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GEOLOGY OF CIMARRON COUNTY OKLAHOMA

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WITH DAKOTA SANDSTONE PLANTS FROM CIMARRON COUNTY, OKLAHOMA

By
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NORMAN
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GEOLOGY OF CIMARRON COUNTY OKLAHOMA

INTRODUCTION

LOCATION AND AREA

Cimarron County is the most western county in the State of Oklahoma, located at the extreme western end of the Oklahoma Panhandle. The northern boundary of the county is the 37th parallel, which is the southern boundary of Colorado and Kansas. The parallel of 36° 30′ is the boundary between Cimarron County and the Texas Panhandle. The line between Cimarron County and New Mexico is the 103d meridian, and from this meridian the county extends eastward to within about a mile of the 102d meridian.

The extent of the county east and west is 54 miles; and north and south, a little over 34 miles. From these figures the area of the county should be 1,836 square miles. The true area, however, may be slightly more, for there is a discrepancy of several hun-

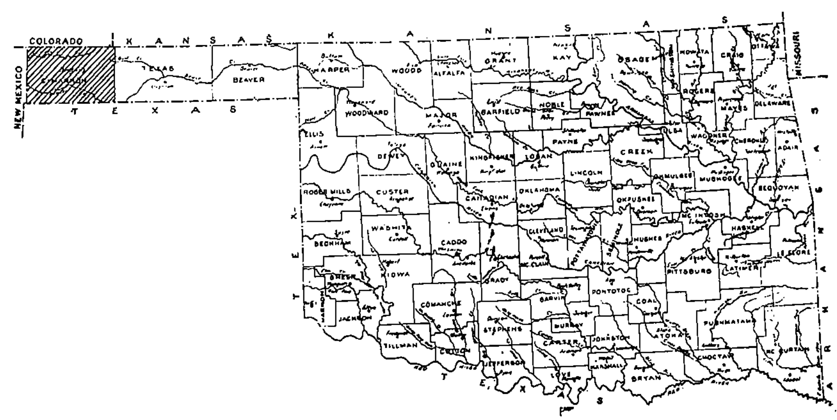


Fig. 1. Map of Oklahoma showing area covered in this report, Cimarron County indicated by shaded area.

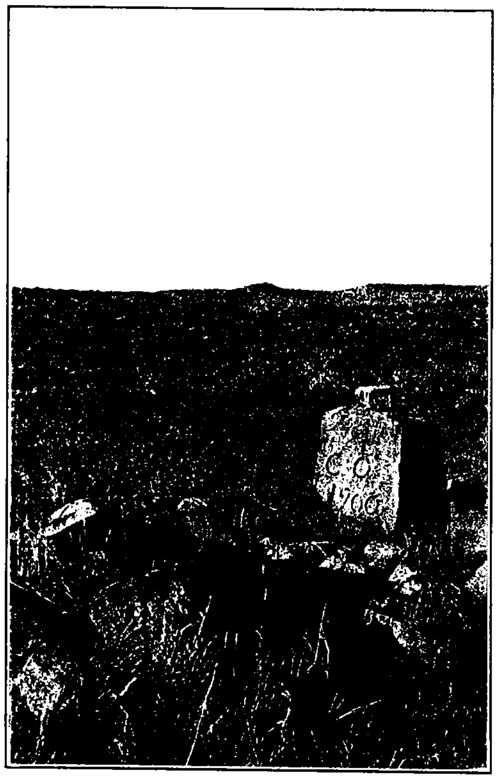
dred feet between the north line of the county, as run by the surveys of 1881 and 1900, and the controversy over its true position has not yet (1922) been settled. This area has been divided into five rows of townships, and four miles of the sixth row, which were measured from the parallel of 36° 30′, and into nine full ranges, measured from the 103d, or Cimarron Meridian, which marks the western limit of the county.

MARKERS

There are two posts marking the northwest corner of the county, the oldest of which is farthest north, and was set by the survey of 1881. It is a sandstone pillar four and a half feet above ground, and one and a half feet square at the end. It is marked "37° NL, 103° WL."

The second corner is about 300 feet south of the first stone and was set by the survey made in 1900. It is a sandstone pillar two feet above ground and one and a half feet square on the end.

PLATE I.



SANDSTONE PILLAR MARKING THE NORTHWEST CORNER OF THE STATE.

(See Plate No. I, page 8.) Both these stones are in an open pasture belonging to Mr. J. R. Collins, just east of the trail down West Carrizo Creek to Kenton.

The southwest corner of the county is marked by a "zinc pot" two and a half feet high and about two feet in diameter, filled with cement. On the south side is inscribed "36° 30′ NL., 103° WL., 1903." It stands in a pasture 400 feet west and 150 feet north of the cross-roads which were supposed to mark the corner. A large stone set by the survey of 1881 was found lying by the roadside, about 200 feet north of the cross-roads. It is a sandstone pillar, five feet long and two feet square on the ends. On the top is the date, "1881," while each of the four sides contains one of the following inscriptions: "C. M., N. M., 130° WL.," and "36° 30′ NL."

The northeast corner of the county is at the junction of two roads and no marker was found. The southeast corner is at the junction of an east-west road and a north-south fence line, but no marker was found there.

PURPOSE OF THE REPORT

This report is a description of the geology of Cimarron County, Oklahoma, the survey of which was undertaken with two points in view. 1. This region has been the center of considerable speculation and prospecting in the search for products of economic value, particularly oil, gas, and copper, and it is hoped that the information contained herein will be of aid to those who may contemplate exploiting this country. In the time available for field work it was not possible to make a thorough investigation of all the indications of economic products found, and this report will do no more than describe the larger geologic features, which are the necessary forerunners of the detailed work which should be done before attempting large scale operations of any sort. The information bearing directly on this phase of the subject will be found under the heading, Economic Geology.

2. The second purpose in undertaking this work was the gathering of scientific information which would be of value to the citizens of Oklahoma and the surrounding states. The nearest area which has been systematically studied geologically is the Raton Mesa coal region, 70 miles to the west,[1] and the nearest region to the south is the area about Amarillo, Texas, 100 miles away. This is, therefore, a strategic area in which to secure information on the character of the Mesozoic and Cenozoic rocks

[1]Lee, W. T., Geology of the Raton Mesa and Other Regions in Colorado and New Mexico, U. S. Geol. Survey, Prof. Paper 101, 1917.

which are so well exposed in the canyons of the upper Cimarron River and its tributaries.

METHODS OF WORK

The field work for this report was done during the summers of 1919 and 1921. There was no base map accurate enough for use; therefore it was necessary to make the map of the county which accompanies this report. Because of the size of the area and the limited time, the mapping had to be of a detailed reconnaissance nature. The cornerstones and other markers of the land office survey are still fairly well preserved, and by plotting on township plats and checking wherever possible on these markers, a fairly accurate map was obtained. Distances were measured by pacing and by using the speedometer on an automobile. Triangulation with an open sight alidade and a reconnaissance plane table was employed in regions which were inaccessible with the automobile.

No level lines have been run in the county and consequently there are no bench marks giving the correct sea level elevations. Therefore much that might have been done, especially in the way of determining structure, had to be left undone because of the impossibility of carrying into the county sufficiently accurate and extensive lines of levels. In some instances differences in elevation were taken with an aneroid barometer, but in most cases the hand level was used. All the geologic sections were measured with the hand level, with the exception of a few small ones on which a steel tape could be used.

ACKNOWLEDGEMENTS

The successful mapping of the county is due largely to the assistance of Mr. John Skelley, Sr., of Wheeless, Oklahoma. Mr. Skelley served on the U. S. Land Survey of Cimarron County, and held the office of land commissioner when the country was first opened for settlement, and he gave freely of the information thus obtained and of his time. The author hereby wishes to express his appreciation of the services rendered by Mr. Skelley. He also wishes to acknowledge the help given by Mr. A. C. Easley of Kenton, who took considerable pains to be of assistance, and also the treatment accorded by the citizens and the business men of the county, who without exception, did all in their power to assist the work. The cheerful and earnest work of Mr. Frank T. Clark and Mr. Guy Mitchell, students of the University of Oklahoma, as field assistants, did much to hasten the work to a satisfactory completion. The drafting of the base map of Cimarron County was done by Mr. Frank Gahrtz, draftsman for the Oklahoma Geological Survey, 1921. Mrs. Bess Mills-Bullard, did the drafting of the geologic map, cross-sections and columnar chart.

PREVIOUS WORK

The information about this area which has been published is the result of rapid reconnaissance work, which was carried on largely because of its bearing on problems outside the county. Between the years of 1900 and 1903, Dr. Chas. N. Gould visited the region and published the results of his work as part of a description of the water resources of Oklahoma.[1] This publication includes descriptions of the formations which occur in the county and a map showing their location. It also includes a stratigraphic section measured on the south side of Black Mesa.[2]

In 1901, Dr. W. T. Lee made a trip down the Cimarron Valley, "to a point seven miles beyond (east of) the boundary of New Mexico."[3] He made the trip again in 1905 in company with Dr. T. W. Stanton.[4] Both trips were made as part of a study of the stratigraphy of the Morrison and Purgatoire formations and were confined to a small part of the Cimarron Valley.

GEOGRAPHY

DRAINAGE

In general the drainage of the county is from west to east, this being the direction of the major streams and also the trend of the larger tributaries. The drainage is divided between two major streams, Cimarron River, which eventually joins Arkansas River near Tulsa, Oklahoma, and Beaver River, which is one branch of North Canadian River. The extreme eastern part of the county is drained by the headwaters of tributaries which empty into Beaver River in Texas County, Oklahoma.

CIMARRON RIVER

Cimarron River is the larger of the streams and it drains the larger area, its basin including some 590 square miles of the county. It enters the county in two forks which cross the New

[1]Gould, Chas. N., Geology and Water Resources of Okla., U. S. Geol. Survey, Water-Supply Paper 148, 1905.

[2]Gould, Chas. N., Op. cit., p. 82.

[3]Lee, W. T., The Morrison Shales of Southern Colorado and Northern New Mexico; Journal of Geology, Vol. X, No. 1, p. 43, 1902.

[4]Stanton, T. W., The Morrison Formation and Its Relation with the Comanche Series and the Dakota Formation; Journal of Geology, Vol. XIII, No. 8, pp. 664-665, 1905.

Mexico line at the center of the west lines of secs. 7 and 18, T. 5 N., R. 1 E. After flowing eastward 2½ miles the two unite at a point directly north of Kenton, sec. 9, T. 5 N., R. 1 E. The stream then flows slightly north of east for 40 miles where, in sec. 25, T. 6 N., R. 7 E., it turns sharply and flows due north into Colorado. The total length of this stream in this county is 52 miles.

There are no large tributaries to the Cimarron in this county, most of the streams being less than 6 miles long. There are a few streams of greater length in the upper portion of the basin. The longest is Cold Springs Arroyo which has a length of 22 miles. Its source is in the northern part of sec. 18, T. 3 N., R. 2 E., about a mile north of Wheeless Postoffice whence it flows north 70° east to the southwest corner of sec. 19, T. 4 N., R. 4 E., a distance of 12½ miles, turns abruptly toward the north and, flowing north 30° east 9½ miles, joins the Cimarron River in sec. 11, T. 5 N., R. 4 E. The name is derived from the fact that the stream contains springs along the lower part of its course which have never been known to run dry. These springs were a welcome camping ground for travellers on the old Santa Fe Trail.

The next longest tributary is South Carrizo, which heads in New Mexico just over the line from the northwest corner of T. 3 N., R. 1 E., flows north 65° east for 7 miles, then north 30° east for 9 miles, and joins Cimarron River in sec. 10, T. 5 N., R. 2 E. In its lower course this stream is joined by two tributaries, each about 6 miles long, which flow roughly parallel to it, the one to the east being known as Swede Creek, and the one to the west as Dry Canyon.

The only other large tributary on the south side of the Cimarron is Tesesquite Creek, a stream 8 miles in length, which has its source in the SE. ¼ of sec. 19, T. 4 N., R. 1 E., and flows almost straight in a north 35° east direction, joining the Cimarron River in the northwest corner of sec. 18, T. 5 N., R. 2 E. These three streams are the only large tributaries of the Cimarron River from the south, though there are quite a number of short, unnamed streams, 6 miles and less in length.

The area north of the river is drained by a number of short streams which originate in Colorado. Most of them are of about the same length as the shorter tributaries on the south side, there being but two which are large enough to be classed as major tributaries. The larger of the two is West Carrizo Creek, which is also the most western tributary entering Cimarron River in the county. The stream enters Cimarron County in sec. 18, T. 6

N., R. 1 E., flows southeast and joins Cimarron River in sec. 34, T. 6 N., R. 1 E. The other one is the Gillenas, formed by the junction of three creeks which unite in sec. 15, T. 6 N., R. 2 E., just south of Regnier Postoffice. From this point the stream flows southwest for 6 miles and joins Cimarron River in sec. 31, T. 6 N., R. 3 E.

BEAVER RIVER

Beaver River is formed by the union of Currumpa and Cieneguilla creeks. The latter is called Seneca by most people living in the neighborhood, this being a perversion of the older Spanish name. Currumpa Creek enters the county from New Mexico in sec. 7, T. 2 N., R. 1 E., and flows in a southeasterly direction, while Cieneguilla Creek enters the county in sec. 7, T. 1 N., R. 1 E., and flows a little north of east, the two streams meeting in sec. 32, T. 2 N., R. 2 E., about 7 miles from the place where they enter the county. From the junction of the two streams Beaver River flows due east for 7 miles and then turns to a direction a little north of east until a point 4 miles south of Boise City is reached, where it takes a southeasterly course and leaves the county for Texas near the southeast corner of T. 1 N., R. 8 E. The course of Beaver River in Cimarron County might roughly be described as the arc of a large circle. The total distance traversed by Beaver River and the two creeks which form it in Cimarron County is 61 miles.

Unlike the Cimarron River, the Beaver has almost no tributaries. There are a few small arroyas never exceeding 3 miles in length and usually not more than a quarter of a mile long. About the same thing can be said of Currumpa and Cieneguilla, but these streams have a few fairly well developed tributaries while Beaver has none. The lack of tributaries is largely due to the sandy nature of the country through which the stream flows, the sand allowing the surface water to sink in rather than run off.

AGUA FRIO (COLD WATER) CREEK

Agua Frio Creek flows through the southwestern corner of the county, south of Beaver River. In this county it is a small stream, having a valley which is little more than a ditch through a large part of its course, and which at no point in this area is more than 50 feet deep. Its drainage basin is more than a mile wide. Farther east, however, it becomes a considerable stream. It starts in sec. 30, T. 1 N., R. 1 E., about a mile south of Delphine Postoffice, flows north of east for 11 miles to sec. 13, T. 1 N., R. 2 E., whence it flows almost due southeast, leaving the county in sec. 35, T. 1 N., R. 3 E. The total length of the stream in this county is 17 miles.

