek, S. ½ sec. 24, T. 25 N., R. 25 W.	6.7	3.4	3.1	3.9	23.8	6.5	5.2	6.1	2.5	......	......	7.2	......	......	......	2.7
126		Boggy Creek, at Whitehead.	6.7	0.5	4.0	1.7	21.7	6.0	6.8	2.7	4.6	......	......	1.1	......	......	......	6.6
127		Wolf Creek, 2 miles north of Whitehead.	6.5	1.3	4.1	5.7	27.8	3.2	6.9	7.3	......	......	1.4	1.6	......	......	......	4.6
128		Beaver Creek, at mouth of Kiowa Creek.	7.6	0.8	13.6	28.9	82.7	6.4	18.7	......	......	2.4	......	......	1.7	47.6	......	12.2
129		North Canadian, at Woodward.	6.3	2.9	9.5	14.9	53.0	3.7	15.3	......	......	0.7	4.8	......	......	19.4	9.0	......
130	South Canadian River.	South Canadian, 11 miles south of El Reno.	17.5	5.3	33.3	4.9	76.0	2.0	42.4	......	......	12.4	1.9	......	......	6.0	4.9	......
131		South Canadian, at 100th meridian.	9.0	3.0	14.5	11.0	64.3	12.0	21.97	......	......	2.4	5.3	......	......	11.7	......	22.96
132		South Canadian, 3½ miles E., ½ mile S. of Taloga.	4.8	1.98	7.6	4.4	31.0	2.9	4.4	......	6.5	5.95	......	......	1.98	7.2	0.5	......
133		South Canadian, at Noble	6.3	2.8	9.2	4.6	37.7	4.2	15.3	......	......	0.3	4.7	......	......	2.4	10.1	......
134	Wichita Mountain streams.	Medicine Bluff Creek, 2 miles above Fort Sill.	5.0	1.1	2.5	1.2	13.5	3.9	4.3	1.9	4.1	......	......	3.2	......	......	......	......
135		Cache Creek, SE. ¼ sec. 29, T. 2 N., R. 11 W.	6.9	1.6	5.1	1.5	24.6	6.8	8.6	2.4	3.9	......	......	2.3	......	......	......	6.4

[a] Not determined.

Analyses of Oklahoma spring waters.

[Grains per United States gallon.]

No.	Kind of spring.	Location.	Calcium oxide (CaO).	Magnesium oxide (MgO).	Sulphuric anhydride (SO_3).	Chlorine (Cl).	Total solid residue.	Carbon dioxide (CO_2).	Supposed combination of constituents. Calcium sulphate ($CaSO_4$).	Calcium chloride ($CaCl_2$).	Calcium carbonate ($CaCO_3$).	Magnesium sulphate ($MgSO_4$).	Magnesium chloride ($MgCl_2$).	Magnesium carbonate ($MgCO_3$).	Sodium sulphate (Na_2SO_4).	Sodium chloride (NaCl).	Sodium carbonate (Na_2CO_3).	Sodium bicarbonate ($NaHCO_3$).
136	Terrace	Lawton, ¼ mile south, on Rock Island right of way.	4.7	0.7	3.7	0.8	25.4	9.1	6.3	1.3	2.4			1.5				13.9
137	Limestone	Lawton, Dunbar Springs, NW. ¼ sec. 16, T. 2 N., R. 12 W.	6.5	1.4	5.0	1.6	18.2	3.5	8.5	2.5	3.1			2.9				1.2
138		Newkirk, NE. ¼ sec. 15, T. 28 N., R. 3 E.	7.1	2.3	1.2	1.3	20.2	7.4	1.98	2.1	9.3			4.9			1.9	
139		Uncas, SE. ¼ sec. 13, T. 27 N., R. 4 E.	7.8	2.2	.7	.5	23.0	7.8	1.2	.8	12.2			4.5			.2	
140	Sandstone	Baker, SE. ¼ sec. 14, T. 16 N., R. 5 E.	3.2	1.4	.4	.6	11.7	3.7	.7	.9	4.3			2.9			.8	
141		Guthrie, lots 11 and 12, block 11	13.4	6.6	4.4	12.9	66.7	14.9	7.4	20.1	.3			12.6			19.7	
142		Pawnee, NE. ¼ sec. 12, T. 21 N., R. 5 E.	6.4	2.3	1.0	.9	19.7	7.1	1.7	1.4	8.9			4.9			1.5	
143		Whitehorse, Whitehorse Springs, NW. ¼ sec. 21, T. 27 N., R. 16 W.	6.1	3.3	4.1	1.2	26.6	8.9	7.1	1.8	4.0			6.96				6.8
144		Whitehorse, SE. ¼ sec. 7, T. 27 N., R. 16 W.	5.2	2.4	9.4	1.9	26.4	3.7	12.6			3.8	2.0			0.9		7.0
145	Tertiary	Alva, Elm Grove Springs	3.1	1.98	.9	.5	10.9	4.1	1.6	.9	3.6			4.1				.7
146		Ringwood	6.9	2.6	2.7	3.1	20.3	5.3	4.6	4.9	4.5			5.4				.9
147		do	6.1	3.1	2.3	2.9	19.6	5.6	3.8	4.5	4.1			6.5				.7
148		do	18.6	9.9	35.3	63.9	173.3	5.4	45.1			13.2	9.5			95.2		10.2
149		Alva, 2 miles north	3.7	1.2	1.2	.9	14.6	3.2	2.1	1.5	3.8			2.4			.6	
150	Salt	Blaine County, in south canyon, head of Salt Creek.	210.8	97.8	164.3	9,065.3	(a)	(a)	279.3	189.6			171.9			14,571.7		(a)
151		Ferguson, in north canyon, Salt Plain.	195.2	78.5	196.7	7,697.3	(a)	(a)	334.7	113.5			137.9			12,431.9		(a)

a Not determined.

Analyses of Oklahoma pond waters.

[Grains per United States gallon.]

No.	Location.	Calcium oxide (CaO).	Magnesium oxide (MgO).	Sulphuric anhydride (SO_3).	Chlorine (Cl).	Total solid residue.	Carbon dioxide (CO_2).	Supposed combination of constituents.									
								Calcium sulphate ($CaSO_4$).	Calcium chloride ($CaCl_2$).	Calcium carbonate ($CaCO_3$).	Magnesium sulphate ($MgSO_4$).	Magnesium chloride ($MgCl_2$).	Magnesium carbonate ($MgCO_3$).	Sodium sulphate (Na_2SO_4).	Sodium chloride (NaCl).	Sodium carbonate (Na_2CO_3).	Sodium bicarbonate ($NaHCO_3$).
	Grant County:																
152	Lamont, 1 mile east and ½ mile north	1.2	0.2	0.0	0.3	13.5	0.4	(a)	0.5	0.9	......	......	......	......	......	0.5	......
153	Pond Creek, 5 miles west	.7	.3	.0	1.2	19.9	1.2	......	......	1.3	......	......	0.6	......	1.9	6.9	......
	Logan County:																
154	Langston, 5 miles west and 1 mile south	1.5	.2	.0	.3	7.0	1.8	......	......	2.6	......	......	.4	......	.5	.5	......

a Traces of calcium and magnesium silicates.

WELL RECORDS.

On the following pages are given descriptive notes of 10 wells from each of the 26 counties in Oklahoma. These data were obtained by a complete canvass of all available sources of information, mainly by schedules sent by mail. Returns from over 5,000 wells were received from all parts of the Territory, probably representing all classes of wells. In the selection of data presented in the table care was taken to include only those which were most typical for each general locality and which represented ordinary conditions. It is believed that these records show the typical hydrologic conditions for the Territory, although in some cases there are local conditions which may differ more or less widely from those indicated.

