

**KANSAS GEOLOGICAL SURVEY
OPEN-FILE REPORT 29-1**

GEOLOGY OF BARBER COUNTY, KANSAS

by

G. L. Knight

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1929

KGIS
OF
29-1

Date late 1920's
or early 1930's

GEOLOGY OF BARBER COUNTY, KANSAS
by
Gerald L. Knight
Introduction

See short report in
Gerkane Fm., in Proc. G.S.A.
for 1933 (1934)
p. 91

For several years the Kansas Geological Survey has been preparing ^{County} maps and reports to give information concerning the geology and natural resources of the state. The maps of the areas thus studied also form ^{ed} units in the new geologic map of Kansas ^{recently} now being compiled. The state geologist chose Barber County as one of the areas to be mapped in 1929. The results of that work form the basis of this report.

Barber county holds a position of unusual geologic interest, ^{both} within its boundaries are the type exposures of several ~~of the~~ Permian Red Bed formations and outcrops of the limited Kansas Comanchean strata. Extensive gypsum beds and large reserves of natural gas are the principal mineral resources of economic importance.

The present report gives in especial detail the stratigraphy and lithology of the Red Beds outcropping in the county, ⁽¹⁾ ^F ^T for the writer believes that such information will be of much interest to geologists working in areas where these formations or their equivalents are exposed. Such ^{a detailed} field study seemed desirable also because the geologic work that has been done during the last few years upon the Permian Red

Beds of Kansas and Oklahoma has shown that some of the formation names given by Cragin to the rocks exposed in Barber and Harper counties should be redefined or abandoned. Many of the descriptions that he gave are indefinite regarding the thicknesses and the upper and lower

Cragin, F. W., The Permian system in Kansas: Colo. College Studies, vol. 6, pp. 18, 20, 23, 24, 1896.

limits of the formations. In many cases he did not define the contacts between successive units and he left no maps to give the areal distribution of the formations as he named them. His work has ~~ing~~ served long and well to give the general character of the rocks but the geologic practice of today demands that formational dividing lines be drawn more sharply.

Cragin gave the name "Harper sandstone^s" to the lower several hundred feet of the Red Beds of Kansas. No essential change is made in the usage of the term, although the final "s" is not used in recent literature. Only the upper part of the Harper sandstone is exposed in Barber County and the writer did little work in the area in which the lower part of the formation crops out. Several oil company geologists who have worked in areas underlain by these lower red strata believe

that the Harper sandstone should be subdivided because of variation in the lithologic character of the rocks. This subdivision may be desirable inasmuch as the various phases are reported to be traceable many miles south into Oklahoma.

The term "Salt Plains^(?) measures" is abandoned as a geologic formation name, ^{for} ~~the areas that were~~ described as being underlain by this formation appear to be topographic flats ^{which} that are local in extent and are not developed at a particular stratigraphic horizon.

The Cedar Hills sandstone, as here used, has a thickness of about 250 feet instead of 50 to 75 feet as estimated by Cragin.

Cragin's term "Cave Creek" is replaced by the name "Blaine", because of the more general usage of the latter. ^{name} The only other change in stratigraphic nomenclature from that employed ⁱⁿ previous Kansas Geological Survey publications is the addition of the name Gerlane formation

— Name available according to records of Committee on Geologic Names, U. S. Geological Survey.

for certain Quaternary deposits in the area.

of Kansas

~~The lower several hundred feet of the Red Beds, all Harper sandstones but several oil company geologists who have worked in the areas underlain by these lower red strata believe that the basal part should be given a separate name because of the predominant shaly character of the rocks. The addition of a new name for part of the Harper formation sand may be desirable inasmuch as the lower shale phase is reported to be traceable many miles south into Oklahoma.~~

The water supply, the effect of geology upon vegetation, the physiography, and other phases of the geology are discussed in somewhat less detail than is the stratigraphy.

Field Work and Acknowledgments

The field study of the county was made during the summer of 1929. A geologic map indicating the areal distribution of the rock formations was prepared and is shown in Plate I. Most

of this map was made in the field using county highway maps and ownership plats ~~in~~ *and* addition to the U.S.G.S. topographic sheets as base maps. ^{The location of} ~~Some of the~~ formation

boundaries in the western part of the county were obtained from maps drawn by men

(1) working for ~~the~~ oil companies, ~~and~~ ^T the boundaries throughout the area have been compared with company maps. Much of the field work was devoted to detailed measurements and descriptions of the various rock formations exposed in the area.

The writer was assisted in the field work by Harold H. Hawkins and is indebted to him for help in the mapping and in subsequent laboratory studies of the rock for-

E. G. Knight

mations. The residents and officials of Barber county helped in every way possible; the officials of the Best Brothers Keene's Cement Company at Medicine Lodge and at Sun City supplied valuable information regarding the gypsum deposits; geologists of various oil companies working in the county ^{the writer} assisted in obtaining a better knowledge of the local stratigraphy; the Barbara Oil Company gave well logs and cuttings; and many individuals contributed drilling records and other geologic ^{also} information. The writer wishes to express his appreciation to all of these for the assistance they have given. He feels especially indebted to W.B. Wilson of the Gypsy Oil Company ^(now Gulf) for information concerning the thickness of certain formations; to Roy Hall of the same company for surface geologic ^{also} maps of the county, to Marvin Lee for geologic ^{also} maps, to C. L. Brewer, jr., for detailed stratigraphic information, and to others to whom specific references are given.

Geography

Location and culture. Barber County, one of the larger counties of the state, extends from the north side of Township 30 South to the Kansas-Oklahoma state line and from Range 10 West to 15 West, inclusive, except for Township 30 South, Range 10 West, which is in Kingman county (fig. 1). The area is approximately $31\frac{1}{2}$ townships.

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Figure 1--Index map of Kansas, showing location of Barber County.

All the land in the county is embraced in the "Thirty mile" and "Three mile" strips formerly owned by the Osage and the Cherokee Indians. This land was ceded to the Government by the treaty of July 15, 1870.

In 1867 an assembly met in a natural amphitheater about ~~two~~² miles southeast of Medicine Lodge and signed a treaty in which the Indians of the plains agreed to make no further attacks on wagon trains or raids on the construction parties building the Union Pacific and the Kansas Pacific railroads. A tablet commemorating the signing of this treaty has been placed in the yard in front of the library in Medicine Lodge. The Kansas legislature has appropriated money to buy ^{and make a state park of} the site at which this meeting was held. Figure 2 shows the crowd attending the sixtieth anniversary celebration of the signing of this treaty.

le The first settlers in Barber County located near the present town of Sun City in 1871. The following year others arrived and established residences near the present sites of Medicine Lodge and Kiowa. The movement into the area increased and during the summer of 1873 ^{much of the} ~~there was rapid settlement throughout much of the~~ northern part of the county was settled.

le For several years following the beginning of immigration the Indians raided the various communities, killing a number of people and stealing much stock. For protection against these attacks the settlers built stockades of cedar posts at Medicine Lodge, Sun City, and other points along the Medicine Lodge River.

Figure 2.

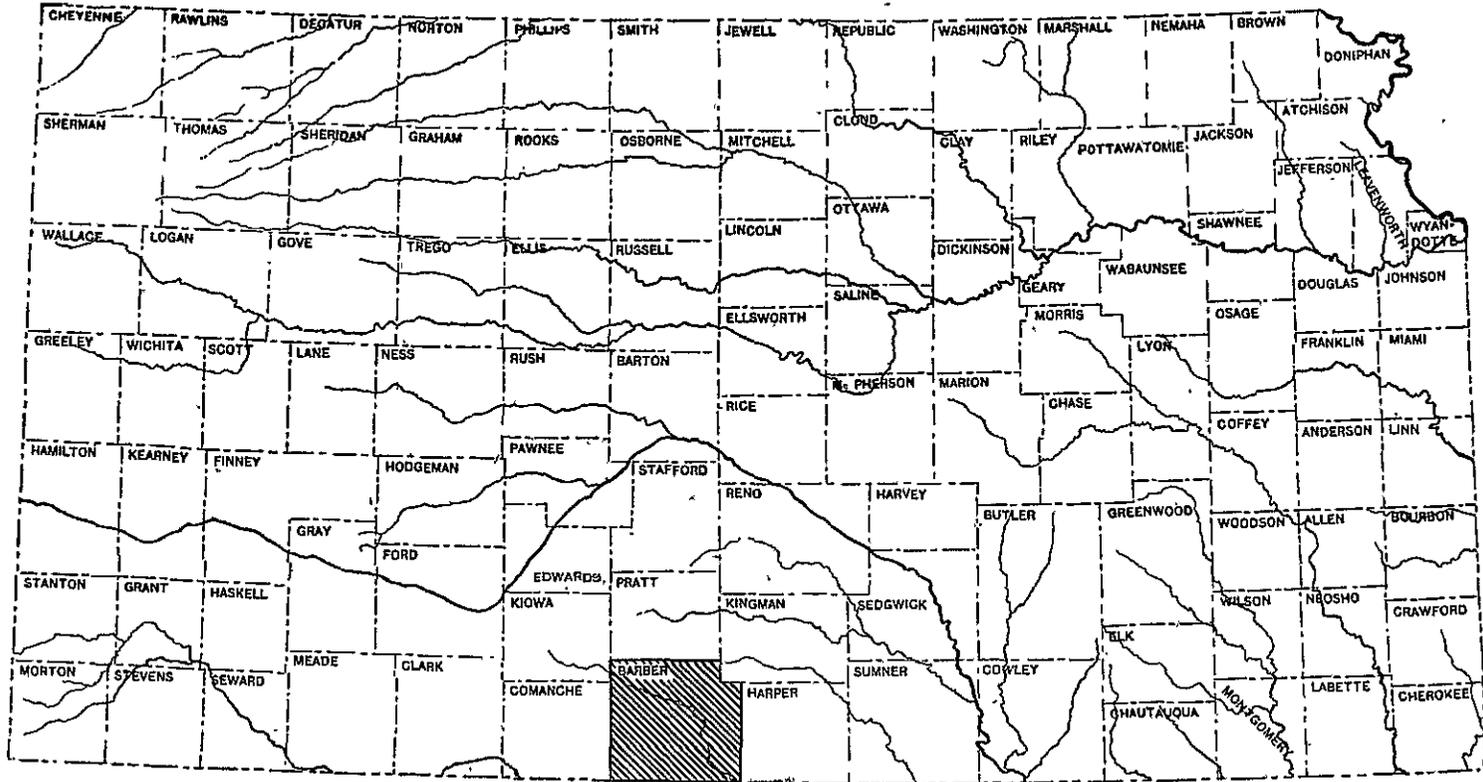
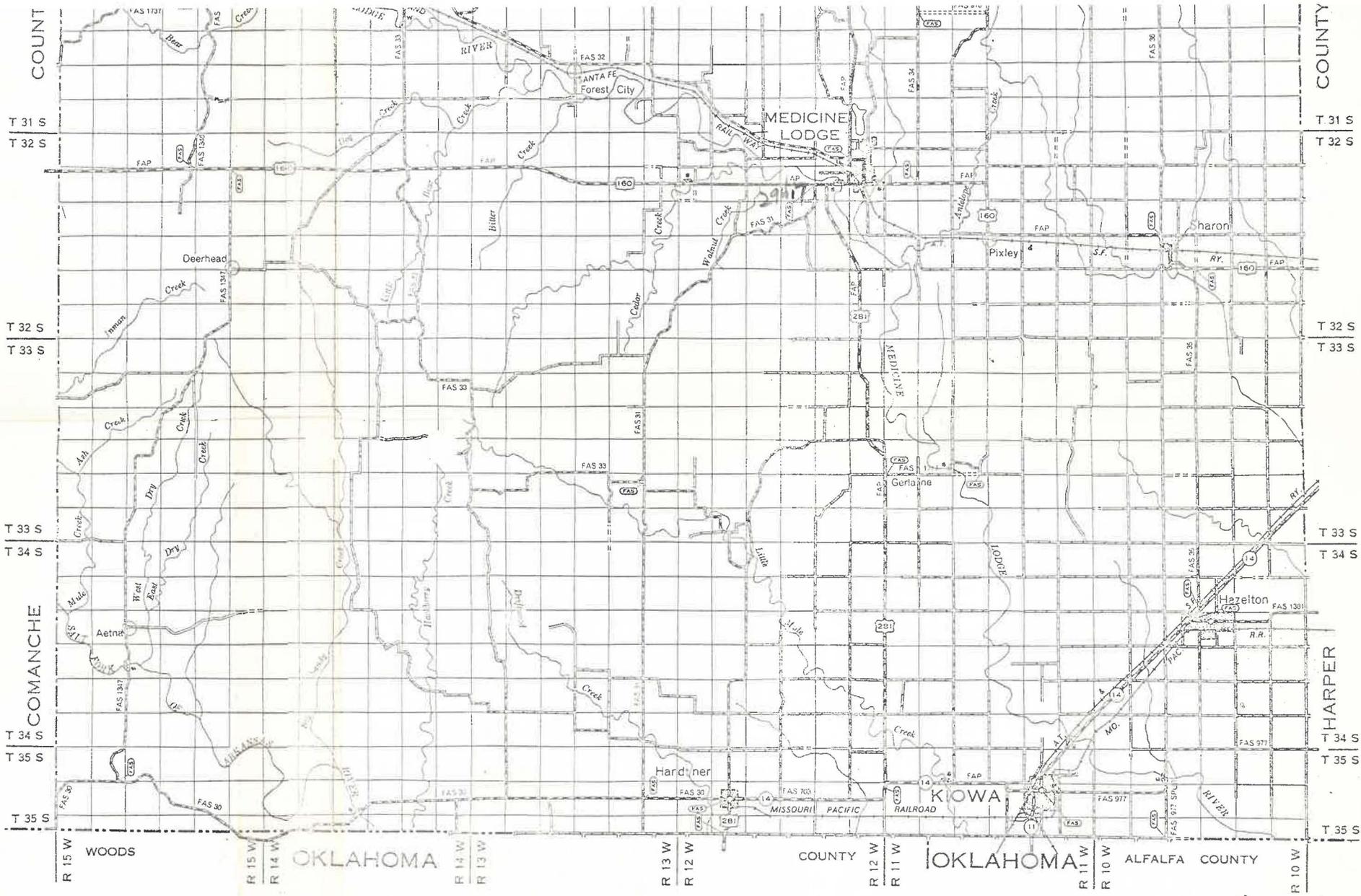


FIGURE 1





BARBER COUNTY
KANSAS



Figure 2

The county organization was effected in 1873 at Medicine Lodge, the present county seat.

The population of Barber County, according to the 1930 census, is 10,178.

Kiowa, population 1,501, and Medicine Lodge, population 1,655, are the largest towns in the county. Kiowa is in the southeastern part of the county near the Oklahoma-Kansas State line and Medicine Lodge is in the east central part of the county.

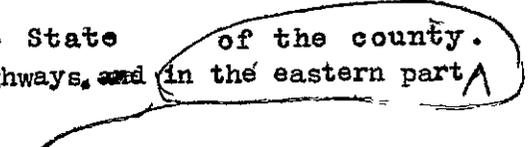
Two railroads operate in the county. The main line of the ^{Atchison, Topeka, and} Santa Fe from

Wichita to Amarillo, Texas, and the west coast turns southwest at Attica and goes through Hazelton and Kiowa in Barber County. From Attica a branch of the Santa Fe extends west into Barber County, through the town of Sharon to Medicine Lodge and from there turns northwest up the Medicine Lodge River valley crossing the county. Another branch of the Santa Fe ^{passes} goes through Isabel in the northeast part of the county. These two branches connect at Belvidere, in Kiowa County, ¹² ~~twelve~~ ¹³ ~~thirteen~~ miles northwest of Sun City. A third branch of the Santa Fe connects Kiowa and Medicine Lodge. This line is temporarily abandoned except for a small amount of freight traffic between Kiowa and Gerlane. A branch of the Missouri Pacific runs ~~east~~ to Hazelton, Kiowa, and Hardtner from Anthony.

Barber County is crossed by ~~several~~ ^{one Federal and two State} ~~crossed~~ highways, ^{and} ~~and~~ in the eastern part ^{of the county.}

There are improved roads along many of the section lines. The roads and railroads are shown on Plate I.

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Climate and vegetation. The mean annual temperature at Medicine Lodge is 57.3° F., and the average rainfall is 24.89 inches per year. The ~~average~~ mean temperature for the months of June, July, and August is 78.67° F., which is the highest given in the Weather Bureau reports

U. S. Dept. of Agriculture, Weather Bureau, Summary of the Climatological Data for the United States, by Sections; Sections 38 and 39-- Kansas.

for any station in Kansas. The high annual and summer temperatures cause rapid evaporation, making the climate more ~~semi~~arid in character than the annual precipitation would indicate.

Timber grows in abundance only along the streams. Cottonwood and elm trees are the most ^{abundant} ~~plentiful varieties~~, although walnut and hackberry trees are common. When the region was first settled the hills were covered with cedars but most of them have been cut off or have died; at present only a few grow here and there in the ^{less accessible} hilly ~~inaccessible~~ places. Wild plum bushes ranging from 2 feet to 8 or 10 feet in height grow on the sand-dunes and on the sand areas, ~~including those~~ ~~underlain by the Tertiary.~~ Yucca, (also known as Spanish-bayonet) and bear grass, and prickly-pear cactus grow in the sand areas but are rarely

found elsewhere # The native grass that covers a large part of the county makes excellent pasture ^{herds} and cattle raising is the chief industry. Field and pasture crops are grown in the more level eastern part as well as along the river valleys and in comparative^{ly} small upland areas throughout the county. Wheat, corn, alfalfa, and oats are the most important of these crops. Industries other than agriculture include the quarrying of gypsum, the manufacture of Keene's Cement, the extraction of gasoline from natural gas, and the development of natural gas resources.

Topography. The surface of the western part of Kansas, roughly one-third of the state, and of large areas in Colorado, Oklahoma, Texas, and Nebraska slopes gently eastward and is broken by comparatively few valleys. This region, known as the High Plains, extends into the northern and western parts of Barber county. The surface breaks off sharply where the streams have cut westward into this upland area and because of the variation in resistance of the strata and the semi-arid nature of the climate, mesas, buttes, and canyon-like valleys develop as the land erodes (fig. 3). Such topography is quite different ~~xx~~ from that throughout most of Kansas, and resembles more the



FIGURE 3A

Figure 3. A--The benches in the foreground are caused by the resistant sandy beds in the Flower Pot shale, the buttes are capped by the Medicine Lodge gypsum, and the even sky-line in the distant background is the undissected High Plains.

B--The flat area in the foreground is developed on the top of the Cedar Hills sandstone. The mesa in the background is developed on resistant sandstones near the top of the Flower Pot shale.

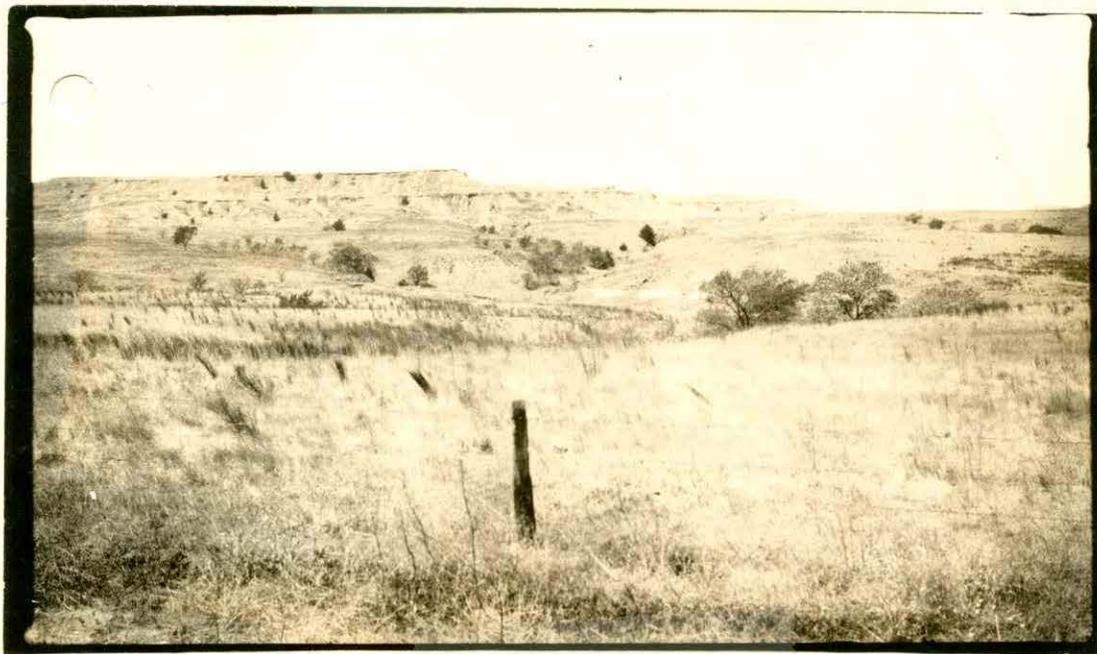


FIGURE 3B

topography of the Colorado Plateau region. The terms "scarped plains" and "Plains border" are applied to the ^{belt of hills} ~~hilly belt~~ fringing the eastern escarpment of the High Plains. Most of Barber county has mature topography (fig. 4). In the northeastern part of the county the surface is characteristically that of the undissected High Plains and in the eastern and southeastern parts, areas of low relief have been produced by alluvial material being deposited in, and partly filling old valleys. The maximum relief is about 800 feet; the highest point in the county is in the uplands seven or eight miles southwest of Sun City where the elevation is slightly above 2,000 feet, and the lowest is along Medicine Lodge river southeast of Kiowa.

Drainage. All the larger streams in Barber county flow in a southeasterly direction and are a part of the Arkansas River system. Sand creek in the northeastern part of the county turns more nearly east after it leaves Barber and enters Kingman county and with several other small streams forms Chikaskia river. Medicine Lodge river follows a diagonal course from the northwest to the southeast corners of Barber county. This river with its principal tributary, Elm Creek, drains most of Barber county. Salt Fork creek and its tributaries

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Figure 4. Relief model

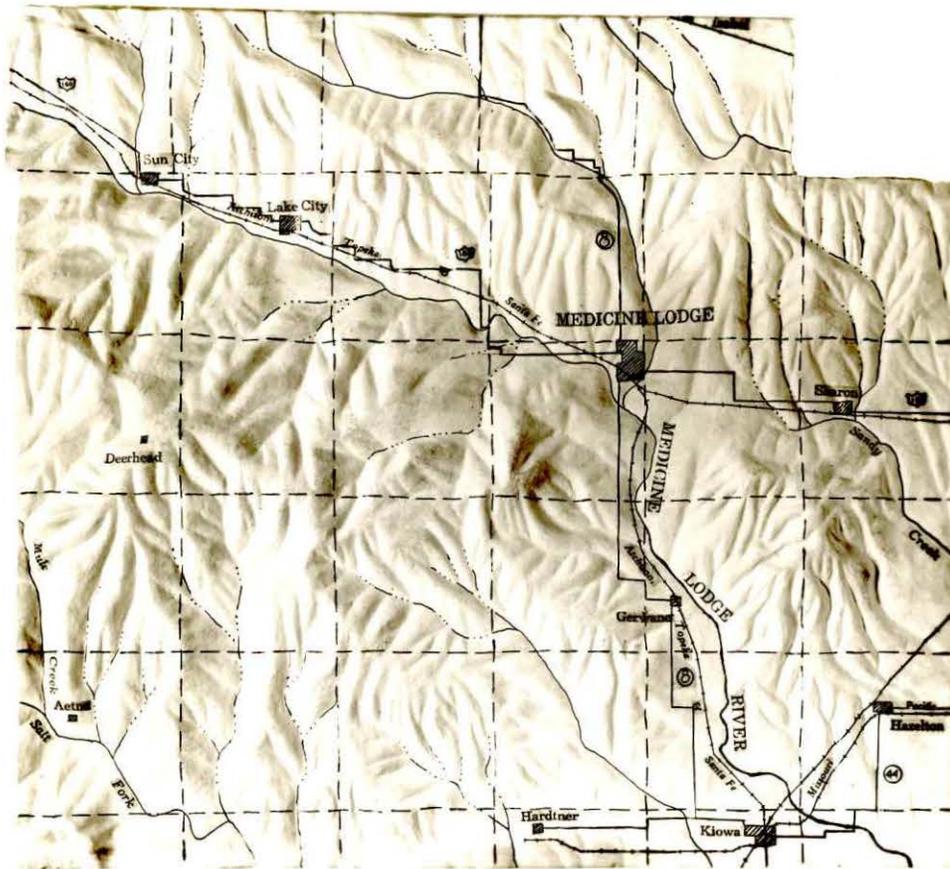


FIGURE 4

drain the southwestern part of the county. Salt Fork creek and Medicine Rodge river unite to form Salt Fork of Arkansas river.