STREAMS OF THE EASTERN PART OF THE COUNTY

The extreme eastern part of Cimarron County is drained by an unnamed tributary of Cimarron and the head waters of two branches of Beaver River. The first stream is formed by the joining of many small streams in the center of T. 5 N., R. 8 E., and flows northeast, leaving the county in sec. 15, T. 6 N., R. 9 E. The two forks of Goff Creek, a tributary of Beaver which joins that stream in Texas County, head 2 and 4 miles south of the head of the stream just described. One fork flows east while the other flows northeast, and joining in sec. 28, T. 5 N., R. 9 E., they flow east out of the county. The North Fork of Beaver rises about 6 miles south of the south fork of Goff Creek and is formed by the joining of several little streams. It flows southeast for a distance of 6 miles and then turns and flows east, leaving the county in sec. 13, T. 2 N., R. 9 E. Both these tributaries of the Beaver have numerous small branches from a quarter to 2 or 3 miles long.

WATER

Few of the streams of the county are permanent. In times of rain, any or all of them may carry much water, and the major streams become veritable torrents, but during most of the year all but the larger ones are dry. Cimarron River carries water nearly all the year though it is normally a very small stream, and West Carrizo has water much of the time. In this latter stream the effect of evaporation is quite marked at times. On a summer day it may have a considerable stream of water in the early morning. The amount, however, gradually diminishes as the day becomes hotter until the water disappears entirely and does not refill again until after sunset.

Water is found permanently in the bottom of some of the tributaries of Cimarron River, of which Cold Springs Arroyo and Water Canyon (sec. 24, T. 5 N., R. 2 E.), are examples. In the channels of such streams there are pools of clear and usually cold water surrounded by water grasses. These are really springs caused by beds of shale in the bottom of the stream. They carry a small amount of water but never form streams that flow for more than a few hundred feet from the pools.

TRANSPORTATION

At present the region is readily accessible from the following railroad points: Elkhart, Kansas; Guymon and Texhoma, Texas County, Oklahoma; Texline and Dalhart, Texas, and Clayton, New Mexico. Though little work has been done on the roads over most of the county, travel is not difficult, for the relatively light rainfall does not render impassable the roads and trails that have been made. Automobile travel is possible everywhere except in areas of sand dunes. The county is rapidly making graded roads to all the principal railroad towns, so that there is at least one good road to every part of the county from Boise City, the county seat. Beaver and Cimarron rivers form the greatest obstacles to travel as there are no bridges over these streams. A concrete crossing on Beaver in sec. 24, T. 2 N., R. 3 E., and a flagging crossing on Cimarron on the Boise City to Springfield, Colorado road are passable except when the streams are in flood. When the water is low there are numerous other crossings on both streams which are used regularly by mail carriers and other travelers.

As this volume is going through press (1925) a railroad line is building into Cimarron County. It is an extension of the Dodge City-Elkhart branch of the A. T. & S. F. Railway. This road enters Cimarron County near the northeast corner and runs southwest to Boise City, thence to a point near the southwest corner of the county.

TOPOGRAPHY

THE PLAINS

Cimarron County lies in the western part of the Great Plains on what has been called the "High Plains" of the state[1]. The surface of the county is a plain which slopes gently toward the east and whose surface is broken by two large valleys, one in the northern and the other in the southern part of the county. The valleys extend almost the entire length of the county. There are two types of topography, (1) that of the high plains, in which ancient stream deposition followed by the action of winds and ground water has shaped the present surface, and (2) that of the valleys, in which stream erosion has been the chief agent responsible for the topography.

The plains or uplands occupy about two-thirds of the area of the county. The only large area not included is the basin of the Cimarron River in the northwestern part of the county which

[1]Snider, L. C., Geography of Oklahoma, Okla. Geol. Survey, Bull 27, p. 59, 1917.

comprises 590 square miles or roughly one-third of the entire area. The narrow valleys of the other streams cover a relatively small part of the area.

The plains area slopes toward the east, the elevation at the western boundary of the county being about 5,000 feet and at the eastern 3,700 feet above sea level. This is a slope of approximately 1,300 feet, or an average rate of about 19 feet to the mile. No exact determinations of elevations are available and the above figures were derived in the following manner: The elevation at the union station in Texline, Texas, 8 miles south and 2 miles east of the southeast corner of the county, is 4,690 feet above sea level, and the elevation at the railroad station at Texhoma, Texas County, Oklahoma, 14 miles due east of the southeast corner of the county is 3,483 feet. These towns are both on the open plain and as the slope of the plain is fairly uniform, the difference in elevation divided by the distance between the stations gives an average grade of 18.5 feet to the mile, which holds apparently throughout the county. The grade was measured with a barometer on some east-west roads running through Boise City, and an average grade of from 18 to 20 feet was found wherever measured. With this grade, it is possible to calculate the approximate elevations of points between the two towns mentioned. The south component of the slope, if such component exists, is so much smaller than the east that, if it could be worked out accurately, it would change the amount and direction of slope but little.

CHARACTER OF SURFACE

This plain is often spoken of as being "flat as a floor," which in a way expresses its character, but the general flatness is broken by miner features which may be divided into three groups, (1) the broad undulations, (2) the basins, and (3) the sand dunes.

UNDULATIONS[1]

Viewed carefully, the surface of the plain is seen to be composed for the most part of broad, low hills separated by very broad, shallow depressions, giving an impression somewhat similar to the waves and troughs of a gently heaving sea. The relief in this topography is 15 to 20 feet, but as the crests of the hills are 1 to 3 miles apart, the slopes are extremely gentle. Here and there rises a ridge-like hill a few miles long, which from a distance and from certain positions appears as a distinct topographic feature but so gentle are its slopes that it is almost imperceptible to one crossing it. One of these hills about 2 miles south of Boise City is composed for the most part of sandy loam, and another in the north half of secs. 32 and 33, T. 3 N., R. 8 E., is capped by Tertiary limestone. In a few instances, as in sec. 22, T. 3 N., R. 9 E., small gullies have developed in the hills which, though quite definite toward the head, spread out and finally merge into the general surface of the hollow into which they flow. These streams are very few, however, and the surface presents simply a series of indefinite, undrained sags and swells with no apparent definite relation to each other.

[1]Johnson, W. D., The High Plains and Their Utilization, U. S. Geol. Survey, 21st Ann. Rept. pt. IV, pp. 615-621, 1899-1900.

Unequal stream deposition, settling of sediments, and wind erosion are the three processes which have developed this surface. It is probable that each of them played an important part in its formation,though the exact relative importance of each is as yet a matter of conjecture.

The surface of the Great Plains was developed on the Late Tertiary formation which formed a sheet of rock waste spread on an arid land surface by streams coming from the Rocky Mountains, in Late Tertiary time. As the process is described by Johnson[1], a fairly even sheet of debris was deposited, thinning from its source to its outer limit. In such a sheet it is hardly to be expected that the surface would be a geometrical plane, for from the nature of stream deposition more material would be deposited in some places than in others. Such differences would make slight elevations and depressions in the surface which might be accentuated by later processes.

Another factor, settling of the sediments, may take place either during deposition or after it has ceased. There are some facts which indicate that the process is still going on in this region, and these will be discussed under the origin of basins. Settling may be caused by a compacting of the sediments, due to the settling of the particles, crowding them together so that the mass occupies less space, or it may be due to the dissolving of soluble materials in the rocks which allows the insoluble portions to settle into the cavities so formed. If more of the limestone of the Late Tertiary formation was dissolved from some places than from others, the overlying sands and clays would settle, leaving the unevenness shown on the surface.

The last factor, the wind, is operative a considerable part of the time, and its action is effective in dry times, as may be seen on any of the sand flats of the main streams, or on patches of earth from which vegetation has been removed. Even in pastures

[1]Johnson, W. D. Op. cit.

the soil is often blown away from the roots of the grass tufts so that they stand up on little mounds one to three inches high. It is possible that the action of the wind on bare spots, or on light sandy spots where the vegetation would not form sod might cause depressions of the sort described. It is not probable, however, that the wind alone was responsible for depressions of this sort but it is likely that it has exaggerated the hills and depressions formed by other causes. Loose material from the depressions was removed and deposited on the top and lee sides of hills which were able to hold it because of their covering of vegetation.

BASINS

Scattered over the plains are saucer-like depressions of various sizes. The smallest are circular in ground plan, one or two hundred feet across and but two or three feet deep. From this size they range to great depressions 2 miles across and 80 to 150 feet deep. The circular outline and saucer-like shape usually persist until the depressions reach a size of a quarter to a half mile across and 20 or 30 feet in depth. Larger basins, though roughly circular in outline are in most cases more irregular in shape. One basin, about 2 miles west of Boise City in T. 3 N., R. 5 E., has the form of a trough 2 miles long and but a little more than a quarter of a mile wide, and has a high ridge along its east side. The bottoms of the basins are flat and are covered with a deposit of black clay which has been washed from the soil on the slopes and has settled in the temporary ponds which form after heavy rains. In a few of the basins there is water for a large part of the year. In the bottom of some of the larger basins there are two or more depressions in which water accumulates.

There is little regularity in the distribution of these basins except that they do not occur outside the area in which Tertiary rocks are at the surface, nor are they found in the sand dune areas. With these exceptions they are scattered over all parts of the county. The largest number are on that portion of the plains between Cimarron and Beaver rivers in the central and western parts of the county, and there is a group of them south of Beaver River in the neighborhood of Wilkins Postoffice in T. 1 N., R. 4 E. There are only a few scattered basins outside of this area south of Beaver River and only a few in the eastern part of the county in Ranges 8 and 9 east. It is not certain that this distribution has any significance, but it may throw some light on the character of the underlying rocks if the accepted theories for their origin are correct.

The popular notion is that the basins were formed by the tramping and wallowing of the great herds of buffalo which once roamed these plains, and they are still called "buffalo wallows." It is possible that some of the shallower ones were formed in this way, but it would hardly be possible to account for basins a mile or two across and 80 to 150 feet deep in such a manner, nor for the elongate shape of such a depression as that 2 miles west of Boise City.

Johnson[1] ascribes the origin of the basins to settling of the sediments due to compacting, to solution of the lime from the underlying "mortar beds" of the Tertiary rocks, and to solution of the beds of gypsum in the underlying red beds. The shallow depressions he ascribed to the first and second causes, and the large basins to the last. He found in many instances cracks in the soil around the rim, roughly concentric with the center of the basin, some of which were formed within the memory of the inhabitants of the country. This shows that there was movement of soil and rock materials toward the center of the basin. He also found that in the bottom of the large basins the red beds are very near the surface, and in one case, that of the Salt Well near Meade, Kansas, the settling had been due directly to solution of the underlying salt and gypsum. Generalizing from such evidence he concludes that all the basins of the Great Plains were formed in this manner. This explains their peculiarities better than other theories which have been advanced. The buffalo would be attracted to such depressions because of the water they contained and there is no doubt that trampling and wallowing tended to deepen them. It is also probable that the wind has played a part in their formation, for in some instances there is an area of sand to the east of the basin which does not appear to the west and south. As the prevailing winds in this region are southwesterly the sand appears to have been blown out of the basins and deposited along the eastern side near the rim.

In summary it may be said in the light of present evidence it is believed that the basins are the result of settling of the sediments due to compacting, and the solution of the underlying rocks, with the work of the wind and the trampling of the buffalo as contributary causes.

DUNES

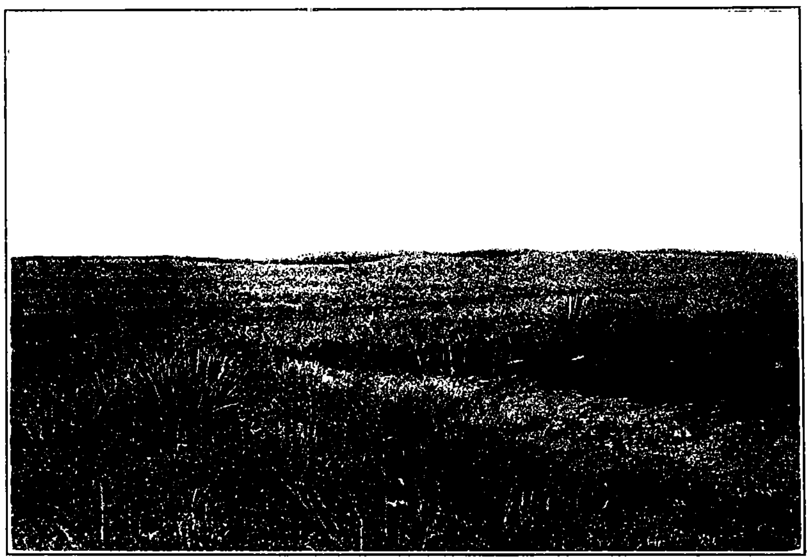
There are three large areas of sand dunes on the plains of Cimarron County. (1) The most northern area is along the Colorado line in the eastern part of the county. This area extends from secs. 14 and 22, T. 6 N., R. 7 E., eastward to sec. 13, T. 6 N., R. 8 E., but is divided into an east and west part by Cimar-

[1]Johnson, W. D., Op. Cit. pp. 703-704.

ron Valley which is here a mile wide. The largest dunes in this area lie just east of Cimarron Valley and cover an area about 2 miles square. All of T. 6 N., R. 9 E., is sandy, and isolated patches of sand drifts and small dunes occur well toward the south side of the township and become more numerous toward the north. A patch of large dunes covers a little more than a quarter section in the northwest quarter of sec. 13. The largest dunes in the northeastern corner of the county reach a height of 20 to 30 feet.

(2) A second dune area of about 20 square miles is found 12 miles west of Boise City. It is more than 10 miles long and almost 4 miles wide at its middle point, from which it narrows

PLATE II.



TYPICAL DUNE TOPOGRAPHY NORTH OF BOISE CITY, OKLAHOMA.

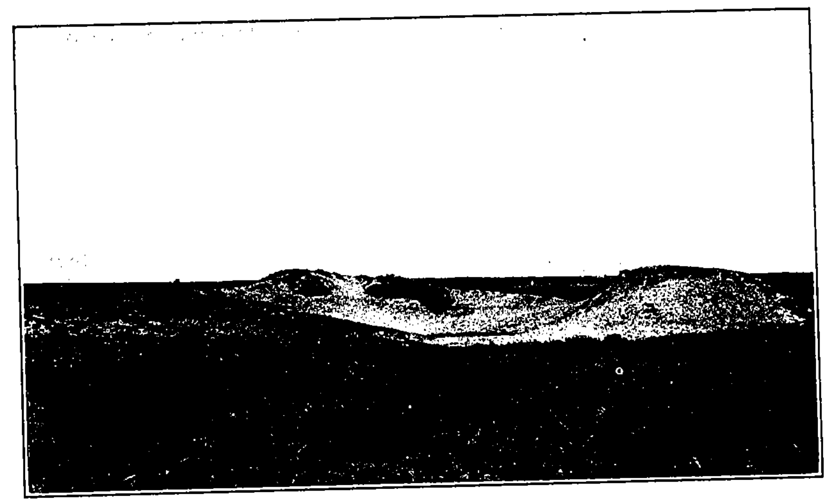
both north and south. Its southern extremity is in sec. 31, T. 3 N., R. 3 E., and from this point it trends northeast and dies out just east of Cold Springs Arroyo, in sec. 17, T. 4 N., R. 4 E. The dunes on the edges of this area are small, but increase in size toward the middle where they attain a height of 20 to 30 feet.