In several instances there has been considerable difficulty in ascertaining the geological horizon of the water-bearing stratum, and for that reason the statements given in the column headed "Geological horizon" are to be accepted only tentatively. Where the term "red beds" is used, it is to be understood in the sense of the Pennsylvanian red beds. When the well is located in the undoubted Permian, that word is used. It will be observed that in general wells in the Tertiary and the (Pennsylvanian) red beds contain soft water, while those in the Permian yield hard water, but in a few localities the conditions are exceptional in that respect.

The height of the water level in the wells as given in the table is in some cases only approximate, for usually there has been no means for accurately measuring it. Moreover, there is often more or less variation in the level from year to year, and the present level may be different from the one found at the time of observation.

Oklahoma

No.	County.	Post-office.	Owner.	Location.			Year completed.	Diameter of well.	Depth of well.	Depth to principal water supply.	Height of water above (+) or below (−) mouth of well.
				Township.	Range.	Section.					
								In.	*Feet.*	*Feet.*	*Feet.*
*1	Beaver	Beaver	T. P. Braidwood...	3	23	19	1890	48	20	18	− 18.0
*2	.....do	.....do	Ira S. Wilson	4	22	29	1900	6	18	12	− 4.5
3	.....do	Clear Lake ...	Frank Long	3	25	24	1901	48	34	32	− 32.0
4	.....do	Custer	D. T. Stanley	3	28	29	1889	54	12	8	− 8.0
5	.....do	Gate	W. J. Cunningham	5	28	35	1903	3	54	34	− 13.0
6	.....do	Guymon	E. C. Langston	3	15	31	1903	6	202	174	−172.0
7	.....do	.....do	Stonebreaker Zea Cattle Co.	2	14	23	1900	6	180	140	−100.0
8	.....do	.....do	J. G. Phagan	1	14	15	1902	54	43	40	− 40.0
*9	.....do	.....do	City well..........	3	15	31	1901	6	200	170	−170.0
10	.....do	Mineral	Jno. Skelley.......	4	1	13	1901	48	30	30	− 21.0
11	Blaine	Greenfield ...	I. E. P. Smith......	15	12	35	1902	48	45	42	− 42.0
12	.....do	Homestead ...	C. N. R. R. (C. O. & G.).	*a*19	*a*11	....	1902	240	24	18	− 16.0
13	.....do	Judson	J. M. Scott.........	14	12	27	1895	6	127	90	− 90.0
14	.....do	Geary	D. Turner	14	12	8	1901	6	98	30	− 30.0
15	.....do	Ferguson	D. S. Schuber......	18	11	23	1894	66	21	18	− 15.0
16	.....do	Judson	A. M. Hill	14	11	28	1901	8	83	35	− 35.0
17	.....do	Watonga	Thos. Remington.	12	15	26	1900	7	110	40	− 40.0
*18	.....do	Geary	Ernest Truman ...	13	10	6	1903	12	127	20	− 20.0
19	.....do	Watonga	Geo. P. Forster....	12	15	11	1897	6	60	45	− 22.0
20	.....do	.....do	W. L. Beal........	15	12	25	1895	48	14	12	− 8.0
21	Caddo	Vrooman	Mrs. Lucy Green..	9	13	7	1902	6	56	50	− 41.0
22	.....do	Laverty	Townsite Co	6	8	17	1902	6	136	100	− 80.0
23	.....do	Hydro	Jno. Dickson......	12	12	25	1901	6	135	100	−100.0
24	.....do	Cement.......	S. A. Todd	5	9	2	1902	6	50	30	− 20.0
25	.....do	.....do	W. J. W. Patchell.	5	3	30	1902	6	150	130	−120.0
26	.....do	Anadarko	C., R. I. and P. Ry. Co.	(*a*)	(*a*)	(*a*)	1902?	16	27	17	− 17.0
27	.....do	Boise	W. T. Motley......	9	13	19	1901	6	70	50	− 50.0
28	.....do	Cement.......	W. H. Todd.......	5	9	25	1901	60	20	19	− 17.0
29	.....do	Libbie	M. E. West.........	12	13	35	1902	6	116	90	− 90.0
30	.....do	Hinton	Allen N. Hubbard.	11	11	2	1902	8	177	175	−125.0
*31	Canadian.....	Elreno	N. J. Meyers.......	13	7	23	1896	48	43	39	− 38.0

* See notes at end of this table. *a* City.

well records.

How obtained at surface.	Quality.	Supply per minute.	Increase or decrease of supply.	Effect of pumping on level of water.	Geological horizon of well mouth.	Geological horizons of water-bearing strata.	No.
		Gals.					
Mill and pump.	Hard ...	....	Decreased (?).	Easy to lower	Permian....	Permian..........	*1
.....do......	....do...	....	Neither.......	No effect	.....do......	.....do...........	*2
Pump	Soft	0.5	.....do........	Not easy to lower.	Tertiary	Tertiary	3
Mill and pump.	Hard ...	32.0	.....do........	.....do.......	.....do......	.....do...........	4
Pump	Soft	....	.....do........	.....do.......	.....do......	.....do...........	5
Mill and pump.	....do...	10.0	.....do........	.....do.......	.....do......	.....do...........	6
.....do......	....do...	10.0	.....do........	.....do.......	.....do......	.....do...........	7
Bucket	....do...	.5	.....do........	Easy to lower	.....do......	.....do...........	8
Mill and pump.	....do...	....	.....do........	Not easy to lower.	.....do......	.....do...........	*9
.....do......	....do...	4.0	.....do........	Easy to lower with the pump in use.	Dakota Cretaceous.	Dakota Cretaceous	10
Bucket	Hard ...	.08	.....do........	Not easy to lower.	Permian....	Permian..........	11
Steam pump	Gypsif ..	4.8	.....do........	Easy to lower	.....do......	.....do...........	12
Mill and pump.	Soft.....	1.25	.....do........	....	.....do......	.....do...........	13
.....do......	....do...	2.77	.....do........	Not easy to lower.	.....do......	.....do...........	14
Bucket	Gypsif ..	.88	.....do........	.....do.......	.....do......	.....do...........	15
Mill and pump.	Soft.....	4.16	.....do........	Not easily lowered.	Permian red beds.	.....do...........	16
.....do......	Gypsif ..	.66	.....do........	Not easy to lower.	Permian....	.....do...........	17
....	Hard ...	6.0	.....do........	Easy to lower with the steam pump used in testing flow.	.....do......	.....do...........	*18
Mill and pump.	Salty ...	10.0	.....do........	Not easy to lower.	.....do......	.....do...........	19
Bucket	Soft.....	.06	.....do........	.....do.......	.....do......	.....do...........	20
.....do......	....do...	.02	.....do........	Easy to lower	.....do......	.....do...........	21
.....do......	....do...	.4	.....do........	Not easy to lower.	.....do......	.....do...........	22
Pump	....do...	....	.....do........	.....do.......	.....do......	.....do...........	23
Bucket	....do...	.02	.....do........	Easy to lower	.....do......	.....do...........	24
Mill and pump.	Hard ...	.15	.....do........	Not easy to lower.	.....do......	.....do...........	25
Steam pump	Soft.....	60.0	.....do........	.....do.......	.....do......	.....do...........	26
Pump	....do...	.06	.....do........	.....do.......	.....do......	.....do...........	27
Bucket	....do...	1.66	.....do........	.....do.......	.....do......	.....do...........	28
Mill and pump.	....do...	.22	.....do........	.....do.......	.....do......	.....do...........	29
.....do.....	....do...	5.3	.....do........	.... do.......	.....do......	.....do...........	30
.....do......	Almost soft.	....	.....do........	.....do.......	.....do......	.....do...........	*31