PHYSIOGRAPHY

Valley Shape. The floors of most of the valleys in Barber county are comparatively broad and flat, ^{In transverse section they are} and approximately level ~~in trans-~~
~~verse direction~~, even though the gradient of the stream may be moder-
ately high. ^T The valley sides rise in terraces rather than in con-
tinuous slopes. The terraces in many cases are wide compared to the
size of the valley, ^T and their escarpments are steep, some being es-
sentially vertical. The valleys have the same general shape regard-
less of the rock formation exposed. Most of the terrace levels in the
consolidated rocks correspond to the upper surfaces of the more res-
istant strata. In the Tertiary formation terraces have been developed
on the "mortar beds" where they are present; however, the terrace-
levels throughout most of the extent of this formation are grass-
covered flats. ^T The heads of the valleys are broad and rounded forming
amphitheater-like depressions. The resulting drainage has a coarse
dendritic pattern rather than the intricate pattern developed in humid
regions.

The valley of Medicine Lodge river is asymmetrical, ^{the} slope of the south side ^{is} ~~being~~ steeper than that of the north. This condition is very marked from the town of Medicine Lodge upstream to Sun City. Cragin pointed out that not only Medicine Lodge river but also many

—/ Cragin, F. W., The Permian system in Kansas: Colo. College Studies, vol. 6, p. 29, 1896.

other easterly-flowing streams of the Plains ~~region~~ flow in asymmetrical valleys. Bass noted this asymmetry and expresses the opinion

—/ Bass, N. W., The geology of Cowley county, Kansas: Kansas Geol. Survey, Bull. 12, pp. 17-23, 1929.

that important and perhaps the chief causes of the condition are, first, the more rapid cutting down of the north than of the south slope by weathering and erosion, and, second, the forcing of the river southward by deposition along its north side of the material eroded from the slope above.

In addition to the terraces which have been developed upon resistant strata, most of the valleys in Barber county contain terraces formed by the incomplete removal of valley fillings ^{which} ~~that~~ are flood-plain deposits previously made by the streams. Terraces of the latter

type occur throughout Kansas. Figures 5A and 5B are views in one of the valleys that was partly filled and from which the filling is now being removed by the ^{intermittent} ~~stream~~ stream which flows only after ^a ~~the~~ rain~~s~~.

The physiographic relations here shown apply to nearly all of the valleys in the county for very few of them contain permanent streams.

The picture shown in figure 5A was taken looking up the valley. In the background near the head of the valley, and on either side, are hills of Permian rocks. The plain in the center of the picture is the upper surface of the valley filling which is seen in section in the foreground where the stream has cut an inner gorge-like valley in the filling. The section at this point is about 15 feet thick.

(1) ✓ The gradient of the valley is high down the slopes of the hills; it decreases sharply on the old flood plain across which the stream follows a meandering course, and increases to almost vertical where the stream drops into the inner valley. The valley filling stands at very high angles and large quantities of it shear off and are carried away during every hard rain.

In figure 5B the picture was taken in the bottom of the inner valley. A point of the Permian bed-rock that was covered by the old flood-plain

Figure 5. A--Valley partly filled by old flood-
plain deposits that are now being eroded. B--Valley cut
in old fill re-exposing Permian.



FIGURE 5A



FIGURE 5B

deposits has been re-exposed and can be seen projecting from the wall in the left foreground. All the other rock is valley filling. It extends up to the higher surface seen in the background. The valley bottom is flat, being a small flood plain of the present stream.

In some cases the streams have not yet reached grade but have cut down to and are eroding the Permian ^{rocks}. The old flood plains and the terraces left by their erosion ^{in most cases} commonly extend for several miles along the valleys. The terraces are as much as 30 feet above the valley bottom in many places. Some of the valleys contain remnants of another of these valley fills occurring above the one that is so well preserved at present.

Oil and Gas. For many years the search for oil or gas in Barber county was fruitless, although test holes were drilled at various points throughout the county. In most of these drill holes there were showings of oil and gas. Some of them had considerable quantities of gas but not enough to make a profitable well under the conditions then existing. However, in 1927 a well was drilled in sec. 15, T. 33 S., R. 13 W. that struck a strong flow of gas that increased as the well was deepened until the open flow is reported to have been about 20 million cubic feet per day. More drilling followed ^{which} and led to the development of a gas field, known as the Medicine Lodge field, covering an area that is about 3 miles from north to south and 2 miles from east to west. Within this area there are ^{eight} gas wells, the estimated open flow of the various wells ranging from 1 to 100 million cubic feet per day, and six tests, reported as dry holes.

The following table gives the name, location, depth, and reported results for all the deep wells in the county upon which the writer was able to obtain information.

Wells in Barber county

<u>Name</u>	<u>Location</u>	<u>Total depth</u>	<u>Reported results</u>
C. E. Pickens No. 1	Gen NL NE. $\frac{1}{4}$ 27-30-14W.	4735 $\frac{1}{2}$	Dry
Hastings No. 1	SW cor SW. $\frac{1}{4}$ 30-30-14W.	4740	Dry ?
Hargis (or Coats)	NE. $\frac{1}{4}$ SW. $\frac{1}{4}$ NE. $\frac{1}{4}$ 33-30-14W.	3385	Dry
Kumberg No. 1	SEC SW SE 2-30-12W.	4825	Dry

Morrissee Estate No. 1	NW cor. SE. $\frac{1}{4}$ SE. $\frac{1}{4}$ 9-30-12W.	4,873	Dry
Gibson No. 1 (?)	SE. $\frac{1}{4}$ NE. $\frac{1}{4}$ SE. $\frac{1}{4}$ 10-30-12W.	3,048	Dry
Gibson No. 2	11-30-12W.	3,142	Dry
E. H. Moore No. 1	12-30-12W.	2,986	Dry
Tincher No. 1	NW. cor. SE. $\frac{1}{4}$ NW. $\frac{1}{4}$ 14-30-12W.	4,318	Dry
Winters No. 1	Cen. E/2 17-31-12 W.	4,530	Dry
Ott No. 1	Cen. of SE. $\frac{1}{4}$ 35-32-14 W.	4,506	Dry
Hillard No. 1 (Powell)	Cen. SE. $\frac{1}{4}$ SE. $\frac{1}{4}$ 11-32-10W.	4,868	Dry
Lonker No. 1	c SW. $\frac{1}{4}$ SE. $\frac{1}{4}$ 1-33-13 W.	4,780	Dry
Carter No. 1	c SE. $\frac{1}{4}$ SE. $\frac{1}{4}$ 2-33-13 W.	3,880	Dry
Carter No. 3	Cen SE. $\frac{1}{4}$ SE. $\frac{1}{4}$ 2-33-13 W.	5,145	Dry
Carter No. 1	NW SE SE SE 2-33-13 W.	3,880	Dry
Rule No. 1	Cen. W. $\frac{1}{2}$ 10-33-13 W.	5,163	Dry
Carter No. 4	NE. $\frac{1}{4}$ SW. $\frac{1}{4}$ NE. $\frac{1}{4}$ 11-33-13 W	4,927	Dry
Carter No. 2	Cen. NE. $\frac{1}{4}$ SE. $\frac{1}{4}$ 11-33-13 W.	4,541	45,000,000' Gas
Lytle No. 1	NE. cor. NE. $\frac{1}{4}$ SW. $\frac{1}{4}$ 12-33-13 W.	4,650	100 M ft. gas
Lytle No. 2	NE NW NW NW 12-33-13 W.	4,580	5,000,000 ft. gas
Alexander No. 1	SE. cor. 13-33-13 W.	4,470	5,000,000 ft. gas
Angell No. 1	Cen SW. $\frac{1}{4}$ NE. $\frac{1}{4}$ 14-33-13 W.	4,637	8 M. gas
Angell No. 2	Cen. NE. $\frac{1}{4}$ NE. $\frac{1}{4}$ 23-33-13 W.	4,506	1 M. ft. gas
Hamblin No. 1	Cen. SW. $\frac{1}{4}$ NW. $\frac{1}{4}$ 24-33-13 W.	4,528	19 M. gas
Root No. 1	Cen. N. $\frac{1}{2}$ SW. $\frac{1}{4}$ 24-33-13W.	4,894	Dry
Alexander No. 1	Cen. NW. $\frac{1}{4}$ 24-33-13 W.	4,465	27 M. gas
Alexander No. 1-B	SW. $\frac{1}{4}$ NE. $\frac{1}{4}$ SW. $\frac{1}{4}$ SW. $\frac{1}{4}$ 7-33-12W.	5,102	Dry
Boggs No. 1	Cen. SW. $\frac{1}{4}$ 19-33-12 W.	6,185	Dry
R. B. Temple No. 1	SE. $\frac{1}{4}$ SE. $\frac{1}{4}$ NE. $\frac{1}{4}$ 13-34-15 W.	5,664	Dry
Dave Blunk No. 1	Cen. NE. $\frac{1}{4}$ NW. $\frac{1}{4}$ 20-34-13 W.	5,395	Dry
Circle No. 1	NW. cor. SW. $\frac{1}{4}$ NW. $\frac{1}{4}$ 24-34-11 W.	2,210	Dry

must be done

Wheeland No. 1	Gen. NW. $\frac{1}{4}$	32-31-11W.	4,426	140 bbls. per d
John George No. 1	Gen. SE. $\frac{1}{4}$	SW. $\frac{1}{4}$ 12-33-10W.	4,982	Dry
Davis No. 1	NE. cor.	13-34-15W.	2,865	Drilling
Morrisse No. 1	Gen. SE. $\frac{1}{4}$	NE. $\frac{1}{4}$ 23-30-10W.	Rig up	
Skinner No. 1	SE. $\frac{1}{4}$	NW. $\frac{1}{4}$ NW. $\frac{1}{4}$ NE. $\frac{1}{4}$ 29-31-14W.	Rig up	

The gas in the Medicine Lodge field comes from a porous zone above the Mississippian limestone, the depths to the producing horizon varying from 4,447 to 4,566 feet. ~~The location and the estimated open flow of the wells in the field are shown in Figure 22.~~ The variation in the size of the wells is ~~very~~ great in comparatively short distances and the distribution of the larger producers is quite irregular. In many areas the amount and the character of the material that occurs just above the Mississippian limestone is known to be extremely variable. These facts suggest that differences in the porosity or the amount of the reservoir rock rather than irregular structural conditions are the cause of the distribution of the gas as it is in the Medicine Lodge field. Where such variable conditions exist the cost of development is unavoidably high, because of the large percentage of dry holes compared to the number of profitable wells.

The gas is under a pressure of about 1,400 pounds per square inch. The *initial* output from the larger wells will, therefore, be very great. However, the length of their productive period cannot yet be judged. The small area covered by the present known field, which is practically surrounded by dry holes, and the irregular geologic conditions which commonly exist just above the Mississippian limestone suggest the possibility that the gas ^{is} ~~may be~~ coming from a comparatively small reservoir that ^{may} ~~ends~~ abruptly either by a change in porosity or by the beds

pinching out. If such be the case, the wells cannot have a long life. However, with such variable geologic conditions the field may continue farther than the dry holes indicate, thus giving a larger reservoir and consequently a longer period of production.

The gas from the Medicine Lodge field contains a considerable amount of gasoline. It is removed at an extraction plant just southeast of Medicine Lodge (Fig. 24).

STRATIGRAPHY

Surface Formations

The consolidated rocks exposed in Barber County belong to the Cimarron group of the Permian system and to the Comanchean ^{group of the Cretaceous} system. An area several miles wide extending across the northern part of the county and also the higher divides in the west central part are covered with sands and gravels of Tertiary age. They are poorly cemented and can hardly be classed as consolidated rocks. The Quaternary deposits include the present river flood plains, sand-dunes along some of the streams, and the older valley fillings.

Give stratigraphic section.

QUATERNARY SYSTEM

lc
Flood plain deposits. Most of the rock formations in Barber County are rather easily eroded by the ^{*run-off following the*} hard, somewhat torrential type of rains that frequently occur in the region. Hence the uplands are rapidly cut away at many points and the lower parts of the streams are overloaded repeatedly. As a result, flood plains have been and are being formed in all the major and many of the minor valleys, even where the gradient is quite high. The deposits are composed of sand and gravel from the Tertiary and of fine sand, silt, and fragments of gypsum derived from the Permian formations.

Sand dunes. There are sand dunes along Salt Fork creek south of Aetna formed by sand from the flood plain of the river. ~~Sand~~ Dunes also occur along several of the small streams in the northeastern part of the county, and on the high Tertiary covered area just east of Deer Head. The sand that forms the dunes near Deer Head was obtained directly from the Tertiary deposits, by the wind. That in the dunes along the small streams was washed out of the same formations by the water and subsequently piled up by the wind. No migrating dunes were observed. The vegetation appears to be sufficient to prevent the sand from shifting very much.

Gerlane formation. The deposits of valley filling and surface wash are of such wide distribution, great thickness, and economic importance that they have been classed as a formation. The name Gerlane was chosen from the village of the same name on Medicine Lodge River in the southeastern part of Barber county.

Robert Hay described various Quaternary deposits in Barber

Hay, Robert, A geological reconnaissance in southwestern Kansas:
U. S. Geol. Survey, Bull. 57, pp. 39-48, 1890.

county, some of which are unquestionably included in what is here described as the Gerlane formation. He classified them under the headings: "The Earlier Gravel", "The Loess", and "The Alluvium". The identity of the several types of deposits that he described is difficult to establish definitely, but from field examination the writer believes they grade into each other and are local facies of the general alluvial formation. Whether or not Hay considered

the "Loess" to be eolian is not clear from the context of his paper. The broad areas covered by alluvial deposits would have been an ideal location for wind work, and there is considerable material in the Gerlane that has probably been reworked to some extent by the wind. The amount of wind work was not sufficient to impart eolian rather than alluvial characteristics to any considerable quantity of the formation.

Description of formation. The Gerlane formation is a fluvial deposit that occurs in the valleys and on the lower slopes of the hills. The material of the formation varies in size from clay to gravel, the major part being in the finer grades of this range. A layer of coarse fragments commonly occurs at the bottom of the formation. Noticeable cementation of the fragments was seen in very few places. Erosional cuts in the finer material stand with loess-like steepness (Pl. B). The thickness of the Gerlane formation varies from zero at its margins to a known maximum of 104

feet. The latter thickness was revealed by core drilling on the plain south of the town of Sharon. The formation is about 60 feet thick in the Medicine Lodge river valley near Kiowa, and at least 57 feet thick in the valley of a tributary to Elm Creek at a point about 8 miles north of Medicine Lodge.

Sediment derived from the erosion of the older surface rocks, chiefly the Permian and Tertiary, has been reworked and redeposited to form the Gerlane. Hence its character varies from place to place and at any particular location may resemble either the Permian or the Tertiary formations, depending upon which of them supplied the major part of the sediment. Where Permian rocks have supplied most of the materials that make up the Gerlane formation, it is red and fine-grained like the Permian, but can be distinguished from the latter by the presence of coarse sand grains derived from the Tertiary and by the fact that bedding follows the sloping surface upon which deposition occurred. Where the Gerlane is composed primarily of material from the Tertiary, the resemblance of the two formations may be quite close. As a rule, however, the Gerlane occurs at much lower elevations and has more distinct bedding and cross-bedding than does

the Tertiary. *Cur Part 71218022* ✓ Such an occurrence, situated on the east side of the road in the southwest corner of sec. 32, T. 31 S., R. 11 W., is shown in figure 7. The gravelly cross-bedded Gerlane is in contact with the Cedar Hills sandstone at an elevation more than 100 feet lower than the base of the Tertiary a few miles to the northeast.

Occurrence and Deposition. The Gerlane may be divided into two types of deposits on a basis of topographic position. One type occurs as fillings in the valleys, giving them broad flat bottoms. The other type forms deposits of surface-wash coating the lower slopes of the hills. The deposits in the valleys are much thicker and control the present topography more than do those on the slopes. The writer believes, however, that this two-fold division is primarily the result of deposition upon an irregular surface and of later erosion, rather than of any fundamental difference in the processes that formed the deposits.

The slope of the uneroded surface of the Gerlane formation ^{*in the valleys*} indicates that the depositing streams reached grade because of excessive load rather than slow current. The slope a few miles from the major streams is about 75 feet drop per mile. The farther up the valley the deposit extends, the steeper the surface slope becomes. It

Fig. 7.--Cross-bedded gravelly Gerlane overlying
the Cedar Hills sandstone in sec. 32, T. 31 S., R. 11 W.



represents the profile of grade of the water that brought the sediment down from the hills. The land must have had at least as much relief when deposition occurred as it has now. The Gerlane that is present in the valleys has essentially the same surface slope, regardless of the direction of the valleys. This is well illustrated in the Cedar Hills southwest of the town of Sharon, an area in which the valleys radiate from a central high point and the Gerlane formation in them slopes outward equally in all directions. Evidently these valley deposits could not have been caused by a depressing or a tilting of the region.

The writer believes that the principal cause of this extensive deposition was a change in climate. During a period of time the rainfall occurred regularly enough and at such rates that the streams could erode and form the valleys. Then came a change giving torrential rains alternating with periods of little precipitation. During the rains more rock material was washed from the steep, deeply-weathered hillsides than could be transported away from the area. Part of this material was left on the lower slopes of the hills over which some of the water probably flowed as a sheet flood, and the remainder was carried on to the valleys

where it was deposited because the streams were overloaded. Gradually the entire system of valleys was aggraded until the lower parts of the larger tributary valleys were filled to such an extent that they could no longer hold the streams during flood periods. At such times the water spread over the entire lower slopes of the hills and flowed down to the major valleys, aggrading the surface over which it flowed. Eventually the deposits formed a sheet that covered the major valleys and the lower slopes of the ridges, with tongues that extended far up the tributary valleys toward the divides.

Later erosional features. When conditions changed so that the streams were again able to degrade the land, they incised themselves into the alluvial material that had choked and filled their valleys. The drainage lines in most cases were not changed much from their former courses, especially in the upper parts of the valleys, for the latter were only partly filled. Many examples may be seen, however, where the present drainage has a somewhat different course than the pre-Gerlane drainage had, and cross-sections of filled channels are visible in river banks. (Pl. A).

Because of the high gradient of the streams and the soft character of the Gerlane formation, it is being eroded rapidly and steep canyon-like valleys are ^{developing} in the flat floors of the partly filled older valleys, leaving terraces of Gerlane along the sides (Pl. B). The erosion has revealed the presence of cedar stumps 12 to 15 inches in diameter within the Gerlane, indicating that the rate of aggradation was very slow and perhaps ceased entirely during considerable periods of time. In one case the ground line at the time of growth, as indicated by the position of the roots, is

2 or 3 feet below the present surface and the charred top of this stump is covered by about a foot of sediment. In many places erosion has cut sufficiently deep to re-expose the older bed-rock below. In the lower areas where the alluvium covered the slopes as well as filled the valleys, the present outcrops of older rocks are confined to the places where erosion has removed the Gerlane, principally in the re-excavated or newly formed valleys, leaving the latter formation on the crests of the secondary ridges, sloping down toward the major valleys.

Economic importance. The Gerlane formation is of considerable economic importance for the following reasons: (1) It forms the best farm land, both because of the even surface and the quality of the soil. (2) In the area of outcrop of the Red Beds the Gerlane is the only widespread aquifer yielding water suitable for domestic use. (3) It is also an important and in some places the only local source of sand and gravel.

Age. The exact age of the Gerlane formation is not yet known. It contains many bison bones and a bear skull has been collected from it, but nothing has been recorded that will place its age accurately. Certain topographic and geologic conditions in eastern Barber County indicate that the Gerlane formation is much younger than the Tertiary deposits. The plain south of Sharon, where the Gerlane is known to be at least 104 feet thick, is about 4 miles wide and has an elevation of about 1,500 feet. Cedar Hills, which is south of the plain, reaches an elevation of 1,700 feet and is capped by an outlier of Tertiary. North of the plain the crest of the main ridge, approximately 11 miles from the top of Cedar Hills,

is covered by Tertiary and rises to an elevation of about 1,775 feet. After the deposition of the Tertiary, erosion must have formed a valley 10 or 11 miles wide at the top and at least 375 feet deep before the deposition of the Gerlane formation began. The valley was probably deeper than the figure given, because some of the Tertiary has undoubtedly been removed from the hilltops since deposition in the valley began. Approximately the lower 200 feet of the valley was cut in Permian rocks. Because of similarity of occurrence and of various other characteristics, *the Gerlane* its ~~age~~^{age} is thought to be about the same ~~as that of~~ the McPherson formation ("Equus beds"), described by Haworth and Beede and classified as Late Pleistocene by Williston.

Haworth, Erasmus, and Beede, J. W., The McPherson Equus beds: Kansas Univ. Geol. Survey, vol. 2, pp. 287-296, 1897.

Williston, S. W., The Pleistocene of Kansas: Kansas Univ. Geol. Survey, vol. 2, pp. 299-308, 1897.

Medicine Lodge River. Conditions seem to indicate that Medicine Lodge River has changed its course near the town of Medicine Lodge and the extensive deposition that occurred during Gerlane time is thought to have been the chief cause of the change. The river enters Barber County near the northwest corner and flows approximately S. 70 degrees E. as far as Medicine Lodge, where it turns sharply and flows almost south for several miles. It turns back to a more easterly course a few miles north of the town of Kiowa. The general trend of the valley is quite straight from the point where the river enters the county to where it turns south near Medicine Lodge, a distance of about 28 miles. Throughout this

TERTIARY SYSTEM

Sands and gravel of Tertiary age cover the bed rock over a considerable portion of the northern and northeastern parts of the county, and cap the higher divides throughout the western part. The outlier on top of Cedar Hills southwest of Sharon indicates that before removal by erosion these deposits extended as an unbroken sheet over Barber county and probably much farther to the southeast.

The Tertiary formation in Barber county is white, tinted with gray, pink, or light-buff depending upon the local composition. The formation consists chiefly of beds of unconsolidated sand and gravel. In most cases there is no sharp break between the various strata but the changes of size of grain are gradational. Clay beds occur at various horizons in the formation and are typically accompanied by numerous nodules of calcium carbonate. No persistent well developed mortar beds are present in the Tertiary of Barber county although the clastic material is cemented by calcium carbonate in some exposures. The sand and gravel are composed of fragments of quartz, granite and other igneous rocks including highly oxidized basaltic types, quartzite, chert, and sandstone that has been thoroughly cemented with iron oxide. The

pieces of sandstone are dark-brown or black in color and look very much as though they came from the Dakota sandstone. Fragments of petrified wood are quite common in the gravel. Most of the pebbles and coarse sand is rounded but the fine sand is sharp and angular.

?

Section of the Tertiary exposed in sec. 39, T. 31 S., R. 10 W.

12-15 feet coarse sand and gravel. Fragments on surface up to 8 inches in diameter, and decrease in size downward. Brown shaly zone in lower part on which occurs nodules of Ca CO_3 .

15-20 feet sand becoming shaly at base. Sand stained with iron oxide.

A 5 to 7 foot well developed mortar bed occurs about the middle of this zone.

10 feet clay that becomes sandy toward base. This zone contains a large amount of Ca CO_3 . A resistant horizon that forms shoulders on the hills.

75 feet clayey and gravelly sand. Most of the sand is medium fine. Zones in which the sand is stained with iron oxide occur throughout this part of the section. They are more abundant in the bottom portion. Minor clay zones accompanied by Ca CO_3 nodules distributed through the sand. About two feet above the base is a layer of light gray sticky clay underlain by a foot or 18 inches of friable sand below which is ^{the} basal sand zone that contains a large amount of iron oxide.

This section is typical of most of the Tertiary throughout the area. The occurrence of the clay and the zones rich in iron oxide near the base of the formation is quite characteristic, as is also the presence of large fragments on top of the ridges. Rocks ten inches in diameter were observed capping a hill in sec. 10.

T. 34 S., R. 13 W. The section given is as thick as any that could be measured accurately. However, 191 feet of Tertiary was penetrated by a well in sec. 2, T. 30 S., R. 12 W. The thickness of the formation as given by well logs is as follows:

191 feet in sec. 2, T. 30 S., R. 12 W.

90 feet in sec. 10, T. 30 S., R. 12 W.

96 feet in sec. 9, T. 30 S., R. 12 W.

134 feet in sec. 11, T. 30 S., R. 12 W.

172 feet in sec. 12, T. 30 S., R. 12 W.

100 feet in sec. 14, T. 30 S., R. 12 W.

124 feet in sec. 27, T. 30 S., R. 14 W.

90 feet in sec. 35, T. 31 S., R. 14 W.

No accurate surface elevations of these wells are available and much of the variations in the thickness of the Tertiary is undoubtedly caused by differences of these elevations. The first two thicknesses given are from wells that are only a little more than one mile apart and both are well north into the area of the Tertiary rocks, where the surface is gently rolling and the local relief is not great. From the topographic base map and from observation, the variation in surface elevation probably does not account for more than ⁵⁰ ~~fifty~~ of the ¹⁰⁰ ~~one hundred~~ feet difference in the thicknesses of the Tertiary at the two wells. Hence it appears probable that the surface upon

which this formation was deposited had noticeable relief. The last well recorded, the one in sec. 35, T. 32 S., R. 14 W., is located on top of a high ridge and the thickness of 90 feet is probably as great as any that now exists in the dissected central part of the county.

The exact age of the Tertiary formation in Barber County is yet to be determined. There is some possibility that it is of Quaternary age, but because of the similarity to the Tertiary of the Great Plains the writer has classed the deposit as Tertiary. The scarcity of mortar beds, the presence of coarse material at the top, and the absence of characteristic Ogallala fossils in the deposit indicate that it is probably not of Ogallala age. The writer found no fossil remains in the formation although the occurrence in it of teeth and tusks of the large vertebrates was reported.