(3) The largest dune area lies along Beaver River extending nearly the entire length of this stream in the county. This area is about 45 miles long, is elongate in an east-west direction, and attains a maximum width of 8 miles directly south of Boise City. Its area is roughly 175 square miles. Beaver Valley has

cut through this area, the sandy material from which the dunes are formed offering an easy channel for the water. It is difficult to draw the line between the dunes and the river deposits since dunes are found down to the stream channel along much of its course. The largest dunes of the area occur in the region between Cieneguilla and Currumpa creeks, in T. 1 N., R. 1 E., and T. 2 N., R. 1. E. They vary greatly in size, some being only drifts a few feet high, while others are immense dunes 40 or 50 feet high.

All these areas are covered with vegetation so that any considerable movement of sand is prevented except along the Beaver Valley and in a few locations where the vegetation is scanty or where it has been broken for cultivation. Where the wind can move the sand, it rapidly tears the dunes to pieces and piles the sand in new drifts behind fences and other obstacles. A number

PLATE III.



SAND DUNE BEING DESTROYED BY WIND.

of instances are known where a wagon trail across a dune has allowed the wind to remove the sand, making great hollows or "blow outs," and in some cases nearly destroying the dune.

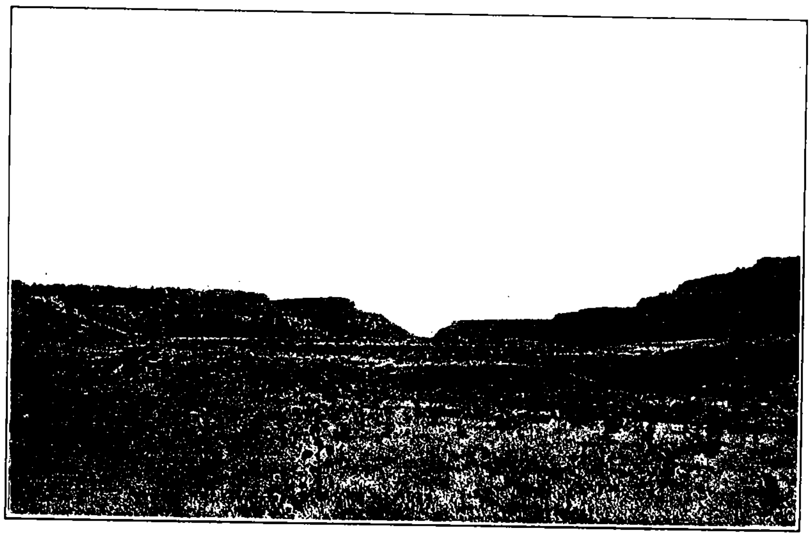
VALLEY TOPOGRAPHY

CIMARRON BASIN

Though not as extensive in area as the plains, the valleys contain a more varied and striking topography. In the Cimarron

Valley there are two types of topography sharply separated from each other by a line which might be drawn north and south through Wolf Mountain, sec. 27, T. 5 N., R. 5 E., in the middle of Range 5. West of this line the topography is characterized by narrow canyons and buttes. Throughout this part of its course the Cimarron Valley has an average width of 1 mile, and flows usually between very steep, in places, almost vertical bluffs of sandstone 200 to 250 feet in height. The tributaries on the south side of the upper part of the stream flow in narrow canyons with a depth corresponding to that of the main stream, but at their mouths they widen into flat areas covering 2 or 3 square miles.

PLATE IV.



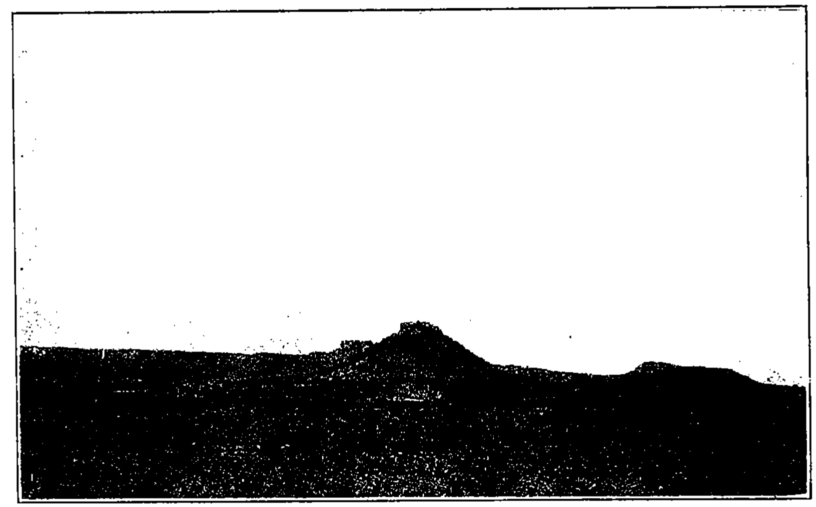
CANYON TOPOGRAPHY IN TESESQUITE VALLEY.

The walls are still steep, but a wide bottom has been formed, due in part to the erosion of non-resistant rocks and in part to the combined action of several small streams which enter the Cimarron at about the same place. The large tributaries from the north, the West Carrizo and the Gillenas, have wider valleys than those on the south side of the river, the steep walls of the canyons being a half mile to 2 miles apart. These two streams have cut through to a soft shaly formation (Morrison formation) and are flowing along its strike. Thus they have been able to cut wider valleys than the other tributaries which do not penetrate this formation. The tributaries from the north, which do not reach

this formation, have narrow canyons like those of the southern tributaries.

The small tributaries have carved buttes out of what once was the wall of the Cimarron Canyon. The height of these buttes is about the same as that of the present canyon walls, and they are from one-eighth to one-half mile across at the base. In all cases they are capped by the Dakota Sandstone. Buttes are to be found along the entire length of the upper part of the Cimarron and also in the valleys of the West Carrizo and the Gillenas.

PLATE V.



CANYON TOPOGRAPHY IN GILLENAS VALLEY.

The most conspicuous feature of the Cimarron Basin is the Mesa de Maya[1] or Black Mesa, as it is called by the inhabitants of the region. It can be seen standing high above its surroundings from almost any point on the bluffs of the Cimarron Valley, and from the plains for many miles south and east. Only the eastern end of the mesa is located in the county, the rest being in New Mexico and Colorado. Its shape is elongate in a northwest-southeast direction, being not more than 6 miles wide at any point,

[1] Mesa de Maya is the name generally applied to the entire volcanic mesa some 50 miles in length lying north of Cimarron River and occupying portions of southern Colorado, and northeastern New Mexico with a 4-mile tongue extending into northwestern Cimarron County. The part in Oklahoma is usually known as Black Mesa. —C. N. G.

and having a length of about 50 miles. In Cimarron County the total length is a little less than 4 miles, and the average width about half a mile. The south side of the mesa is straight because it has been recently undercut by the Cimarron River, but the northern side is deeply indented by valleys tributary to the West Carrizo. On the south side, the mesa rises 600 feet above the floor of the Cimarron Valley and on the north side 400 feet above the floor of a tributary to the West Carrizo. Its surface has a uniform slope toward the east, from an elevation of some 6,000 feet above sea level at its extreme western end in Colorado, to about 4,900 feet at its extreme eastern end in Cimarron County. This latter elevation is about 60 or 80 feet higher than that of the plains south of the Cimarron Valley. The mesa is capped by a basalt flow which has preserved the underlying soft sediments from erosion following the outpouring of the lava.

The easternmost of the buttes is Wolf Mountain in sec. 27, T. 5 N., R. 5 E., the last feature of the canyon topography of the upper part of the valley. Below this point, instead of the steep valley walls topped by vertical cliffs, the valley has gentler and more rounded slopes without buttes or canyons. The sudden change in topography is due to a change in the character of the underlying rocks, which in the upper part of the valley are predominantly sandstones and so have been able to stand in vertical walls, while in the lower part of the valley they are predominantly shales and poorly consolidated sediments which yield readily to erosion. The Dakota sandstone does not occur east of the line through Wolf Mountain, and the character of the underlying rocks changes from predominant sandstone to the west, to predominant shale to the east. The relief in this part of the valley is in the neighborhood of 200 feet.

BEAVER BASIN

The valley of Beaver River is like a long trough. It has precipitous cliffs in only a few places, the highest of which is the 60-foot cliff of Dakota sandstone on the Cieneguilla in the NW. 1/4 of sec. 10, T. 1 N., R. 1 E. Through much of its course it has gently sloping banks covered with sand dunes and wind-blown sand. Where it flows out of the sand area, as it does directly south of Boise City, and for the last few miles of its course in the county, the tops of the bluffs are capped with limestone which makes a cliff from 20 to 40 feet in height, while below the cliff the slope is much less steep down to the channel. The average depth of the valley is 50 to 100 feet and the width from one-half to one mile.

OTHER STREAM VALLEYS

The other stream valleys in the county, those of Agua Frio, Goff Creek, and North Fork of the Beaver, are little more than ravines, in all cases less than 50 feet in depth. To a traveller unfamiliar with the country, they appear in the floor of the plains with surprising abruptness. They are too youthful to have developed any features except those characteristic of gullies and small ravines.

AGE OF THE TOPOGRAPHY

The surface of the county is youthful both in topography and in years. The broad stretches of plains as yet undrained, the narrow, steep-sided valleys, which in the case of the Cimarron and its tributaries have become canyons, the lack of large tributaries, and the small flood plain areas all signify topographic youth. Geologically it is evident that the present topography has been formed in recent times. The Cimarron and West Carrizo have cut into the lava flow which caps the Mesa de Maya, and the tributaries of the West Carrizo have cut through it, making several mesas near their sources in Colorado. This shows that the present streams began to dissect the country after the lava flow, which, as will be shown later, was in very Late Tertiary time. It is evident that a considerable portion of the valleys was cut at the close of the Pleistocene, for the bones of a pre-historic elephant were found in the flood plain deposits of the West Carrizo just north of the county line. Therefore the present streams must have begun to cut into the plains early in Pleistocene times. The presence of great lakes in the Great Basin Region of Utah and Nevada in the Pleistocene Period shows that there must have been a moist climate in this part of the country at that time.[1] This being the case, these streams must have contained more water than at present, and they may have been the channels for considerable torrents of water which probably fell for the most part in the Rocky Mountains. This would account for the considerable erosion during the Pleistocene which the presence of the elephant bones in the lower flood plain deposits of the West Carrizo valley implies. The relatively slight amount of erosion which has gone on since that time is due to the smaller amount of water which has since gone down the streams.

[1] Johnson, W. D., Op. cit. p. 630.

STRATIGRAPHY

INTRODUCTION

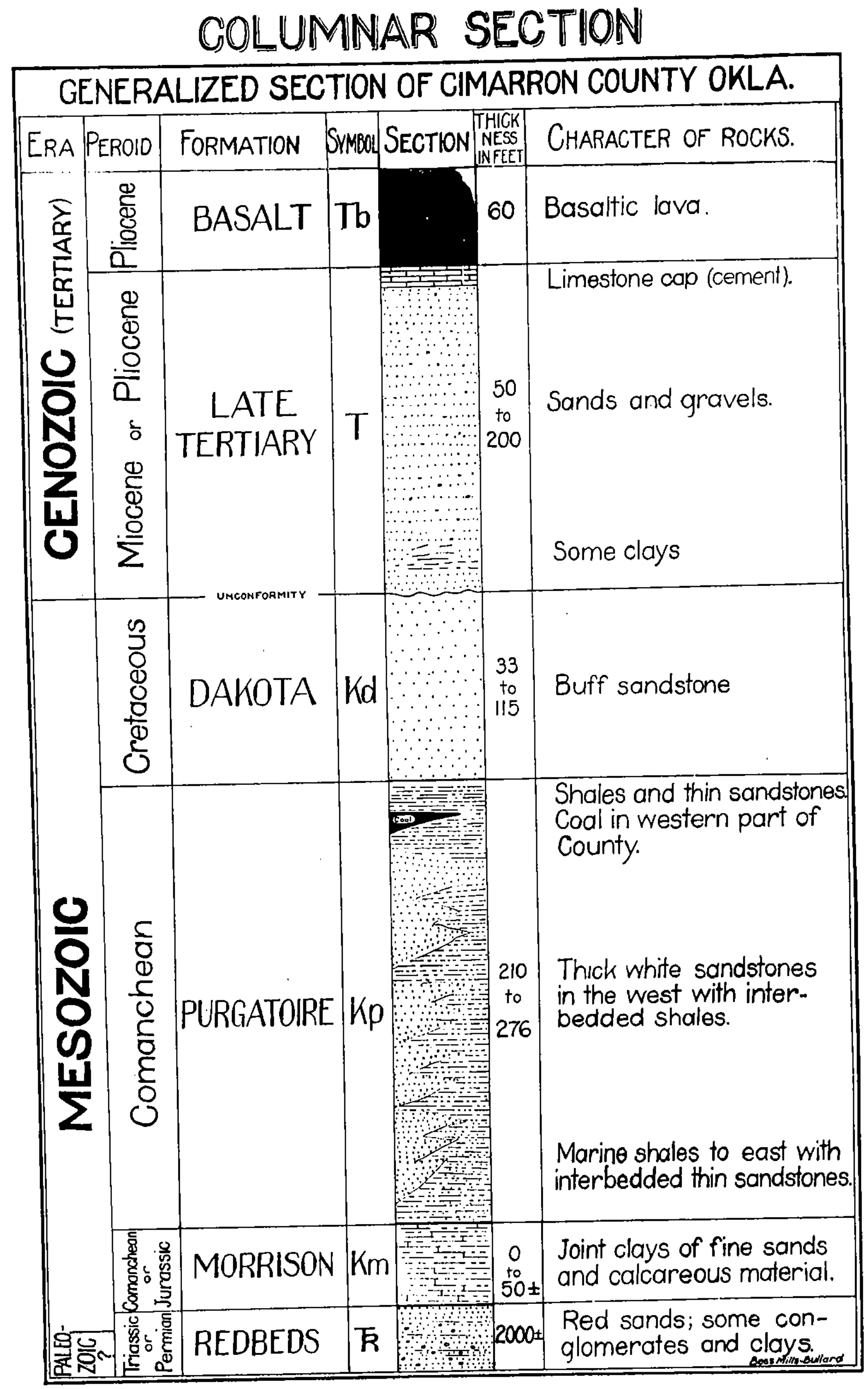
The rocks exposed in Cimarron County range in age from Permo-Triassic to Recent. Every geologic system between the Permo-Triassic and the Cretaceous is represented. Then there is a break in the stratigraphic record, rocks of early Tertiary being absent. The Late Tertiary is represented by extensive deposits, covered with a flow of lava in the extreme northwestern part of the county. Recent and probably Pleistocene deposits are found as alluvium along the beds of the streams. These rocks have been tilted slightly to the east, but otherwise have suffered slight deformations since their deposition. The late dynamic history of this region is merely a series of slight adjustments to the deformations of the Rocky Mountains. The geological history of the region, therefore, as revealed by exposed rocks, has been a succession of fairly quiet times of deposition with intervals of erosion. Some of the formations were deposited in shallow seas near shore, and some were laid down by streams on broad plains. The character of the rocks and the history of the region will be discussed in the detailed account of the stratigraphy and its interpretation which will follow.