Oklahoma well

No.	County.	Post-office.	Owner.	Location. Township.	Location. Range.	Location. Section.	Year completed.	Diameter of well.	Depth of well.	Depth to principal water supply.	Height of water above (+) or below (−) mouth of well.
								In.	Feet.	Feet.	Feet.
*32	Canadian	Mustang	Frank Dotton	11	5	33	1896	6	32	20	— 12.0
33	do	do	S. E. Perkins	10	2	12	1892	48	44½	40	— 38.0
*34	do	Frisco	Jas. Smith	12	6	12	1899	4	78	33	— 18.0
*35	....	Elreno	W. J. Newland	11	7	11	1898	42	38	38	— 26.0
*36	do	Hinton	D. E. Bray	11	10	5	1901	8	119	90	— 90.0
37	do	Elreno	Luther Foster	13	7	23	1895	9	62	56	— 44.0
*38	do	do	J. C. Carter	13	7	15	1901	8	40	36	— 36.0
39	do	Calumet	Mr. Jerue	13	10	13	1902	5, 6	82	82	— 17.0
*40	do	Eda	Cecil Pratt	13	5	11	1902	8	45	40	— 4.0
*41	Cleveland	Moore	Public well	10	3W	14	1892	6	212	200	—112.0
*42	do	Norman	University of Oklahoma.	9	2W	31	1903	8	282½	275	—232.5
*43	do	Moore	Norman Milling and Grain Co.	10	3W	14	1902	6	193	183	—123.0
*44	do	Morgan	George Foster	10	1W	18	1893	60	32	27	— 19.0
*45	do	Case	Thos. Shanley	10	1W	15	1889	4	20	17	— 10.0
*46	do	Oklahoma, well near Moore.	J. H. Smith	10	3W	7	1902	5	365	327	—110.0
*47	do	Noble	W. Murphy	8	2W	27	1898	6	240	235	— 90.0
*48	do	Norman	R. C. Cain	(a)	(a)	(a)	1903	6	77	62	— 37.0
*49	do	Lexington	Herman Turk	10	3W	28	1900	6	269	258	—100.0
*50	do	Moore	Kenneth McLennan.	10	3W	17	1899	6	262	250	— 25.0
51	Comanche	Nellie	Tom Watson	1N	9	12	1902	6½	51	39	— 31.0
52	do	Temple	Adolph Sorge	4S	10	24	1902	1¼	19	10	— 10.0
53	do	Sugden, Ind. T	Chas. Stone	5	8	30	1901	6	60	40	— 30.0
54	do	Lawton	J. P. Samplon	2S	9	....	1902	6	60	52	— 44.0
55	do	Hulin	Louis L. Young	1S	10	17	1902	72	21	13	— 10.0
*56	do	Hess	R. W. Briscoe	2	20	1	1890	54	50	50	— 48.0
57	do	Hastings	W. P. Corden	4	9	10	1902	36	18	16	— 15.0
*58	do	Duncan, Ind. T	E. B. White	1	8	20	1902	6	18	15	— 15.0
*59	do	Cache	Frisco R. R. Co	2	14	24	1902	60	13	11	— 7.0
60	do	Baird	Scogins	1S	9	17	1902	6	45	30	— 25.0
61	Custer	Osceola	Joel Hudgens	15	18	21	1900	6	205	205	— 90.0
62	do	Weatherford	Jno. Bradshaw	12	15	15	1898	48	30	30	— 27.0
63	do	Swan	J. A. Ohls	14	14	27	1899	6	75	35	— 35.0
64	do	Osceola	Jake Vedder	15	19	22	1901	6	80	60	— 50.0
65	do	Gip	W. T. Hudgens	14	18	5	1900	6	96	85	— 75.0

*See notes at end of this table. *a* City.

records—Continued.

How obtained at surface.	Quality.	Supply per minute.	Increase or decrease of supply.	Effect of pumping on level of water.	Geological horizon of well mouth.	Geological horizons of water-bearing strata.	No.
		Gals.					
Mill and pump.	Soft		Neither	Mill can run day and night.	Permian	Permian	*32
	Slightly hard.		Increased	Not easy to lower.	do	do	33
Mill and pump.	Salty		Neither		do	do	*34
do	Hard		Abundant supply.	Not easy to lower.	do	do	*35
Bucket	Soft	.044	Neither	Not easily lowered.	do	do	*36
do	Hard		do		do	do	37
Pump	do	.2		Easy to lower	do	do	*38
Mill and pump.	Soft		Abundant supply.	Not easy to lower.	do	do	39
Bucket	do		Neither	do	do	do	*40
Mill and pump.	do	2.77	do	do	Red beds	Red beds	*41
Steam pump	Hard	11.69	do	do	do	do	*42
do	Soft	.55	do	do	do	do	*43
Bucket	Hard		do	do	do	do	*44
do	Soft		do	do	do	do	*45
Mill and pump.	do		do	do	do	do	*46
do	do	1.7	do	do	do	do	*47
Bucket	do	.11	do	do	do	do	*48
Pump	Alkali		do	do	do	do	*49
Mill and pump.	Alkaline	2.33	do	do	do	do	*50
Bucket	Soft	.044	do	do	Permian	Permian	51
Pump	Hard	.44	do	do	do	do	52
Bucket	Soft	.04	do	Easy to lower	do	do	53
do	Hard		do	Not easy to lower.	do	do	54
do	Soft	.55	do	do	do	do	55
Mill and pump.	Hard	2.66	Increased	do	do	do	*56
Bucket	Soft	1.0	Neither	do	do	do	57
do	Hard		do	Easy to lower	do	do	*58
Steam pump	Soft	22.5	do	Not easy to lower.	do	do	*59
Bucket	do		do	do	do	do	60
Mill and pump.	Gypsif	3.33	do	do	do	do	61
Bucket	Hard	1.16	do	do	do	do	62
Mill and pump.	Soft	.22	do	do	do	do	63
Bucket	Gypsif	.08	do	do	do	do	64
do	do	.22	do	do	do	do	65

Oklahoma well

No.	County.	Post-office.	Owner.	Location. Township.	Range.	Section.	Year completed.	Diameter of well.	Depth of well.	Depth to principal water supply.	Height of water above (+) or below (−) mouth of well.
								In.	*Feet.*	*Feet.*	*Feet.*
66	Custer	Etna	Louis Sturgis	12	14	7	1901	6	125	75	−75.0
67	....do	Elm	Frank Davis	15	18	24	1901	6	142	112	−112.0
68	....do	Butler	N. L. Blake	14	20	12	1901	6	182	164	−144.0
69	....do	....do	H. E. Reynolds	13	19	13	1898	8	165	120	−105.0
70	....do	Arapahoe	Marion Lucas	14	16	30	1898	6	120	90	− 45.0
71	Day	Arnett	Herman Schultz	19	24	7	1901	42	42	37	− 37.0
72	....do	Reason	Jno. Reed	18	23	24	1902	6	171	165	− 20.0
73	....do	Craft	C. M. Atwood	19	24	2	1903	42	111	107	−107.0
74	....do	Grand	Cleo Paine	17	24	21	1902	8	121	103	−103.0
*75	....do	Gage	Pearley Cloyd	19	23	1	1902	40	126	123	−123.0
*76	....do	Arnett	J. E. Brown	19	24	16	1902	2	182	180	−160.0
*77	....do	Shattuck	Schultz	19	25	1	1901	48	56	54	− 53.0
78	....do	Arnett	A. C. Beattie	19	24	20	1901	6	164	164	−134.0
79	....do	Craft	P. F. Bradshaw	19	24	3	1902	2	146	106	−106.0
80	....do	....do	I. W. Fortney	19	24	10	1901	48	57	57	− 55.0
*81	Dewey	Burmah	Ben Oswald	17	17	32	1902	48	30	23	− 23.0
82	....do	Fay	Wm. A. Boyd	16	14	27	1901	6	90	70	− 70.0
83	....do	Jacks	Arthur Jewett	16	14	13	1900	6	186	158	−158.0
84	....do	Lenora	B. P. Mayfield	17	18	1	1900	6	98	98	− 48.0
85	....do	....do	A. M. Towner	17	18	13	1891	6	171	......	−100.0
86	....do	Putnam	A. E. Agee	17	17	25	1900	6	128	90	− 80.0
87	....do	Raymond	W. H. Dodson	17	18	35	1900	48	45	42	− 42.0
88	....do	Roseland	M. L. Drake	16	16	16	1902	6	47	41	− 41.0
89	....do	Deltis	Geo. W. Harris	17	19	27	1902	6	140	140	−120.0
90	....do	Webb	Henry Schultz	17	18	29	1902	6	112	100	−100.0
*91	Garfield	Glenella	G. L. Bushwisel	23	8	34	1895	6	40	29	− 29.0
92	....do	Waukomis	H. T. Roach	21	6	22	1895	48	12	12	− 8.0
*93	....do	Garber	Wm. Walker	23	4	27	1893	6	30	20	− 20.0
94	....do	Waukomis	C. White	20	6	3	1894	6	41½	22	− 22.0
*95	....do	Carrier	J. C. Palmer	23	8	17	1900	6	31	28	− 28.0
96	....do	Billings	C. C. Rosencrants	23	3	3	1895	48	30	+25	− 25.0
97	....do	Waukomis	Chas. Thain	21	7	27	1895	48	73	72	− 60.0
*98	....do	Carrier	John Pope	24	8	11	1893	36	10	10	− 8.0