✓
COMANCHEAN SERIES

The Comanchean rocks in southern Kansas outcrop in Barber, Kiowa, Comanche, and Clark counties. The age and the detailed stratigraphy of the series in this area has been the subject of much study by various writers beginning at least as early as 1878 with the work of Mudge. The most comprehensive of the early reports

1/ Mudge, B. F., Kansas State Board of Agriculture, First Biennial Report, p. 47.

2/ is by Prosser, in which he reviews the earlier work and gives a large amount of in-

3/ Prosser, C. S., Comanche Series of Kansas: Kansas Geol. Survey, vol. 21, pp. 96-181, 1897.

formation concerning the distribution and the stratigraphy of the formation.

4/ Twenhofel has restudied the rocks of the Comanchean series and presents additional

5/ Twenhofel, W. H., Geology and Invertebrate Paleontology of the Comanchean and "Dakota" Formations of Kansas: Kansas Geol. Survey, Bull. 9, 1924.

facts concerning their character and origin. He makes some changes in the group-

ing of the various stratigraphic units and divides the Comanchean rocks of

southern Kansas into two formations, the Cheyenne and the Belvidere. The

6/ Idem, p. 12.

Belvidere formation, which overlies the Cheyenne, consists of three members which

in ascending order are the Kiowa shale, the Spring Creek member, and the Greenleaf

member.

Cheyenne sandstone. The Cheyenne sandstone, named by Cragin from

Cragin, F. W., Contributions to the paleontology of the Plains:

Bull. Washburn College Lab. Nat. Hist., vol. 2, no. 10, p. 65, 1889.

Cheyenne rock near Belvidere, Kansas, is the basal formation of the southern Kansas Comanchean strata and is the only one well exposed in Barber county. The distribution of the Cheyenne sandstone shown on the geologic map accompanying this report is less extensive than is given by most of the older maps. Prosser recognized the fact that the

Op. cit., p. 136.

areas shown as Comanchean on the maps of that time, and essentially the same distribution has been shown on those made since, was probably incorrect. Concerning the area east and southeast of Deer Head he states: "It is probable that over some of this area the pre-Tertiary erosion has removed all of the Comanche and a portion of the upper part of the Red Beds, so that the line indicated as the outcrop of the Comanche does not represent the actual position of that series."

The Cheyenne was deposited upon an erosion surface from which had been removed large and varying amounts of the Permian strata. Eastward this erosion had cut progressively lower into the Permian section so

that the Cheyenne overlapped onto older and older beds. The Medicine Lodge gypsum and its basal dolomite bed was one of the horizons that most effectively resisted erosion. Terraces and mesas were developed at this horizon much as they have been ^{developed} during the present cycle of erosion. At various points across the northern part of Barber county, especially in Range 14 West, small patches of sandstone a few feet in extent rest upon the Medicine Lodge dolomite at the edge of steep bluff-like slopes, with the Dog Creek shale forming the gentle slopes above. A study of the mineral assemblage and of the type of grains in these sandstones proves beyond much question that they are remnants of the Cheyenne. Other small isolated bodies of this sandstone occur along the ridge east and southeast of Deer Head. These outliers are not shown on the map because of their small size and discontinuity. Large boulders of white quartzitic sandstone, 3 to 4 feet across, are present on top of the high ridge in sec. 16, T. 32 S., R. 13 W. They appear to be erosional fragments from the Cheyenne sandstone and indicate that the formation previously extended at least that far east. Twenhofel[/] noted this quartzitic

PHASE of the Cheyenne. He wrote: "As a rule the sandstones are poorly cemented, but locally they are quartzitic."

The Cheyenne sandstone in Barber county is primarily white with tints and bands of all the colors that can result from iron oxide staining. Cross-bedding is abundant throughout the formation. It weathers into fantastic shapes because of the irregularity of cementation, forming isolated pinacles and "rocks" standing above the surrounding surface. Fossil leaves and fragments of wood occur at various horizons. The characteristics throughout are those given by Cragin, Prosser, and other early writers, and more recently by Twenhofel. The maximum thickness of the Cheyenne observed in Barber county is 55 feet in sec. 30, T. 31 S., R. 15 W.

5

The sandstone contains very little feldspathic material. Fragments of granite are present in the coarser phases but ~~they~~ are much less abundant than are pebbles of quartz, quartzite, and weathered chert. The finer portions consist almost entirely of quartz. The greater part of the formation is made up of medium-sized to very fine grains, but near the bottom local beds of gravel occur in which some of the pebbles are $1\frac{1}{2}$ to 2 inches in diameter. A gravel bed in the Cheyenne in sec. 18, T. 30 S., R. 15 W. is shown in ~~fig.~~ ^f 8. Note also the steep cross-bedding of some strata. ^{g/} Twenhofel gives a mechanical analysis of the sands of the Cheyenne sandstone, showing their grade and composition. ~~Throughout~~

^{g/} Op. cit., pp. 42-45.

~~most of the formation the coarser grains are frosted and somewhat roundish, although a high degree of rounding is not common. Many grains, both large and small, have well developed bright crystal faces and edges. These may in part have been present on the grains before deposition but in some cases appear to have resulted from later crystal growth.~~

Throughout much of the formation the larger quartz grains show a fair degree of rounding although spherical grains are not common. The roundish grains have polished and frosted surfaces. Many grains, large and small, have well developed crystal faces and edges. In some cases the edges have been worn off somewhat round but in others the faces are ~~light~~ ^{high} and the edges sharp.

Figure 8. Gravel bed in Cheyenne sandstone in
sec. 18, T. 30 S., R. 15 W.



FIGURE 8

The latter type are believed to have been formed by crystal growth since deposition. Some of the frosting of the surfaces is also thought to have been caused by deposition of silica, and perhaps to be a stage in the process of crystal growth, for grains were studied which exhibited the common frosted appearance but upon rotation one observed small plane surfaces developed at scattered points on top of the frosting. The surfaces appeared to be parallel and to be portions of a crystal face or faces. Roth^B observed the same type of

—/ Roth, Robert, Evidence indicating the limits of Triassic in Kansas, Oklahoma, and Texas: Jour. Geology, vol. XL, no. 8, pp. 719-720, 1932.

frosting on grains of the St. Peter sandstone. The surfaces of many very angular grains are frosted, some of them being quite small. If they underwent enough erosion to mechanically frost the surface it seems probable that they would have suffered some rounding. Numerous grains were observed whose surfaces are part frosted and part bright. The bright parts occur as isolated spots. In some cases they are slightly depressed below the surrounding frosted part as though they might be points at which two grains were in contact during the time

that deposition of silica coated the rest of the surface. Such areas of contact would remain as pits after the grains have been separated.

Lamar noted similar pits in grains of the St. Peter sandstone.

Lamar, J. E., Geology and economic resources of the St. Peter sandstone of Illinois: Illinois Geol. Survey, Bull. 53, p. 49, 1928.

In other cases there appears to be little difference in the elevation of the frosted and the bright parts of the surface. No grains were observed in which the original surface surrounded by the secondary growth could be detected. However, this ^{condition} ~~phenomena~~ would probably not be evident unless the grain was coated with iron oxide or some other stain before enlargement occurred.

Kiowa shale. Fragments of the shell beds of the Kiowa shale were widely distributed over Barber county by the streams that formed the Tertiary deposits and are incorporated in the basal part of the latter formation. As a result, considerable quantities of Kiowa fossils are present in positions that have no significance as far as the location of the present outcrop of the Kiowa shale is concerned. All the students of the area have observed this distribution, and Prosser, recognizing

Op. cit., p. 137.

the lack of relation between the outcrop and the loose fossils in the vicinity of Deer Head wrote: "It is probable that former erosion has swept away nearly, if not quite all, of the Kiowa shales and perhaps part of the Cheyenne, so that the Comanche series is represented by only about 21 feet."

The Kiowa shales are well exposed a short distance west of Barber county in northeastern Comanche and southeastern Kiowa counties, but thin to the south and southeast from the vicinity of Belvidere at the rate of about 10 feet to the mile, as is shown by Prosser's sections. The only outcrop of the Kiowa observed in Barber county is in sec. 6, T. 30 S., R. 15 W. At this point there are about 15 to 20 feet of black fissile shale with the associated thin shell beds overlying the variegated sandstone and shale of the Cheyenne. The area covered by the outcrop is too small to be shown on the map. At a few other locations, one of which is in sec. 9, T. 30 S., R. 15 W., dark-colored shales outcrop, which have been classed as Kiowa by some observers. But because of the character of the shale, the absence of the shell beds, and the associated occurrence of variegated shale and sandstone,

the writer believes the dark shales belong to the Cheyenne sandstone.

Prosser [/] cites a similar occurrence of dark shale in the Cheyenne along

[/] Op. cit., p. 138.

Mule creek in northeastern Comanche county.

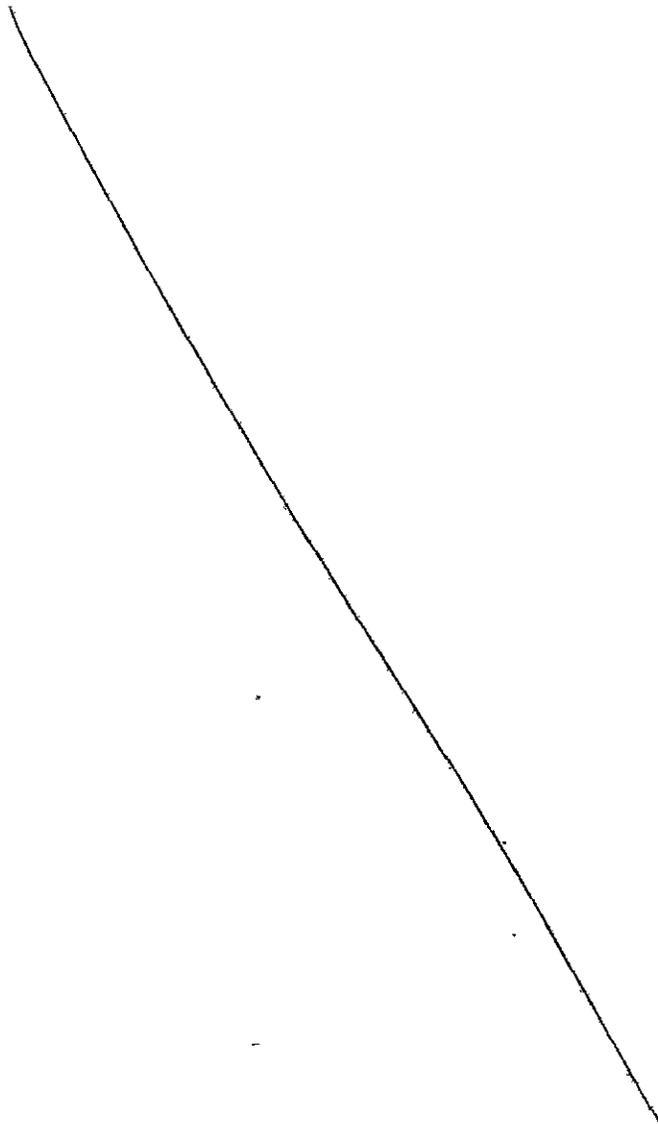
PERMIAN SYSTEM

General. All the Permian rocks exposed in Barber county belong to the Red Bed phase, the upper part, of the system. Rocks of this series, the Cimarron, outcrop in southern Kansas in an area that is roughly triangular in shape. The northern apex of the triangle is in the vicinity of Hutchinson in Reno county and the base extends along the Kansas-Oklahoma line from western Sumner county to the west side of Clark county. East of this area the underlying marine Permian formations are exposed and to the west and northwest the Red Beds are covered by Cretaceous and Tertiary rocks. The Red Beds and their equivalents extend south and southwest and form a part of the great series that underlies so much of Oklahoma and Texas.

The maximum thickness of the red strata in Kansas, as indicated by well records in Meade and Clark counties, is at least 1,650 feet. At the outcrop the series consists of interbedded sandstones and shales with several persistent beds of gypsum and dolomite in the upper part. The Cimarron beds in Barber county have the characteristics of subaqueous deposits. They have even-bedding, much of which consists of very fine laminae, beds are traceable for long distances, many horizons of ripple marks that appear to be oscillation ripples are preserved, beds

of dolomite and gypsum are present, and cross-bedding is not as abundant as would be expected if the rocks were of sub-areal deposition. In Kansas these formations are unfossiliferous, indicating that the water bodies in which they were deposited were unsuitable to support life. Hence the deposits cannot be considered to be either normal marine or lacustrine type. The amount of salt and gypsum in the Red Beds suggests that the concentration of these compounds in the water was high. These Cimarron seas appear to have been broad comparative quiet water bodies ^{in which} ~~where either~~ ocean water or surface run-off was concentrated, presumably by evaporation, to such an extent that life could not exist in the water and, at least periodically, the saturation points of dolomite, gypsum, and salt were reached. The presence in the Whitehorse sandstone of Oklahoma and Texas of the so-called "channel sands" which carry a marine fauna indicates that there was some connection with water bodies where marine invertebrates existed. Wells that have been drilled back from the outcrop far enough that the rocks are protected from leaching by surface water have penetrated a number of salt beds in the middle and lower part of the series. The aggregate thickness of the salt beds at various localities varies from 225 to 300

feet. Whether or not the rocks in the area of outcrop once contained equally large amounts of salt that has been carried away in solution is unknown. However, abundant evidence remains that some salt was present.



12
Ranch-men can point out spots in Barber County where, before the land was tilled, the cattle licked the soil to obtain the salt. At various horizons in the rock formations there are casts and molds of cubic crystals that must have been salt.

20 West and southwest of Barber County there ~~are~~ ^{now exist} salt springs ~~at the present~~.

Solution of salt and subsequent slumping of the overlying rocks seems to be the most probable cause of the abnormal dips and contortion of beds that are present at various places in the county.

In any locality the fracturing and bedding of the rocks may be such as to permit deep circulation of the surface water within a limited area. ^{should} If these conditions exist where salt beds are present in the rocks some distance below the surface, the resulting solution of salt would probably produce caves because the overlying rocks could temporarily support their own weight. The ultimate collapse of such caves would produce sinkholes and depressions at the surface. The depressions known as Big Basin and Little Basin in secs. 24 and 25, T. 32 S., R. 25 W., Clark County, Kansas, may have been formed as outlined above. They are flat bottomed and have steep sides that in places are sheer bluffs. Big Basin is somewhat elliptical in plan, its major axis being about a mile long. The floor of each basin is 125 to 150 feet below the surrounding hills. The log of a well drilled in sec. 17, T. 31 S., R. 22 W., which is about fifteen miles from these basins, shows that a salt bed in the red Permian strata 225 feet thick was

reached at a depth of 310 feet. The overlying beds include none that are structurally competent enough that they would be expected to permanently support the rock mass above. The collapse of a cavern resulting from the local removal of such a body of salt could easily produce depressions as large and deep as Big and Little basins.

Cragin suggested the same origin for these basins, although he

Cragin, F. W., Observations on the Cimarron Series: Am. Geologist, vol. 19, p. 361, 1897.

apparently thought that the caverns were developed by solution of salt from the Whitehorse sandstone. This formation is so near the surface in the vicinity of Big and Little basins and it contains so little salt, as indicated by well logs, compared to the depth of the basins that solution from the Whitehorse alone appears to be inadequate to develop caverns large enough to form these basins.

~~reached at a depth of 310 feet. The overlying beds include none that are~~ (#)
~~structurally competent enough that they would be expected to permanently support~~
~~the rock mass above. The collapse of a cavern resulting from the local removal of~~
~~such a body of salt could easily produce depressions as large and deep as Big~~
~~and Little Basins.~~

Previous work. Many early writers on the geology of Kansas contributed

to the knowledge that we now have of the Permian Red Beds in the state. The work of these men has been well summarized by Prosser and the reader is referred

✓ Prosser, G. S., The Upper Permian: Kans. Geol. Survey, vol. II, pp. 75-83, 1897.

to his paper for the account of this early work. Gould published a paper in 1901

✓ Gould, C. N., Notes on the fossils from the Kansas-Oklahoma Red Beds: Jour. of Geol., vol. 9, pp. 337-340, 1901.

in which he gave the evidence upon which the Red Beds of Kansas and Oklahoma were assigned to the Permian and described fossils that had recently been found in the rocks.

Classification. When first studied in southern Kansas the Red Beds were

assigned to the Dakota sandstone. Later they were classified as Triassic or Jura-Trias and still later as Upper Permian. Cragin named and described the rocks

✓ Cragin, F. W., The Permian System in Kansas: Colorado College Studies, vol. 6, pp. 2-5, 1896.

and subdivided them into ten formations as follows:

The Cimarron Series

Divisions	Formations
	Big Basin sandstone
	Hackberry shales
Kiger	Day Creek dolomite
	Red Bluff sandstones
	Dog Creek shales
	^a Cave Creek gypsums
	Flower Pot shales
Salt Fork	Cedar Hills sandstones
	Salt Plains measures
	Harper sandstones.

a
 The Cave Creek gypsums *are* divided into three members, the Medicine Lodge gypsum
at the bottom
 below separated from the overlying Shiner gypsum by the Jenkins shale.

Prosser objected to Cragin's division of the series into ten formations

Op. cit., pp. 82, 94.

on the grounds that the division had been carried farther than the lithologic differences justified and thought that a division into three formations was preferable.

Prosser's Classification

Cimarron series	}	Kiger formation
		Cave Creek gypsum
		Salt Fork formation

Prosser retained the formational names of Cragin, but classed them as sub-formations. He felt, however, that the Big Basin sandstone should be classed as part of the Comanche series.

After a hurried study of the Cimarron series across parts of Oklahoma and Texas Cragin published a revised subdivision of the series that he thought

Cragin, F. W., Observations on the Cimarron Series: Am. Geologist, vol. 19, pp. 351-363, 1897.

would be adaptable to all the occurrences that he had seen.

Classification of the Rocks of the Cimarron Series

Divisions	Formations	Subformations
Kiger	{ Tolga (Taloga?) Day Creek Red Bluff	Quite variable with locality
		None
		None determined
Salt Fork	{ Dog Creek (Stony Hills)	*Chapman dolomite
		*Amphitheatre dolomite
	{ Cave Creek	Shimer gypsum
		Jenkins clay Medicine Lodge gypsum
{ Glass Mountains	Flower Pot shales	
	*Cedar Hills sandstone	
{ Kingfisher	Salt Plain	
	Harper	

*Not known to be clearly recognizable outside of type locality.

After several seasons devoted to the study of the Red Beds of Oklahoma,

Gould revamped Cragin's revised classification to more accurately describe the

lc
Gould, C. N. Geology and Water Resources of Oklahoma. U. S. Geol. Survey, Water Supply Paper 148, pp. 34-77, 1905.

sequence as he had found it. The following table gives the relation between the two classifications.

Cragin's Classification

Classification by Gould

~~Red~~

Quartermaster
~~Quartermaster~~ formation

Tologá (Talogá?)

Greer formation

Mangum dolomite member

Collingsworth gypsum member

Cedartop gypsum member

Haystack gypsum member

Kiser gypsum member

Chaney gypsum member

Day Creek

Day Creek dolomite member

Red Bluff

Woodward formation

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

Gould renamed the Red Bluff sandstone, calling it the Whitehorse sandstone,

because the earlier name was preoccupied.

In the description of the geologic formations of Kansas, Moore adopted

Moore, R. C., Oil and Gas Resources of Kansas, Geology of Kansas: Kans. Geol. Survey, Bull. 6, part 2, p. 54, 1920.

some of the formation names used by Gould, but retained the name Cave Creek for the gypsum-bearing formation. His division of the Cimarron group is as follows:

Group	Formation	Member
Cimarron	Greer	Big Basin sandstone shale
	Woodward	Day Creek dolomite
		Whitehorse sandstone
		Dog Creek shale
	Cave Creek	Shimer gypsum
		Jenkins shale
		Medicine Lodge gypsum
	Enid	Flowerpot shale
		Cedar Hills sandstone
		Salt Plain shale
Harper sandstone		

Moore made note of a reported unconformity between the Day Creek shale

Idem, p. 71.

and the Whitehorse sandstone and suggested that the Dog Creek shale be placed in

the Cave Creek formation if the report was substantiated by subsequent work. Various writers have since expressed the opinion that such an unconformity exists. Roth is one of the more recent supporters of this

Roth, Robert, Evidence indicating the limits of Triassic in Kansas, Oklahoma, and Texas: Jour. Geology, vol. XL, no. 8, p. 688, 1932.

view and he believes that the unconformity marks the break between the Permian and the Triassic systems. He proposes the name Custer for the beds that he considers to be of Triassic age, namely those between the Dog Creek shale and the Comanchean formations. Roth refers to the angular discordance between the Dog Creek and the Whitehorse formations in sec. 18 1/2 T. 30 S., R. 15 W., Barber county, Kansas, in giving evidence supporting his hypothesis. (Fig.). Anderson

Anderson, G. E., The Permian-Triassic problem in western Oklahoma: Jour. Geology, vol. XLI, no. 8, p. 834, 1933.

disagrees with Roth as to the existence of the unconformity and cites field evidence which he considers to be contradictory to certain views held by the latter. He also differs from Roth in the interpretation of various lithologic and structural characters of the rock. Regarding

the occurrence in Barber county, Anderson wrote: "...it should be noted that in this area the Dog Creek is less than 40 feet in thickness. With this thickness and with a dip of only 1° the formation would be entirely removed, up dip, in less than one-half mile. The formation, however, continues throughout the area maintaining its normal thickness. The angular contact, therefore, seems more likely due to cross-bedding, which is of frequent occurrence in the Oklahoma Red Beds." The writer agrees with Anderson as to the probable explanation of the discordant relation between the Dog Creek and the Whitehorse formations. Such relations were observed in none of the many other exposures of this contact seen in the county.

~~the Dog Creek formation if the report was substantiated by subsequent work.~~

~~Various writers have since expressed the opinion that such an unconformity exists.~~

~~However, the writer saw no evidence in Barber County or the adjacent areas to~~

~~indicate that there is an unconformity at this point in the section. Evans~~

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Evans, Noel, Permian beds of Northwestern Oklahoma: Am. Assoc. Petroleum Geologists, Bull., vol. 15, no. 4, p. 419, 1931.

stated that he had never seen the Whitehorse resting in place on any bed lower than the top of the Dog Creek. Changes of interval, which were probably caused by depositional thickening and thinning, he gave as the only conditions suggesting an unconformity at this horizon that he had ever observed.

Gould revised his earlier classification, basing the changes upon

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Gould, C. N., A New Classification of the Permian Red Beds: Bull., Am. Association. Petroleum Geologists, vol. VIII, no. 3, pp. 322-341, 1924.

additional information that he and other observers had obtained from more extensive work, especially in the Anadarko Basin area. He added two formations, the Duncan sandstone and the Chickasha formation, both of which are equivalents of the upper part of the Enid. The name "Woodward" was abandoned and the Dog Creek shale, the Whitehorse sandstone, and the Day Creek dolomite were each given the rank of a formation. The name "Greer" was also abandoned. Gould had described

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Gould, C. N., Geology and Water Resources of Oklahoma: U. S. Geol. Survey, Water Supply Paper 148, p. 59, 1905.

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this formation as being present in an eastern and a western area. The eastern Greer he changed to Cloud Chief. The rocks of the western Greer area had been subsequently identified as belonging to the Blaine, Dog Creek, Whitehorse, and Cloud Chief formations. These changes made the classification of the formations of the Red Beds in Oklahoma as follows:

Quartermaster formation

Cloud Chief formation

Day Creek dolomite

Whitehorse sandstone

Dog Creek shale

Blaine formation

Chickasha formation

Duncan sandstone

Lower Enid formation

In 1926, Aurin and others subdivided the Enid formation in greater

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— Aurin, F. L., Officer, H. G., and Gould, C. N., The Subdivision of the Enid Formation: Bull. Geol. Soc. Amer. ^{east} vol. 10, pp. 786-799, 1926.

detail than had been done by Gould in 1924. They changed the term "Enid" from a formation to a group name and gave each of its six subdivisions the rank of formation. The Enid group was also defined as including all of the formations in north-

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central Oklahoma that are the stratigraphic equivalents of the Kansas formations from the base of the Cottonwood limestone to the top of the Flowerpot shale. The

Enid formation as originally described by Gould included only the rocks from the

le Gould, C. N., Geology and Water Supply of Oklahoma: U. S. Geol. Survey,

Water Supply Paper ~~148~~ 148, p. 39, 1905.

base of the Harper sandstone to the top of the Flowerpot shale. The correlation

of the subdivisions of the Enid group with the formations in Kansas as given in

the paper by Aurin, Officer, and Gould is shown below.

Units Recognized in Kansas	Names Proposed in this Paper
Flowerpot shale Cedar Hills sandstone Salt Plains measures	Chickasha formation
Harper sandstone: Upper Harper Middle Harper	Duncan sandstone
Lower Harper	Hennessey shale: Bison Banded member Fairmont shale member
	Garber sandstone Hayward sandstone member Lucien shale member
Wellington shale Marion formation: Pearl shale member	Wellington formation and Pearl shale member of Marion formation mapped together
Herrington limestone member Enterprise shale member Luta limestone member Chase group: Winfield limestone Doyle shale Fort Riley limestone Florence flint Matfield shale Wreford limestone Council Grove group: Garrison shale Cottonwood limestone	Stillwater formation

The relations between the various Permian formations of the southern Great Plains area, as these relations were understood in 1927, were set forth in a paper by Gould and Willis. The part of their correlation table that gives

Gould, C. N., and Willis, Robin, Tentative Correlation of the Permian Formations of the Southern Great Plains: Geol. Soc. America Bull., vol. 38, pp. 431-442, 1927.