RED BEDS

DISTRIBUTION

The oldest rocks exposed in Cimarron County are the red beds which outcrop over a very limited area in the eastern part of the Cimarron Valley. Although these rocks occur on the surface in a smaller area than any other formations in the county, they underlie the entire area and are quite near the surface for 8 or 10 miles along the Cimarron Valley. The formation outcrops in three small tributaries of Cimarron River in R. 6, and along the low cliffs which border the channel of the river. The greatest area of red beds exposed is in a northward-flowing stream on the Burnett Ranch where a small structure cut into by the stream has exposed an elliptical area of outcrops in secs. 4, 9 and 16, T. 5 N., R. 6 E. From this place red beds can be traced eastward along Cimarron River for a distance of about 2 miles. A second northward-flowing tributary of the Cimarron, about 2 miles to the east of the one just mentioned, contains some red beds in the bottom of the valley in sec. 7, T. 5 N., R. 6 E. Across the river from the two localities mentioned, red beds occur at the mouth of a south-flowing tributary of Cimarron River. The

PLATE VI.



rocks occur on the west side of the valley only, being carried below the surface to the east by a rather sharp east dip. Red beds are reported from the Cimarron Valley a short way beyond the state line in Colorado, and it is probable that they occur in the bed of the river down stream from the outcrops noted above, although covered by sands and other river deposits.

THICKNESS

The thickness of the formation in this region can not be determined from information now at hand and so must be estimated from available records of wells drilled in the county, and by comparison with known thicknesses in neighboring regions. Along Cimarron River, cliffs 7 to 10 feet high represent the exposed thickness of the formation, and the thickest section measured, on a small stream in sec. 9, T. 5 N., R. 6 E., amounted to only 20 feet.

A well was drilled for oil near the center of sec. 22, T. 4 N., R. 1 E., to a depth of 2,040 feet. No log of this well was obtainable, but an examination of the sludge showed no trace of any rock other than red beds, in the last material bailed. As the top of the well is in the Dakota formation, 370 feet, more or less, should be subtracted for the thickness of overlying formations. This would leave a thickness of something more than 1,670 feet for the red beds. Another well was drilled for oil at the southwest corner of the NW. 1/4 of sec. 22, T. 5 N., R. 5 E., to a depth of 1,583 feet, the top of the well being at or very near the top of the red beds. Then the rig was skidded a short distance and a second hole drilled to a depth of 1,155 feet. It is certain that the last hole drilled did not go through the red beds, for the sludge was fairly fresh when seen. From the information obtainable it is impossible to say with certainty whether the first hole drilled at this place went through the red beds. The lowest bed which is called "red clay and gyp" in the log of the well given below is at 1,100 feet, but gypsum is reported at a depth of 1,460 feet, 360 feet below the last bed specified as "red." The sludge from the first hole was covered up with that from the second, so it was impossible to get any information as to the character of the material from that source. It is probable, however, that the bottom of that hole was still in the red beds. A well drilled 4 miles north of Liberal, Kansas, in the southeast corner of sec. 20, T. 33 S., R. 33 E., which is 60 miles east of Cimarron County, reports 1,640 feet of red beds. A well drilled near Channing, Texas, 50 miles to the south shows at least 2,500 feet of red beds.

At Gate, Beaver County, Oklahoma, 150 miles to the east 1,750 feet of red beds were measured,[1] but it is doubtful whether the same stratigraphic horizons are represented at Gate and in Cimarron County, as those at the first place are Permian, while the top of those at the latter are probably Triassic, as will be shown later. In the Rocky Mountains, 180 miles to the west, Lee[2] gives a thickness of 14,000 feet for the red beds, but suggests that this great thickness may be due to duplication by faulting.

From the foregoing it may be deduced that the red beds of Cimarron County are at least 1,100 feet thick, while the well in T. 4 N., R. 1 E., indicates that they have a thickness of 1,670 feet or more. From thicknesses east, west and south of the county. it is reasonably certain that the red beds of the county have a thickness of about 2,000 feet.

CHARACTER

It is not possible to form an accurate idea of the character of the rocks of this formation in the county from the very small outcrops which are exposed. In general, however, it may be said to consist of brick, red and buff sandstones, some fine conglomerates and red shales. The sands of the sandstones are very fine-grained and one of the layers exposed contains considerable clayey material. These sandstones are composed largely of quartz, with a cement of iron oxide which gives the characteristic red color, and occur in massive beds, 7 to 10 feet thick. In the canyon of Cimarron River, New Mexico, some miles to the west, similar beds occur, and there show cross bedding, the beds forming large lenses or wedges. However in the small outcrops seen in this county such conditions of stratigraphy could not be noted. In the sandstone beds are lenses of coarse sand and fine conglomerate ranging from 10 to 40 feet in length, and from 1 to 5 feet in thickness, with pebbles averaging one-eighth to one-quarter of an inch in diameter. Red shale is also found in small lenses, and is noted in wells drilled into the formation.

The thickest section measured is on the east side of the stream near the center of sec. 9, T. 5 N., R. 6 E.

Section, Center of sec. 9, T. 5 N., R. 6 E.

	Ft. In.
Top—	
Sandstone, buff, in beds 1-foot thick. Much tiny cross-bedding	5′ 6″

[1]Aurin, F. L., Geology of the Red Beds of Oklahoma, Okla. Geol. Survey, Bull. 30, p. 41, 1917.
[2]Lee, W. T., Op. cit. p. 41.

Top—	Ft.	In.
Soil, brick red, on slope between benches, typical red bed sandstone exposed at this horizon 200 feet to the west	8′	6″
Sandstone, buff to red, makes a ledge..................	5′	6″
Soil, red, indicating red sandstone......................		

Some idea of the nature of the formation may be obtained from the following well log, furnished the Oklahoma Geological Survey, by the company which did the drilling:

Well drilled by the Empire Gas and Fuel Co., sec. 22, T. 5 N., R. 5 E., Cimarron County, Oklahoma.

Drilling commenced April 27, 1917. Date of completion not given.

Formation	Thickness Feet	Depth Feet	Formations	Thickness Feet	Depth Feet
Soft red shale............	130	130	Red clay	20	1,058
Gray sand	40	170	Red clay and gyp.........	42	1,100
Gray lime	15	185	Gypsum	30	1,130
Soft red sand...........	20	205	Sand and gyp	20	1,150
Soft red shale...........	60	265	Gypsum	20	1,170
Hard lime	15	280	Clay, gravel and gyp......	20	1,190
Soft sandy lime	22	302	Clay, gravel and gyp.....	40	1,230
Soft red sand...........	217	519	Fine sand and shale......	45	1,275
Soft red rock	23	542	Sand and shale	30	1,305
Water sand	10	552	Sand shale and gyp......	30	1,335
Red rock	15	567	Sand	9	1,344
Red clay	20	587	Fine sand	15	1,359
Red rock	98	685	Sand	15	1,374
Lime	37	722	Fine sand	26	1,400
Red rock	92	914	Sand and clay	15	1,415
Shale	3	917	Sand	10	1,425
Lime	3	920	Clay, sand and gravel.....	15	1,440
Red rock	63	983	Sand and gyp	20	1,460
Red clay and gravel......	3	986	Sand	30	1,490
Red clay and gravel	5	991	Sand and clay...........	15	1,505
Red clay	42	1,033	Sand	70	1,575
Red clay and gyp.........	5	1,038	Sand and clay	8	1,583

RELATIONS

The contact of the red beds with the overlying Purgatoire formation could not be seen because of talus slopes which covered it, but in order that the red beds should underlie the Morrison beds in the western part of the county, and the Purgatoire in the east, there must have been a time of no deposition or erosion in the eastern part of the county, and therefore an unconformity where these beds are exposed. Wherever the contact of the red beds with the Morrison beds was observed, there is an unconformity. In the upper Cimarron Valley in New Mexico this amounts to a distinct angular unconformity in which the red beds have dips as high as 10°. It is not known what lies beneath the red beds in the county, and therefore there is no information concerning their lower contact.

AGE AND CORRELATION

These red beds are believed to be a part of the formations of the Rocky Mountain front, for beds of similar lithologic character can be traced from the red beds of the Raton Mesa region down the Cimarron Valley to within a few miles of the western border of the county. The sandy character and the alternation of brick red and lighter reddish color of the beds exposed in Cimarron County are very similar to the characters seen in the red beds in the Raton Mesa region. The absence of gypsum in the upper part, and the comparatively small amount of shale are notable differences between these red beds and those seen farther east in Oklahoma.

The absence of fossils makes it impossible to determine the age more exactly than Permian or Triassic. It is known that the red beds in Beaver County, 150 miles to the east, are Permian, while those to the west in New Mexico have usually been called Permo-Triassic. Stanton mentions the finding of Triassic dinosaur bones in the red beds near Folsom, New Mexico,[1] which is 70 miles west of the outcrop in Cimarron County, so that he is inclined to put the red beds of the upper Cimarron Valley in the Triassic. Judging from the lithologic similarity between the rocks of the red beds in Cimarron County and those in New Mexico, one would be inclined to assign the same age to both exposures.

MORRISON FORMATION

The easternmost outcrop of the Morrison beds are found in the western end of the basin of Cimarron River in Cimarron County. There are in the county only small exposures of this formation showing the bottoms of the larger streams where the folding of the rocks has brought them within reach of stream erosion. These exposures occur along the banks on the western side of the West Carrizo from the Colorado line almost to the base of the Mesa de Maya, and appear on the south side of the mesa west of Kenton in a narrow belt skirting the base of the mesa, and probably extending into New Mexico. This belt of exposures is covered for half a mile east of the state line by talus and stream deposits of the Cimarron River, but may be seen in the creek bottom at the western edge of Kenton. Steep east dips, seen at the last mentioned place and also in the West Carrizo Valley, quickly carry the formation below the surface, and it does not re-

[1]Stanton, T. W., The Morrison Formation and its Relations with the Comanche Series and the Dakota Formations; Jour. Geol. Vol. 13, p. 665, 1905.

appear again until a small area is encountered on the north side of Cimarron River near the northeast corner of sec. 8, T. 5 N., R. 2 E., where the mail road from Kenton to Campo, Colorado, leaves the valley of the Cimarron, and turns up the hill toward the valley of Gillenas Creek. The easternmost outcrops of the formation are on the west side of the Gillenas Valley where a few feet of the top of the formation are exposed in the valleys of two tributaries to the Gillenas, one in sec. 34, and the other in sec. 22, T. 6 N., R. 2 E., where the road crosses these tributaries. Exposures do not appear on the east side of the Gillenas Valley, partly because of the gentle slopes covered with talus and stream deposits, and partly because an east dip carries them below the surface.

It is not possible to state how far the exposures of the Morrison extend east of the Gillenas Creek, for the bottom of the Purgatoire formation is not exposed again for 20 miles and the Morrison beds are not present at this place. A water well drilled on the Julius Kohler Ranch in the SW. ¼ of sec. 21, T. 6 N., R. 5 E., went through 55 feet of red shale and into a white sandstone, and an oil well in sec. 22, T. 5 N., R. 5 E., reports 130 feet of soft, red, shale near the bottom of the Purgatoire formation. The shales on the Kohler Ranch, however, are probably shales near the bottom of the Purgatoire, while those at the other well are probably the top of the red beds. Therefore it would be safe to assume that the Morrison formation thins out and probably disappears in Range 4.

THICKNESS

Only the top of the Morrison formation is exposed in Cimarron County, so it is impossible from data here secured to give its thickness. The only place where it was possible to measure a section was on the West Carrizo in the north half of sec. 28, T. 6 N., R. 1 E., where its total thickness is 55 feet. Lee states that its thickness in the Cimarron Valley near Raton, New Mexico, is 300 feet.[1]

CHARACTER

The following section was measured at the place mentioned above and gives a good idea of the sorts of material to be found in the Morrison of Cimarron County.

[1]Lee, W. T., Geology of the Raton Mesa and Other Regions in Colorado and New Mexico. U. S. Geol. Survey, Prof. Paper, 101, p. 40, 1917.

Section of Morrison Formation, sec. 28, T. 6 N., R. 1 E.

	Ft. In.
Top—	
Massive, white sandstone of the Purgatiore. Clayey, light gray material, no bedding. Grains angular or sub-angular 0.018 to 0.033 mm. in diameter. Composition: quartz 50-80 percent; orthoclase, very little; calcite 50 percent in fine grained portions, but very little in coarser. Many dolomite rhombs scattered throughout................	5′
Sandstone, fine-grained, white, weathers buff. Average size of grain, 1 mm. Composition: quartz 85 percent; orthoclase 5 percent; andesine; calcite 5 percent; some dolomite rhombs; iron stain. Rock cemented partly by calcite and partly by interlocking grains..	7′
Sandstone, fine-grained, friable, arkosic. Forms concretionary masses showing rounded faces at outcrop. Color gray with bluish cast. Composition: quartz 55 percent; labradorite 2 percent; orthoclase 5 percent; calcite 38 percent; many dolomite rhombs; chloritized material and iron oxide stains the cement. Calcite forms the cement	1′ 4″
Clay, deep red with green or greenish-gray mottlings which increase in number toward the top forming bands and layers, bedding indistinct. Breaks into little joint blocks. Composition: quartz 80-90 percent (av. diameter .15 mm.); feldspars; zircon; trace of an altered mineral so changed to chlorite and iron as to be indistinguishable................	5′ 7″
Sandstone, light buff, weathering gray-buff. Grains average 0.225 mm. in diameter and are well rounded; 90 percent quartz. Rock firmly cemented by calcite containing scattered dolomite rhombs 0.033 mm. long. Iron stain all through cement	4″
Clay-like material, light green, composed entirely of dolomite rhombs, largest 0.033 mm. in diameter, average 0.011 mm. Bedding thin, ¼ to 3 inches. Typical close jointing. Fractures conchoidal. Bottom layer contains sandstone lenses, ¾ inch long and ¼ inch thick	4′ 0″
Shale, soft, very finely laminated, bright green. Composition: quartz 15-20 percent in rounded and sub-angular grains 0.099 mm. across; plagioclase feldspar, trace; calcite and rhombic crystals of dolomite (0.033 mm. long); matrix 60-80 percent composed of sericitic and chloritic material too fine to be identified	5″
Clay-like material, soft, chocolate colored. Composition: quartz 50 percent, angular and sub-angular grains 0.003-0.075 mm. in diameter; calcite and dolomite rhombs; much greenish-red stain all through the slide................	6″
Clay-like material. Brick red at bottom, slate colored at top. Grades from one color into the other. Red portion blotched with green. Typical close jointing with larger fracture surfaces conchoidal. No distinct bedding. Composed of about equal parts of quartz and calcite with dolomite rhombs scattered through it. Average size of grain 0.016 mm	7′ 0″

Top—	Ft. In.
Limestone with some clayey material. Color light gray, weathering lighter, red along joint cracks. 1 or 2-inch beds rather indistinct. Characteristic close jointing. Composition: dolomite in rhombs 30 percent; quartz 20 percent; some white mica, chlorite, etc.	6′ 0″
Limestone, very fine-grained, brick red, with gray streaks and patches throughout which give it a mottled appearance. Weathers but little lighter in color. Bedding indistinct. Extremely jointed, giving characteristic small blocks. Composition: Calcite 99 percent, iron stain	16′ 9″
Limestone, light gray to reddish, impure. Much jointed giving characteristic blocks. Composition: quartz 46 percent in rounded and elongate grains 0.082 mm. across; calcite 48 percent; sprinkled with dolomite rhombs; kaolin 5 percent; white mica 1 percent; zircon, a trace	3′ 0″
Sandstone, very compact, limey. Light gray or buff, weathering lighter gray. Composition: quartz 60 percent; grains sub-angular and elongate; calcite 39 percent; part dolomite rhombs; chloritized material; biotite; kaolin; white mica; a little iron stain	2′ 8″
Limestone, very fine-grained. Bedding distinct 1-16 to 1-inch beds. Characteristic block jointing. Composition: quartz 40 percent; plagioclase feldspar a trace; calcite with scattered dolomite rhombs 60 percent; zircon, very little; iron stain	1′ 10″
Limestone, some parts gray but mostly pink, weathers gray. No distinct bedding. Characteristic jointing into little blocks. Composition: calcite 97 percent, dolomite rhombs scattered abundantly through it; quartz 0.5 percent, grains 0.05 mm. across; plagioclase feldspar, a trace; iron stain which gives color to the rock	3′ 8″
Total thickness	55′ 1″

The distinctive features of the Morrison formation as exposed in Cimarron County are its shaly character, variegated colors, and extremely close jointing. This last character causes the shales to break up on weathering into a mass of small block chunks, one-eighth to one-quarter of an inch across, and because of this they have received the name of "joint clays." This jointing is one of the distinguishing characteristics of the formation wherever shales are seen. These rocks appear to be clays, and possess many of the physical properties of clays, but under the microscope it can be seen that they are very fine-grained sandstones and limestones or dolomites, the clayey minerals such as kaolin, micas, chlorite, etc., being scarce. There is a great deal of calcite and dolomite, the latter being recognized by the tiny rhombic crystals throughout the entire section observed. The colors are due to varying amounts of iron oxides and chlorite in the different layers.