*See notes at end of this table.

records—Continued.

How obtained at surface.	Quality.	Supply per minute.	Increase or decrease of supply.	Effect of pumping on level of water.	Geological horizon of well mouth.	Geological horizons of water-bearing strata.	No.
		Gals.					
Mill and pump.	Soft	.44	Neither	Not easy to lower.	Permian	Permian	66
Bucket	Gypsif	.08	do	Easy to lower	do	do	67
Mill and pump.	Hard	.44	do	Not easy to lower.	do	do	68
do	Gypsif	.111	do	Easy to lower	do	do	69
Bucket	Hard	.111	do	Not easy to lower.	do	do	70
Pump	Soft	4	do	do	Tertiary	Tertiary	71
Mill and pump.	Gypsif		do	do	Permian	Permian	72
do	Hard	2.0	do	do	Tertiary	Tertiary	73
do	Soft	5.5	do	do	do	Permian(?)	74
Bucket	do	.5	do	Easy to lower	do	Tertiary(?)	*75
Mill and pump.	do	1.116	do	Not easy to lower.	do	do	*76
Bucket	do	.06	do	Easy to lower	do	do	*77
Mill and pump.	do	20.0	do	Not easy to lower.	do	do	78
Pump	do	3.0	do	do	do	do	79
Bucket	do	.133	do	do	do	do	80
do	Hard, a little salty.	.66	do	Easy to lower	Permian	Permian	*81
Mill and pump.	Soft	.44	do	do	Tertiary	Tertiary	82
Bucket	Hard	2.0	do	Not easy to lower.	do	do	83
Mill and pump.	Gypsif	1.66	do	do	Permian	Permian	84
do	do	.26		Easy to lower	do	do	85
Bucket	Alkaline	.5	Increased	do	do	do	86
do	Gypsif	.04		Not easy to lower.	do	do	87
Mill and pump.	do	.44	Increased	do	do	do	88
Pump	Soft	.22	do	do	do	do	89
Bucket	Hard	.44		do	do	do	90
Mill and pump.	do	.22	Increased	Not easily lowered.	do	do	*91
do	Soft	2.22	Neither	Can't pump out water.	do	do	92
Pump	Hard		do	Runs in as fast as pumped out.	do	do	*93
	Slightly salty.	.333	do	Not easy to lower.	do	do	94
Mill and pump.	Hard		do	Can't lower	do	do	*95
Bucket	Soft		do	Easy to lower	do	do	96
Pump	Hard	.5	do	Lowers level.	do	do	97
Mill and pump.	Soft		do	Can't lower	do	do	*98

Oklahoma well

No.	County.	Post-office.	Owner.	Location. Township.	Range.	Section.	Year completed.	Diameter of well.	Depth of well.	Depth to principal water supply.	Height of water above (+) or below (−) mouth of well.
								In.	*Feet.*	*Feet.*	*Feet.*
*99	Garfield	Kremlin	H. D. Lacy	24	7	20	1894	48	18	14	− 13.0
100	....do	Lahoma	Chas. B. Longcor	21	8	7	1898	48	36	36	− 30.0
*101	Grant	Numa	O. J. Wilkison	27	4	9	1896	48	23	12	− 8.0
*102	....do	Florence	D. M. Thomas	27	8	18	1903	3	59	56	− 3.0
*103	....do	Gibbon	J. A. Johnson	29	7	28	1902	6	25	11	− 7.0
*104	....do	Deer Creek	W. H. Raymond	26	3	10	1895	72	45	45	− 32.0
*105	....do	Pond Creek	V. Rapp	27	8	14	1903	1½	71	6	− 8.0
*106	....do	Renfrow	T. H. Paris	28	3	19	1894	72	48	40	− 10.0
*107	....do	Manchester	C. W. Alley	29	7	18	1893	12	40	22	− 20.0
*108	....do	Jefferson	C. T. James	26	5	14	1897	1¼	35	35	− 18.0
*109	....do	Renfrow	C. W. Foetisch	28	4	22	1899	6	93	85	− 35.0
*110	....do	Lamont	D. P. Moffett	26	3	33	1899	48	28	−28	− 8.0
111	....do	Medford	W. S. Robertson	27	5	22	1894	48	23	6	− 4.0
112	Greer	Martin	John Brim	2N	25	29	1900	6	63	60	− 43.0
113	....do	....do	L. P. Tyler	1	25	17	1901	6	105	94	− 97.0
114	....do	Mangum	C., R. I. and P. Ry.	(*a*)	(*a*)	(*a*)	1902	192	30	30	− 30.0
115	....do	Hollis	J. M. Prock	2	26	15	1900	7	96	90	− 87.0
116	....do	....do	W. J. Branigan	3	26	11	1902	6	120	75	− 60.0
*117	....do	Doans, Tex	S. B. Everett	2	20	13	1898	48	10	10	− 8.0
118	....do	Greer	W. C. West	2	25	14	1901	6	30	30	− 30.0
119	....do	Duke	Stirling Soloman	2 N	23	27	1902	6	57	53	− 40.0
120	....do	Carl	J. A. Kinjkendall	6	26	23	1901	42	37½	34	− 34.0
121	....do	Salton	Isaac C. Stewart	6	25	6	1901	72	44	40	− 34.0
*122	Kay	Newkirk	City	28	2 E	26	1901	360	45	42	− 35.0
*123	....do	Ponca City	Oscar Taylor	26	2 E	32	1894	2	25	23	− 23.0
*124	....do	Uncas	M. L. Devore	27	3 E	24	1898	60	47	44	− 44.0
*125	....do	Tonkawa	A. H. Miller	25	1 W	19	1895	36	12	11	− 8.0
*126	....do	Eddy	W. High	25	2 W	5	1894	36	18	14	− 14.0
*127	....do	....do	J. B. Bush	26	2 W	29	1902	6	88	70	− 20.0
*128	....do	Kildare	S. Spore	27	2 E	9	1898	72	40	38	− 18.0
*129	....do	Tonkawa	Samuel Stahl	25	1 W	19	1901	8	40	38	− 28.0
*130	....do	Blackwell	N. D. Kistler	26	1	2	1897	1¼	30	26	− 26.0
*131	....do	Nardin	John McFarlin	27	2 W	30	1897	6	47	36	− 31.0
132	Kingfisher	Kiel	Geo. Jameson	17	8	8	1898	60	12	8	− 4.0
133	....do	Kingfisher	Mrs. N. L. St. Clair	17	7	7	1902	60	35	33	− 25.0
134	....do	Dover	Wm. Homier	17	7	18	1898	60	34	32	− 28.0

*See notes at end of this table.

a City.

records—Continued.