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the relation of the formations in Kansas to those in adjacent parts of Oklahoma is shown below:

Southern Kansas	Central and western Oklahoma	
Big Basin	quartermaster	
Hackberry Day Creek Whitehorse Dog Creek	Cloud Chief Day Creek Whitehorse Dgg Creek	
Blaine	Blaine	
Flower Pot Cedar Hills Salt Plains [?]	Permian	Chickasha
Upper Harper		Duncan
Lower Harper		Hennessey Garber
Wellington (salt)		Wellington (salt)
Marion Chase Council Grove		Stillwater

In 1931 Evans published a paper in which he made several changes in

Evans, Noel, Stratigraphy of Permian Beds of Northwestern Oklahoma: Am. Assoc. Petroleum Geologists, Bull., vol. 15, No. 4, pp. 405-439, 1931.

correlation and in the naming of various members and beds in the series. He reduced the rank of the Cloud Chief formation to that of a member of the Whitehorse formation, thus placing the Cloud Chief below rather than above the Day Creek dolomite. In the original description of the Blaine formation, Gould named the

✓ Gould, C. N., Geology and Water Resources of Oklahoma: U. S. Geol. Survey Water Supply Paper 148, p. 44, 1905.

lowest gypsum bed of the formation the Ferguson. The next one above he correlated with the Medicine Lodge gypsum of Kansas and gave it the same name. The third and top bed of the Blaine, as he described it, was called the Shimer gypsum and correlated with the Shimer gypsum of Kansas. Thus the base of the Blaine, as originally defined, was below the base of the Medicine Lodge gypsum of Kansas. Evans pointed out that he and various other geologists had followed the Medicine Lodge from Kansas south through northwestern Oklahoma and that this gypsum is the same bed as the Ferguson gypsum of Gould. Evans redefined the names "Medicine Lodge" and "Shimer" in Oklahoma to make them apply to the same beds as they do in Kansas, dropped the name Ferguson, and added two new member names above the redefined Shimer, thus giving the Blaine four instead of three members.

The following table taken from Evan's paper gives his classification as compared with that of Gould and Willis.

Classification of Permian Beds, Northwestern Oklahoma

This Paper (1930)		Gould and Willis (1927)	
Western and Northwestern Oklahoma		Southern Kansas	Central and Western Oklahoma
Quartermaster formation (Hackberry and Big Basin names are dropped)		Big Basin	Quartermaster
Day Creek dolomite (two beds, Upper and Lower Day Creek)		Hackberry	Cloud Chief
		Day Creek	Day Creek
Whitehorse formation	Cloud Chief member	Whitehorse	Whitehorse
	Rush Springs member Weatherford dolomite		
	Marlow member Relay Creek dolomites (Upper and Lower Relay Creek)		
Dog Creek formation		Dog Creek	Dog Creek
Haskew gypsum member Lovedale gypsum member Shimer gypsum member Medicine Lodge gypsum member			
Flower Pot shale		Flower Pot	Enid Chickasha

In addition to these various classifications that have dealt with all or a considerable number of the formations in the Red Beds section, there have been many others published during the past dozen years in which smaller parts of the section have been subdivided in great detail. The result is a large number of

formation and member names that, although each fits the section in the area in which it was applied, are difficult to correlate one with the other. This condition is caused by the fact that the greatest possible subdivision is frequently valuable and necessary in structural mapping, that many of the observers worked in limited areas, and that strata in the Red Beds are so variable in character from one locality to another.

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The following table taken from one of the charts by Wilmarth gives the

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Wilmarth, M. Grace, Tentative Correlation of the Named Geologic Units of Oklahoma, Chart I: U. S. Geol. Survey, 1931.

relation between the nomenclatures employed in Kansas and in various parts of Oklahoma.

A geologic field conference for the purpose of studying the Red Beds of southern Kansas and northwestern Oklahoma was held in April, 1930, under the auspices of the Oklahoma Geological Survey. The party attending the conference visited Cragin's type localities in Harper, Barber, Comanche, and Clark counties, Kansas, and followed the various formations south as far as possible into Oklahoma. Griley prepared a chart for use on the conference giving his interpretation of the relation of various of the stratigraphic units. The chart has been re-drafted and is shown in Figure 9. The lensing character of the formations so well portrayed in the diagram is one of the chief obstacles encountered in making a

classification that is satisfactory for large areas. Gould, State Geologist of Oklahoma, in summarizing the results of the conference, wrote:

I. Practically all type localities of Cragin's Permian red beds were visited. In case the type locality was not seen, typical exposures of the various formations were studied, usually many times.

II. It was found that all of these formations first described in Kansas may be carried south into Oklahoma, but that on coming south physical and lithologic characters often change.

III. Largely as the result of the work done and ideas gained by various men during the past few years, which ideas were crystallized, at least in part, on this conference, it seems logical that considerable revision is necessary in the nomenclature of the rocks of this region. Among other things which should be gone into, the following seem to be outstanding:

A. The term Harper should be revised. It is now generally believed that the ^{Wingate sh.} ("lower" Harper) of Cragin, first encountered near Milan^{ky} and exposed near Bluff City, is in fact the approximate northern equivalent of the Garber sandstone of Oklahoma. West of and above this lies a bed of shale, the northern equivalent of the Hennessey. The base of the Harper, as the term is now generally used, comes in just east of the towns of Anthony and Manchester. It has also been shown that Cragin's Salt Plains Measures is not a valid formation, being simply a topographic phase of the Harper or of the Cedar Hills. It has been suggested that the upper part of the Harper, the Salt Plains, and the Cedar Hills be thrown together as one formation and a new name proposed.

B. The term Chickasha should be revised, and in all probability a new name should be proposed. Already the name is used in three senses: First, as described by the author to include the upper part of the Enid below the Blaine formation; Second, as now used locally by the men working in the vicinity

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of Chickasha to include everything from the Duncan up to the base of the Whitehorse; and Third, as used by Griley in the Hitchcock-Watonga area to include the cross-bedded phase of the lower Flower-pot.

C. The various members of the Blaine formation, should, in all probability, be renamed, or at least the terms revised. Schaeffer, Griley, and others have shown that the Ferguson of Oklahoma is the same bed as Cragin's original Medicine Lodge of Kansas. It is not yet clear whether the Medicine Lodge of Oklahoma thins out to the north near the Kansas line, or carries under the Tertiary beds to become the Shimer of Kansas. If the Medicine Lodge of Oklahoma does thin out near the Kansas line, then the Shimer of Oklahoma would also be the Shimer of Kansas. There should be additional work done in the Blaine in order to correlate the two gypsum beds of Kansas with the three beds in Blaine County, Oklahoma, and with the five gypsum beds in Greer County, Oklahoma, extending south into Texas. Also, additional work is needed to attempt to carry the horizon of the Blaine through the clastic material around the southeastern end of the Anadarko Basin.

D. The matter of the Day Creek and Cloud Chief needs careful field study. For many years the Day Creek has been considered to lie on top of the Whitehorse, and at the base of the Hackberry in Kansas and base of the Cloud Chief in Oklahoma. Evans and others would now place the Day Creek on top of the Cloud Chief in the area of Woodward, Major, and Dewey counties, Oklahoma, and include the Cloud Chief with the Whitehorse.

E. The matter of the Hackberry and Big Basin should be gone into carefully. According to Cragin's definition, the Big Basin sandstone was a separate formation, lying above the Hackberry shales. Recent studies seem to indicate that there are several 'Big Basin' sandstones interbedded with Hackberry. At one place in southeastern Harper County, Oklahoma, 80 feet of Hackberry with at least three 'Big Basin' sandstones were seen by members of this conference.

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There are several ideas prevalent as to the correlation of the Hackberry-Big Basin with formations farther south. Griley believes that the Hackberry-Big Basin is equivalent to the Quartermaster. Others think that it should correlate in part at least with the Cloud Chief. Clifton would abandon the term Cloud Chief.

F. The whole work on the stratigraphy of the Permian has been most difficult and much confusion of correlation has resulted because of the apparent absence of true stratigraphic horizons. Unless we can recognize such horizons the final settlement of points of controversy and differences of opinion on equivalency of formations now defined will continue to be difficult. Many of us believe with Griley that the red beds as a whole consist of a series of lentils. Some agreement must be reached on these matters before the stratigraphy of the red beds can be revised to the satisfaction of all concerned."

The renaming of the members of the Blaine formation, to which Gould refers in paragraph III, C, has been done by Evans.

Op. cit., pp. 409-412.

The various classifications of the Red Beds that have been made and the unsatisfactory status of the present correlation and nomenclature, as indicated by the above summary of the results of the field conference, only emphasizes the fact that a great amount of careful geologic work is still necessary before a satisfactory correlation is possible.

Names and Their Application

Cimarron Series. The Permian Red Beds in Barber County and southern

Kansas all belong to the Cimarron series. The name "Cimarron", taken from the Cimarron River, was applied to them by Cragin when he first classified, described,

Cragin, F. W., The Permian System in Kansas: Colorado College Studies,

vol. 6: pp. 1, 3, 18, 1896.

and named the various formations of the series. He describes the Cimarron

series as follows:

"With the Wellington formation, ends the Big Blue, lower, or limestone-bearing series of the Permian. Succeeding it without break, but possibly with a gradually introduced angular unconformity, are the Harper sandstones and higher prevailing red formations that comprise the remainder of the Kansas Permian, and constitute the Cimarron series, which, for Kansas, is nearly the same as the 'red beds'.

So far as known, the series is destitute of any trace of organic remains."

Harper Sandstones. Excerpts from the original description of this formation by Cragin are here given:

Idem, pp. 18-20.

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"These constitute the lowest and thickest formation of the Cimarron series. They comprise several hundred feet of more or less mottled, but pre-
vailingly dull-red, or brownish red, argillaceous and arenaceous shales and sandstones, above the Wellington shales and below the Salt Plain measures.

The word sandstones, as applied to this formation, is intended to imply, not that its rocks consist mainly of sandstones throughout their thickness, but that the frequent low ledges of rock which accentuate the formation are of sandstone.

Much of the latter is of the sort quarried at Harper—a reddish-brown or roan-colored sandstone, sometimes mottled and streaked, soft enough to be easily quarried and dressed but becoming harder by seasoning, and constituting an excellent dimension stone. As this stone first became well known as a building material from its use at Harper, and as the outcrops of the formation which includes it occupy a large portion of Harper County, the name Harper seems doubly appropriate for the formation". Speaking of the distribution of the formation, he says: "As one travels westward from Wellington, the red shales and sandstones of the Harper outcrop are first met with near Milan. They occur thence westward to the vicinity of Sharon, but in their western extent are seen only in the lower parts of the county^{ly}". Cragin gave the thickness of the Harper as about 650 feet, *surface measurements and* using ^{as a basis for his estimate,} the records of a well drilled at Anthony and ~~of surface measurements.~~

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The equivalent of the Harper sandstone in Oklahoma has been divided into three formations and two of them into two members each. This classification by Aurin, Officer, and Gould, showing its relation to the Kansas nomenclature, is given in the preceding section of this bulletin. The authors of the above

Aurin, F. L., Officer, H. G., and Gould, C. N., Subdivision of the Enid Formation: American Assn. of Petroleum Geologists, Bull., vol. 10, no. 8, pp. 786-799, 1926.

cited paper did not agree as to the limits of their subdivisions. They wrote: "As stated above, it is probable that the Chickasha includes the greater part of Cragin's Flowerpot shales, and probably also his Cedar Hills sandstone and Salt Plain Measures. Upon this point, however, the authors are not in agreement. This being true, it is not now possible to draw a definite line between the Duncan and the Chickasha in northern Oklahoma. Some geologists would include both the Salt Plain and the Cedar Hills with the upper part of the Duncan."

Many geologists who attended the field conference at which the Red Beds were studied have worked in the area of outcrop of the Harper in Kansas. Some of them expressed the opinion that the formation could be subdivided upon a basis of lithology, but there were differences of opinion as to just where divisions should be made and what ^{are} the Oklahoma equivalents of certain units in the Kansas section. ~~are~~

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Only the uppermost beds of the Harper sandstone are exposed in Barber County and no detailed study of the formation was made farther east in its area of outcrop. Recognizing the fact that the Harper might well be subdivided but lacking the detailed information necessary to properly limit the divisions, the writer ^{has chosen to} ~~will~~ designate the lowest part of the Cimarron series as the Harper group, deferring further subdivision in Kansas until its stratigraphy within the state is better known. This leaves the ^{meaning} ~~usage~~ of the term ^{Harper} the same as ^{that given} ~~to it by~~ Cragin, ~~applied to~~.

The Salt Plains Measures and the Cedar Hills Sandstones. Although the Salt Plains Measures underlie the Cedar Hills sandstone, Cragin described the

Idem, pp. 20-24.

stratigraphic and geographic position of the former with respect to that of the latter formation. His description of the Cedar Hills sandstone will, therefore, be given first.

"The Salt Plain Measures are succeeded by a zone of rocks in which unevenly hard, in part massive concretionary, fine grained, bright-red sandstones, having some resemblance to those of the Red Bluff terrane of the Kiger division, constitute the leading feature. This may be seen a few miles northwest of Hazelton, Kansas, below the Neocene sands which there form the summit of the Cedar ^h Hills. From

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this occurrence the terrane takes its name. It is finely displayed in the canyon cut basal incline of the Gypsum hills, southwest of Medicine Lodge, and in the same southeast of Aetna. The bright red sandstone in the low bluff north of Sharon and that outcropping on the south fork of the Ninnescah River west of Kingman are provisionally referred to the Cedar Hills formation.

This formation has nowhere been measured. From memory, it is roughly guessed at 50 to 75 feet as seen in the basal incline of the Gypsum hills of the Medicine Lodge River and the Salt Fork."

Only those parts of Cragin's description of the Salt Plain measures are quoted that bear directly upon the character of the formation.

"Occupying an interval between the Harper and the Cedar Hills sandstones, in southern Kansas and northern Oklahoma, is a zone of red shales (? with some sandstones) in which saline impregnations are common, giving rise to salt springs, salt creeks, salt or brackish wells and other saline waters within and near the area of their outcrop, and resulting in a topography characterized by various closely allied features termed salt-plains, salt-marshes, salt draws, salt-bars, salt-licks, salines, etc., in which the chloride of sodium is often practically pure, but sometimes associated with other salts....As local saline impregnations occur to some extent in most of the terranes of the Kansas-Oklahoma Permian, it is possible that it may not always be easy to distinguish the limits of the Salt

Plain measures, but the salt zone which is here especially designated as the Salt Plain measures is of considerable extent and is that from which is derived the salt of the Salt plain of the Cimarron River (called ^{often} after the Great Salt plain), which is the saline usually referred to in the literature of this region when the unqualified expression, "the Salt plain", is employed.

The stratigraphic position of this salt zone may be seen in Kansas on the east slope of the Cedar hills of Harper County and on the south side of the ^{Salt} South Fork, a few miles ^{below} between Aetna, where, in each case, beginning immediately below the bright red Cedar Hills sandstones, are the saliferous clay-shales which are the source of the salt that at the one locality gives character and name to the Little Salt ~~creek~~ creek that traverses adjoining parts of Barber and Harper counties, and at the other has given rise to one of the peculiar flats, or base-levels, so frequent in salt shale topography, and which are evidently produced through the agency of the salt itself. Little Salt Creek, though having the highest source of its salt in a horizon of saline impregnations immediately below the base of the Cedar Hills sandstones, apparently cuts other saline horizons at somewhat lower levels, and its lower portion may inter-graduate with and be only arbitrarily separable from the upper of the Harper sandstones.

At Pratt, salt deposits were encountered a few years since, in drilling, without first passing through any thick body of gray shales like the Wellington; and the relation of these to not far distant outcrops of the Cimarron series and to sea level, indicates that they belong to the upper, or Salt Plain, measures.

The following is a condensed record of the boring at Pratt:

	<u>Thickness</u>	<u>Depth</u>
Neocene marl, sand and gravel	89	89
Red sandstone and clay, with veins of water at intervals.		
(A vein of salt water was cased out at 150 feet)	537	626
Shales, almost wholly red, more or less saline	89	715
Rock-salt, with small admixture of shale	30	745
Salty red and blue shale (mostly red)	13	758
Rock-salt, with small admixture of shale	22	780
Shaly salt gradually becoming red and blue shale	20	800
Red shale with some blue spots	50	850
Rock-salt, with small admixture of shale	20	870
Dark red shale, blue mottled	134	1004

This section affords the only data here available with which to indicate the thickness of the Salt Plain measures, giving for the vertical range of the rock-salt 155 feet, which, with a few feet added for transitional sediments above and below, probably approximates the thickness of these measures as developed at and near their outcrops in Kansas.

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The saline springs on the upper part of Little Mule creek, in Barber county, Kansas; the great salt spring at the head of Salt creek in Blaine county, Oklahoma, from the brine of which several tons of table-salt are now made daily, and which is said to furnish brine enough for the manufacture of 160 tons a day; and (with less confidence) the Salt plain of the Salt fork in Woods county, Oklahoma (sometimes known as the Little Salt plain) are provisionally referred to the Salt Plain measures."

Cragin gives the thickness of his Salt Plain measures in the area of outcrop as about 155 feet. This figure is the thickness of the salt beds and the interbedded shales recorded in his log of the well at Pratt. From the descriptions of the material passed through, there must be within that 155 feet of rock, 60 to 75 feet of salt that would be dissolved and carried away as surface waters reached it. Even if the salt-bearing zone were considered a stratigraphic unit, its thickness at the outcrop would surely be reduced by the thickness of the salt beds.

From ^{now} Cragin's discussion there appears to be no convincing evidence that the salt in the Pratt well occupies the stratigraphic position of his Salt Plain measures. The base of the lowest salt bed is only 134 feet above the bottom of the well which, judging from the log, did not go through the Red Beds. He must have assumed either that the thickness of the Harper sandstone diminishes from 650

feet at its area of outcrop to 134 feet at Pratt or that a great thickness of Red Beds, perhaps as much as 500 feet, lies below the depth reached by the well.

Other wells drilled more recently in southern Pratt and northern Barber counties have penetrated salt beds and also have gone through the Red Beds. The follow-

ing table gives the occurrence of salt in these wells.

Location of well	Depth to top of Red Beds	Thickness of red section	Thickness of salt	Distance from bottom of salt to base of Red Beds
Sec. 15, T. 28 S., R. 14 W.	200	1,145	80	325
Sec. 30, T. 30 S., R. 14 W.	0	1,155	40	405
Sec. 27, T. 30 S., R. 14 W.	125	1,140	25	355

The first of these three wells is only 10 or 12 miles from Pratt and the salt-bearing zone is, therefore, probably the same as the one recorded by Cragin in the well at Pratt. The similarity of position of the salt in each of the wells here listed indicates that it ^{probably} is a single body. The third well of the three is near the area of outcrop of the Red Beds and enters them a short distance above the top of the Flowerpot shale. The thickness of the red section penetrated below this known horizon ~~of~~ indicates that there is no appreciable thinning of the Harper sandstone at that location. The second well is within the area of outcrop of the Red Beds. The surface beds there are stratigraphically lower than the horizon first reached in well number three. The record of the second well indicates a

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thickening rather than a thinning of the Red Bed section.

From the information that these well records give the writer is led to the conclusion that the salt zone encountered in the well at Pratt occurs near the middle of the Harper sandstone and not above it as was thought by Cragin. Gould has noted that one of the salt plains in Oklahoma occurs at this

—/ Gould, C. N., The Oklahoma Salt Plains: Kansas Acad. of Science, Trans.,
vol. ¹⁷ ~~XVII~~, p. 182, 1901.

same general horizon. He wrote, concerning the salt-bearing measures, "But that all or even a greater part of these measures are confined to a definite horizon remains to be proven. In fact, it has been demonstrated that the largest salt plain in Oklahoma--the Salt Fork plain--is located near the middle of the Harper".

Many holes that penetrate the Red Beds have been drilled in Kansas since Cragin made his studies. The records of these wells indicate that Cragin probably spoke better than he knew when he said that "local saline impregnations occur to some extent in most of the terranes of the Kansas-Oklahoma Permian". Salt is distributed over such a great vertical range in the Red Beds of southern Kansas that its occurrence seems hardly a sound basis for stratigraphic classification.

Cragin pointed out in a later paper one of the difficulties of recog-

Cragin, F. W., Observations on the Cimarron Series: ~~American~~ Geologist,
vol. ¹⁹~~17~~, no. 5, p. 352, 1897.

nizing the limits of his Salt Plains measures on the basis of salt content for
he wrote: "The saline character of the Harper is manifest west of the river
and of Dover by the frequent brackish and salt wells encountered. Thus the
difficulty of drawing a line between the Harper and the Salt Plain is increased,
and these should perhaps be considered as composing a single saliferous formation,
for which, from its being traversed by Kingfisher Creek and having the town
of Kingfisher within its area, the name of Kingfisher would be appropriate."

The following table gives the aggregate thickness of salt, its vertical
range, and its position within the Red Beds, as given by the logs of a few wells
in Meade and Clark counties, Kansas. These are typical of a large number of others
that have been drilled in Kansas and Oklahoma.

Well No.	Location	Depth	Thickness	Position
1	2	3	4	5
6	7	8	9	10
11	12	13	14	15

Location of well	Aggregate thickness of salt	Distance from top of Red Bed to highest salt bed	Vertical range of salt beds	Distance from bottom of lowest salt bed to base of Red Beds.
sec.10, T.30 S., R.25 W.	295 ft.	310	860	370
Sec.17, T.31 S., R.22 W.	250	294	925	325
Sec.20, T.32 S., R.21 W.	225	270	1,055	305
Sec. 9, T.33 S., R.28 W.	242	467	945	255.

In these cases the middle one-half to two-thirds of the series is characterized by the presence of salt beds and the upper 250 to 300 feet of the salt-bearing zone contains from about one-half to nearly all the salt present in the section. Although the salt in the Pratt well is low in the red section, the chief salt-bearing strata in the ^{Cimarron} series can hardly be as low as the position that Cragin assigns to his Salt Plain measures.

The occurrence of a salt plain at any particular horizon within a section so replete with salt beds would appear to depend more upon other ^V conditions that chanced to be favorable rather than upon the presence of salt at any one stratigraphic position.

The fact that Cragin gave so few measured thicknesses in his descriptions of the formations makes the problem of field recognition of his units difficult. He states that he did not measure the thickness of the Cedar Hills sandstone, but from memory guessed it to be 50 to 75 feet thick. Guided by these figures and

the descriptions of the lithology of the Salt Plains measures and of the Cedar Hills sandstone the writer endeavored to identify the contact between these formations, as Cragin intended it to be, at Cedar Hills, the type locality of the sandstone. Underlying the Tertiary sand and gravel which caps the hills is a great thickness of alternating sandstone and shal^e beds. The section is marked by the heavy massive character of many of the sandston^e beds. They form precipitous ledges and bluffs from 10 to 30 feet in height. Sandstone strata of this type are present down through a stratigraphic range of approximately 250 feet. At no point in this section is there a change of lithology to give "a zone of red shales (? with some sandstone)" of sufficient prominence or thickness to correspond to Cragin's description of the Salt Plains measures. The upper parts of the valleys contain valley-fillings that give them flat gently ^{sloping} steeping floors. The upper ends of the fillings are about 60 feet below the base of the Tertiary formation. Cragin may possibly have mistaken the thinly bedded valley-filling for Permian shale and ^{believed} the flat bottom to be a salt flat.

The difficulty of identifying the Salt Plain measures and the question as to whether the term as a formation name should be perpetuated have long been recognized. Prosser, in discussing the geologic section from Medicine Lodge

Prosser, C. S., The Upper Permian: Kansas Geol. Survey, vol. II, p. 86, 1897.

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River to the top of the Gypsum Hills, wrote: "The soft red sandstones below these shales, forming the upper part of No. 4, belong in the Cedar Hills sandstone of Cragin, while the base of the bluffs near the river is probably in the division that he terms the Salt Plain Measures, though there is hardly any line of separation between the two divisions." (To correspond with the description of the section that he gave, No. 4 in the quotation should be No. 1).

Gould wrote "Stratigraphically, the Salt Plain is the most unsatisfactory

Gould, C. N., The Oklahoma Salt Plains: Kansas Acad. Science, Trans., vol. 17, p. 182, 1901.

formation in the Kansas-Oklahoma Red Beds. Indeed, it is still an open question whether it would not be wise to either assign it to subformation rank under the Harper or drop it altogether from the nomenclature of the series."

Inasmuch as studies of the occurrence of salt in the Red Beds and of the lithology of the rocks at the outcrop have failed to establish the Salt Plain measures as a stratigraphic unit, there appears to be no reason for retaining the term in the nomenclature of the Cimarron series. This opinion is shared by practically all who are familiar with the stratigraphy of the Kansas-Oklahoma Red Beds. The term "Salt Plain Measure" will, therefore, be dropped.