PLATE VII.

SHALES OF THE MORRISON FORMATION CAPPED BY PURGATOIRE SANDSTONE.

RELATIONS

Since only the upper part of the formation is exposed in Cimarron County, its contact with the underlying red beds is nowhere visible. West of the county line, in New Mexico, the red beds are folded slightly, and as these folds were beveled off before the Morrison Epoch, it is probable that there is an unconformable contact between the two formations in Cimarron County as well as to the west. If the angular unconformity mentioned above is not present, there must at least be a disconformity, for there is a time interval between the two formations during which the Exeter sandstone was deposited in New Mexico. The Exeter formation, which lies above the red beds and below the Morrison, wedges out to the east in the Cimarron Valley before reaching Oklahoma.

The contact of the Morrison beds with the overlying Purgatoire formation in the one locality where it was seen (sec. 28, T. 6 N., R. 1 E.), seems to present a transition in the upper three layers. The 1-foot 4-inch sandstone, which is the third member from the top of the section given above, is very much like the typical Purgatoire in size of grain and mineral composition but contains the dolomite rhombs characteristic of the Morrison beds. The next bed above is very much like the first and is followed by light green shale which has the characteristics of the Morrison and which underlies the lower thick, white sandstones of the Purgatoire.

ORIGIN

There is scarcely enough of the formation exposed to warrant conclusions concerning its origin. Mook[1], who has made a study of this problem, states that it is the product of stream deposition, the streams flowing from some low area far to the southwest of Cimarron County. The materials were deposited on a peneplain or flat surface which contained swamps or lakes in places, in which the very finely laminated clays and the limestones were laid down. If such is the correct interpretation, one of the lakes must have occupied this region in which the limestones shown in the section were deposited.

AGE AND CORRELATION

The age of the Morrison beds has been a matter of considerable controversy, and up to the present there has been no solution of the problem which is satisfactory to all geologists interested in it. It is agreed that it is either later Jurassic or early Cretaceous (Comanchean), but there is not yet sufficient evidence to definitely place the formation in either system.

No fossils were discovered in the formation in Cimarron County. Therefore, the correlation is based entirely on stratigraphic position and lithologic character of the rocks. The variety of color and the extreme jointing are characteristic of the formation in all localities from which it has been described. It is described in the areas in southeast Colorado which are covered by folios of the U. S. Geological Survey[2], and it has been traced down the Cimarron Valley from the Raton Mesa region.[3] Therefore no hesitation is felt in classing these beds as Morrison, even though fossil evidence is lacking.

[1]Mook, C. C., The Origin and Distribution of the Morrison Formation; Geol. Soc. America, Bull., vol. 26, pp. 295-322, 1915.
[2]Finlay, J. R., U. S. Geol. Survey, Geol. Atlas, Colorado Springs folio (No. 203), 1916.
Richardson, C. H., U. S. Geol. Survey, Geol. Atlas Castle Rock folio (No. 198), 1915.
Stose, G. W., U. S. Geol. Survey, Geol. Atlas, Apishapa folio (No. 186), 1912.
[3]Stanton, T. W., Op. cit., pp. 657-669.

PURGATOIRE FORMATION

DEFINITION

Gould[1], who first studied the rocks in this region, described all the Cretaceous beds as one formation—the Dakota sandstone. The work of Lee[2] and Stanton[3] in 1905, however, showed that there should be a separation of these beds, at least in the southern part of Colorado and the northeastern part of New Mexico. The divisions recognized by these men were noted and more fully described in the work done along the Rocky Mountain front in southeastern Colorado by later writers[4].

In general there is a tripartite division of the Cretaceous strata in the region. The lowest zone is composed chiefly of massive layers of white or cream colored sandstone. It is overlain by a zone composed predominantly of dark shales grading in places to very black shales and in one place to coal, but having thin sandstones in places. In many areas in southeastern Colorado the top of this zone is marked by a bed of fire clay. The uppermost division is buff colored sandstone, about 100 feet thick. The shale zone contains a fauna of Comanchean age, while the buff sandstone contains a well known Dakota flora. This would limit the use of the term Dakota to the sandstone above the dark shales and necessitate a renaming of the lower part of the series. Lee and Stanton have used the term Purgatoire formation, so named because this formation is well exposed in the walls of the canyon of Purgatory River in southeastern Colorado.

DISTRIBUTION

The Purgatoire formation outcrops along the Cimarron River and its tributaries and can be followed continuously from the western border of the county to the eastern side of Range 6, a distance of about 35 miles. It forms the lower slopes and the bottom of the valley along most of its length. The only large area where this formation is continuously exposed is in T. 5 and 6 N., R. 5 E., where the structure of the rocks has caused it to appear at the surface, over an area of about 60 square miles.

[1]Gould, Chas. N., U. S. Geol. Survey, Water-Supply Paper (No. 148), p. 78, 1905.
[2]Lee, W. T., Op. cit.
[3]Stanton, T. W., Op. cit. pp. 657-669.
[4]Finlay, J. R., Op. cit.
Stose, G. W., Op. cit.
Richardson, C. W., Op. cit.

The very top of the formation is exposed beneath the Dakota sandstone on both the Currumpa and Cieneguilla creeks in the southeastern part of the county. A strip of black shale about 5 feet thick lies under the massive Dakota cliff on the south side of the latter stream, and can be traced nearly a mile. On the Currumpa, 57 feet of the formation are exposed in a small anticline. Although the Purgatoire is the thickest of the formations exposed in the county, except the red beds, it outcrops over a very small area as compared with the exposures of younger formations.

THICKNESS

The thickness in the western part of the county is about 275 feet. In the eastern part 210 feet are exposed in T. 5 N., R. 5 E. These figures correspond to the maximum thicknesses given the formation in Colorado and New Mexico, where, in the canyon of the Purgatory River, its thickness is 230 to 260 feet[1].

COMPOSITION

In general the formation consists of sandstones and shales with some conglomerates and a very little limestone. It is to be distinguished from the overlying Dakota by the white color of the sandstone and the presence of conglomerates and arkose.

Two divisions are recognized in all the localities from which it has been described. The lower division is a white to cream colored sandstone, and the upper a series of gray to black shales with inter-bedded, thin sandstones. In the Colorado Springs region the lower division is called the Lytel sandstone member and the upper the Glencairn shale member[2]. In the valley of the Purgatory River, Butler[3] states that the lower two-thirds of the formation is almost entirely of white and buff sandstone, while the remainder is largely of shale containing thin sandstone beds

In Cimarron County the same two divisions can be made, though they are not everywhere so distinct as in the Colorado Springs area. At all places where the overlying Dakota sandstone makes cliffs, there is a covered slope of from 30 to 60 feet below the cliff, but where a glimpse may be had of the rock under the talus, it is found to be black shale and sometimes thin-bedded sandstone or black, sandy shale. Below this talus slope lies a thick bed of sandstone, 20 to 50 feet thick. In most places this

[1]Butler, G. M., The Clays of Eastern Colorado; Colo. Geol. Survey, Bull. No. 8, p. 106, 1915.
[2]Finlay, J. R., Op. cit., p. 788.
[3]Butler, G. M., Op. cit., p. 106.

layer is white, though in a few localities, on the butte north of Mesa de Maya on the West Carrizo in sec. 20, T. 6 N., R. 1 E., it is buff. The top of this sandstone is taken as the top of the sandstone member, and the covered interval as the shale member of the formation.

SANDSTONE MEMBER

This member comprises the lower 200 feet of the formation and is characterized by the thick, white beds of sandstone which are so prominent in the western part of the Cimarron Valley. There are really a number of sandstone layers, some white and some buff, but the white layers are the more conspicuous. The beds vary in thickness from 12 to 50 feet or more and from a distance appear massive. On close examination, however, it appears that they are extremely cross-bedded, and that there are scattered conglomerate lenses at rare intervals throughout.

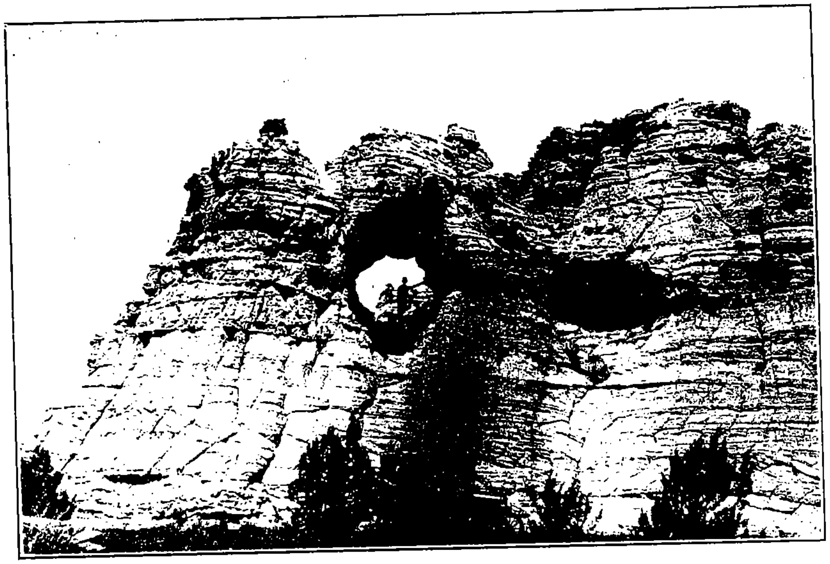
CHARACTER OF SANDS

The sand as a whole is very poorly cemented and therefore yields readily to weathering, forming smooth, rounded surfaces and in some localities making fantastic mushroom and pillar forms, somewhat like those found in the Dakota sandstone. A group of such forms is to be seen on the east side of 101 Gap in the NE. 1/4 of sec. 15, T. 5 N., R. 1 E., along the road between

PLATE VIII.

SANDSTONE OF THE PURGATOIRE FORMATION IN EASTERN CIMARRON VALLEY.

PLATE IX.

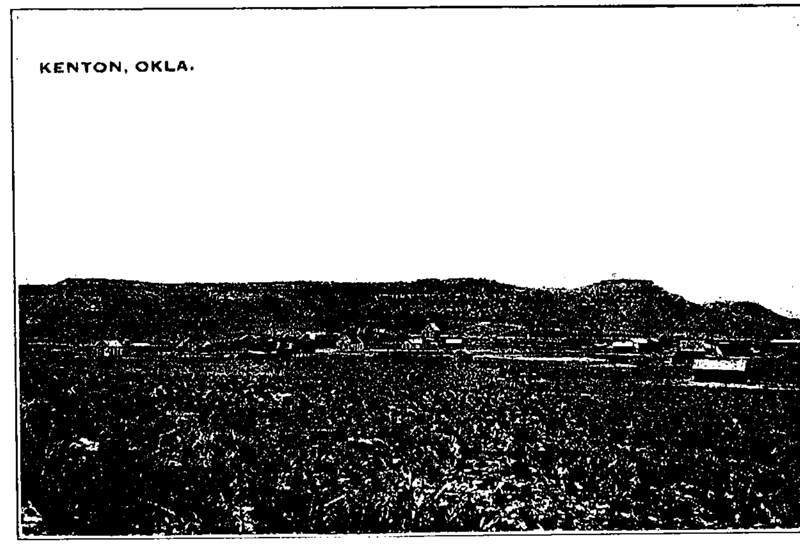


EROSION FORMS IN LOWER MEMBER OF THE PURGATOIRE SANDSTONE, WESTERN CIMARRON VALLEY.

Kenton and Boise City. The origin of these forms in this formation is the same as for those in the Dakota sandstone. At the top of each pillar there is a cap of iron oxide, apparently originally deposited by ground water, which protects the top while weathering is taking place along vertical joints. Near the bottom of the formation the white layers are frequently cemented firmly enough to form quartzite, and not infrequently diffusion rings of iron oxide form in this quartzite, making it look like a bed of great concretions. There is much of this quartzite at the foot of the Mesa de Maya on the south side, and also at the foot of the cliffs on the west side of the valley of the Gillenas, near its mouth. The diffusion rings are very well developed just south of Dr. Regnier's house, near the Oklahoma-Colorado line in the Gillenas Valley, where they are in white sandstone near the middle of the formation.

These sands are composed predominately of quartz, most of which came from igneous rocks, as indicated by the numerous inclusions of apatite and rutile needles. Some grains are made up of a mass of more or less minute crystals differently oriented, and joined by very irregular edges. These are either bits of vein quartz or granulated quartz from metamorphic rocks. Feldspar

PLATE X.



LOOKING WESTWARD FROM KENTON, OKLAHOMA.
Cap rock on cliff to the right is Dakota sandstone.
Ledge occurring below is of the Purgatoire formation.

grains can be seen in many sands with the naked eye and in most of them with the aid of a lens. In the thin sections examined, both orthoclase and plagioclase were found. The plagioclase is acid, being basic oligoclase or acid andesine. Bits of other minerals, from igneous rock, such as apatite and zircon, are scattered through some of the sands, though in no place do they make any appreciable part of the whole. A little calcite was found in the cement of the lower sandstones collected north of the Mesa de Maya, but it was evidently very local and had been brought in by ground water from nearby limestones, for it was found at no other place. Iron oxide occurs in some of the sands in sufficient quantity to give the buff color noted above. It also is found on the weathered surface of the quartzite, sometimes giving the surface a red or buff color, and in other instances filling the pores of the rock and the holes formed by the weathering of the feldspars with black iron oxide, thus giving the rock a speckled appearance. It also makes the diffusion rings mentioned above, the concentrations of iron oxide being sufficient to make the rock tend to split off in roughly concentric layers, much like the exfoliation seen in granite. An average of the mineral composition of the slides examined would give quartz 75 percent, orthoclase 2 percent, plagioclase 3 percent, cement and pore space 20 percent. In some specimens the feldspar runs higher, but never more than 10 percent. The rocks therefore should be called arkosic sandstones rather than true arkose.