How obtained at surface.	Quality.	Supply per minute.	Increase or decrease of supply.	Effect of pumping on level of water.	Geological horizon of well mouth.	Geological horizons of water-bearing strata.	No.
		Gals.					
Mill and pump.	Hard	.66	Neither	Not easily lowered.	Permian	Permian	*99
Bucket	Soft		do	Not easy to lower.	Tertiary	Tertiary	100
Pump	Salty		do	Goes down	Permian	Permian	*101
do	Soft		do	Constant	Tertiary	Tertiary	*102
do	Hard		do	Easy to lower.	Permian	Permian	*103
Mill and pump.	do		do	Can be lowered.	do	do	*104
Pump	Soft		Varies with the season.	None	Tertiary	Tertiary	*105
	Hard		Varies	To lower	Permian	Permian	*106
Bucket	do		About the same.	Lowered	do	do	*107
Windmill	Soft		Constant	Not affected.	do	do	*108
Pump	Hard		About the same.	Lower	do	do	*109
do	do		Neither	Can't pump dry.	do	do	*110
Flowing	Salt		do	Can be lowered.	do	do	111
Mill and pump.	Gypsif	3.33	do	Not easy to lower.	do	do	112
do	Salty		do	do	do	do	113
do	Soft	30.0	do	do	do	do	114
do	Hard	.66	do	do	do	do	115
do	Gypsif	.88	do	do	do	do	116
Bucket	Hard	2.66	do	do	do	do	*117
Mill and pump.	do	.22	do	do	do	do	118
Bucket	Gypsif	1.37	do	do	do	do	119
do	Hard	.11	do	Easy to lower	do	do	120
Mill and pump.	Gypsif	.08	do	Not easy to lower.	do	do	121
Steam pump	Soft	11.8	do	do	do	do	*122
Mill and pump.	do		do	Mill runs day and night.	do	do	*123
do	do	.42	do	Not easy to lower.	do	do	*124
Pump	Hard and salty.	.083	do	Easily lowered.	do	do	*125
Mill and pump.	Hard	3.33	do	Not easy to lower.	do	do	*126
do	do		do	do	do	do	*127
do	do		do	do	do	do	*128
Pump	Alkaline	.055	do	Easy to lower	do	do	*129
do	Soft	7.0	do	Can not lower	do	do	*130
Mill and pump.	do	4.0	do	Not easy to lower.	do	do	*131
do	Hard	4.0	do	do	do	do	132
do	do	.133	do	do	do	do	133
do	do	5.0	do	do	do	do	134

Oklahoma well

No.	County.	Post-office.	Owner.	Location. Township.	Range.	Section.	Year completed.	Diameter of well.	Depth of well.	Depth to principal water supply.	Height of water above (+) or below (−) mouth of well.
								In.	*Feet.*	*Feet.*	*Feet.*
135	Kingfisher....	Dover	Harvey Jameson..	17	8	2	1902	60	17	11	− 5.0
136	.....do	Cashion	R. A. Bryant......	15	5	12	1901	6	55	55	− 45.0
137	.....do	.....do	B. F. Harmon.....	15	5	15	1901	6	52	43	− 40.0
138	.....do	.....do	S. S. Cole..........	15	5	12	1901	8	55	50	− 43.0
139	.....do	Parvin	A. W. Parvin......	19	9	33	1892	42	20	13	− 8.0
140	.....do	Hennessey ...	J. O. Wright	20	6	33	1890	36	14	13	− 1.0
141	.....do	Wandel	J. W. Crum........	17	5	3	1904	$1\frac{1}{4}$	15	10	− 10.0
142	Kiowa........	Lone Wolf....	D. C. Bruce	5	19	18	1903	56	10	8	− 8.0
143	.....do	Mountain Park.	J. Campbell.......	3	17	22	1903	8	21	14	− 4.0
144	.....do	Chadwick	D. P. Churchwell.	1 N	19	23	......	3.6	12	10	− 10.0
145	.....do	Lone Wolf....	A. B. Shelton	6	19	35	1903	60	17	16	− 10.0
146	.....do	Harrison	Jas. H. Lister	7	15	6	1902	8	19	20	− 12.0
147	.....do	Nesbitt	Willis Stanfill.....	7	5	7	......	42	37	35	....
148	.....do	Mountain Park.	Lewis Viluen	4	16	35	1902	60	19	16	− 10.0
149	.....do	Cloverton	J. A. Willits........	3 N	16	1	1902	60	18	13	− 13.0
150	.....do	Hobart	Wm. H. Pearl.....	6	17	5	1902	48	28	26	− 22.0
*151	.....do	Snyder	C. T. Gorton	2 N	17	11	1902	6	26	20	− 16.0
*152	Lincoln	Carney	Wm. Bedford	16	3 E	20	1902	$6\frac{3}{4}$	$103\frac{1}{2}$	100	− 53.5
*153	.....do	Tryon	Jones	16	2 E	18	1902	$6\frac{3}{4}$	141	$85\frac{1}{2}$	− 75.5
*154	.....do	.....do	J. H. Harter	16	4 E	8	1902	$6\frac{3}{4}$	$103\frac{1}{2}$	100	− 78.5
*155	.....do	Fallis.........	Joe Dufraine......	15	2 E	28	1900	6	40	38	− 22.0
*156	.....do	Riddle........	C. A. Sherwin, sr..	12	4 E	26	1894	36	22	20	− 17.0
*157	.....do	.....do	C. A. Sherwin, jr..	12	4 E	34	1901	6	124	115	−104.0
*158	.....do	Clifton	Farmers' Gin Co ..	12	4 E	20	1902	120	36	36	− 16.0
*159	.....do	Wellston	G. W. Blakeley....	16	2 E	19	1895	7	45	39	− 29.0
*160	.....do	Perkins.......	Jose Hert	17	3 E	22	1901	$6\frac{3}{4}$	72	68	− 52.0
*161	.....do	Clifton	I. C. Boulson......	12	4	33	1903	6	57	45	− 35.0
*162	Logan	McKinley	David Swank	16	1 E	34	1893	8	92	86	− 76.0
*163	.....do	Coyle.........	O. L. Jewitt.......	18	1 E	30	1898	60	54	54	− 50.0
*164	.....do	McKinley	D. K. Campbell ...	16	1 E	27	1893	10	85	80	− 70.0
*165	.....do	Mulhall	J. H. Wesley.......	18	3W	9	1899	8	52	37	− 32.0
*166	.....do	Langston.....	Freeman Wallace.	17	1 E	22	1902	6	63	50	− 40.0
167	.....do	Crescent......	A. C. Ringold	17	3W	31	1893	60	28	21	− 21.0

*See notes at end of this table.

records—Continued.