07

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Cragin
~~His~~ study of the Permian in Oklahoma led *him* Cragin to make the following

✓ Cragin, F. W., Observations on the Cimarron Series: ~~American~~ Geologist, vol. 19, p. 355, 1897.

statement concerning the Cedar Hills sandstone: "The Cedar Hills sandstone of my Kansas Permian section has not been satisfactorily identified in central Oklahoma, and it is doubtful whether it is possible to distinguish there the lower or theoretically Cedar Hills, part of the beds between the Salt Plain and the Caye Creek, from the lower part of the Flower-pot shales, which, however, in Oklahoma as in Kansas differ somewhat from their more specialized upper part."

The Cedar Hills sandstone is now recognized in northern Oklahoma and has been traced southeast from its outcrop in Kansas to a point a few miles beyond Okeene in northeastern Blaine County, Oklahoma. Throughout most of its extent the change from the Cedar Hills sandstone to the Flower-pot shale is marked not only by a change in lithology but also in physiography. ^{Where} ~~When~~ the land has been subjected to a great amount of erosion the top of the Cedar Hills characteristically forms a terrace or a dissected plain above which rise the slopes of the Flower-pot shales.

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The lithologies of the part of the section that Cragin called the Salt Plain measures and the part that he called the Cedar Hills sandstone are so similar that for southern Kansas the writer proposes to retain the name "Cedar Hills sandstone" and redefine the term to include all the beds above the Harper to the top of the Cedar Hills sandstone, as Cragin defined it.

Flower-pot Shales. Cragin took the name for this formation from a hill

lc Cragin, F. W., the Permian System in Kansas: Colorado College Studies, No. 6, pp. 24-27, 1896.

that has been carved from the shale by erosion and is locally known as Flower-pot mound. ^(Fig.) The following quotations are from his description of the lithology and the topographic expression of the formation.

"These, for the most part, are highly gypsiferous clays...Light-red, dark-red, bluish-red, pink, greenish-white, bluish-white and gray, mixed in confusion with red in the ascendancy, give much of the outcrop of this terrane a variegated aspect; or as viewed at some distance, a hue approaching the late fashionable color known as 'crushed strawberry'. The surface is often strewn with fragments of white, pink, red or water-clear satin-spar flecked with green or red clay and is sometimes also set off with sparkling crystals of selenite...

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tributary valleys toward the major divides. The slope of the Gaviota surface was greater at higher elevations, farther from the main stream, and probably caused the profile of equilibrium of the floods of water, retaining sediment down from the hills. That the process of aggradation was very slow, and perhaps ceased entirely during considerable periods of time is indicated by the

Flower Pot Mound



Flower Pot Mountain
Barber Co. Kan.

FLOWER POT MOUND

may be seen, however, that the present drainage has a somewhat different course than the pre-Gaviota drainage had, and cross-sections of tilted channels are visible in river banks. (Fig. 1, fig. 2.)

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"As seen in canyon walls or other vertical exposures, the satin-spar forms a network with irregular rhomboidal meshes. It lies, in fact, in a trestle-work of warped plates traversing the clay in all directions, but chiefly in oblique positions tending toward horizontal. The clay is thus inclosed, sometimes between tortuous subhorizontal and subparallel seams, sometimes in spacious sublentitoid compartments subject to partition in various directions by intersecting veins. The seams vary from mere paper-seams to plates several inches in thickness.

"A noticeable and picturesque feature of the Flower-pot clays is the manner in which their outcrops are carved by the elements. They are, in fact, a theater of rapid erosion, and many weird spectacles present themselves in their relief-forms. In localities where their protective covering of Medicine Lodge gypsum has been removed by erosion, as for example, near the head of Little Mule creek and in the district between Eldred and Aetna, they are frequently cut into rather steeply sloped faces having that peculiar pattern of sculpture that is best designated as cone-and-gully erosion, consisting of alternate cones (more strictly semi-cones) and rain-gullies. The cones are sometimes arranged in a close and remarkably uniform palisade-like series on the face of a rampart-like

or amphitheater-like bluff, and in such instances are calculated to arrest the attention even of those most indifferent to natural phenomena. Such a palisade of cones may conveniently be called a conarium....Its mineral-surcharged character renders its occasional smoother tracts little less barren than the rugged portions, so that the Flower-pot lands are generally waste lands...

"The thickness of the Flower-pot shales on the Salt fork, southeast of Aetna, is in the neighborhood of 150 feet."

~~Southward into Oklahoma the Flower-pot shale becomes much thicker. The chart by Galley gives its thickness at Fairview as 425 feet.~~

Cave Creek Formation. Cragin defined the Cave Creek formation as follows:

— Idem, pp. 27-39.

"Above the Flower-pot marls is an important gypsum bearing formation, consisting usually of either a single stratum of massive gypsum or two such strata separated by an interval of red clay-shale. It may be called the Cave Creek gypsums, or formation, because well displayed in its fuller development on Cave Creek, in Comanche County, Kansas....The lower gypsum horizon (below named and described as the Medicine Lodge) is the heavier and persists throughout the present known extent of the formation; while the upper, or Shamer (so named after the township through which Cave Creek flows), is less constantly developed as a distinct

bed of massive gypsum, not appearing at all on the valley of the Medicine Lodge river, so far as observed.

"At the only locality at which it has been measured, viz., on Cave Creek at the Comanche cave, the formation has a thickness of not less than 50 feet, of which the Medicine Lodge gypsum occupies a thickness of 25 to 30 feet, the Shimer gypsum about a third as much, and the interval of red clay, the Jenkins clay (named after the former Jenkins postoffice, near Cave creek), 7 to 10 feet.

"The Medicine Lodge Gypsum. While the Shimer gypsum and the Jenkins clay require merely brief notice here, the former resembling the Medicine Lodge gypsum and the latter the commoner gypsiferous red clay-shales of the Salt Fork division, the Medicine Lodge gypsum calls for a special description, on account of its stratigraphic importance and its more than ordinarily interesting general character." Cragin ~~went on to~~ describe in glowing terms the scenic effect of the red hills capped by the white gypsum. Describing the occurrence of the gypsum in the hills southwest of Medicine Lodge, he says: "As seen in their eastern border about six miles southwest of Medicine Lodge, the foundations of the Gypsum hills are laid in Cedar Hills sandstone, their walls are reared in the variegated sediments of the Flower-pot shales, and they have, as capping,

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a massive bed of gypsum to which the stratigraphic name, Medicine Lodge gypsum, is here given, in double allusion to its overlooking the valley of the Medicine Lodge river for so many miles and to its prominent position opposite the picturesque county-seat of Medicine Lodge, in which was established the first mill to make large commercial use of this gypsum."

Cragin continued the discussion of the Medicine Lodge gypsum by tracing its general line of outcrop in southern Kansas and the adjacent part of Oklahoma, citing points along Cimarron River in Woods and Blaine counties, Oklahoma, at which the bed is exposed.

He described its lithology as follows: "In minor parts, the Medicine Lodge gypsum is nearly pure white; in others it is suffused with leaden gray or dusky-brownish shades; most commonly it is greyish-white, mottled with feebly defined dark spots. The latter are generally the expression of a tendency that existed in the gypsum, under the original conditions of precipitation to form crystals, as is shown by the occurrence of the 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 patterns, others are of the stellar type....The uneven color and more or less saccharoidal texture of the Medicine Lodge gypsum give ^{to} its freshly exposed surfaces, as seen in the quarries

10

of Barber County, an aspect not unlike that of marble, and the resemblance to marble is further increased by the fact that the gypsum takes a fine polish."

After describing the effects produced by solution of the gypsum, Cragin ended his discussion of the formation with the following paragraph that indicates he appreciates the magnitude of the gypsum deposit of which he was describing a part.

"Some local use has been made of the Medicine Lodge gypsum almost since the founding of the towns of Medicine Lodge and Sun City; but within the last few years two mills have been built for the manufacture of plaster from it on a commercial scale, and this is doubtless but the beginning of a vast industry that will ultimately be built up in this great gypsum-belt in southern Kansas, Oklahoma and Texas, a belt which is far greater than the discontinuous one of the Gauda, and is, indeed, one of the greatest gypsum deposits in the world."

In 1897 Cragin described the Cave Creek formation as he had seen it on a

—/ Cragin, F. W., Observations on the Cimarron Series: ~~American~~ Geologist, vol. 19, pp. 356-358.

trip across Oklahoma and part of Texas. In this paper he pointed out the fact that the Shiner gypsum bed was not merely of local development but was almost coextensive with the Medicine Lodge. He described the outcrops of the Cave Creek

along Cimarron and Canadian rivers in Oklahoma and gave the thickness of the formation at the head of Salt creek in Blaine county as 70 or 80 feet. Of this total he gives the thickness of the Medicine Lodge gypsum as 18 to 24 feet, the Shimer gypsum as 15 to 18 feet, and the Jenkins clay as nearly equal to the sum of the two gypsums. From the location given for the outcrop of the formation on across western Oklahoma into Texas, Cragin appears to have mistaken, in some localities, gypsum beds higher in the section for the Cave Creek beds.

Gould applied the name "Blaine division" to this gypsum-bearing

Gould, C. N., General geology of Oklahoma: Oklahoma Dept. of Geol. and Nat. History, 2d Bien. Rept., p. 47, 1902.

formation. He wrote: "The characteristic which justifies its recognition as a division is the abundance of gypsum contained in it and its extent and limits are defined accordingly". In part of the area of outcrop of his Blaine division it consists of three instead of the two beds of gypsum that comprise the Cave Creek. The lowest one of these he thought to be lower than the Medicine Lodge gypsum of Kansas, but they have since been shown to be the same bed. These conditions appear to have been his reason for introducing a new name for the gypsum-bearing strata. Inasmuch as the gypsum beds in Oklahoma were known to be the southern

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where it was deposited because the streams were overloaded. Gradually the entire system of valleys was aggraded until the lower parts of the larger tributary valleys were filled to such an extent that they could no longer hold the streams during flood periods. At such times the water spread over the entire lower slopes of the hills and flowed down to the major valleys, aggrading the surface over which it flowed. Eventually the deposits formed a sheet that covered the major valleys and the lower slopes of the ridges, with tongues that extended far up the tributary valleys toward the divides.

Later erosional features. - When conditions changed so that the streams were again able to degrade the land, they incised themselves into the alluvial material that had choked and filled their valleys. The drainage lines in most cases were not changed much from their former courses, especially in the upper parts of the valleys, for the latter were only partly filled. Many examples may be seen, however, where the present drainage has a somewhat different course than the pre-Gerlane drainage had, and cross-sections of filled channels are visible in river banks. (Pl. A).

Because of the high gradient of the streams and the soft character of the Gerlane formation, it is being eroded rapidly and steep canyon-like valleys are ^{being} developing in the flat floors of the partly filled older valleys, leaving terraces of Gerlane along the sides (Pl. B). The erosion has revealed the presence of cedar stumps 12 to 15 inches in diameter within the Gerlane, indicating that the rate of aggradation was very slow and perhaps ceased entirely during considerable periods of time. In one case the ground line at the time of growth, as indicated by the position of the roots, is

continuation of those that Cragin had studied and named in Kansas, it appears that to have added another member to the Cave Creek would have adequately named the various beds and also would have avoided the duplication of names for the formation.

Although the name Cave Creek has priority over Blaine, the latter term has been used in Oklahoma and because of the great amount of geologic work done by the oil companies the term has become better known than is Cave Creek. For this reason the writer has adopted the name Blaine.

The Dog Creek shale and Whitehorse sandstone are, in ascending order, the formations of Cragin's Kiger Division and are the only ones of the

F. W., The Permian System in Kansas: Colorado College Studies, vol.

10.

that are exposed in Barber County. In his original description of the shales Cragin wrote: "The lowest member, or Dog Creek terrane, of the thickness of some thirty feet, or locally of a less or greater thickness, of bluish-gray to blackish-lanceous shales, with laminae of gypsum in the basal part and one or two thin layers of unevenly lithified dolomite in the upper. The color of these shales is gray to dark-gray, and clay-impregnated portions may

partake of the red color of the including shales. In lithological character, it varies from solid stone which serves a fair purpose as a building-stone for the rougher uses, to that which is so contaminated with clay as to be soft and worthless. It is often cellular or cancellated.

"The thickness and stratigraphic relations of the Dog Creek formation are well displayed south of Lake City on Dog creek, from which the formation is named..."

In his later paper Cragin changed his description of the formation, as follows:

lc
— Cragin, F. W., Observations on the Cimarron Series: ~~American~~ Geologist, vol. 19, p. 358, 1897.

"The Dog Creek formation persists and finds greater emphasis in Oklahoma, being more positive there in its character than in Kansas, and thicker and more complex than the ~~Cave~~ Creek. In central Oklahoma it is a great dolomite formation..." He suggests that "Stony Hills" would be a better name for the formation than "Dog Creek" because of its development in the Stony Hills east of Watonga, Oklahoma.

lc
— Gould, C. N., Geology and ~~Water~~ Resources of Oklahoma: U. S. Geol. Survey, ~~Water~~ Supply Paper 148, pp. 54-55, 1905.

formation and not in the Dog Creek. The latter formation is thicker in Oklahoma ~~than~~ in Kansas.

However, there is a great difference in the values given for its thickness by various writers. Gould stated that near Quinlan, in eastern Woodward County, the thick-

Idem, pp. 54-55.

ness, as indicated by aneroid readings, is 225 feet and that readings of 150 and 175 feet were obtained in a number of localities. In a later paper Gould added the

Gould, C. N., A New Classification of the Permian Red Beds of Southwestern Oklahoma: Amer. Assoc. Petroleum Geologists, Bull., vol. 8, no. 3, p. 334, 1924.

following statement regarding the thickness of the Dog Creek: "Still farther south in Blaine and adjoining counties its entire thickness cannot be measured at any one place, but it is believed to be still thicker, possibly 400 or 500 feet." Becker

Becker, Clyde M., Oil and Gas in Oklahoma, Caddo and Grady Counties: Oklahoma Geol. Survey, Bull. 40, vol. II, pp. 105-118, 1930. (Originally published as Bull. 40-I, 1927).

reported 90 to 115 feet of Dog Creek in Grady County and gave 125-150 feet as the combined thickness of the Dog Creek and Blaine formations in Caddo County. Freie

Freie, A. J., Sedimentation in the Anadarko Basin: Oklahoma Geol. Survey, Bull. 48, p. 54, 1930.

stated: "The logs of wells in Kiowa County give the Dog Creek a thickness of about 400 feet". Evans described the thickness throughout Harper and northern Woodward

✓ 23

✓ Evans., Noel, Stratigraphy of Permian ~~beds~~ of Northwestern Oklahoma: Amer. Assoc. Petroleum Geologists, Bull., vol. 15, no. 4, pp. 412-414, 1931.

counties as approximately 50 feet and from there southward as gradually increasing to about 175 feet in the Anadarko basin. The chart by Griley, Fig. 9, shows a variation in thickness comparable to that given by Evans.

Differences of opinion as to just what should be considered the top of the formation are probably the reason for the wide range of values given for the thickness. Gould considered the Verden Channel sandstone as part of the upper Dog

✓ Gould, C. N., A New Classification of the Permian of Southwestern Oklahoma Red Beds: Amer. Assoc. Petroleum Geologists, Bull., vol. 8, no. III, p. 335, 1924.

Creek, whereas, that sandstone has since been classified as part of the overlying Whitehorse. The values given by Evans and Griley are for the thickness of the Dog Creek as it is now recognized in northwestern Oklahoma. Farther southwest the formation becomes more like the underlying Blaine and they are classed as one formation in Texas by Lloyd and Thompson.

✓ Lloyd, A. M., and Thompson, W. C., Correlation of Permian Outcrops on Eastern Side of West Texas Basin: Amer. Assoc. Petroleum Geologists, ^{Bull.,} vol. 13, No. 8, p. 950, 1929.

Whitehorse Sandstone. Cragin described this formation under the name Red

Bluff Beds as follows: "This formation consists of some 175 or 200 feet of light-

Cragin, F. W., The Permian System in Kansas: Colorado College Studies, vol. 6, pp. 40-44.

red sandstones and shales...Viewed as a whole, it is very irregularly stratified,

....

"The Red Bluff beds exhibit the most intense coloration of any of the rocks of the Cimarron series, being approached in this respect only by the Cedar Hills sandstones...The sandstones of the Red Bluff are generally too friable for building-stone; but in some instances selected portions have proved hard enough for such use and fairly durable.

"A marked characteristic of most of these sandstones is their unusually fine texture...

"The Red Bluff beds, once uncovered, yield rapidly to subareal erosion and their outcrops generally show a rugged, canyon-cut relief which, in connection with their bright-red color and their frequent setting-off with dark green cedars, makes some of their landscapes exceedingly picturesque. The sandstones are frequently trimmed off by stream erosion in a long, straight, vertical wall that resembles the face of a quarry...

"On the Medicine Lodge river, the Red Bluff beds constitute the highest surviving formation of the Cimarron series and occur as far west as Belvidere. At the latter place, they are unconformably overlaid by the Cheyenne sandstone, only the lower part, about 100 feet, of their thickness being represented."

The Whitehorse sandstone, like many of the other formations in the Cimarron series, thickens southward into the Anadarko Basin. Sawyer gave 490 feet as the

cc — Sawyer, Roger W., Oil and Gas in Oklahoma, Kiowa and Washita Counties: Okla. Geol. Survey, Bull. 40, vol. II, p. 317, 1930.

cc thickness of the formation in Grady County, Oklahoma. In addition to increasing in thickness the character of the formation changes to the south, so much so that it has been subdivided into members. Two of these, the Marlow and the Rush Springs members, were named by Sawyer, and Evans added a third by classing the Cloud Chief

— Idem.

— Op. cit.

as a member of the Whitehorse sandstone.

DETAILED STRATIGRAPHY

Subdivisions of a rock series and contacts between formations based upon differences of lithology may vary in stratigraphic position or even become invalid from one locality to another because of lithologic changes. Most of the great mass of Permian Red Beds are composed of a limited number of lithologic types; of these the fine-grained red sandstones and red to red-brown shales are by far the most abundant. Repeated vertical and lateral alternations and gradations between such similar rock types make this series extremely difficult to satisfactorily subdivide.

The writer realizes that some of the formations as defined and described in this paper may not apply to other areas, but he believes that they portray the stratigraphy of the Red Beds of Barber county, Kansas, and in general correspond to units that are traceable south into Oklahoma.

Histograms of several sandstone beds are shown in figure These particular sandstones were chosen because they are more nearly free from shale than most of the beds and are believed to represent the purer sandstone strata. In order to avoid crushing the sand grains, the samples were prepared for screening by grinding them in a mortar,

count

30' below top of Cedar Hills (gray)

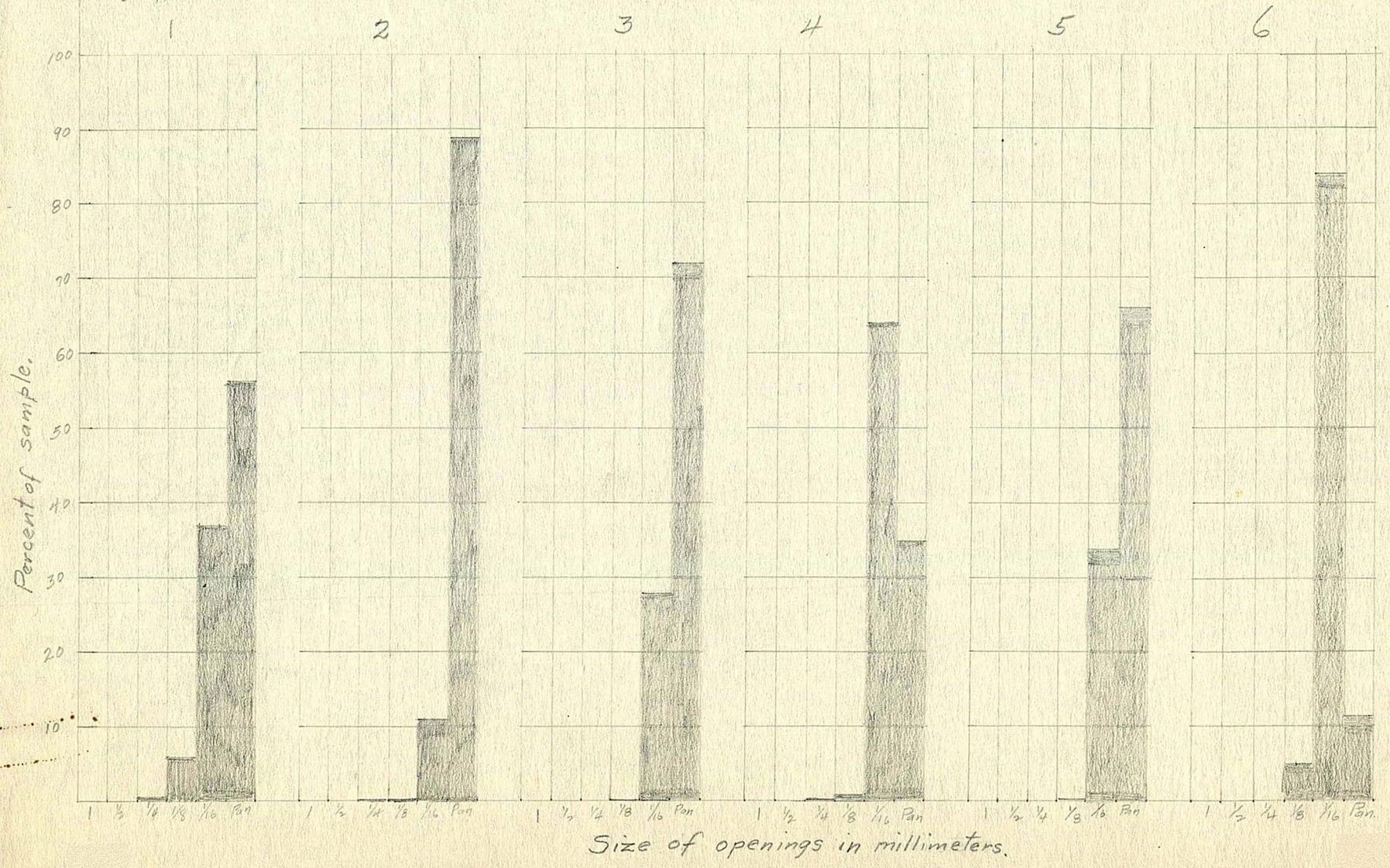
70' below top of Cedar Hills

135' below top of Cedar Hills

17' above base of Dog Creek

27' above base of Dog Creek

Whitehorse



Size of openings in millimeters.

Sand samples for which histograms are shown.

- 1 Greenish gray sandstone about 30 feet below top of Cedar Hills sandstone.
- 2 Massive red sandstone 70 feet below top of Cedar Hills sandstone.
- 3 Massive sandstone 135 feet below top of Cedar Hills sandstone.
- 4 Massive sandstone 17 feet above base of Dog Creek shale.
- 5 Massive sandstone 27 feet above base of Dog Creek shale.
- 6 Representative sample of Whitehouse sandstone.

using a rubber pestle. The results show all the samples tested to be very fine-grained; four of them might well be classed as siltstones since most of the material passed the 1/16 mm. screen.

Freie has made mechanical analyses of many samples of the Red Beds

Freie, A. J., Sedimentation in the Anadarko Basin: Okla. Geol. Survey, Bull. 48, 1930.

of Oklahoma. His results show the entire series to be very fine-grained.

Partial chemical analyses giving the silica, alumina, and iron oxide in several samples of shale and sandstone, made in the chemical laboratories of the University of Kansas, along with values given by Clarke and Washington for the average composition of sedimentary rocks

Clark, Frank Wigglesworth, and Washington, Henry Stephens, The composition of the earth's crust: U. S. Geol. Survey, Prof. Paper 127, p. 29, 1924.

given in the accompanying table
are shown in figure . The samples analyzed are as nearly pure shale and sandstone as could be determined from hand specimens. The quantity of iron oxide in all samples is high, as would be expected in red beds. The light-colored sandstones contain considerably less iron oxide than the red ones. This difference, even within a single bed, is well illustra

	<i>White Dog Creek ss</i>	<i>White Cedar Hills ss</i>	<i>Red Cedar Hills ss</i>	<i>Red Cedar Hills shale</i>	<i>Red Cedar Hills ss</i>	<i>Reddish-brown Flowerpot shale</i>	<i>Mottled Flowerpot ss</i>	<i>Avg. shale</i>	<i>Avg. ss</i>
	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>	<u>7</u>	<u>8</u>	<u>9</u>
SiO ₂	66.85	76.35	66.84	65.74	75.80	51.81	61.66	58.11	78.3
Al ₂ O ₃	7.27	5.96	5.80	12.55	11.51	17.82	7.16	15.40	4.7
Fe ₂ O ₃	1.29	3.53	6.03	8.43	5.69	8.25	1.10	4.02	1.0

1. White ripple-marked sandstone from Dog Creek shale, 28 feet above base of formation.
2. White sandstone 75 feet below top of Cedar Hills sandstone.
3. Red phase of same sandstone as number 2.
4. Red shale 49 feet below top of Cedar Hills sandstone.
5. Bright-red friable sandstone from 20 feet below top of Cedar Hills sandstone.
6. Reddish-brown shale 105 feet above base of Flower Pot shale.
7. Gray and red mottled gypsiferous sandstone 120 feet above base of Flower Pot shale.
8. Average shale
9. Average sandstone.