TEXTURE

The size of the grains varies considerably, the smallest measured being 0.099 mm. and the largest 0.7 mm. If the conglomerates are included, the size of the largest grains would be about an inch. All the sandstones, however, are composed of grains having an average size of from 0.1 to 0.2 mm. in diameter, larger and smaller grains being the exception.

CONGLOMERATES

Conglomerates are scattered through the formation at widely separated intervals, as more or less lenticular masses, usually in sandstone which is coarser than the average. The lenses are not more than 5 or 6 feet thick nor 10 to 30 feet long. They are composed of pebbles rarely more than an inch or an inch and a half in diameter, and from that size down to one-eighth of an inch. They are made up, for the most part, of sub-angular pieces of chert, flint, and considerable vein quartz. Where noted in this county, they are near the upper part of the member of the Purgatoire formation. The source of pebbles is unknown, but their size and shape suggests that they have travelled for a great distance. As these conglomerates are common to the formation in all the localities from which they are described, it is probable that the pebbles were brought from the land area to the west which supplied the material of this formation.

SHALE PARTINGS

The white and buff sandstones are separated at irregular intervals by shale beds. These shales are usually represented by covered slopes where it is very difficult to get any idea of the rock beneath. The sandstones are very poorly cemented and crumble readily, making it almost impossible to find their contacts with the shale partings. The best exposure is on 101 Hill, near the center of sec. 18, T. 5 N., R. 2 E., where the grading of the road from Kenton to Boise City has exposed the upper 80 feet of this formation.

Sandstone member of Purgatoire Formation in sec. 18, T. 5 N., R. 2 E.

	Ft. In.
Top—	
Shale member: Black shale.	
Sandstone member: White, even grained, cross-bedded. Some beds massive. Weathers into fantastic, rounded forms. Lenses of carbonaceous shale 2 to 3 inches thick in the upper 5 feet	42′ 0″
Conglomerate in loosely cemented, red sandstone. Pebbles ½-inch to 3 inches in diameter	5′ 0″
Shale, pure brown or bluish with some streaks of yellow sandstone ½ inch thick. A 1-foot sandstone layer at 15 feet from the base. Shale weathers light gray-blue and crumbles into flakes ½ to 1-inch across	21′ 0″
Sandstone, heavy, white or buff. WeWathers lighter in some places and more buff in others. Quartzite forming in nodules in the upper layers	12′ 0″
Covered	75′ 0″
	155′ 0″

At places throughout the county where it is possible to get a hint of the sort of rock beneath the talus slopes which separate the sandstones, it is always found to be either shale or friable sandstone.

LIMESTONE

About 100 feet below the base of the Dakota formation in the valley of the West Carrizo, there is a limestone 5 feet thick. It is very compact, slightly argilaceous and dove colored; it breaks with a pronounced conchoidal fracture, and thin pieces have a ringing sound when struck. Though compact, it breaks up on weathering into beds or layers 1 to 6 inches thick. Under the microscope it appears to be made almost entirely of calcite; the only other mineral showing in the thin sections examined being quartz in grains 0.033 to 0.115 mm. in diameter, constituting no more than 0.5 percent to 1 percent of the slide. The calcite is in very small grains or crystals, so fine that it was impossible to determine which, even under the high power of the microscope. As nearly as could be measured the size of the calcite grains is about 0.0033 mm. No fossils were found, though careful search was made for them.

Similar limestone is reported from near the center of the eastern part of T. 4 N., R. 1 E., where it outcrops on some small hills in the pastures of the John Skeeley Ranch.

In the eastern part of the area where the Purgatoire formation is exposed, a limestone of about the same thickness and of the same composition and character can be traced 6 to 8 miles in the Cimarron Valley. In some places the lower part of the eastern limestone is red on the weathered surface, though the upper two feet or more weathers gray like the western limestone. This limestone can be seen in the bed of the Cimarron River near the middle of the west side of sec. 11, T. 5 N., R 4 E. It can be traced eastward from that point, rising higher and higher on the hills, reaching its highest point in the vicinity of Wolf Mountain, sec. 27, T. 5 N., R. 5 E.

It is not certain that this last limestone is the same bed as that found in the valley of the West Carrizo, for the beds could not be traced through the intervening 15 miles, but their lithologic similarity would suggest identity. They occur at about the same distance below the base of the Dakota sandstone, the interval on the West Carrizo being 111 feet and at Wolf Mountain 90 feet.

GRADATION FROM SHORE TO MARINE CONDITIONS

As the sandstone member is traced eastward down the valley of the Cimarron, there is a change in its character which indicates a gradation toward marine conditions. The top sandstone in the western part of the valley is white or light buff, a gradual change takes place, and in sec. 5, T. 5 N., R. 4 E., it becomes coarse-grained and buff, with considerable conglomerate and much feldspar in it. Instead of the massive sandstone of the western part of the valley, the beds are here from 1 to 3 feet thick. From this point eastward all thick layers of white sandstone are gone and in their place occur thin sandstones and shales. The sandstones in this part of the exposure vary from 2 to 25 feet thick, but do not reach the 40 to 60 foot thicknesses which were seen farther west. The light color is still predominent and in some cases becomes creamy white, but often is buff to red. The shale beds increase in number, their prevailing color being light to dark gray and in some cases black. Reddish sandy shales are found in places and there is one horizon of yellowish, sandy shales toward the top of the formation. The shale beds measure 10 to 26 feet in thickness and the sandstones 5 to 25 feet. Another feature noted in the eastern part of the exposed formation is the increase in the amount of limy material. Thin limestones and lime cement in sandstones occur at frequent intervals. One such bed can be seen on the road up Ute Canyon about 3 miles north of Cimarron River, and here it is a very sandy, reddish limestone carrying casts of Comanchean fossils.

The above facts indicate that there was a gradation from land or nearshore conditions of deposition to marine conditions during which time there were either oscillations of the sea level or differences in the rate at which sediments were supplied, while this formation was being laid down. This change was first noted by Lee[1] and Stanton[2] on their trip up the Cimarron Valley in 1904, and also by Darton[3] at Two Buttes in Colorado.

[1]Lee, W. T., Op. cit.
[2]Stanton, T. W., Op. cit. p. 660.
[3]Darton, N. H., Op. cit.

SHALE MEMBER

The beds of this member are rarely exposed and therefore it is difficult to study it. A good section of carbonaceous shale, 32 feet thick, is exposed at 101 Hill near the center of sec. 18, T. 5 N., R. 2 E. It is of a bluish-black color, weathering slightly lighter in spots. Similar black shales occur at the base of the Dakota sandstone in the cliffs of the Cimarron at many places, and also along Cieneguilla Creek. They also appear at a number of places where there are no cliffs as, for instance in the hills about the old townsite of Mineral in secs. 12 and 13, T. 4 N., R. 1 E., and secs. 7 and 18, T. 4 N., R. 2 E. They also occur in the slope below a deserted house and sheep corral on the Strong Ranch near the center of the east line of sec. 17, T. 5 N., R. 4 E. About the old townsite of Mineral there are, at this horizon, white, light gray and yellow clays. In the southeastern part of Colorado there are fire clays at the top of the upper member of the Purgatoire, and it is possible that the clays found at Mineral may be more extensive than their limited exposures indicate. They may be the equivalent of the Colorado fire clays.

Many springs occur at the base of the Dakota sandstone, caüsed by the presence of these impervious shale beds beneath. Such springs are to be found on the Mesa de Maya at Nigger Springs, and at Dripping Springs, in sec. 28, T. 4 N., R. 1 E., in Dripping Springs Creek, tributary of the South Carrizo Creek. The springs in Water Canyon on the Al. Baker Ranch in sec. 24, T. 5 N., R. 2 E., and the three big springs on the old Santa Fe Trail, located on the Hughes and Hood Ranches on Cold Springs Arroyo, in secs. 8 and 4, T. 4 N., R. 4 E., and at Flagg Springs, 7 miles to the east, on a small unnamed tributary of the Cimarron River, in sec. 32, T. 5 N., R. 4 E., are in similar stratigraphic positions.

In the extreme western part of the county, 18 inch beds of coal occur at the top of the upper member of the Purgatoire, probably as lenses in the shales and sandstones. A section taken at the strip pit on the Will Baker Ranch in sec. 32, T. 4 N., R. 1 E., shows the following rocks at the top of the shale member.

Shale Member of Purgatoire Formation in Sec. 32, T. 4 N. R. 1 E.

	Ft.	In.
Top—		
Shale, gray sandy		10″
Sandstone, thin bedded, gray, medium-grained	1′	4″
Beds 1 and 2 inches thick		6″
Lignite	1′	
Shale, sandy, some black, grading into sandstone below		7″
Sandstone in bed of the stream	?	
Total thickness	4	4-5

Sandy shales are frequently indicated in the talus of the slope covering the upper member, and are exposed in the outcrop on Currumpa Creek.

Section on Currumpa Creek

Top—	Ft.	In.
Sandstone, buff. Weathers gray to yellow. Extremely cross-bedded, beds being about 1 inch to 1 foot thick	44′	0″
Sandstone, thin bedded, shaly. Bluish, due to organic matter. Some beds white, weathering yellow	8′	6″
Sandstone, massive. White, weathers with a bluish tinge. Grades into sandy shale at the top	2′	0″
Shale, black, fairly pure. Occasionally thin shaley sandstone interbedded	23″	0″
Sandstone, soft, crumbly. Weathers yellow or brown. Beds about 8 inches thick	5′	6″
Sandstone, white and buff with some pebbles ⅛ to ¼-inch in diameter. Sandstone rather massive. Breaks along joints into big blocks	11′	0″
Sandstone, thin bedded, shaly, white. Weathers yellow		3″
Sandstone, white. Weathers buff in spots. Thin beds	7′	6″
Total thickness	101′	9″

It may be that the three white sandstones at the base of the section belong to the sandstone member of the formation, but as there is so little of the formation exposed here it is impossible to separate the lower member from the upper member with certainty.

East of the west side of Range 4 it is difficult to draw the line between the two members of the formation, for the lower one has taken on the marine character described above. The shales of the two members are not different in composition or thickness, and the sandstones of the lower member, so prominent in the western part of the county, have become so thin as to destroy the lithologic distinction between the two.

FOSSILS

The upper member of the Purgatoire formation carries a marine invertebrate fauna. The beds in which it is found lie only a little above the dove colored limestone of the lower member in the eastern part of the outcrop where they are most easily found. The fossiliferous beds in most instances are yellowish, shaley, sandstone lenses varying considerably in thickness. The best collecting locations were found on Wolf Mountain, where 16 feet of yellow sandstones were exposed with a 22 foot covered interval above and a 1 foot covered interval below, at the southwest corner of sec. 31, T. 5 N., R. 6 E., where the section of the fossil bearing beds was measured.

Fossil Beds.

Top—	Ft.	In.
Sandstone, yellow, limey, fine grained, very fossiliferous	15′	0″
Shale, pure brown	3′	0″
Sandstone, yellow like above. Little slabs of sandy limestone at the base. Very fossiliferous	15′	0″
Shale, pure, gray; only top of the layer showing	6′	0″
Total thickness	39′	0″

Fossils were also found at about the same interval above the dove colored limestone, on the Boise City-Springfield, Colorado road, about 3 miles north of the Bickel Crossing on Cimarron River, in sec. 25, T. 6 N., R. 4 E., in a red, sandy limestone. This is probably the place where Lee and Stanton collected the fauna listed below. Stanton says that members of this fauna can be found in the upper member of the Purgatoire up the Cimarron Valley as far as Folsum, New Mexico.

AGE AND CORRELATION

The lower member of the Purgatoire formation has to be correlated largely on stratigraphic evidence, as it carries no fossils except petrified logs. Petrified wood has not been reported from this formation in the other localities from which it has been described, and as yet there has been no determination of the wood. This member therefore, is correlated with the upper member which carries a characteristic fauna, largely because it is so different lithologically, from the Morrison beds.

As stated above, the upper member of the Purgatoire formation carries a prolific fauna. No fossils were found which were not included in a collection made by Lee[1] and Stanton[2] in sec. 25, T. 6 N., R. 4 E., near the old postoffice of Garrett. Their list is as follows:

Gryphaea corrugata Say
Ostrea subovata Shumard
Ostrea quadruplicata Shumard
Plicatula incongrua Conrad
Inoceramus comancheanus Cragin
Gervilliopsis invaginata White
Trigonia emoryi Conrad
Prolocardia multilineata Shumard
Pholadomya sanctirabae Roemer?
Turritella seriatim-granulata Roemer
Anchura kiowana Cragin
Hamites fremonti Marcou?
Pochydiscus brazoensis Shumard

According to Stanton[3], this is a typical Comanchean fauna, of Washita age, similar to the fauna in the Kiowa shales of Kansas, and the Washita beds of Texas. The *Gryphaea* were

[1]Lee, W. T. Lee, Op. cit.
[2]Stanton, T. W., Op. cit., p. 664.
[3]Idem., p. 665.

found at this horizon by Lee[1], westward to a point within 30 miles of Folsom, New Mexico, in the valley of the Cimarron River, and from there the beds are correlated with the Purgatoire of the Rocky Mountain front by stratigraphic means and a fauna, which, though different in character, belongs to the same horizon. This fauna is described in the Colorado Springs and the Apishapa Folios of Colorado[2].

RELATIONS

The Purgatoire formation rests conformably on the Morrison beds in the only place where the contact is exposed, sec. 28, T. 6 N., R. 1 E. This transition has been described (p. 35). The base of the formation can not be seen in many parts of the county, but in the eastern end of the Cimarron Valley red beds are seen to underlie it, though the exact contact is not visible. The contact of the Purgatoire and the red beds in the eastern part of the Cimarron Valley shows that there is an unconformity between the two in that region.

ORIGIN

The persistence of the limestone and shale beds and even of the white sandstone beds, the completeness of the sorting, the presence of carbonaceous shales, the white color of much of the sand, indicating little oxidation of the iron contained, and the presence of the marine fauna in the upper member, all go to show that the formation, or at least much of it, is of marine origin. The great amount of cross bedding all through the formation, the presence of conglomerate and of logs buried in the sand, prove that it was formed very near the shore. Swamps or marshes were present on the shore or low lying coast, as is evidenced by the fire clays and coals found in the western part of the county. The abundance of feldspar in the sandstones and the relative coarseness of the sands, as compared with the sands of the Morrison beds, make it evident that there was a source of material other than that which supplied sediments for the Morrison formation. Such a source must have been to the west of the area here described, and probably west of the Rocky Mountains, judging from the distribution of the formation along the mountain front. The materials must have come from crystalline rocks or arkoses which, because of some rejuvenation of the streams, were rapidly broken up and transported to the present situation where the waves worked them over into the deposits now found. The alternation of sandstones and shales, which is especially

[1]Stose, G. W., Op. cit.
[2]Finley, J. P., Op. cit.

noticeable in the eastern part of the county, was caused by oscillations of the sea level relative to the land, or by differences in the amount of material brought in at various periods as the bottom of the sea was settling. At times when little sediment was being furnished, the shoreline may have advanced farther toward the west and shale was deposited in the county, while in times when a great amount of sediments were being furinshed, the sea may have been filled faster than diastrophism took place, the shore driven eastward again or the sea filled till it was very shallow.