How obtained at surface.	Quality.	Supply per minute	Increase or decrease of supply.	Effect of pumping on level of water.	Geological horizon of well mouth.	Geological horizons of water-bearing strata.	No.
		Gals.					
Mill and pump.	Hard, nearly soft.	40.0	Neither	Not easy to lower.	Permian	Permian	135
Pump	Soft	10.0	do	do	do	do	136
do	Hard		do	do	do	do	137
do	Soft		do	do	do	do	138
Bucket	do		do	do	do	do	139
	do		do	do	do	do	140
Pump	Salty		do	do	Tertiary	Tertiary	141
Bucket	Gypsif		do	Easy to lower	Permian	Permian	142
Pump	Soft		do	Not easy to lower.	do	do	143
Bucket	do		do	Easy to lower	do	do	144
do	Salty		do	do	do	do	145
do	Soft		Increased	Not easy to lower.	do	do	146
Pump	Hard		Neither	Easy to lower	do	do	147
Bucket	Soft	.04	do	Not easy to lower.	do	do	148
do	do		do	Easy to lower	do	do	149
do	do	.02	do	Not very easy to lower.	do	do	150
Pumps	Salty and soda.	.04	do	Not easy to lower.	do	do	*151
Bucket	Soft	3.0	do	Can be lowered to 23 feet.	Red beds	Red beds	*152
	do	2.2	do	Not easy to lower.	do	do	*153
Bucket	do		do	Not easily lowered.	do	do	*154
do	do		do	Not easy to lower.	do	do	*155
do	Hard	.44	do	do	do	do	*156
do	Soft		do	Easy to lower	do	do	*157
Steam pump	do	3.33	do	Not easy to lower.	do	do	*158
Bucket	Medium soft.		do	do	do	do	*159
Pump	Hard	1.66	do	do	do	do	*160
Bucket	do		do	do	do	do	*161
Mill and pump.	do		do	Easily lowered.	Permian	Permian	*162
do	do	.83	do	Easy to lower.	do	do	*163
Bucket	Soft		do	Is easily lowered.	do	do	*164
Pump	Hard	.14	do	Not easy to lower.	do	do	*165
Mill and pump.	do	.087	do	Easily lowered.	do	do	*166
Pump	do	.27	Increase	Can be pumped dry in 4 hours.	do	do	167

Oklahoma well

No.	County.	Post-office.	Owner.	Location. Township.	Range.	Section.	Year completed.	Diameter of well.	Depth of well.	Depth to principal water supply.	Height of water above (+) or below (−) mouth of well.
								In.	Feet.	Feet.	Feet.
*168	Logan	Guthrie	Jas. Knox	16	1W	14	1902	7	150	70	− 70.0
*169	do	Mulhall	Peter Beleele	18	3W	5	1901	8	42	41	− 21.0
*170	do	Crescent	John Wilson	17	4W	22	1890	48	85	75	− 45.0 to − 65.0
*171	do	Coyle	C. W. Longan	17	1 E	4	1902	8	91	80	− 70.0
172	Noble	Ceres	W. A. Chessher	23	1W	11	1896	66	28	18	− 12.0
173	do	Day	A. Seals	21	2 E	26	1897	6	40	27	− 20.0
174	do	Perry	M. M. Barnard	21	1W	24	1900	8	104	90	− 10.0
*175	do	Ceres	E. J. Waltermire	23	1W	22	1899	6	40	37	− 15.0
*176	do	Billings	J. J. Lentz	23	3W	14	1900	6	70	55	− 35.0
*177	do	Orlando	Geo. Ketch	20	2W	25	1895	8	132	102	− 82.0
*178	do	Burton	J. E. Writt	24	1W	7	1901	7	47	12	− 11.0
*179	do	Morrison	Hull Bros	21	3 E	17	1903	7	110	100	− 30.0
*180	do	Billings	Jay R. Graves	23	3	14	1902	6	181	180	− 16.0
181	do	Perry	Henry Koelzer	21	1 E	30	1901	48	53	52	− 17.0
*182	Oklahoma	Choctaw	John Quim	12	1W	34	1902	6	54	37	− 37.0
*183	do	Luther	Lee Dalrymple	13	1 E	28	1903	6	64	42	− 42.0
*184	do	Britton	Henry Hasley	13	3W	31	1900	10	160	155	−100.0
*185	do	Choctaw	J. A. Kennedy	12	1 E	29	1900	10	71	45	− 45.0
186	do	do	Carrie Miller	12	1W	23	1902	10	34	22	− 22.0
*187	do	Jones City	C. A. Chandler	12	1 E	9	1900	6	112½	100	− 95.0
*188	do	do	Homer Britton	13	1 E	20	1903	6	58	41	− 40.0
*189	do	Oklahoma	W. F. Young	13	1W	25	1903	6	68	60	− 50.0
190	do	Luther	Grant Stanley	14	1 E	25	1896	10	78	60	− 60.0
*191	do	Jones City	C. H. McLung	12	1W	3	1903	6	43	38	− 28.0
*192	Pawnee	Pawnee	Lone Chief	22	6 E	18	1894	6	42	28	− 27.0
*193	do	Glencoe	S. Vandment	21	4 E	32	1895	10	77	75	− 67.0
*194	do	Masham	W. C. Legrande	23	4 E	34	1894	6	82	77	− 37.0
*195	do	do	B. F. Harmon	26	4 E	24	1901	8	28	26	− 18.0
*196	do	Pawnee	E. C. Wheeler	23	5 E	35	1899	6	136	134	− 66.0
*197	do	Masham	J. S. Stritch	29	4 E	26	1894	60	12	8	− 6.0
*198	do	Pawnee	Louis Demieville	22	5 E	5	1896	7	46	23	− 23.0
*199	do	Filson	Fred Strobal	23	5 E	18	1899	6	40	32	− 32.0
*200	do	Pawnee	L. P. Botts	22	5 E	4	1897	7	65	40	− 40.0
*201	do	Ralston	Jas. Bogle	23	5 E	12	1899	2	21½	20	− 19.5
*202	Payne	Westpoint	Hiram B. Allnutt	20	4 E	22	1901	7	45	18	− 18.0

* See notes at end of this table.

records—Continued.

How obtained at surface.	Quality.	Supply per minute.	Increase or decrease of supply.	Effect of pumping on level of water.	Geological horizon of well mouth.	Geological horizons of water-bearing strata.	No.
		Gals.					
Bucket	Soft	.135	Neither	Easily lowered.	Permian	Permian	*168
Pump	Hard		do	Not easy to lower.	do	do	*169
Bucket	Soft	10.4	Increase	do	do	do	*170
do	do		Neither	Not easily lowered.	do	do	*171
Mill and pump.	Hard	.13	do		do	do	172
Bucket	do		do		do	do	173
Mill and pump.	do		do	Easy to lower	do	do	174
do	Alkaline		do	Can not lower	do	do	*175
Bucket	do		do	Easy to lower	do	do	*176
Mill and pump.	Salty	14.0	do	do	do	do	*177
Pump	Soft	1.33	do		do	do	*178
	do		do	Not easily lowered.	do	do	*179
Bucket	do	4.16	do	do	do	do	*180
Mill and pump.	do	.266	do	Easily lowered.	do	do	181
Bucket	do		do	Easy to lower	Red beds	Red beds	*182
do		2.0	do	Easily lowered.	do	do	*183
Mill and pump.	Hard and salty.	10.0	do	Easy to lower	do	do	*184
do	Hard		do	Not easy to lower.	do	do	*185
Bucket	Soft	4.16	do	do	do	do	186
do	do		Decreased	Easily lowered.	do	do	*187
Pump	Hard	1.66	Neither	Easy to lower	do	do	*188
Bucket	do	3.33	do	Not easy to lower.	do	do	*189
Pump	do	4.0	do		do	do	190
Bucket	do	2.5	do	Easy to lower	do	do	*191
do	Soft		do	Not easy to lower.	Pennsylvanian.	Pennsylvanian	*192
do	Salty			Easy to lower	do	do	*193
Pump	Soft		Decreased	do	do	do	*194
Bucket	do		Neither	do	do	do	*195
Mill and pump.	do	1.3	do	Not easy to lower.	do	do	*196
Bucket	Hard		do	do	do	do	*197
Pump	do	.13	do	do	do	do	*198
Bucket	Soft	.03	do	Easy to lower	do	do	*199
do	do	.03	do	do	do	do	*200
Mill and pump.	do	6.6	do	Not easy to lower.	do	do	*201
Bucket	do		do	Easy to lower	Red beds	Red beds	*202