Numbers 8 and 9 are values given in U. S. Geol. Survey, Prof. Paper 127.

ted in samples 2 and 3.

[Insert table on page 4]

The average of the four sandstone beds analyzed gives 70.22 percent SiO_2 and 7.95 percent Al_2O_3 . Both in texture and composition the sandstone of the Red Beds are more shale-like in character than is the average sandstone. Hence the repeated alternation of these beds which we call sandstones and shales in the Red Beds probably represent smaller variations of depositing conditions than are indicated by changes from sandstones to shales that are less similar in character. The terraces formed by differential erosion of the Cimarron beds occur on the sandstones but their greater resistance is in many cases caused by gypsum that has been carried in by subsurface water and has cemented the sand grains, *rather* ~~other~~ than because of a marked difference in the grain size or other original lithologic character of the various beds.

Profile sections giving the detailed lithology of the Red Beds in the county are shown in figure . The figure is not drawn to scale horizontally and hence does not show the extent of the terraces developed on the resistant sandstone beds, but the bluff-like faces of the massive beds are clearly visible.

Harper Group. Only the upper part of the Harper group occurs at the surface as far west as Barber county. In the southeastern part of the county, where these rocks would otherwise be exposed, the surface is covered by the Gerlane formation. Exposures of the Harper occur here and there, where small hills were not completely covered by the Gerlane and along some of the valleys where the latter formation has been removed by erosion. Few of the outcrops extend very far either laterally or vertically. One of the best exposures of the formation in the area is in a railroad cut about a mile east of Hazelton. The rocks are thin-bedded, dark-red/ sandy shale or shaly sandstone and contain no massive resistant beds. The upper part of the Harper is heavily charged with mineral salts, mostly gypsum, some of which appears to have been derived from leaching of overlying rocks.

A well drilled in the SW. $\frac{1}{4}$ of sec. 11, T. 32 S., R. 10 W. penetrated 745 feet of red strata, of which the upper 40 or 45 feet is Cedar Hills sandstone, hence the Harper at this location is approximately 700 feet thick.

Cedar Hills Sandstone. The Cedar Hills sandstone outcrops in a broad north-south belt across the east-central part of Barber county. The lower 150 to 200 feet of the hills bordering the valley of Medicine Lodge river in the central part of the county are carved from the Cedar Hills. The lower part of the formation is covered throughout most of its extent by the Gerlane formation. In the eastern part of the county inliers of Cedar Hills sandstone project through and rise above the Gerlane beds. The contact of the Harper and the Cedar Hills is, therefore, exposed at only a few places. This contact is placed by the writer at the bottom of what appears to be the lowest of a series of massive resistant beds of sandstone. Such sandstones are a conspicuous feature of the Cedar Hills outcrops, but comparable beds are not present in the upper part of the Harper exposed in western Harper county. The difference in the lithology of the two formations is reflected in the topography; the local relief is slight in the Harper area because of its uniform resistance to erosion, whereas the inequality of resistance of the various beds causes the area of outcrop of the Cedar Hills sandstone to be hilly.

The formation consists of about 240 feet of alternating beds of sandstone and of shale. The shale beds are much less resistant to erosion, and form slopes between the main ledges of sandstone. The slopes are characteristically broken every few feet by minor ledges developed on thin sandstone beds. In many cases the shale is stripped off the surface of a sandstone bed over considerable area. The manner in which various beds of the Cedar Hills sandstone erode may be seen in figure 11.

The sandstone beds of the formation vary in color from light to medium red, and most of them are abundantly speckled and mottled with greenish or bluish-white. In places there are laminae and thin beds of the light sand. Some of these beds, especially one at the top of the formation, are persistent enough to be of value in stratigraphic work. The shales are darker in color than the sandstones and vary from dark-red to purplish-red or reddish-brown. The light-colored markings in the shales are light-green to bluishgreen and in general follow the bedding. The shales are not speckled as are the sandstones. The light color in both sandstone and shale is believed to be largely secondary, produced by reducing the iron from the ferric to the ferrous condition. The solutions that brought the gypsum into the rocks may

omit

Fig 11

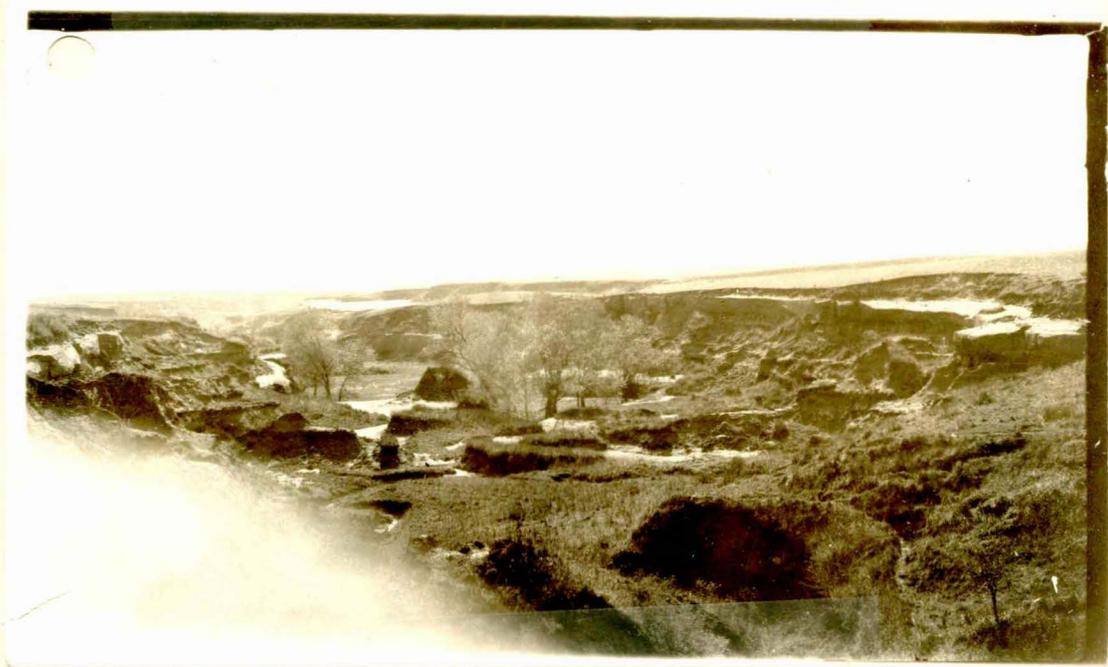


FIGURE 11

have effected the chemical reduction, for the light-color in many cases was observed to be quite abundant at horizons which are well cemented with gypsum. Some of the iron was probably removed by these solutions for, as has been mentioned, the light-colored rock now contains less iron than does the red phase of the same bed. Spots and stringers of light color cross the bedding planes, this relation also suggests that the lighter markings developed subsequent to the deposition of the beds.

Broad flat areas mark the top of the Cedar Hills sandstone in many outcrops because it is more resistant to erosion than is the overlying rock. This physiographic feature is illustrated by the terrace that exists about half way to the top of the Gypsum Hills. In figure 3 the comparatively flat immediate foreground is just above the top of the Cedar Hills. A white sandstone which is the upper bed of the formation is exposed in the small valley near the center of the picture.

Flower-pot shale. The Cedar Hills sandstone is overlain conformably by the Flower-pot shale. Its area of outcrop lies to the west and north of that of the Cedar Hills, reaching essentially to the top of the eastern edge of the High hills in western Barber county and

to the west line of the county in the southwest corner and up the Medicine Lodge river valley. The material in the Flower Pot is practically the same as that in the Cedar Hills sandstone, but the ratio of the very fine to the coarser grades is much greater. The formation consists of dark reddish-brown to reddish-purple shale with many thin and a few thick beds of sandstone. Thin beds and lamellae of greenish and bluish white color are common in the shale, just as they are in the shale beds of the Cedar Hills. Many of the sandstone beds are cemented by gypsum and a perfect net-work of gypsum veins cut the shale beds. The veins are at all angles to the horizontal but their dip is rarely greater than 45 degrees. In some of the veins the gypsum occurs as selenite and in others as satin spar. The fibers of the satin spar are oriented vertically or nearly so, even though the veins have considerable dip. Fragments of the sandstone beds and of the gypsum veins weather out and cover the slopes of the Flower-pot outcrop. The thick beds of sandstone occur in the higher part of the formation and are present wherever these upper beds crop out, ~~in the county~~. Erosion has developed terraces on these sandstone beds (fig. 8) and they are an important factor in giving the butte and mesa topography to the Flower pot shale area of Barber county

Rapid erosion on the steep slopes prevents the accumulation of much soil and that which is present is of poor quality. The lack of fertile soil, together with the climate of the region, results in a scant growth of vegetation in the Flower-pot shale area. Much of it is entirely barren and may be classed as Badlands.

The Flower-pot shale thickens toward the Anadarko Basin; near Lake City the thickness is 173 feet and southwest of Medicine Lodge it is 195 feet. The chart by Griley gives its thickness at Fairview, Oklahoma, as 425 feet.

Medicine Lodge gypsum. The Medicine Lodge gypsum is one of the most interesting formations in Barber county. The white color sets it apart from the Red Beds, it is the most resistant to erosion of any formation in the area, caves have been formed in the gypsum because of its solubility, and it has long been the source of gypsum for the local manufacture of Keene's Cement and other gypsum products.

The main area of outcrop of the formation forms a band around the high ridge that extends southeast and northwest through the west-central part of the county and upon which Deerhead is situated. The band reaches to about the middle of the county east and west. ~~It~~

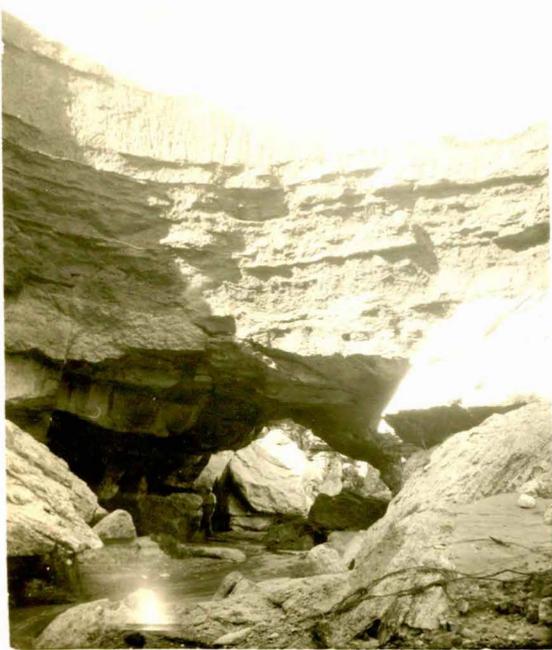
~~paraxixixix~~ North of Medicine Lodge river the outcrop extends for 6 or 7 miles east from the west line of the county and there are a few outliers beyond the main band of the outcrop. The chief of these outliers are those on Gypsum Hills southwest of Medicine Lodge and on the hills in the extreme southwestern corner of the county. The outcrop is rather narrow in most cases because the formation is thin. It forms steep escarpments where the underlying shale has been eroded, allowing fragments of the gypsum to break off. Because of its resistance to erosion the Medicine Lodge gypsum has formed the capping of numerous long narrow ridges and isolated hills, whereas the surrounding area from which the gypsum was removed has been deeply eroded.

The Medicine Lodge gypsum is the only recognizable member of the Blaine formation in Barber county. At the base of the gypsum, throughout most of the area of outcrop, is 6 to 8 inches of gray to buff granular dolomite, although no dolomite is present on the Gypsum Hills in sec. 30, T. 32 S., R. 12 W. North of Medicine Lodge river the outcrop of the dolomite is quite continuous across ranges , whereas the gypsum occurs only in isolated masses. The writer believes this distribution is the result of partial removal of the gypsum by solution or erosion.

The dolomite is separated from the gypsum in most cases by a thin greenish shale parting, but in some occurrences the contact is gradational. The gypsum is characteristically massive in structure and is quite pure, being free from shale and other foreign material. The lower part is rather coarsely crystalline and contains clusters of selenite crystals that give the gypsum a porphyritic appearance, especially if seen in a weathered face. The color is white to gray; the selenite crystals are darker than the surrounding finer-grained portion of the rock. The texture is progressively finer and the color lighter from the bottom to the top of the bed. The material of the upper several feet is quite white and fine-grained, some of it is alabaster-like in appearance. Scattered small crystals of selenite are present in places. The uppermost part of the gypsum is cut by numerous incipient fracture surfaces that are essentially parallel, although they are not geometric planes. These surfaces have a silky luster caused by minute satin spar needles which are all parallel in orientation and appear to have been formed by recrystallization resulting from differential movement along the fracture surfaces. The movement was probably differential slumping, which is known to have

Where exposed at the surface or covered by only a few feet of overburden the upper surface of the gypsum is quite irregular because of solution. Quarrying and mining operations show that in places solution has enlarged the joints for many feet down into the gypsum bed. Numerous caves and subsurface water channels have been developed by solution within the gypsum. In many cases the only surface evidence of the existence of these cavities is the sink-holes which lead to them. Many and perhaps the larger part of such openings have no immediate connection to the surface and their presence is not recognized. In cases where erosion has cut deeply enough the channels may be seen in the rocks of the valley walls. One of the well known examples of the latter type of occurrence is at the natural bridge on Bear creek, about 6 or 7 miles south of Sun City (fig.). The bridge, under which the stream now flows, is the lone remnant of the collapsed roof of a solution channel that developed in the gypsum and eventually stole the surface drainage. The old stream channel is well defined and is a few dozen yards east of the bridge (to the right of the picture). Enlargement of two intersecting joints form a passageway in the west bluff of the creek. One opening is approximately at the left edge of the picture and the other is about opposite the man

Figure .--Gypsum bridge on Bear creek south of
Sun City.



standing under the bridge.

The gypsum averages from 21 to 25 feet in thickness, the greatest observed thickness being 28 feet. The gypsum was probably deposited as anhydrite for small quantities of the latter have been found in the gypsum. Drilling records show that underground from the out-crop gypsum grades into anhydrite.

Dog Creek shale. The Dog Creek shale overlies the Medicine Lodge gypsum in Barber county, although higher members of the Blaine formation are present a few miles farther west. Where the gypsum of the Medicine Lodge member has been removed the Dog Creek rests upon the dolomite at the base of the gypsum. Erosion of the Dog Creek typically develops rather gentle slopes rising above the prominent ledge of gypsum. The slopes are broken by minor benches caused by the resistant sandstone and dolomite beds in the shale. Except for the beds of dolomite, the material of the Dog Creek is very much like that of the Flower Pot shale. Thus the Red-bed deposition was interrupted long enough for the deposition of 27 or 28 feet of gypsum, or the equivalent amount of anhydrite, that is entirely free from sand and shale, even though the material of the Red-beds is fine enough to be easily transported by wind.

The Dog Creek, throughout most of its outcrop, contains several thin beds of impure granular dolomite, but in parts of northwestern Barber county the dolomites are absent and at about the same stratigraphic positions thin beds of gypsiferous sandstones occur. The latter phase is well exposed west of the Best Bros. Quarry southwest of Sun City. At this location the thickness of the formation is about 50 feet thick which appears to be about the average maximum thickness in the region. Similar measurements were obtained at Hell's Half Acre and in sec. 17, T. 32 S., R. 13 W. Wherever the White Horse sandstone still covers the Dog Creek, the upper part of the latter formation consists of several feet of red shale in which are three or four thin beds of dolomite or dolomitic sandstone. This uniformity of occurrence indicates that such variation as exists in the thickness of the formation is the result of unequal deposition rather than pre-White-horse erosion.

Whitehorse sandstone. The Whitehorse sandstone, the highest member of the Cimarron series in Barber county, overlies the Dog Creek shale. The question as to whether this sequence is conformable or unconformable has been discussed under the heading "Classification" in this chapter.

The Whitehorse occurs only in the west-central and northwestern parts of the county. Much of the formation is massive-bedded, friable sandstone which erodes easily but seems to be quite resistant to weathering. As a result the slopes on the Whitehorse formation are commonly quite steep and in many cases are essentially vertical, although a few harder beds give rise to minor benches on some slopes. The Whitehorse has the smallest percent of shale of any of the Red Beds in the county. The color is a lighter more brilliant red than that of any of the other formations. Spots and layers of light color, light-green to greenish or grayish-white, are common to all of the Red Beds but in the lower part of the Whitehorse the spots are large blotches of irregular shape that are elongated vertically, across the bedding (Fig.). This marking is not present in all outcrops but is well developed in T. , R. , and in Hell's Half Acre in northeastern Comanche county.

Fig. .--Lower part of Whitehorse sandstone.



✓

Erosion that preceded the deposition of the Comanchean strata and that which later preceded the Tertiary deposition removed variable amounts of the Whitehorse sandstone, with the result that the thickness of the formation differs with each exposure and gradually increases to the west. Fifty-five to sixty feet is the greatest thickness observed in Barber county, but at Hell's Half Acre 100 feet of Whitehorse sandstone is exposed. In this area also the lower part of the formation is characterized by the large irregular masses of whitish sandstone.

✓ 30 $\frac{450}{30}$
100

Structural Geology

The rock formations from the Ozark Highlands to the Rocky Mountains form a great geosyncline upon which have been developed other rock structures that vary in magnitude from those that affect the attitude of the formations over thousands of square miles to those that can be detected only by the most detailed mapping. The Anadarko Basin in the northern part of western Oklahoma and of the Texas Panhandle is one of the important structures that have been superimposed upon the great geosyncline. The Anadarko Basin is an asymmetrical syncline that pitches toward the center from each end, forming an elongated structural basin that trends about N. 70° W. In the longitude of Barber County the deepest part of the structure is about 120 miles south of the Kansas-Oklahoma line. The north flank of the basin has the gentler dip and the attitude of the rocks in southern Kansas adjacent to this structure is affected by it. Barber County lies on the east limb of the regional geosyncline and almost directly north of the deepest part of the Anadarko Basin. The regional attitude of the rock formations in the county is the resultant of the effects produced by both of these structural features.

The Cedar Hills sandstone and the Medicine Lodge gypsum strike N. 40° to 60° W. and dip to the southwest. Using ~~subsurface~~ ^{the} correlations made by Mr. Robert ~~EXX~~ of the formations reached by several wells in the county, Roth the strike of the top of the Kinderhook beds averages about S 86° W. and the

that
~~strike~~ of the top of the Decorah about N 83° W. The Kinderhook dips east of south and the Decorah west of south. The average dip in feet per mile of the Decorah is about 95, of the Kinderhook about 35, and of the surface formations about 7 to 10. The rock formations thicken toward the center of the basin. This condition is thought to have been caused partly by subsidence during deposition and partly by truncation, during periods of erosion, of the strata forming the limbs of the syncline. The variation in the thickness of formations is very probably one of the chief causes of the differences in the direction and amount of dip of the various formations.

Detailed mapping of the surface formations reveals the fact that small anticlines and synclines are present throughout most of the county. The rocks dip away in all directions from many of the points of high surface elevation. The capping formations *on the* ~~or~~ ridges extending out from the major divides typically dip toward the main valleys. Local dips of this character in many cases are ~~steep~~ enough to be easily seen by the unaided eye. A small dome in sec. 1, T. 31 S., R. 14 W. is an excellent example of the small structures in which the rocks have very steep dips. In this instance the rock formations dip away sharply on all sides within a few hundred feet of the center of the dome. These minor structures are very probably caused by slumping of the overlying beds, contemporaneous with or following the solution of salt that was originally present lower in the Red

Beds. In some cases solution of gypsum may have been a contributing factor. There also may have been some settling of the rocks that cap the secondary ridges, caused by creep of the underlying shale when saturated with water. The location of some of the present high topographic areas may have been determined in part by the structural highs that resulted from the general slumping following solution. The shale erodes much more easily than the sandstone, gypsum, or dolomite, and would be rapidly stripped off leaving a surface controlled by the hard beds. These small slump structures have no bearing upon the possible accumulation of oil or gas in the deeper strata. A structural contour map showing the relation between the highest points of the various small structures present in the surface rocks probably gives a more accurate representation of the structure of the deeply buried rocks.

102 ✓ In an area such as Barber county where the rocks that can produce oil or gas are so deep and where the conditions of sedimentation and leaching have been so variable, surface structures must, as a rule, be of considerable size if they affect the strata down to and including the reservoir rock.

Economic Geology

②

Water Supply. The quantity and the quality of the subsurface water in Barber County bear a very close relation to the geology. In the parts of the county where the Permian formations are exposed at the surface the best source of water is the Gerlane formation occurring as valley filling. The Red Beds themselves are quite impervious and the water that does seep through the sandy beds or circulate along the joints is highly charged with gypsum. However, in those parts of the county that are overlain by the Tertiary sands and gravels little difficulty, in general, is experienced in obtaining plenty of well water of suitable quality for domestic use. Most of this rock formation is very porous and in some places the water works down until the zone of saturation is rather deep and may be just above the underlying bed rock. However, in many areas strata of impervious clay are interbedded with the coarser material giving perched water-tables and providing a source of water at shallow depth. Water comes to the surface as seeps and springs along much of the outcrop of the contact between the Tertiary formation and the underlying Red Beds. Springs at this horizon are particularly abundant where the south flowing tributaries of Medicine Lodge River are cutting back into the southern edge of the large area of Tertiary rocks to the north. Many of these streams are spring fed and would

be dry much of the year if they received only the surface drainage. The abundant and constant supply of water furnished by the springs has made possible the formation of two artificial lakes, one known as Elm Mills and the other as Ninety Nine Springs Lake. The former is in sec. , T. .. R. .. and the latter is in sec. , T. .. R.

The chief supplies of water for the towns come from the underflow of the streams or from gravel horizons in the Gerlane formation. Medicine Lodge and Kiowa have municipal water systems. The water for Medicine Lodge is secured from the underflow through the gravel in the bed of Elm Creek a few miles above the town and is brought down by gravity flow. Often during very dry periods the surface flow of Elm Creek ceases, but the municipal supply, although it has been low at times, is reported to have never failed. At Kiowa the water formerly came entirely from wells in the flood plain of Medicine Lodge River, but during the summer of 1931 wells were sunk in the Gerlane formation near the southwest corner of town and both sources are now used. ~~In the wells in the Gerlane formation~~ by the wells in the Gerlane formation a bed of gravel was reached at a depth of about 60 feet from which a good supply of water is obtained. The quality of the water in these wells is better than that secured from the flood-plain wells and the latter supply may eventually be abandoned.

The other towns in the county get water from individual wells, most of

which are drilled or dug in the Gerlane formation.

Brick Clay. There are several old buildings in Medicine Lodge, one of which is shown in Figure 20A, built of bricks of local manufacture. The brick clay was obtained from pits just southwest of town and wood was used to fire the kilns. The resulting bricks were not of high quality, being too soft and sandy. An attempt was made at about the same time to manufacture bricks at a point in the northeastern part of the Gypsum Hills a few miles southwest of Medicine Lodge. The clay was molded and stacked for firing but there the project ended. In Figure 20b can be seen what is left of the stack of unfired brick after 45 years of weathering.

The material from which these bricks were made contains large amounts of iron oxide, fine quartz sand, and variable quantities of gypsum. Such clay would probably yield an inferior grade brick even with proper firing. It is doubtful if any clay in Barber county would make good quality brick.

sand and Gravel. Most of the sand and gravel deposits of the county that are now being used are in the Gerlane formation, ~~they~~ ^{and} occur at places where ^{much} ~~most~~ of its material was derived from the erosion of the Tertiary beds. Many of the deposits are comparatively free from clay and fine sand. ~~and where there was enough sorting to remove much of the clay and fine sand~~ ^{are} of the Tertiary. Sand and gravel ~~is~~ obtained from pits in the eastern part of

20.—

Fig. 20a, Building in Medicine Lodge made of bricks
manufactured from local clay.

Fig. 20b, Unfired bricks. Those within the mound have retained
their shape through 45 years of weathering.