DAKOTA FORMATION

DEFINITION

At the beginning of the description of the Purgatoire formation (p. 37), it was stated that the term Dakota should be restricted to the sandstone beds above the shale zone carrying the Comanchean fauna. In almost every place observed, the base of this sandstone is at the top of a talus slope which can be traced throughout the county so easily that there is little chance of mistaking the position of the base of the formation.

DISTRIBUTION

The largest area of exposed Dakota sandstone is in the northwestern part of the county in the basin of Cimarron River. This area forms a rude sort of wedge, having its apex in T. 5 and 6 N., R. 5 E., and spreading from that place so that the north limb leaves the county near the north central part of T. 6 N., R. 4 E., and the south limb leaves it at the northwest corner of T. 3 N., R. 1 E. It is exposed in the Mesa de Maya where it makes a great projecting ledge at the east end, very conspicuous as viewed from the south. The ledge is caused by the stripping of the non-resistant Late Tertiary formations from above it. The Dakota sandstone is the cap rock on nearly all the buttes along Cimarron River, and forms the top of the cliffs throughout the whole basin. It runs up Cold Springs Arroyo to the middle of T. 4 N., R. 3 E., but can not be found east of sec. 11, T. 4 N., R. 5 E., and sec. 16, T. 6 N., R. 5 E., having been removed by the erosion which preceded the deposition of the Late Tertiary formations. Fragments of the sandstone were found in the Late Tertiary conglomerates in the east side of T. 5 N., R. 5 E. The last conspicuous outlier is the capping of Wolf Mountain, sec. 27, T. 5 N., R. 5 E.

Beaver River cuts into the Dakota, exposing three patches of the formation. The two most conspicuous outcrops are on Currumpa and Cieneguilla creeks and the third is a rather inconspicuous exposure in the bottom of the Beaver Valley, extending about a mile upstream from the cement crossing, a quarter of a mile south of the NE. corner of sec. 24, T. 2 N., R. 3 E. More of the formation might be exposed here were it not for the abundance of sand in the riverbeds and on the banks. The outcrop on the Currumpa was traced for about 2 miles along the stream in the east central part of T. 2 N., R. 1 E. It forms conspicuous low cliffs where a trail crosses the stream at the Wilson crossing. The outcrop on the Cieneguilla is more striking in that on the south side bold cliffs of massive sandstone rise abruptly 65 feet above the stream bed. This outcrop covers 1½ square miles in the north central part of T. 1 N., R. 1 E.

THICKNESS

The Dakota formation consists of a single sheet of sandstone of rather uniform thickness. The thinnest section measured was that on Wolf Mountain, sec. 27, T. 5 N., R. 5 E., where it was only 33 feet thick. The thickest section (115 feet) in the county was found about 8 miles to the northwest, in the massive sandstone cliffs on the Strong and Clark ranches, particularly conspicuous in secs. 4 and 9, T. 5 N., R. 4 E. Sections taken up the Cimarron Valley, west from this point to the state line, varies only a few feet in thickness, ranging from 59 to 72 feet, with an average of about 66 feet. The greater thickness (72 feet), is in the Mesa de Maya, and this is probably the most accurate figure, for at this place an almost vertical section from the Purgatoire to the Late Tertiary formations is accessible. The sandstone made the top of the cliffs in the other sections. The amount of erosion which had taken place was not determinable, though the probability is that it was comparatively slight.

On the Currumpa thickness of 44 feet was measured, but here the top was not located precisely because displaced gravels and sands of the Late Tertiary formations concealed the contact. On the Cieneguilla a thickness of 62 feet was exposed in a steep bluff, which is probably about the total thickness for that region.

The difference between the extremes in thickness of the formation, is 82 feet, but the average thickness, which holds over most of the county, lies between 60 and 70 feet. The difference may be due in part to differences in thickness as originally deposited, but more probably, to the unconformity at the top of the formation.

COMPOSITION

In general the formation is buff colored, fine to medium-grained, cross-bedded, massive sandstone. Most of the grains are quartz, originally from igneous rocks, for they contain inclusions of rutile and apatite. In some thin sections there are grains of quartz composed of many smaller particles with irregular boundaries, showing that they are either bits of vein quartz or quartz which had been granulated by metamorphic processes. A few grains of apatite in a slide made from the Dakota at 101 Hill, sec. 18, T. 5 N., R. 2 E., and in slides secured from the outcrop on the Currumpa, show 5 percent less of sericite and chlorite. The original mineral is not determinable. The cementing materials are silica and iron oxide, probably hematite. In thin sections, the iron oxide is seen to surround the grains as a cement in most of the thin sections and is present as a stain where it does not form a cement.

TEXTURE

These sections show the grains to vary somewhat in size and shape, but they are in all cases sub-angular to fairly well rounded. In size they range from fine to coarse, and on the Currumpa there is a zone of fine conglomerate in coarse sand, containing pebbles somewhat less than one-eighth inch in diameter. Measurements under the microscope show that the grains vary from 0.045 mm. to 0.33 mm. in diameter. A specimen taken from the butte on the West Carrizo, in T. 6 N., R. 1 E., shows two sizes of grains, 80 percent of the grains averaging about 0.2 mm. and 20 percent averaging 0.33 mm. At 101 Hill, sec. 18, T. 5 N., R. 2 E., the size of the grains vary from 0.7 mm. to 0.1 mm. In the finer grained beds at the base of the formation on the Currumpa, in the east central part of T. 2 N., R. 1 E., the grains range from 0.045 mm. to 0.15 mm., while in the upper part of the formation, the grains of the medium-grained sandstone average 0.225 mm. and the sand in the conglomeratic zone 0.375 mm. The average size of grain for the formation is about 0.1 mm. in diameter.

COLOR

The characteristic color of the Dakota formation is buff and this color is persistent, not only over this county, but also in adjoining parts of New Mexico and Colorado. In some places various shades of dark gray are seen; in others the rocks are almost black, and in some of the quartzitic phases there is a mottled, streaked coloration of various shades of red. The differences in color are due almost entirely to variation in the amount of iron oxide. Where iron is not abundant the rock is gray, as in the cliffs on the north side of the Cimarron River in secs. 31 and 32, T. 6 N., R. 4 E., in the cliffs in T. 6 N., R. 5 E., and along the Boise City-Springfield road north of Cimarron River. The characteristic buff color is due to a partial cementation of the sand by iron oxide. In many places the rocks are very black, due to great concentration of iron. The most noteworthy case of this is in the cliffs on the east side of Gillenas Creek, in sec. 24, T. 6 N., R. 2 E., where the cliffs appear black for almost their entire height, and from a distance resemble a basalt flow. There are many places where this concentration of iron has taken place along joints, causing black ridges a foot or two high which are traceable for several hundred feet on the surface. In other areas irregularly shaped patches have a black color.

CEMENT

The cementing substances are iron oxide and silica. Iron oxide is found in all parts of the formation, in some cases forming a very dense cement, and in others appearing as red or black specks through the gray rock. It is very abundant along joint plains and in some porous beds which offer good channels for circulating ground water. Examination of thin sections of the formation under the microscope shows that iron oxide is present as a stain even in those portions which are cemented with silica. In other thin sections no silica is visible, but the openings between the grains have been filled with iron oxide. This cementation may be so complete that the rock is very firm. Such a condition is to be seen in the cliffs on the east side of the Gillenas Valley, near the middle of the east side of sec. 24, T. 6 N., R. 2 E., where the rock is so much indurated that it breaks off in huge blocks 10 to 15 feet on the side. In some cases this cementation is merely on the surface and when that surface is penetrated to a depth of 2 or 3 inches, soft, friable sandstone is exposed.

Silica is not so common a cement as iron oxide, but is found in many places, and, toward the eastern edge of the Dakota exposure has changed the sandstone into a quartzite. This quartzite is especially conspicuous in the outcrops in the valley of Cimarron River north of Boise City, in T. 5 N., R. 5 E. At Flagg Springs, sec. 31, T. 5 N., R. 5 E., the top of the formation is hard quartzite which is broken into large, irregular blocks, 3 to 10 feet in diameter. The surfaces of the blocks tend to become rounded on weathering and have the appearance of mottled porcelain, colored with dull to bright red blotches by the iron contained in the cement. Similar quartzites are to be seen on Wolf Mountain, and just east of the road in sec. 2, T. 4 N., R. 5 E., and at a number of other localities in this vicinity. No such quartzite

was noted in the outcrops farther west in the Cimarron Basin nor in the outcrops on the Currumpa, Cieneguilla creeks, or Beaver River.

At many places over the county small areas of the formation are firmly cemented with silica, without making the massive quartzites described above. This occurs most often in small beds a few inches to a foot thick and is characterized by the gray color. One such spot is found at the top of the cliffs above the ranch house on the Clark Ranch, near the center of sec. 33, T. 6 N., R. 4 E.

The thin section cut from a sample taken from 101 Hill shows that part of the cement in the buff parts of the sandstone is silica. This slide shows well cemented sandstone, the cement being composed of tiny crystals of quartz which are not oriented to form enlargements of the sand grains, but are packed among the grains with no apparent order. This cement is colored by spots of iron oxide which give the color to the rock.

BEDDING

There are places in the formation in which no bedding is apparent. The only layers of this sort exposed are in the cliffs on the Cieneguilla and also in the cliffs on the Strong Ranch on

PLATE XI.

MASSIVE DAKOTA SANDSTONE ON CONTACT OF BLACK PURGATOIRE SHALES. CLIFFS ON CIENEGUILLA CREEK.

the Cimarron. At the first place about 60 feet of the formation is exposed in a vertical cliff showing no bedding except toward the top, while at the second place the cliffs are 115 feet high and for the most part the rock is massive. Wherever the erosion has not been so rapid as at these places, cross bedding is a striking and characteristic feature. Horizontal beds from a foot to many feet thick are made up of small "cross" beds from 1 to 3 inches thick. In other cases a series of beds 6 inches to a foot thick form the cross beds in 5 to 10 foot layers. This cross bedding is a feature common to the formation wherever it has been described.

WEATHERING

In weathering the general tendency is for the color to darken. This may be so extreme as to cause the black color mentioned above. In a few cases the color becomes lighter on weathering, and instead of the buff or black color, the rock becomes yellow

PLATE XII.

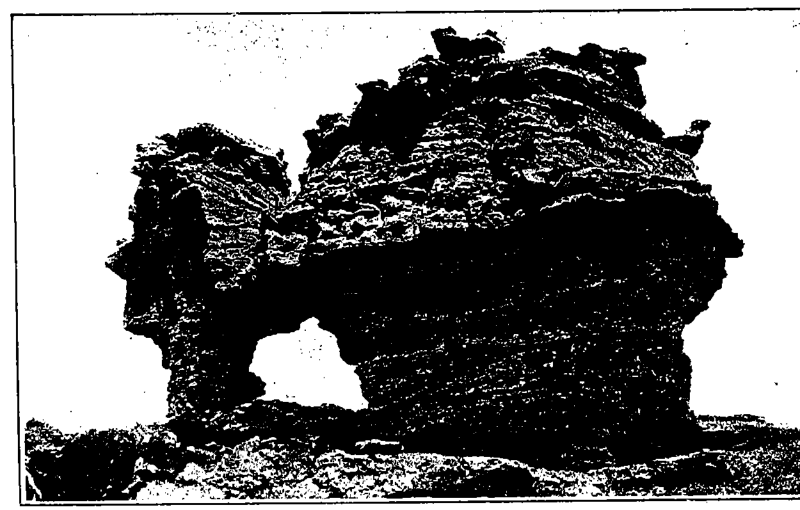
THE THREE SISTERS.
DAKOTA SANDSTONE EROSION FORMS, FIVE MILES EAST OF KENTON.

or even gray or whitish. This last sort of weathering is more noticeable in the outcrops on the Currumpa and Cieneguilla creeks than in those on the Cimarron River.

The fantastic forms made by erosion, while found also in the Purgatoire to some extent, are much more common in the Dakota.

There are many areas in which there are groups of pinnacles resembling the columns of a Greek temple. The "Three Sisters" pictured on Plate 12 are good examples. They were formed by the erosion of material along more or less vertical joints, which left the rock between as pillars. In every case there is a cap of iron oxide protecting the top from erosion, and the horizontal position of the small layers, which make up the cap, shows that the iron was precipitated along bedding plains of horizontal beds, thus allowing erosion to take place only along the less protected vertical joints. These forms have developed on the cliffs along Cimarron River where the rock was not firmly cemented. Two areas in which they are well developed and readily accessible are in the northeast corner of T. 5 N., R. 3 E., and west of the Boise City-Springfield road, in T. 6 N., R. 4 E., about 1½ miles north of the Bickel crossing on Cimarron River. Where the rock is better indurated, other unusual forms sometimes develop. Such is the "Tea Kettle," just north of the state line in the Gillenas

PLATE XIII.



OLD WOMAN'S HEAD.
EROSION FORMS IN DAKOTA SANDSTONE, SIX MILES EAST OF KENTON.

Canyon, about one-half mile from Regnier Postoffice. Another such form is the "Old Woman's Head," Plate 13, about 1½ miles east of the "Three Sisters" in the NW. ¼ sec. 15. T. 5 N., R. 2 E., and can easily be seen just north of the Kenton-Boise City road where it descends from the west into the valley of South Carrizo Creek.

RELATIONS

The Dakota sandstone lies with apparent conformity on the underlying Purgatoire formation. In some places there is an abrupt change from the top shale of the Purgatoire to the sandstone of the Dakota, but in others there is suggestion of a transition in the form of sandy shales at the top of the Purgatoire, and of thin bedding and lenses of carbonaceous shale in the bottom of the Dakota. Such a gradation is best illustrated by the section on Currumpa Creek (p. 46). It will be noted that the top of the Purgatoire here is thin bedded, shaly sandstone, with a bluish color due to organic matter, characteristic of the upper shales of that formation. Shale lenses and blue, sandy shales were also noted in the base of the Dakota at 101 Hill, sec. 18, T. 5 N., R. 2 E.

POST-CRETACEOUS EROSION INTERVAL

At Raton Mesa, New Mexico, 75 miles west of Cimarron County, 4,300 feet of Cretaceous sediments are found above the Dakota sandstone. It is probable that a somewhat similar thickness was deposited over the Dakota in Cimarron County, since the Cretaceous sea is known to have covered this area. The absence of these sediments is probably due to the erosion which followed their deposition. How much erosion took place can not be stated, as there are no means of knowing definitely what formations were deposited above the Dakota before erosion began. It was sufficient, however, to remove all of the younger Cretaceous strata and the Dakota in the eastern part of the county and to develop an undulating topography with a relief of 100 or 200 feet, as is shown by the contact of the Late Tertiary formations, with the older formations in the Cimarron and Beaver basins.

AGE AND CORRELATION

A number of leaves and stems of plants were collected from the NE. ¼ of sec. 14, T. 4 N., R. 1 E., the E. ½ of sec. 2, T. 3 N., R. 1 E., and a number of plant stems from near the SE. corner of the NE. ¼ of sec. 24, T. 6 N., R. 2 E. These, along with several specimens collected at widely scattered localities in the Dakota, were identified by Dr. A. C. Noe' of the University of Chicago as typical Dakota fossils. A list of those plants with their description is to be found on page 92.