Oklahoma well

No.	County.	Post-office.	Owner.	Location. Township.	Location. Range.	Location. Section.	Year completed.	Diameter of well.	Depth of well.	Depth to principal water supply.	Height of water above (+) or below (−) mouth of well.
								In.	Feet.	Feet.	Feet.
*203	Payne	Lawson.......	Reuben Wilson ...	19	5 E	14	1901	48	26	22	− 22.0
*204	.....do	Ingalls	S. T. Kirby........	19	5 E	20	1897	6	20	18	− 8.0
*205	.....do	Stillwater	O. F. Weaver	18	1 E	2	1891	60	42	22	− 22.0
*206	.....do	Ingalls	Frank A. Henderson.	19	5 E	23	1901	7	140	138	− 80.0
*207	.....do	Glencoe	F. C. Jessee	20	4 E	31	1902	6½	60	50	− 40.0
*208	.....do	Westpoint	Wm. Dodd	20	4 E	7	1895	6	104	102	− 49.0
*209	.....do	Ripley........	John F. Oldham ..	18	4 E	20	1892	8	77	66	− 66.0
*210	....do	Marena.......	R. C. McKee.......	19	1 E	34	1895	48	21	20	− 16.0
*211	.....do	Perkins.......	J. W. Carr	18	3 E	34	1895	9	50	43	− 23.0
212	Pottawatomie	Moral.........	W. B. Trousdale...	7	3 E	21	1902	6	130	127	− 40.0
213	.....do	Bellmont.....	Edgar Mack	11	4 E	2	1903	6	137	130	−107.0
214	.....do	.....do	L. D. Cavins.......	11	4 E	2	1902	6	81	71	− 65.0
215	.....do	Moral.........	J. S. Lamm	7	2	12	1893	6	84	80	− 70.0
*216	.....do	.....do	J. W. Foster	7	3 E	19	1893	6	50	40	− 15.0
217	.....do	.....do	B. I. Martin	7	3 E	18	1898	6	48	44	− 36.0
*218	.....do	Shawnee	J. H. Wallace......	10	3 E	18	1899	6	135	130	− 65.0
*219	.....do	Bellmont.....	Dick Quinn	11	4 E	4	1902	6	90	85	− 74.0
*220	.....do	.....do	Hugh Woklee (Indian).	11	4 E	3	1903	6	62	55	− 46.0
*221	.....do	Anderson.....	J. E. Jarman	7	3 E	15	1892	6	95	90	− 70.0
222	Roger Mills...	Doxey	J. Hilderbrand	10	22	8	1901	8	144	43	− 43.0
223	.....do	Ural	T. J. McReynolds..	....	21	....	1904	6	62	54	− 35.0
224	.....do	Carter	Jno. King.........	9	22	35	1898	36	40	35	− 30.0
225	.....do	Poarch	Jas. Adkerson.....	8	21	11	1900	60	18	15	− 15.0
226	.....do	Grimes	W. L. Blackburn ..	12	24	27	1902	6	110	95	− 95.0
227	.....do	Berlin	Wm. Kohn	12	23	19	1902	6	132	120	−120.0
228	.....do	Grimes	T. L. Sherrill	11	24	19	1902	7	30	28	− 24.0
229	.....do	Berlin	F. E. Richardson ..	12	24	13	1902	6	119½	103½	− 93.0
230	.....do	Elk City	J. W. McDonald ...	11	20	19	1898	60	27	24	− 8.0
231	.....do	Grimes	I. F. Meeks	12	24	32	1901	72	33	30	− 27.0
232	Washita	Cowden	Jas. Rhodes	9	14	20	1900	6	86	60	− 60.0
233	.....do	Burns	J. A. Jester	10	19	14	1900	6	65	44	− 40.0
234	.....do	Shelly	C. Ediger..........	11	16	14	1898	7	200	180	− 60.0
235	.....do	Cordell	John T. Dazey	10	18	32	1899	36	31	30	− 23.0
236	.....do	Rainy	A. B. Brown	8	17	24	1902	6	184	128	−128.0
237	.....do	Boise	S. A. Gamble	9	14	24	1902	6	113	100	− 90.0
238	.....do	Burns	Browers...........	9	19	5	1898	42	18	17	− 14.0

*See notes at end of this table.

records—Continued.

How obtained at surface.	Quality.	Supply per minute.	Increase or decrease of supply.	Effect of pumping on level of water.	Geological horizon of well mouth.	Geological horizons of water-bearing strata.	No.
		Gals.					
Pump	Hard	.02	Neither	Not easy to lower.	Red beds	Red beds	*203
Fucket	do		do	do	do	do	*204
do	Soft		do	do	do	do	*205
Pump	do	.11	do	do	do	do	*206
	do		do	do	do	do	*207
Mill and pump.	do		do	do	do	do	*208
do	do		do	Easy to lower	do	do	*209
Bucket	Hard	.166	do	Not easy to lower.	do	do	*210
Mill and pump.	Soft	.55	do	Easy to lower	do	do	*211
Bucket	do		do	Not easy to lower.	do	do	212
do	Hard		do	do	do	do	213
do	do		do	do	do	do	214
do	do		do	do	do	do	215
do	do	.1	do	Easy to lower	do	do	*216
do	do	1.0	Increased		do	do	217
do	do	.05	Neither	Easily lowered.	do	do	*218
do	Soft		do	Not easily lowered.	do	do	*219
do	Hard		do	do	do	do	*220
do	Soft	1.33	do	Easily lowered.	do	do	*221
do	Hard		do	Easy to lower	Permian	Permian	222
do	do		do	do	do	do	223
Mill and pump.	do		do	Not easy to lower.	do	do	224
Bucket	Gypsif		do		do	do	225
do	Soft	1.66	do	Easy to lower	do	do	226
Pump	do	.08	do	Not easy to lower.	do	do	227
Bucket	do	.016	do	Easy to lower	do	do	228
do	do	.04	do	Not easy to lower.	do	do	229
Pump	do	21.3	do	do	do	do	230
Bucket	do	.08	do	Easy to lower	do	do	231
Mill and pump.	Hard	8.0	do	Mill does not lower.	do	do	232
do	Soft	10.0	do	Can be lowered very little.	do	do	233
Bucket	Hard, salty.		do	Not easy to lower.	do	do	234
do	Hard	.5	do	do	do	do	235
Pump	Soft	8.3	do	do	do	do	236
Bucket	do	.088	do	do	do	do	237
do	do	.04	Decreased	Easy to lower	do	do	238

Oklahoma well

No.	County.	Post-office.	Owner.	Location.			Year completed.	Diameter of well.	Depth of well.	Depth to principal water supply.	Height of water above (+) or below (−) mouth of well.
				Township.	Range.	Section.					
								In	*Feet.*	*Feet*	*Feet.*
239	Washita	Burns	J. N. Arnold	10	19	20	1898	66	30	26	14.0
240	do	Korn	P. Settkeman	11	15	7	1902	48	12	10	− 8.0
241	do	Kiel	Geo. Jameson	8	17	8	1895	42	13	8	− 8.0
242	Woods	Amorita	Henry Witte	29	10	31	1896	1¼	40	27	− 26.0
243	do	Ringwood	Jonah Grieve	22	10	4	1894	54	60	55	− 45.0
244	do	Helena	Edgar Hubbel	24	10	16	1901	6	72	70	− 30.0
245	do	Ingersoll	C. Haas	27	11	29	1894	2	27	20	− 10.0
246	do	Cherokee	J. T. Millspaugh	26	11	3	1894	1¼	32	16	− 16.0
*247	do	Alva	R. C. Brown	(*a*)	(*a*)	(*a*)	1901	6	123	83	− 63.0
248	do	Auburn	C. M. Ingram	26	12	1	1896	10	51	45	− 36.0
249	do	Byron	W. F. Brown	28	10	9	1901	2	30	28	− 19.0
250	do	Chester	Frank Forward	20	16	8	1900	10	65	50	− 50.0
251	do	Concord	Geo. Picler	22	10	1	1902	3	144	85	− 65.0
252	Woodward	Oleta	G. W. Sleeth	22	23	31	1896	3	40	45	− 30.0
253	do	Speermore	E. E Strohmeier	25	25	30	1901	42	25	24	− 21.0
254	do	Belva	R. A. Doles	23	17	1	1901	72	27	23	− 23.0
255	do	Waynoka	J. J. Russell	25	17	26	1901	48	35	24	− 24.0
256	do	Oleta	Martha N. Smith	21	22	1	1895	72	18	12	− 12.0
257	do	Speermore	Aaron Hartfield	25	26	26	1902	6	78	78	− 55.0
258	do	Laverne	Geo. W. Ralls	26	25	28	1901	1½	35	34	− 30.0
259	do	Shattuck	A., T. & S. F. Ry	(*a*)	(*a*)	(*a*)	1887	96	95	35	− 35.0
260	do	Curtis	Wm. Martindale	22	18	24	1901	10	112	110	−107.0
261	do	Detroit	O. A. Nickerson	21	20	17	1902	24	91	89	− 87.0

* See notes at end of this table.

a City.

records—Continued.