FIGURE 20B

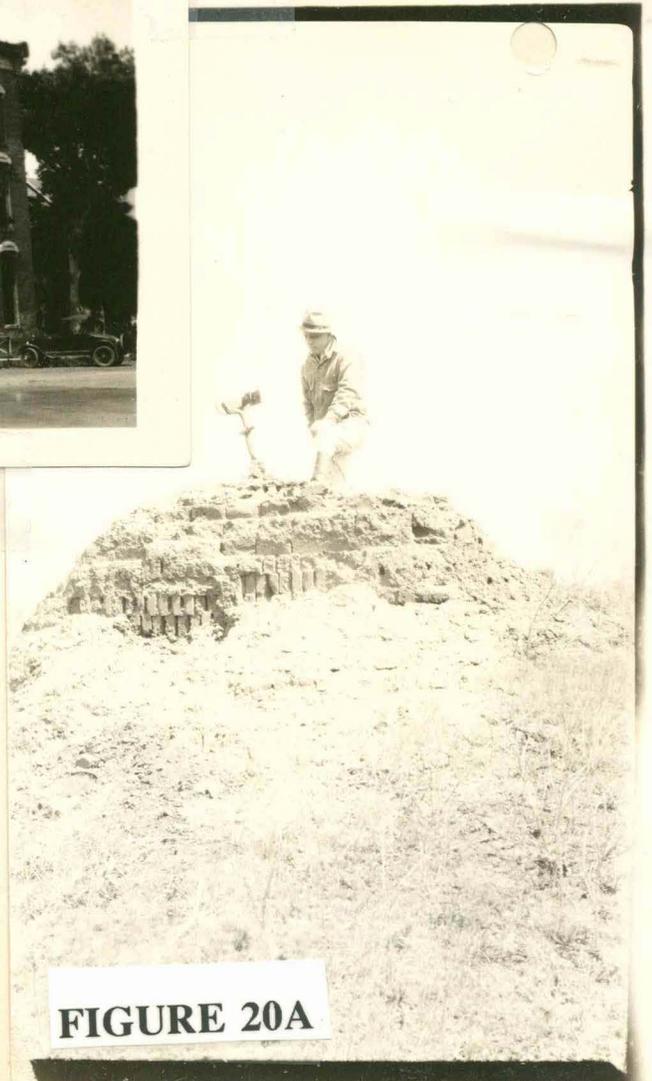


FIGURE 20A

the town of Medicine Lodge and in the small hills along the southern part of Elm Creek. These deposits were formed by the deposition of material carried by a stream that had about the same course as the present Elm Creek. They are confined to an area of several square miles just northeast, east, and southeast of Medicine Lodge. Gravel that was deposited in old stream channels has been used in some cases. The pit on the east side of the Medicine Lodge-Kiowa road just south of Medicine Lodge River is an example of this type of occurrence. Such deposits are of rather wide distribution in the area of Permian outcrop south and west of Medicine Lodge River, but few of them are large enough to be of value as a source of gravel.

The material of some of the Tertiary beds can be used for those purposes not requiring that the sand or gravel be free from clay.

Salt. Well records show that under most of Barber county there are salt beds of great thickness. Most of the salt occurs at a depth of 1,000 to 1,500 feet, but in a well in sec. 13, T. 33 S., R. 13 W. salt was reached at a depth of 840 feet. This bed is recorded as 110 feet thick. At towns a few miles east and north of Barber county salt has been mined for many years. With the supply of natural gas that is now available as fuel, salt mining using the brine method, may be considered a potential industry in Barber county.

Gypsum. The utilization of the gypsum deposits began soon after the county was settled. In 1889 William C. and Thomas J. Best began the manufacture of Keene's Cement at Medicine Lodge and the company has operated continuously since then under the name of Best Brothers Keene's Cement Company. As the name implies their chief product is Keene's cement. Like plaster of Paris, it is made by calcining gypsum but at a much higher temperature. This treatment removes essentially all of the water of crystallization of the gypsum. The resulting material, if mixed with water, crystallizes and sets too slowly to be of value as a cement. Some chemical, usually a simple sulphate or an alum of one of the alkaline metals, is added to hasten the rate of setting. This product is known as Keene's cement. When it has set it is harder, takes a better polish, and is stronger than plaster of Paris. Keene's cement can be retempered without injury to the quality of the cement or plaster, a property entirely lacking in plaster of Paris.

~~A comparison of the original with the present~~ ^{The} Best Bros. mill is shown in Figure 21. The Best Bros. company make ^{more than} over 50 per cent of the Keene's cement manufactured in the United States. Before the business decline of the last few years the total production amounted to about 50,000 short tons annually.

~~Gypsum was originally obtained~~ ^{at the gypsum} from quarries in the hills a few miles southwest of Medicine Lodge. Later, quarries were opened in the northwestern

~~Fig. 21a. Original Best Bros. mill.~~ NOT AVAILABLE

Fig. 21b. ^{94 present} ~~Present~~ Best Bros. mill. ^{at Medicine Lodge}



part of the county where the gypsum bed had not been so badly cut by erosion and larger quarries could be operated. For many years all the gypsum used by the company was obtained from quarries on the south side of the Medicine Lodge valley just west and south of Sun City. As the quarries were cut back into the hill the amount of overburden that had to be removed became greater and greater.

In about 1930 or ¹⁹³¹ ~~1930~~ the quarrying operations were abandoned and the gypsum is now mined by the room and pillar method from horizontal entries driven in from the old quarry-face. This method has other advantages, ^{also} for the working conditions are pleasanter and more uniform, there is less loss of time because of weather conditions, and the gypsum is obtained entirely free from clay and soil without the constant precaution and care necessary in quarrying.

Figure 22a shows the face of one of the quarries when it was in operation, and 22b ~~shows~~ shows a working face underground. The gypsum is 25 to 27 feet thick where it has not been affected too much by solution or erosion and is of excellent quality. Throughout most of the deposit there is hardly any calcium carbonate or anhydrite, the anhydrous calcium sulphate, ^{except in} and away from the scattered solution channels and fractures there is no clay in the gypsum.

The reserves of gypsum in western Barber county are so large that the amount thus far removed is negligible compared to that which remains.

Fig. 22. a Sun City quarry.

22 b Gypsum Mine



FIGURE 22A



FIGURE 22B

BORING
IN BIGHT CO. CO.

Fig. 24. Gasoline extraction plant.



FIGURE 24

BINNING
MEDICINE LODGE, KAN.

Stratigraphic Section, Barber Co., Kan.

Quaternary { River flood plains
Sand dunes
Gerlane formation

Cenozoic

Tertiary

Mesozoic Cretaceous Comanchean { Kiowa shale
Cheyenne sandstone

1000

Geology of Barber County, Kansas.

I Introduction
Field notes and acknowledgments.

II Geography
Location & culture.
Climate & vegetation
Topography.
Drainage

1 orig
3 carbons -

III Physiography
Valley shape

IV Stratigraphy
Surface formations
Permian
General
Previous work
Classification
Names and their application.
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51/20r

E-Ord.

GR

George¹

Woodfordsh 4630-58

Hampton 4688-90

Sylvan Sl 4690-4702

Viola LS 4702-10

W. West Sand 4752-4855

24
37

TT
TT
TT

Blank

2 1/2 inches

Boggs

~~2500~~
~~1600~~
~~4100~~
~~2650~~ 2000
~~1600~~
~~4250~~

1376
 - 2500
 3876

George

Lower #
 refer to
 top of
 or where
 they rest on
 datum plain

Blank

Boggs

Powell

Winters

Hastings

2500
 - 1600
 4100

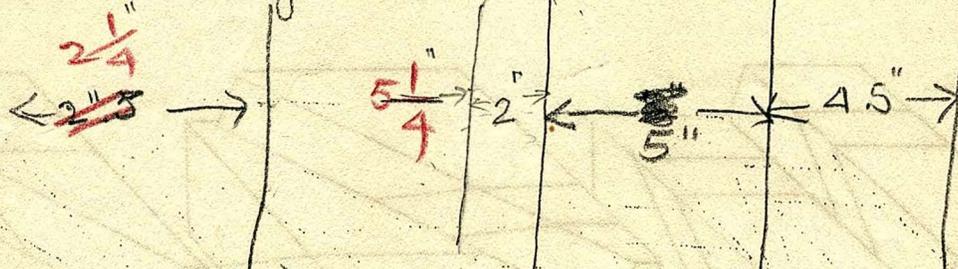
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 4035

- 2500
 1516
 4016

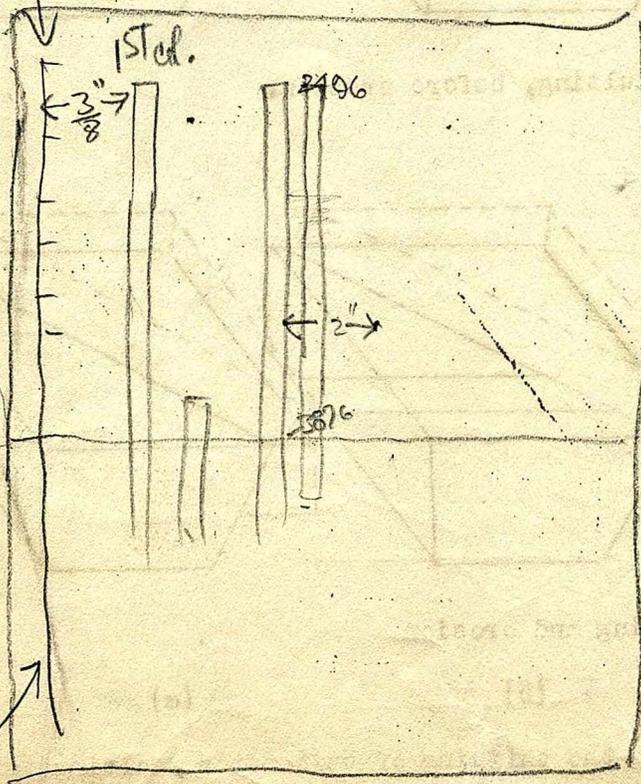
2500
 1627
 4127

2500
 1812
 4312

- 2500
 1600
 4200



Ver. Sec 500' inf. (3/4" wide)



1" for sized Descriptive terms and fossil names

4100
 2650
 1450

3571
 4100
 1470

Blank. +14.5 above datum
 Boggs - 14.7 below datum (4100)

14.7
 14.5
 29.2

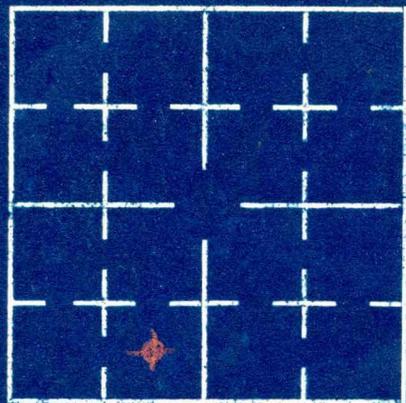
Border

9 1/2 inch

Ver. Sec.

WELL LOG

State **Kansas** Co. **Barber** Farm **George** 1-4 **12** Twp. **33S** Rge. **10W**



Location **C-SE-SW** Well No. **1**
 Lessee **I. T. I. O. et al** Operator _____
 Date Location Made _____ By _____
 Drilling Commenced **7-15-34** Drilling Completed **8-26-34**
 Drilling Contractor _____
 Method of Drilling **Rotary** Elevation **1376** Total Depth **498**
 Commenced Producing _____ I. P. First 24 Hr. _____
 Gravity _____ °Baume _____ Per Cent Water _____ Color _____ Water _____
 Gas From _____ ft. to _____ ft. I.O.F., M. cu. ft. _____ R.P. lbs. _____
 Gas From _____ ft. to _____ ft. I.O.F., M. cu. ft. _____ R.P. lbs. _____

Casing Record			Left in Hole		Shot Record			
Landed at	Size Ins.	Wt per ft	Length	From	To	Date	Quarts	Shot Between

Remarks: (Methods used in protecting all oil and gas sands from top and bottom water)

Dry Hole

FORMATION RECORD

- 220-230 — Red Brown Gyp. shale, trace gyp and light gray shale
- 230-240 — Reddish brown gypsiferous shale, trace free gyp.
- 240-250 — Reddish brown gypsiferous shale
- 250-270 — Reddish brown gypsiferous shale, trace free gyp.
- 270-280 — Reddish brown gypsiferous shale, little pale green shale, trace gyp.
- 280-290 — Reddish brown shale part gyp, little gyp., trace pale green shale
- 290-300 — Reddish brown gyp. shale, little gyp., trace green shale
- 300-310 — Reddish brown gyp. shale little gyp, little pale green shale
- 310-320 — Reddish brown gyp shale, little gyp., trace pale green shale
- 320-340 — Brick red shale, little pale green shale, trace gyp.
- 340-360 — Brick red shale, little pale green shale
- 360-370 — Brick red shale, little pale green shale, trace gyp.
- 370-380 — Brick red shale, little pale green shale
- 380-440 — Brick red shale, few pale green shale spots
- 440-450 — Brick red shale, few pale green shale spots and green shale streaks
- 450-500 — Brick red shale, few pale green shale spots streak green shale (one frag. dol.)
- 500-510 — Brick red shale, with pale green shale spots
- 510-520 — Brick red shale, with pale green shale spots, trace yellowish brown shale
- 520-550 — Brick red shale, with pale green shale spots, streak pale green shale
- 550-560 — Brick red shale, little pale green shale
- 560-570 — Brick red shale, little pale green shale
- 570-580 — Brick red shale, with pale green shale spots
- 580-650 — Brick red shale, little pale green shale spots
- 650-670 — Brick red shale, little pale green shale, trace greenish gray shale
- 670-680 — Brick red shale little pale green shale, trace light green dolomite and trace greenish gray shale
- 680-690 — Greenish gray shale
- 690-700 — Greenish gray shale, trace gray sucrose, argill. dolomite, trace anhydrite
- 710-720 — Greenish gray shale, trace anhydrite
- 720-730 — Greenish gray shale, trace anhydrite, trace gray to buff dolomite

Base "red" 680

FORMATION RECORD

- 730-740 - Greenish gray shale, trace gray to buff dolomite
740-750 - Greenish gray shale, trace gray to buff dolomite, trace anhydrite
750-760 - Greenish gray shale, trace anhydrite
760-780 - Greenish gray shale
780-790 - Greenish gray shale, trace anhydrite
790-800 - Greenish gray shale
800-810 - Greenish gray shale, trace light gray to buff angular dolomite, trace anhydrite
810-820 - Greenish gray shale, trace light gray to buff angular dolomite
820-830 - Greenish gray shale, trace anhydrite
830-840 - Greenish gray shale, little anhydrite
840-850 - Greenish gray shale, trace anhydrite
850-860 - Greenish gray shale, little yellowish brown shale, trace anhydrite and trace sucrose angular dolomite
860-870 - Greenish gray shale, trace yellowish brown shale, trace anhydrite
870-880 - Greenish gray shale, trace angular dolomite and gyp.
880-890 - Greenish gray shale, trace anhydrite
890-900 - Greenish gray shale, little anhydrite
900-910 - Greenish gray shale, little gray angular dolomite, trace anhydrite
910-920 - Greenish gray shale, little gray marly dolomite, trace anhydrite
920-930 - Greenish gray shale, little dark gray shale and anhydrite, trace marly dolomite
930-940 - Greenish gray shale, little bright red shale, trace anhydrite, trace marly dolomite
940-950 - Greenish gray shale, some anhydrite
950-960 - Greenish gray shale and anhydrite, little bright red shale, trace marly dolomite
960-970 - Greenish gray shale, some anhydrite, trace marly dolomite
970-980 - Anhydrite part porous, little marly dolomite
980-990 - Greenish gray to light gray shale and anhydrite, little marly dolomite
990-1000 - Light gray shaly dolomite and anhydrite, little green gray shale
1000-1010 - Light gray shaly dolomite and anhydrite, little green gray shale
1010-1020 - Bright red shale, little anhydrite
1020-1030 - Bright red shale, little anhydrite, trace gyp.
1030-1040 - Bright red shale, some anhydrite
1040-1050 - Anhydrite, little bright red and green gray shale
1050-1060 - Soft green gray and red shale, little anhydrite
1060-1070 - Anhydrite and soft green gray and red shale
1070-1080 - Anhydrite and soft green gray and red shale
1080-1090 - Anhydrite
1090-1100 - Anhydrite, little soft green gray shale
1100-1110 - Anhydrite part porous, little soft green gray shale
1110-1120 - Anhydrite part porous, little dark gray shale
1120-1130 - Anhydrite, little gyp.
1130-1140 - Anhydrite, part porous
1140-1150 - Anhydrite (?), (salt on sample bag)
1150-1160 - Anhydrite (?), (salt on sample bag), little gray shale
1160-1170 - Anhydrite (?), little grayish, some salt crystals
1170-1180 - Anhydrite, little greenish gray shale, few salt crystals
1180-1190 - Anhydrite, little greenish gray shale
1190-1200 - Anhydrite, some green gray and red shale
1200-1210 - Green gray and red shale, little anhydrite
1210-1220 - Red shale, little dark gray shale, trace anhydrite
1220-1230 - Red shale and little green gray shale, little anhydrite
1230-1240 - Red shale, little green gray shale, trace black shale, trace anhydrite
1240-1250 - Anhydrite, little red and green gray shale
1250-1260 - Anhydrite part porous and little green gray and red shale

FORMATION RECORD

- 1260-1270 - Anhydrite part porous
1270-1280 - Anhydrite part porous, and little green gray and red shale
1280-1290 - Green gray and red shale, little anhydrite
1290-1300 - Green gray and red shale, some anhydrite
1300-1310 - Green gray and red shale, little anhydrite
1310-1350 - Anhydrite part porous
1350-1370 - Anhydrite part porous, little green gray shale
1370-1390 - Anhydrite part porous
1390-1400 - Anhydrite little green gray and red shale
1400-1410 - Anhydrite, trace green gray shale
1410-1420 - Anhydrite, little green gray shale
1420-1430 - Anhydrite
1430-1440 - Anhydrite, some green gray shale, trace red shale
1440-1450 - Anhydrite
1450-1460 - Anhydrite, and green gray shale
1460-1470 - Anhydrite, and green gray shale, (few qtz. pebbles)
1470-1480 - Anhydrite
1480-1490 - Anhydrite, trace green gray shale
1490-1500 - Anhydrite, little green gray shale
1500-1510 - Green gray, little red shale, little anhydrite
1510-1520 - Anhydrite, little green gray shale
1520-1530 - Anhydrite
1530-1540 - Anhydrite and some green gray shale
1540-1550 - Green gray shale, trace anhydrite
1550-1560 - Anhydrite, little buff sucrose dolomite
1560-1570 - Anhydrite and soft green gray and red shale
1570-1580 - Red shale, trace green gray shale
1580-1590 - Red shale, little buff dolomite, partly argillaceous
1590-1600 - Dolomite partly argillaceous, little dark chert, little anhydrite
1600-1610 - Gray dolomite lime, partly argillaceous, little dark chert and green gray shale
1610-1620 - Gray argillaceous dolomite, trace dark chert, little anhydrite, trace brown shale
1620-1630 - Gray brown porous dolomitic lime
1630-1640 - Gray brown porous dolomite, partly argillaceous
1640-1650 - Gray brown porous dolomite, little green gray shale
1650-1660 - Green gray and dark gray shale, little porous dolomite, trace chert
1660-1670 - Green gray and gray shale, some sucrose, argillaceous dolomite
1670-1680 - Green gray and gray shale, little mottled, light gray and gray lime
1680-1690 - Gray argillaceous lime, partly finely calcareous
1690-1700 - Gray argillaceous lime, trace chert
1700-1710 - Light gray finely foss. lime, part slightly porous, trace chert
1710-1720 - Light gray finely foss. lime, little gray argillaceous lime, little green gray shale
1720-1730 - Light red and brown shale, little gray lime, partly argillaceous
1730-1740 - Light green to buff lime, little white chert
1740-1750 - White chert, little gray shaly lime
1750-1760 - Gray to buff argillaceous lime, trace white chert
1760-1770 - Gray to buff argillaceous lime
1770-1780 - Gray to buff argillaceous lime, trace dark chert
1780-1790 - Gray to buff argillaceous lime
1790-1800 - Gray speckled lime, partly argillaceous, part finely foss
1800-1810 - Gray to buff argillaceous lime
1810-1820 - Gray to buff lime, part slightly argillaceous argillaceous, little gray shale

Lessee I. T. I. O. Operator Farm George Well No. 1

FORMATION RECORD

- 1820-1830 — Buff sucrose lime, part slightly argillaceous
 1830-1850 — Buff lime, part slightly argillaceous, little gray chert
 1850-1860 — Soft light gray to buff lime, little gray chert
 1860-1870 — Soft light gray to buff lime, little gray shale, trace chert
 1870-1880 — Soft light gray to buff lime, trace gray brown finely crystalline lime, little light and dark gray chert
 1880-1890 — Gray shaly lime, little gray calcareous shale
 1890-1900 — Buff lime, part slightly argillaceous, little gray shaly lime, fus. abundant
 1900-1910 — Gray to buff sucrose lime, partly speckled, partly argillaceous, trace greenish cast lime
 1910-1920 — gray sucrose argillaceous lime, little gray calcareous shale
 1920-1930 — Gray to greenish gray shale, trace bright green shale, trace red shale
 1930-1940 — Gray shale, little light gray to buff lime
 1940-1950 — Gray to buff lime little gray brown finely crystalline lime, trace gray shaly lime
 1950-1960 — Gray to buff lime and some brown chert with spines
 1960-1970 — Gray brown sucrose to finely crystalline lime, trace chert with spines
 1970-1980 — Gray lime, partly argillaceous, little gray shale, trace bright green shale
 1980-1990 — Gray lime, party shaly, little gray shale,
 1990-2000 — Gray brown dense to finely crystalline lime, some gray calcareous shale
 2000-2010 — Gray shale, partly calcareous, little gray shaly lime
 2010-2020 — Gray to brown sucrose lime, partly argillaceous, trace brown dense lime, trace gray shale
 2020-2040 — Gray to buff lime, partly argillaceous, trace gray shale
 2040-2050 — Light gray soft lime, little gray sucrose shaly lime, little chert
 2050-2060 — Light gray to buff lime, trace gray brown dense lime
 2060-2070 — Gray shale, little black shale
 2070-2080 — Gray shale, little gray brown dense lime
 2080-2090 — Gray brown dense lime, some gray shale
 2090-2100 — Gray brown dense lime
 2100-2110 — Gray to green gray shale, some red shale (?) Cavings
 2110-2120 — Gray and light gray lime, partly argillaceous
 2120-2130 — Gray calcareous shale, little gray shaly lime
 2130-2140 — Gray calcareous shale, little shaly lime, little light gray soft lime
 2140-2170 — Light gray to buff lime
 2170-2180 — Light gray to buff lime, little gray shale
 2180-2190 — Light gray to buff lime, little gray shale, trace chert
 2190-2200 — Light gray to white chalky lime and finely crystalline lime
 2200-2210 — Light gray lime, some gray brown dolomite, porous
 2210-2220 — Brown granular porous dolomite, little gray oolitic foss. lime (oil stained)
 2220-2230 — Gray oolitic and fossiliferous lime, porous
 2230-2250 — Dark gray sucrose argillaceous lime, little gray shale
 2250-2260 — Gray shale, little gray brown sucrose to finely crystalline lime
 2260-2270 — Gray Brown lime, little black shale
 2270-2280 — Light gray to white chalky lime, little gray shale
 2280-2290 — Light gray lime, little dark gray shale
 2290-2300 — Dark gray to black shale
 2300-2310 — Dark gray shale, little light gray to buff lime
 2310-2320 — Light gray to gray lime, partly slightly argillaceous, trace gray chert
 2320-2330 — Gray speckled lime, slightly oolitic, dark oolite
 2330-2340 — Light gray to buff lime, little gray shale
 2340-2350 — Light gray to buff lime, little gray shale, trace white chert
 2350-2360 — Gray to dark gray shale

FORMATION RECORD

- 2360-2370 - Gray to dark gray shale, trace brown lime
- 2370-2380 - Brown sucrose to finely crystalline lime
- 2380-2390 - Brown sucrose to finely crystalline lime, partly argillaceous, little green shale
- 2390-2400 - White chalky lime, little gray and dark gray calcareous shale
- 2400-2410 - Gray brown sucrose lime, little white lime, trace dark gray shale
- 2410-2420 - Dark gray lime, little gray shale
- 2420-2430 - Light gray to buff lime, some gray shale
- 2430-2440 - Gray to green gray shale
- 2440-2450 - Gray to green gray shale, little brown lime
- 2450-2460 - Gray to dark gray shale
- 2460-2470 - Light gray to white chalky lime, trace glauconitic lime
- 2470-2480 - Light gray to buff lime
- 2480-2490 - Buff to light brown lime, partly dense, little gray shale
- 2490-2500 - Buff lime, little gray shale, trace very fine micaceous calcareous sand
- 2500-2510 - Gray micaceous sandy shale, trace black shale, trace very fine micaceous calcareous sand
- 2510-2520 - Gray micaceous sandy shale, trace very fine dense micaceous calcareous sand
- 2520-2530 - Gray and black shale, little micaceous sandy shale, trace brown lime
- 2530-2540 - Gray shale, partly micaceous and gritty, little gray argillaceous lime
- 2540-2550 - Gray and dark gray shale, little gritty shale, little gray shaly lime
- 2550-2560 - Gray shale, partly micaceous and sandy, little brown lime, finely crystalline
- 2560-2570 - Gray shale, some gray brown lime
- 2570-2580 - As above
- 2580-2590 - Gray shale, some gray brown lime, some gray gritty shale
- 2590-2600 - Light gray and gray sucrose lime, partly argillaceous, little gray micaceous gritty shale
- 2600-2610 - Light gray sucrose lime partly argillaceous, little gray micaceous gritty shale and finely white micaceous sand
- 2610-2620 - Light gray to buff chalky lime, little fine white micaceous calcareous sand
- 2620-2630 - Gray brown sucrose and fine crystalline lime and gray shale
- 2630-2640 - Fine gray micaceous and calcareous sand
- 2640-2650 - Fine dense impure calcareous sand, little sandy lime and gray calcareous shale
- 26 2650-2660 - Gray and dark gray shale, trace sandy lime and little gray lime, part argillaceous *Emporia lime 2657*
- 2660-2670 - Light gray and brown lime, little gray shale
- 2670-2680 - Gray shale, some white chalky lime, little light brown finely crystalline lime
- 2680-2690 - Light gray and white chalky lime
- 2690-2700 - Light gray and white chalky lime, little dark gray shale, trace gray brown fine crystalline lime
- 2700-2710 - Light gray and white chalky lime, little gray brown fine crystalline lime
- 2710-2720 - Gray shale, some light gray to brown lime, Trace sandy lime, trace chert
- 2720-2740 - Light gray sucrose and brown finely crystalline lime, little gray shale, trace chert
- 2740-2750 - Light gray sucrose and brown finely crystalline lime, trace pale green shale
- 2750-2760 - White chalky lime, little gray brown fine crystalline lime, little dark gray shale
- 2760-2770 - Light gray to gray brown fine crystalline lime, part finely foss., trace oolitic lime
- 2770-2780 - Light gray to gray brown fine crystalline lime, part finely foss.,
- 2780-2790 - Light gray to white chalky lime, little buff finely porous lime
- 2790-2800 - Light gray sucrose to finely crystalline lime, part oolitic and porous

Lease

I. T. I. O.

Operator

Farm

George

Well No. 1

FORMATION RECORD

- 2800-2805 — Light gray sucrose to finely crystalline lime, trace brown dense lime, very slightly porous
- 2805-2810 — Light gray chalky lime
- 2810-2815 — Light gray chalky lime, part slightly porous
- 2815-2820 — Light gray chalky lime, little light brown dense lime
- 2820-2825 — Light gray chalky lime, few thin carbonaceous streaks, little light brown dense lime
- 2825-2830 — Light gray chalky lime
- 2830-2835 — Light gray to buff lime, part porous
- 2835-2845 — Gray brown semi-crystalline lime, part finely porous
- 2845-2850 — Gray oolitic lime, porous
- 2850-2860 — Light gray lime, part oolitic and little brown finely crystalline porous lime
- 2860-2900 — Light gray to white lime
- 2900-2910 — Light gray to buff sucrose lime
- 2910-2930 — White chalky and light gray sucrose lime
- 2930-2940 — White chalky and light gray sucrose lime, trace light brown finely crystalline lime
- 2940-2950 — White chalky and little light brown finely crystalline lime, little dark gray shale
- 2950-2960 — Dark gray shale, little gray lime
- 2960-2970 — Dark gray shale, little light brown sucrose to finely crystalline lime
- 2970-2980 — Dark gray shale, and fine white angular dense micaceous calcareous sand
- 2980-2990 — Fine white angular dense calcareous sand, little sandy shale, little buff lime
- 2990-3000 — Gray shale, little light gray to buff lime
- 3000-3040 — Gray and dark gray shale, trace brown dense lime
- 3040-3050 — Gray and dark gray shale, some light gray lime, part oolitic
- 3050-3060 — Gray and dark gray shale, trace brown dense lime and chert
- 3060-3070 — Gray and dark gray shale, little brown dense lime
- 3070-3080 — Light gray and gray brown finely porous lime
- 3080-3090 — Light gray lime, trace oolitic lime
- 3090-3100 — Light gray lime, little dark brown finely crystalline lime, little gray dense glassy sand
- 3100-3110 — Dark brown dense to finely crystalline lime, trace dense gray sand
- 3110-3120 — Gray dense sand, little light gray lime, little gray shale, trace red shale
- 3120-3130 — White fine dense calcareous sand, little gray shale, little lime, trace red shale
- 3130-3140 — Gray and dark gray shale, little dense fine white calcareous sand
- 3140-3150 — Gray shale, little reddish brown shale, trace dense white sand
- 3150-3160 — Gray and dark gray shale, little fine white dense sand, trace red shale and chert
- 3160-3170 — Light gray to white chalky lime, little gray shale, trace red shale
- 3170-3180 — Gray and dark gray shale, little fine white dense calcareous sand, trace lime
- 3180-3190 — Gray and dark gray shale, trace red brown shale, trace gray brown lime
- 3190-3200 — Gray and dark gray shale, trace red brown and pale green shale
- 3200-3210 — Light gray sucrose little grayish brown finely crystalline lime, trace finely porous lime
- 3210-3220 — Gray shale, little gray lime, trace white chert
- 3220-3230 — Gray shale, little light gray lime
- 3230-3240 — Grayish brown sucrose lime, some gray shale, trace red shale
- 3240-3250 — Light gray to grayish brown lime, little gray shale
- 3250-3260 — Gray and dark gray shale, little reddish brown shale
- 3260-3270 — Gray shale, little light gray lime

Topok 3046

Lesse I. T. I. O. Operator Farm George Well No. 1

FORMATION RECORD

- 3270-3280 — Gray shale, trace coal
- 3280-3290 — Gray shale, white dense fine to medium sand, little grayish brown lime
- 3290-3300 — Fine white dense sand, part calcareous
- 3300-3310 — Fine to medium white sand, part calcareous and micaceous
- 3310-3320 — Fine to medium white sand, part calcareous and micaceous, little dark gray shale
- 3320-3330 — Dark gray shale, little medium white micaceous sand
- 3330-3340 — Gray to dark gray shale, little red shale, trace fine impure dense sand
- 3340-3350 — Gray to dark gray shale, trace red shale, little light gray lime
- 3350-3360 — Gray to dark gray shale, some brown sucrose to finely crystalline lime
- 3360-3370 — Gray to dark gray shale, trace black shale
- 3370-3380 — Gray to dark gray shale
- 3380-3390 — Gray to dark gray shale, some light gray sucrose lime
- 3390-3400 — Black carbonaceous shale
- 3400-3410 — Black carbonaceous shale, some grayish brown lime
- 3410-3420 — Grayish brown sucrose and brown dense to finely crystalline lime
- 3420-3430 — White chalky and little grayish brown dense to finely crystalline lime
- 3430-3440 — White chalky and little grayish brown dense to finely crystalline lime, trace gray shale
- 3440-3450 — White chalky and light gray dense lime, little dark gray shale
- 3450-3455 — Gray and dark gray shale, some white chalky lime and light gray lime
- 3455-3460 — White chalky lime and light gray lime, little gray shale
- 3460-3465 — (Circulated 1 hour at 3465) light gray lime and very fine sand slightly micaceous.
- 3465 (circulated 1 hour and 45 min.) very fine grained sand, slightly micaceous, part shaly.
(Note: Formation softened at 3458 which is probably top of sand)
Cored 3465 to 3475, recovered 7 ft.
- Top 3' Dark gray shale
- Next 18" Gray to brown shaley lime and limey shale
- Bottom 2'6" Greenish gray slick shale
- 3475-3480 — Gray shale, little dark brown dense to finely crystalline lime
- 3480-3485 — Gray shale to dark gray shale, trace brown dense finely crystalline lime
- 3485-3490 — Gray to dark gray shale, little gray lime
- 3490-3495 — Gray to dark gray shale, trace gray brown lime and fine white sand
- 3495-3500 — Gray to dark gray shale, trace light gray lime
- 3500-3505 — Gray shale, trace black carbonaceous shale and trace brown argillaceous lime
- 3505-3510 — Gray and dark gray shale, trace brown lime (few fragments of coal)
- 3510-3515 — Gray and dark gray shale, trace gray dense micaceous sand
- 3515-3520 — Gray and dark gray shale, trace gray dense micaceous sand and trace lime
- 3520-3525 — Gray and dark gray shale, trace fine shaly sand
- 3525-3530 — Gray shale, part sandy, trace fine gray dense micaceous sand
- 3530-3535 — Gray shale, trace fine dense gray micaceous sand part shaley
- 3535-3540 — Gray shale, little fine dense gray micaceous sand, part calcareous
- 3540-3545 — Gray shale, little fine dense gray micaceous sand, part calcareous, trace sandy shale
- 3545-3550 — Gray shale, little fine dense gray micaceous sand, trace argillaceous lime
- 3550-3555 — Gray shale, little sandy shale
- 3555-3560 — Gray shale, trace sandy shale and trace fine dense micaceous sand
- 3560-3565 — Gray shale, little light gray lime, trace chert
- 3565-3570 — Gray shale, some fine white dense calcareous sand
- 3570-3575 — Gray shale, trace fine white dense calcareous sand, trace lime
- 3575-3580 — Gray shale, little fine white dense micaceous sand

FORMATION RECORD

- 3580-3585 — Gray shale, trace lime and fine shaly sand
- 3585 — Circulated 1 1/2 hours at 3585) Gray shale little soft gray lime, little fine shaly sand
- 3585-3590 — Gray shale, little fine gray impure sand
- 3590-3595 — Gray shale, little gray lime, trace fine gray micaceous sand
- 3595-3600 — Gray shale, little sandy shale, fine micaceous shaly sand
- 3600-3605 — Gray shale, little sandy shale, trace gray lime
- 3605-3610 — Gray shale, little light gray lime, trace dark brown lime and trace fine micaceous sand
- 3610-3615 — Gray shale, part sandy, trace fine to medium micaceous sand
- 3615-3620 — Gray shale, part sandy
- 3620-3625 — Gray shale, part gritty, trace gray lime
- 3625-3630 — Gray shale, part gritty
- 3632 — (Circulated 1 1/2 hours) gray sandy shale, little gray shale
- 3632-3635 — Gray shale, little sandy shale,
- 3635-3640 — Gray shale, little sandy shale, trace red shale cavings
- 3640-3655 — Gray shale, little sandy shale
- 3655-3660 — Gray shale, trace sandy shale
- 3660-3665 — Gray shale, little sandy shale, trace gray argillaceous lime
- 3665-3670 — Gray shale, little sandy shale
- 3670-3675 — Gray shale
- 3675-3680 — Gray shale, trace gritty shale
- 3680-3690 — Gray shale
- 3690-3695 — Gray shale, trace argillaceous lime
- 3695-3700 — Gray shale, little grayish brown lime
- 3700-3705 — Gray shale, trace buff lime
- 3705-3710 — Gray shale, part sandy, little brown finely crystalline lime
- 3710-3715 — Gray shale, trace dark brown crystalline lime
- 3715 — (Circulated 2 hours) fine gray micaceous sand
 Cored 3715-3733, recovered 6 feet
 Gray, very fine impure sandy lime grading into a fine micaceous shaly sand at the base. The bottom 9" has some thin dark gray shale streaks
 (Note: the top of the sand is placed at 3705, from the drilling change)
- 3733-3735 — Fine gray micaceous sand
- 3735-3745 — As above
- 3745-3750 — Fine gray micaceous sand, part dense calcareous
- 3750-3755 — Fine gray micaceous sand
- 3755-3760 — Fine gray micaceous sand, part dense calcareous
- 3760-3770 — Fine gray micaceous sand
- 3770-3775 — Fine gray micaceous sand, part dense calcareous, trace dark gray shale
- 3775-3785 — Fine gray micaceous sand
- 3785-3790 — Fine gray micaceous sand, trace gray shale
- 3790-3795 — Fine gray micaceous sand, trace brown lime
- 3795-3805 — Fine gray micaceous sand, part dense calcareous, little dark gray shale
- 3805-3815 — Fine gray micaceous sand, little dark gray shale
- 3815-3820 — Fine gray micaceous sand, little dark gray shale, little gray lime
- 3820-3825 — Fine gray micaceous sand
- 3825-3830 — Fine gray micaceous sand
- 3830-3835 — Fine gray micaceous sand, little dark gray shale
- 3835-3840 — Gray shale, little brown lime, part argillaceous, little micaceous sand, trace chert
- 3840-3850 — Fine gray micaceous sand
- 3850-3855 — Gray to dark argillaceous lime, part oolitic, dark oolites, little dark gray shale

FORMATION RECORD

3855-3860	Gray to dark argillaceous lime, part oolitic, trace black shale
3860-3870	Gray to brown sucrose lime, part argillaceous
3870-3880	Gray to brown sucrose lime, part argillaceous, trace dark gray shale
3880-3890	Dark shaly lime and a little dark gray calcareous shale
3890-3900	Dark shaly lime and dark gray calcareous shale
3900-3920	Dark gray shale, part calcareous, little dark shaly lime
3920-3930	Dark gray shale, part calcareous
3930-3940	Dark gray and black shale, trace brown dense lime
3940-3950	Black shale
3950-3960	Black shale, trace gray lime
3960-3970	Black shale, some grayish brown lime, part argillaceous
3970-3980	Grayish brown sucrose, lime part argillaceous
3980-3990	Grayish brown sucrose lime and black shale
3990-4000	Gray sucrose and brown dense lime, trace brown chert
4000-4020	Light gray sucrose lime, little gray chert
4020-4040	Light gray sucrose lime and brown finely crystalline lime, trace chert
4040-4050	Light gray sucrose lime with carbonaceous seams, little brown finely crystalline lime
4050-4060	Brown dense to finely crystalline lime, trace dark gray shale and chert
4060-4070	Light gray to buff lime, little brown finely crystalline lime, little dark gray shale
4070-4080	Light gray to buff lime, little brown finely crystalline lime
4080-4090	Dark gray shale, little brown and buff sucrose lime, trace brown shale and chert
4090-4100	Brown sucrose to finely crystalline lime
4100-4110	Brown sucrose to finely crystalline lime, part argillaceous, trace chert
4110-4120	Brown sucrose to finely crystalline lime and dark gray shale, trace maroon shale
4120-4130	Gray to brown sucrose lime, trace chert
4130-4140	Gray to brown sucrose lime, little chert
4140-4150	Black shale, little gray to brown sucrose lime
4150-4160	Black shale and gray to brown sucrose lime
4160-4170	Grayish brown finely crystalline lime, trace black shale
4170-4180	Dark gray shale, little grayish brown lime
4180-4190	Dark gray shale and gray to brown lime, part argillaceous
4190-4200	Brown dense to finely crystalline lime, little shaly lime
4200-4210	Dark gray shale, little gray to brown lime
4210-4220	As above, and trace chert
4220-4230	Dark gray shale, little gray to brown lime, little chert
4230-4240	Gray to brown dense lime, little gray calcareous shale, trace chert
4240-4250	Dark gray shale, little brown dense to finely crystalline lime
4250-4260	Brown dense to finely crystalline lime, trace chert
4260-4270	As above
4270-4280	Grayish brown dense lime, little gray calcareous shale, trace chert
4280-4290	As above, and trace micaceous sand
4290-4300	Grayish brown dense lime, little gray calcareous shale
4300-4310	Dark brown dense to finely crystalline lime, little gray argillaceous lime, trace calcareous shale
4310-4320	Dark gray cal. shale, little gray sucrose arg. lime
4320-4330	Dark gray cal. shale, little gray sucrose arg. lime
4330-4340	Dark gray cal. shale
4340-4350	As above, and trace brown dense lime
4350-4360	Gray sucrose lime, little dark gray shale
4360-4365	Dark gray shale and little gray sucrose and brown dense lime
4365-4370	Dark gray shale, trace brown dense lime and trace variegated shale
4370-4375	Dark gray shale, trace variegated shale

3876
1900
2496

Lessee I.T.I.O.

Operator

Farm George

Well No. 1

FORMATION RECORD

4375-4380	Dark gray shale, some variegated shale
4380-	Cir. dark gray shale, trace variegated shale, trace white chert
4380'10"	Cir. dark gray shale and little white chert, part weathered
4380-4385	Dark gray shale, little variegated shale and little gray chert
4385	Cir. variegated shale, some green gray slick shale, little gray and green chert
4385-4389	Variegated shale, some green gray slick shale, little gray and dark green chert
4389	Cir. variegated shale, some green gray slick shale, little gray and green chert
	<u>Cored 4389-94'</u> , rec. 6", conglomerate, variegated shales and various colored chert fragments
4394-4400	Variegated shale and chert fragments, little white coarsely crystalline lime.
	Top Miss. lime (chester ?) 4397'.
4400	Cir. white chalky and coarsely crystalline lime
4400-4405	White to gray chalky and coarsely crystalline lime
4405-	Cir. white to gray chalky and coarsely crystalline lime
4405-4410	White to gray chalky and coarsely crystalline lime bry shells
4410-4415	White soft coarsely crystalline lime
4415	Cir. white soft coarsely crystalline lime
4415-4420	White coarsely crystalline lime
4420-4425	White coarsely crystalline lime, part with reddish cast
4425-4430	As above, trace pale green shale
4430-4440	White coarsely crystalline lime, part with reddish cast
4440-4445	As above, and trace pale green shale
4445-4455	White coarsely crystalline lime, part with reddish cast
4455-4460	As above - Ost.
4460-4490	White coarsely crystalline, lime, part with reddish cast
4490-4495	As above, and large Ost.
4495-4515	White coarsely crystalline lime, part with reddish cast
4515-4520	As above, and little green gray shale
4520-4525	White coarsely crystalline lime, part with reddish cast
4525-4530	White coarsely crystalline lime, part with reddish cast, little green gray shale
4530-4535	Gray to green gray shale
4535-4540	As above, little white coarsely crystalline lime
4540-4545	As above
4545-4550	Gray to green gray shale
4551 -	Cir. gray shale
4551-4555	Gray shale, trace green gray greasy shale
4555-4560	As above
4560-4567	Gray shale, (gray to green gray)
4567 -	Cir. gray to green gray shale and brown dense lime
4567-4572	Gray shale and white crystalline lime with little br. dense to crystalline lime
4572-	Cir. gray shale and little brown dense lime
4572-4577	Gray to green gray shale, little gray crystalline and brown dense lime
4577-4582	Gray to green gray shale
4582-	Cir. gray to gray (green gray) shale, trace gray sucrose lime
4582-4585	Gray to green gray shale
4585-4595	As above
4595-	Cir. gray to green gray shale
4595-4600	Gray and green gray shale, part greasy
4600-4605	As above, and part greasy
4605 -	Cir. gray and green gray shale, part greasy

Lessee I.M.I.O.

Operator

Farm George

Well No. 1

FORMATION RECORD

- 4605-4625 Gray and green gray shale
 4625 - Cir. As above, part greasy
 4625-4630 Gray and green gray shale, some light gray sucrose to dense lime
 4630-4635 Gray and green gray shale, and black fine textured shale
 4635-4645 Dark gray to black shale 4630' probably top of Chattanooga
 4645- Cir. dark gray to black shale
 4645-4665 Dark gray to black shale
 4665- Cir. Black shale - spores
 4665-4675 Black shale spores
 4675 Cir. As above
 4675-4680 Black shale spores
 4680 - Cir. As above
 4680-4690 Black shale spores
 4690 - Cir. Black shale spores and little med. sub-angular shaly sand and white crystalline dolomite.
TOP HUNTON 4688' (Note: Had thin bed of Misner sand probably less than 1')
- Cored 4690-98', rec. $7\frac{1}{2}'$. All greenish gray shale, little disseminated pyrite (Sylvan 4690')
- Cored 4698-4709', rec. 8'. Top $3\frac{1}{2}'$ - greenish gray shale
 Bottom $4\frac{1}{2}'$ - gray to white coarsely crystalline lime, few pink crystals.
 (Note: Top Viola 4702'. $2\frac{1}{2}'$ below top of lime that was recorded showed oil in a bank about 1/4 to 1/2" thick after being out in sun for some time there was also a fragment of lime 6" below this that showed some porosity with a little oil staining in the pores.)
- 4709-4710 Drilled gray coarsely crystalline lime
Cored 4710-14', rec. $3\frac{1}{2}'$ - gray coarsely crystalline lime, few thin shale bands.
Cored 4714 $\frac{1}{2}$ -24 $\frac{1}{2}$ ', rec. 8' - Top 3' gray coarsely crystalline lime with few buff sucrose dol. seams and few dark shale streaks.
 Balance - brown to buff suc. dol. with few irregular shale streaks.
- 4724 $\frac{1}{2}$ -4730 Gray brown gran. dolomite, little gray suc. lime
 4730 - Gray brown gran. dolomite and gray sucrose and brown dense lime, little gray chert
 4730-4735 Gray gran. dol. and gray sucrose to dense lime and little gray chert
 4735 - Cir. Gray sucrose and gray dense sil. lime, trace chert
 4735-4740 Gray to buff sucrose dol. and some gray dense sil. lime
 4740 - Cir. Gray to buff sucrose dolomite and some gray dense sil. lime
 4740-4745 Gray brown dense sil. lime and little buff sucrose dolomite
 4745 - Cir. As above
 4745-4750 Gray dense sil. lime and little buff sucrose dolomite
 4750 - As above
 4750-4752 $\frac{1}{2}$ Gray dense sil. lime, and little buff sucrose dolomite
 4752 $\frac{1}{2}$ -4755 Light gray sucrose lime, little dense sil. lime
 4755 - Cir. Gray sucrose lime, part dolomitic
 4755-4760 Gray sucrose lime, part dolomitic, and little gray dense sil. lime
 4760 - Cir. Gray brown dense to finely crystalline lime, part sil, little brown gran. dolomite
 4760-4765 Gray brown dense to finely crystalline lime, part sil.

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4765- Cir. Gray brown dense lime, part sil, some light gray sucrose lime
 4765-4766 Gray brown sucrose lime, trace brown dense lime
 4766-4770 Gray brown sucrose lime, little dark brown granular dolomite
 4770 - Gray brown sucrose lime and little brown dense sil. lime
 4770-4775 Light gray sucrose lime, trace brown dense sil. lime, trace chert
 4775 - Cir. Brown dense to finely crystalline lime
 4776 - Cir. Gray brown crystalline lime
Cored 4776-86', rec. 9' Top 5' Grayish brown coarsely crystalline
 foss. lime
 Bottom 4' - Med. to coarse ang. to sub-angular
 arg. sand, part tightly cemented,
 some thin dark gray and green shale
 seams. TOP SAND 4781' *Wilcox*
Cored 4786-4791', rec. 4'8" Top 1' Gray med. to coarse ang. to sub-
 rounded arg. sand, part tightly
 cemented, few dark gray shale seams
 Balance - Dense med. grained sub-rounded
 sand, few thin arg. seams
Cored 4791-4801', rec. 7' All - Med. grained sub-rounded sand, part
 tightly cemented, few dark gray
 arg. seams.
 4801-4807 Free med. to coarse sub-rounded frosted sand
 4807-4835 As above
 4835-4840 As above
 4840-4845 As above, trace dark green gray shale
 4845-4850 Free med. to coarse sub-rounded frosted sand, little dark green gr. shale
 4850-4855 Greenish gray shale, little med. dense sand, trace gray. glauc. shale
 4855-4860 Dark greenish gray shale, trace sand
 4860 - Cir. Dark greenish gray shale
 4860-4865 Free fine to med. sub-angular sand and little dark green gray shale
 4865- Cir. Dark green gray shale
 4865-4870 Dark green gray shale, trace med. sub-angular sand
 4870-4875 Dark green gray shale
 4875-4894 As above
 4894 - Cir. Dark green gray shale, trace med. sub-angular sand
Cored 4894-4898', rec. 2'6" Top 3' Med. grained shaly sand with
 abundant black phosphatic (?) frag
 some bright green shale inclusions
 4" Very coarse grained rounded frosted
 sand, part argillaceous
 8" Mixed green greasy shale and
 impure arg. sand, sub-rounded grain
 Bottom 15" - Greenish gray greasy shale
 4898-4909 Greenish gray greasy shale
 4909- Cir. Greenish gray greasy shale, little med. dense sub-rounded sand
 4909-4915 Greenish gray greasy shale, trace med. dense sub-rounded sand
 4916 - Cir. Greenish gray and bright green shale, trace med. dense sub-rounded s
 4916-4920 Greenish gray and bright green shale
 4922 - Cir. As above, and little coarse rounded frosted sand
 4922-4925 Greenish gray and bright green shale, trace coarse rounded frosted sand
 4925-4930 Greenish gray and bright green shale, some coarse rounded frosted sand
 4930- Cir. Greenish gray and bright green shale
 4930-4935 As above, and little coarse rounded frosted sand
 4935-4940 Greenish gray and bright green shale
 4940 - Cir. Greenish gray shale
 4940-4945 Med. coarse rounded sand *Siliceous lime 4944*

FORMATION RECORD

4945 -

Cir. Med. coarse rounded sand, trace gray sucrose dolomite
Cored 4945-55', rec. 1 $\frac{1}{2}$ ' - Top 1' (All broken fragments) gray to buff
suc. and finely crystalline dolomite,
part showing some porosity
Bottom - 6" - Dense coarse grained sandy dol.
very hard

Cored 4955-67', rec. 5' Top 8" (Broken fragments) 2" med. grained
dol. sand to dense sandy dol.
oil stained, had strong sulphur odor.
Balance gray sucrose to finely
crystalline dolomite with green
shale bands.

Next 1' - Gray dense sandy dol. with little
gray brown finely crystalline dol.
2 $\frac{1}{2}$ ' Dark gray to brown sucrose and
finely crystalline dol., part cherty,
showing some porosity. Had a light
sulphur odor on fresh break.

3" Greenish gray shale

Next 4" (Broken fragments) dark gray finely
crystalline dol. part showed porosit

Bottom 3" Greenish gray shale

Cored 4967-82', rec. 3' Top 5" Gray sucrose dol, part arg.
4" (Broken fragments) dark gray dense to
fine crystalline dol, little chert
5" Gray sucrose to dense dol.
4" Green shale, dol. bank at base
3" Gray sucrose dolomite
7" Mixed green shale and dolomite
Bottom 8" Gray sucrose dolomite

4982' T.D.