How obtained at surface.	Quality.	Supply per minute.	Increase or decrease of supply.	Effect of pumping on level of water.	Geological horizon of well mouth.	Geological horizons of water-bearing strata.	No.
		Gals.					
Bucket	Soft	2.0	Neither	Not easy to lower.	Permian	Permian	239
do	Hard	.83	do	do	do	do	240
Mill and pump.	do		do	Can not lower	do	do	241
Pump	do	5.0	do	Not easy to lower.	do	do	242
Bucket	do		Increased	Easy to lower	Tertiary	do	243
Pump	do	2.2	Neither	Not easy to lower	Permian	do	244
Mill and pump.	do	2.22	do	do	do	do	245
Pump	do	.22	do	do	do	do	246
do	Gypsif	.4	Decreased	Easy to lower	do	do	*247
Mill and pump.	Soft	.3	Neither	do	do	do	248
do	do	.22	do	Not easy to lower.	Tertiary	Tertiary	249
do	do	6.6	do	do	do	do	250
Pump	do	.22	do	do	do	do	251
do	do	.03	do	Not easily lowered.	do	do	252
do	do	06	do	Easy to lower	do	do	253
do	Hard		do	Not easily lowered.	Permian	Permian	254
do	Salt		do	Easy to lower	do	do	255
do	Hard	.03	do	do	Tertiary	Tertiary	256
do	Soft	.17	do	Not easy to lower.	do	do	257
do	do		do	Not easily lowered.	Permian	Permian	258
Steam pump	Hard	69.44	do	Easy to lower with sand pump.	Tertiary	Tertiary	259
Mill and pump.	Soft	.05	do	Easy to lower	Permian	Permian	260
Pump	do	.03	do	Not easily lowered.	Tertiary	Tertiary	261

NOTES ON WELLS OF OKLAHOMA.

No. 1. Flows an inch stream nearly all the time.

No. 2. Tertiary sands are mixed with the Permian to some extent.

No. 9. The water from this well is hauled for miles by the settlers, many of whom have no other water near. The location is given from the Cimarron meridian (103°). Water analysis No. 2.

No. 18. This is a test well. Pump was removed.

No. 31. Water in sand and gravel.

No. 32. Water in gravel.

No. 34. Water in red sand.

No. 35. Water in shale.

No. 36. Water in shelly sand rock.

No. 38. Water in sand.

No. 40. Water in sandy gravel.

No. 41. Water in sand.

No. 42. Water in sandstone. Water contains iron, Glauber's salt, chlorine, and perhaps other elements. Water analysis No. 22.

Nos. 43 and 44. Water in sand.

No. 45. Water in clay.

No. 46. Water in coarse sandstone.

No. 47. Water in gravel.

No. 48. Water in sandstone.

No. 49. Water in sand.

No. 50. Surface water in clay at 25 feet, main supply in sand rock.

No. 56. Used to irrigate garden.

No. 58. The well is in Oklahoma.

No. 59. Temporary watering station.

No. 75. Well is in Day County. Post-office in Woodward County.

No. 76. The owner says the amount is inexhaustible.

No. 77. The well is in Day County. Post-office in Woodward County. The above flow is about all it will yield. (I visited the well in person.—Long.)

No. 81. The well is not far southeast from the Canadian River and is dug in a sandy loam with water in quicksand.

No. 91. Water in gravel.

No. 93. Water in sand.

No. 95. Abundance of water in quicksand.

No. 98. An abundance of water in sand. Used for irrigation.

No. 99. Water in sand rock. Is used for irrigation.

No. 101. Water was found in a clay formation.

No. 102. Water was found in gravel.

No. 103. Water found in red gravel.

No. 104. Water found just under a hard cap rock in sand.

No. 105. Water in gravel.

Nos. 106 and 107. Water was struck in rock.

No. 108. Water found in sand.

No. 109. Water in red kiel.

No. 110. Water was struck in rock.

No. 117. The well is in Oklahoma.

No. 122. Water in gravel.

No. 123. Water in gravel. It is used to irrigate garden.

No. 124. Water in gravel.

No. 125. Water in slate.

No. 126. Water in sand.

No. 127. Water in soapstone.

No. 128. Water in blue soapstone.
No. 129. Water in gray gypsum rock.
No. 130. Water in sand.
No. 131. Water in sand and gravel.
No. 151. Water analysis No. 48.
No. 152. Water in sandstone.
No. 153. This is a test well put down by a railroad company. Water found in sandstone.
No. 154. Water under sandrock. A strong flow.
No. 155. Water in sand.
No. 156. Water in iron-sandstone.
No. 157. Water in sandrock.
No. 158. Water in sand.
No. 159. Water in clay.
No. 160. Water in shelly sandstone. (Well in Lincoln, post-office in Payne County.)
No. 161. Water in gravel.
Nos. 162, 163, and 164. Water in sandstone.
No. 165. Water in sand.
No. 166. Water in clay.
No. 168. Water in soft sandstone.
No. 169. Water in gravel.
No. 170. Water in gravelly clay.
No. 171. Water in clay.
No. 175. The owner says it is like putting a pump into a river to try to pump it dry.
No. 176. Analysis No. 52.
No. 177. Water in soft red sandstone.
No. 178. Water in clay.
No. 179. Water in white sandstone.
No. 180. Water in clay.
No. 182. Water in clay and sand.
No. 183. Water in sandrock.
No. 184. Water in white sandstone.
No. 185. Water in sandrock.
Nos. 187, 188, 189, and 191. Water in sandstone.
Nos. 192 and 193. Water in sand.
Nos. 194 and 195. Water in sandrock.
No. 196. Water in white sand.
No. 197. Water in sand and gravel. The well will fill up in 30 minutes.
No. 198. Water in limestone.
No. 199. Water in flint.
No. 200. Water in blue clay.
No. 201. Water found in fine gravel.
No. 202. Water in sandstone. A fair supply.
No. 203. Water between gravel and soapstone.
No. 204. Water in clay.
No. 205. Water found in sandstone.
Nos. 206 and 207. Water in sandrock.
No. 208. Water in limestone.
No. 209. Water in sandrock; supply abundant, but no record of the flow.
Nos. 210 and 211. Water in gravel.
No. 216. Water contains traces of soda.
No. 218. Water in white sandstone.
Nos. 219 and 220. Water in sandstone.
No. 221. Water in sandrock.
No. 247. The well has since gone dry.

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O

PUBLICATIONS OF UNITED STATES GEOLOGICAL SURVEY.

[Water-Supply Paper No. 148.]

The serial publications of the United States Geological Survey consist of (1) Annual Reports, (2) Monographs, (3) Professional Papers, (4) Bulletins, (5) Mineral Resources, (6) Water-Supply and Irrigation Papers, (7) Topographic Atlas of United States—folios and separate sheets thereof, (8) Geologic Atlas of the United States—folios thereof. The classes numbered 2, 7, and 8 are sold at cost of publication; the others are distributed free. A circular giving complete lists may be had on application.

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