The formation corresponds lithologically and paleontologically to the Dakota sandstone described from the Raton Mesa region. New Mexico[1], from the Colorado Springs[2] and Castle Rock[3] areas in Colorado, from the Black Hills of South Dakota, and from various exposures in Kansas and Nebraska[4]. In all these localities it is described as a much cross-bedded, buff sandstone, about 100 feet thick, and is separated from the underlying formations in the same manner as in this region.

ORIGIN

The facts which will shed light on the origin of this formation are: (1) extreme cross-bedding in almost all outcrops; (2) the angularity of the grains which by some would be considered to suggest little transportation; (3) wind ripples, which were found in the top of the outcrop on the Cieneguilla; (4) the scarcity of conglomerates, the only ones found being a zone of very small pebbles on the Currumpa; (5) the lack of feldspars in the thin sections studied, and (6) the flora which consist entirely of fresh water and terrestrial plants.

These are all features of non-marine deposits and the flora suggests strongly that fresh water played a conspicuous part in the deposition of the Dakota sandstone. The total absence of marine fossils indicates that the Cretaceous sea was not an agent in its formation. Lee[5] thinks that the Dakota was formed from the material of a deeply weathered, pre-Dakota peneplain. The absence of conglomerates and of feldspar and the presence of altered material would substantiate such a view.

LATE TERTIARY FORMATION

DISTRIBUTION

A formation of the Tertiary age is exposed over an area greater than that of any other formation in the county. It is at the surface in the entire area of the plains and also in the extreme eastern end of the Cimarron Valley. It is exposed in the western part of the Cimarron Valley under the lava cap of the Mesa de Maya, and gravels from there are found on the tops of some of the hills in this region. The formation is at the surface

[1]Lee, W. T., Op. cit., p. 40.
[2]Finlay, J. R., Op. cit.
[3]Richardson, C. H., Op. cit.
[4]Gould, Chas. N., The Dakota Cretaceous of Kansas and Nebraska, Kans. Acad. Sci., vol. 17, 1909. p. 122, bibliography.
Twinhofel, W. H., State Geol. Survey of Kansas, Bull. 9, 1924, bibliography.
[5]Lee, W. T., Relation of the Cretaceous Formations to the Rocky Mountains in Colorado and New Mexico; U. S. Geological Survey, Prof. Paper 95-C, pp. 33-37, 1915.

in more than 31 of the 54 townships of the county, or 60 per cent of the entire area.

THICKNESS

It was not possible to get an accurate measurement of the thickness of the formation, for it does not stand in steep banks or cliffs, and no logs were kept of the water wells drilled through it. The drillers say that it is 180 feet to "the rock" (probably meaning the Dakota sandstone) in a well drilled 2 miles east of Wheeless Postoffice. A well drilled in Boise City to a depth of 168 feet encountered no "rock." At Wilson's crossing on the Currumpa, the thickness was estimated at 75 feet. A section measured with a barometer at the head of South Carrizo Creek showed 80 feet. The best section was measured with the hand level at Nigger Springs, on the Mesa de Maya. The thickness here was 110 feet. It is evident, from the above figures, and from field observations that the thickness of the formation is not uniform but varies from 75 to 200 feet. Over most of the county, however, it is 150 to 200 feet.

CHARACTER

This formation consists of a heterogenius mixture of clays, sands, and gravels, the last two being cemented in many cases by a lime cement which is a very conspicuous part of the formation. There are no good sections exposed, because it is made almost entirely of poorly consolidated materials, so that it must be studied from small sections exposed on the banks of the larger streams, and from material on the surface of the plains.

CLAYS

So far as known, clays outcrop in two localities only, one being in sec. 30, T. 6 N., R. 8 E., and the other on the south bank of the Beaver River, secs. 10 and 11, T. 5 N., R. 2 E. In the first locality there are 7 feet of chocolate colored clays which contain very little grit and are very cohesive. In the second place there is an outcrop one-half to three-fourths of a mile long, showing two beds of clay separated by a brown sand parting about a foot thick. The upper clay bed is 12 feet thick, but it is impossible to determine the thickness of the lower bed since only the top of it is above the channel of the stream. The material is a massive, dark brown clay which contains flecks of black material caused by organic matter deposited with the clay. These clays also contain little grit.

PLATE XIV.

LATE TERTIARY CLAYS ON SOUTH SIDE OF BEAVER RIVER, SECS. 10 and 11, T. 5 N., R. 2 E.

CONGLOMERATES

Conglomerates are found throughout the formation outcropping as gravel beds on the tops of hills or the bluffs of small streams. In some instances they make slight ledges which can be traced for half a mile along the slopes of the valleys. There is no predominance of these conglomerates in any part of the county, the distribution in one part being about like that of any other where erosion has cut the formation similarly. Neither does there seem to be an uneven vertical distribution. In some places conglomerates are found at the base of the formation, while in others they occur well toward the top. At the Creigh Ranch in sec. 18, T. 6 N., R. 8 E., four good sized beds were noted within a vertical distance of about 100 feet, in the east bluff of the Cimarron Valley. In many of the small stream cuts where 20 or 30 feet are exposed, two to four thin beds can be seen.

The thickest bed measured was in sec. 30, T. 6 N., R. 8 E., where 8 feet of conglomerates formed the top of the section along a tributary of the Cimarron. This section is shown on page 66. From this thickness the beds thin to a few inches.

Some of the conglomerate beds are composed almost entirely of pebbles, but in many cases there is a matrix of fine, brown sand. The sand increases in proportion till there is merely a zone of sand in which pebbles are scattered promiscuously, as in the

PLATE XV.

LATE TERTIARY FORMATION, SEC. 30, T. 6 N., R. 8 E.

outcrop on Beaver River directly south of Boise City, in secs. 10 and 11, T. 5 N., R. 2 E. The conglomerate beds are lenses of pebbles running through the formation, often not more than 5 or 10 feet long, and in no case traceable for more than half a mile.

The constituents of the conglomerates range from boulders, mostly small, through cobbles to pebbles. The largest measured was a boulder of basalt 2½ feet in diameter. Boulders measuring a foot in diameter are often encountered, but the average for the large cobbles of quartzite and similar rocks, which appear to have come from a distance, is 5 or 6 inches. From this size they grade down to pebbles one-fourth of an inch or less in diameter. The diameter of most of the pebbles is 1 or 2 inches. There is no great amount of sorting, coarse and fine material being mixed with sand in almost all cases. In beds which are composed of 1 or 2-inch pebbles, the size is more uniform than in those which contain larger ones.

The character of the pebbles is best shown by the following pebble counts, made by counting 100 pebbles taken at random from each locality. The determinations were all made in the field, and therefore liable to slight error, but the table gives an idea of the kinds of rocks represented, and their proportions.

Table Showing Character of Tertiary Pebbles in Cimarron County, Oklahoma.

Rocks	Nigger Springs	Sec. 22 T. 4-2	Sec. 32 T. 5-6	Sec. 22 T. 5-9	Sec. 35 T. 1-8	Average
Quartzite	36	39	42	46	32	36.6
Vein quartz	7	25	8	13	30	16.6
Quartz schist	5		5	1	2	2.6
Schist			7			1.4
Unclassed metamorphic	4					0.8
Quartz mica schist	4	11	4	7	10	7.2
Slate	3		1	1		1.0
Hornblende schist					1	0.2
Granite	3	4	6	6	4	4.6
Syenite	9	1	5	5		4.0
Felsite	9			2		2.2
Basalt	5		1	1	5	2.4
Felsite porphyry		5				1.0
Basalt porphyry	1	7	3	1		2.4
Basalt vesicular			1	5		1.2
Sandstone		6	6	7	7	5.2
Sandstone like Dakota	14		15			5.8
Arkose			1			0.2
Feldspar plagioclase		1				0.2
Feldspar orthoclase			1			0.2
Chert (wood?)		1				0.2
Chert					7	1.4
Flint			1			0.2
Hematite					5	0.1

It will be seen that many sorts of rocks are contained in these beds, some from nearby formations, and some from a distance. An average of 67.4 percent of the rocks is metamorphic, 18.2 percent igneous, and 14.2 percent sedimentary. The igneous and metamorphic rocks, with the exception of the basalts, must have come from the crystalline rocks which form the core of the Rocky Mountains in southeast Colorado and New Mexico, as there are no such rocks exposed between these mountains and Cimarron County. This means that they were carried at least 180 miles from the nearest mountains, the Sangre de Criston Range in New Mexico, to the western edge of Cimarron County, and 234 miles from those mountains to the eastern edge of the county. The basalts are evidently from the early Tertiary flows in New Mexico and southern Colorado. That they are not of the same age as the flow which forms the cap of the Mesa de Maya is shown by the fact that they are found in the gravels lying under the cap of the mesa. A large proportion of these basalts is of a larger size than other igneous and metamorphic rocks in the gravels. The 14.2 percent of the pebbles of sedimentary rock consists, for the most part, of sandstones, many of which came from the Dakota sandstone, while the rest probably came from that formation or from one below it. The chert did not come from any nearby formation, but probably from older limestones toward the mountains, or from gravels of the Purgatoire far to the west. In all cases the chert and flint pebbles are small, never over half an inch or so in diameter, but the sandstones vary greatly in size, some measured in sec. 30, T. 5 N., R. 6 E., being from 1¼ to 2 feet in diameter. These large masses are angular and evidently have been carried only a short distance, as they are not firmly cemented rock. The smaller pieces of sandstone in some cases are well rounded, and in others rather angular. In one conglomerate ledge, in sec. 30, T. 5 N., R. 6 E., many pieces of limestone and an oyster shell were found which came from a bed in the Purgatoire not more than a mile away. By combining percentages, it can be seen that about 85 percent of the pebbles came from a distance of 70 to 234 miles, while 15 percent came from nearby.

Another thing to be noted from the above table is the uniformity of material in these gravel beds in different parts of the county. In the order in which they are given, the counts form a series taken at intervals of about 15 miles from west to east across the county. It will be noted that everywhere quartzite and vein quartz are the most abundant, making about 50 percent of the pebbles. Metamorphic rocks other than quartzite are everywhere present, and form about 10 percent of the pebbles. Igneous rocks appear in every count, and make about 16 percent, while sedimentary rocks vary from 7 percent to 21 percent.

SANDS

The great bulk of the formation is composed of sand. Where exposed, this sand is almost uniformly brown in color. The only exception was found in sec. 30, T. 6 N., R. 8 E., where 10 feet of gray sand is exposed. The size of the grains varies considerably in different outcrops. Most of it is medium-grained, but in some instances it is so coarse as to grade into fine conglomerate. Such sand is exposed in sec. 14, T. 2 N., R. 9 E. An outcrop of sand in sec. 21, T. 5 N., R. 9 E., shows it to be so fine that when wet it can be pressed together into a ball much like a clay, while in sec. 22 of the same township, both very fine and very coarse sands are mixed.

The predominant mineral of the sands is quartz. Feldspars are abundant, however, and are usually acid plagioclase or orthoclase. Streaks of magnetite sand can be seen in the outcrop in sec. 30, T. 6 N., R. 8 E. This is the only place where this sort of sand was seen in the county, but it is a rather common ingredient of the formation in Kansas[1].

The brown color and average size of grain are remarkably uniform over the county. The sand looks the same in the extreme northwestern part under the lava flow on the Mesa de Maya as in the northeast, where it is exposed typically in the dune area in T. 6 N., R. 8 E. It has the same appearance in the southwest, where it is exposed in the dunes at the junction of Cieneguilla and Currumpa creeks, as in the extreme southeast, in sec. 16, T. 2 N., R. 9 E. Typical exposures are to be seen in the cuts made in building the Boise City-Clayton road through the dune area, about 12 miles west of Boise City. It can also be seen in almost any of the little cliffs in the bluffs of the Beaver, Agua Frio, and Cimarron valleys, and the small streams in the eastern part of the county.

CEMENT

So far as can be determined, the greater part of the formation is uncemented or but slightly cemented. At the surface, the sands, and in some instances the conglomerates are firmly cemented with calcareous material. The firmly cemented material makes the white cliffs which line the bluffs of the Cimarron and Beaver rivers and is typical of the formation. It also forms small cliffs in the valleys of the smaller streams that cut the formation.

A chemical analysis of the firmly cemented sandstone, taken from near the center of the north line of sec. 31, T. 6 N., R. 8 E., gave the following:

Anaylsis of Tertiary Sandstone

	Percent
Silica, insoluble in acid	10.04
Al_2O_3, Fe_2O_3	0.30
MgO	0.42
CaO	47.37
H_2O	0.27
H_2O + organic matter	1.03
CO_2	38.32
	99.75

[1]Haworth , E., Physical Properties of the Tertiary; The University Geol. Survey of Kansas, vol. II, p. 255, 1897.

This is an analysis of the most firmly cemented portion of rock obtainable, and so gives the rock as well as the cement. However, as the original rock is largely of quartz, the above analysis gives a good idea of the composition of the cement if the silica is subtracted. A recalculation of the minerals of the rock from this analysis gives 85 percent calcite, 2 percent dolomite, 10 percent quartz, and 3 percent iron oxides and clay minerals. A study of thin sections under the microscope discloses a rock made largely of calcite with small grains of quartz scattered through it.

In most of the outcrops there is a graduation from brown sand at the bottom of the cliff to a hard, dense cap of rock of the sort from which the above analysis was made. The following sections illustrate the change.

Section of Late Tertiary Formation,
sec. 17, T. 1 N., R. 3 E.

Top—	Ft. In.
Limestone cap	1′ 6″
Limestone, concretionary, contains inclusions of brown sand with stringers of lime	12′ 0″
Sand, brown, very full of lime stringers which run both horizontally and vertically. Grades into zone above	5′ 0″
Lime, concretionary with sand grains	2′ 0″
Sand, brown	1′ 0″
Sand, brown with lime stringers at bottom, stringers increase in number; top is nearly all lime	3′ 0″
Lime layer	1′ 0″
	25′ 6″

Section of Late Tertiary Formation,
sec. 10, T. 2 N., R. 5 E.

Top—	Ft. In.
Limestone cap	1′ 0″
Limestone, rubbly. Lime becomes less toward the bottom and	
Top—	Ft. In.
grades into section beds below it	15′ 0″
Rubble, limestone, and sand. Sand increases toward bottom; filled with lime stringers	11′ 0″
Sand, brown with 4-inch lime layers	4′ 0″
Conglomerates. Pebbles in pockets in brown sand	4′ 0″
Shale, brown, very few lime stringers. A 2-inch lime layer at base	12′ 0″
Sand, brown with a 1-inch lime layer at base	1′ 0″
Total	48′ 0″

In the lower part the sections contain brown sand with stringers of calcium carbonate running through it, sometimes vertically, sometimes diagonally, and where there is a definite

bedding plane there is apt to be a streak of the calcium carbonate along it. Farther up in the section the number of these stringers increases and finally, as the top is approached, the cement encloses patches of sand. (Plate 16.) It is this phase which the Kansas geologists call the "mortar beds." These patches become

PLATE XVI.

MORTAR BED STRUCTURE IN THE LATE TERTIARY FORMATION.

smaller and smaller higher up in the outcrop and finally grade into a zone which is composed of nodules, probably concretionary, about the size of the fist which form a rubbly surface when weathered. The patches of sand have disappeared here with the exception of a few isolated spots. The rubbly phase becomes more and more dense till, at the top of the cliff,there is a one or two-foot layer of very dense limestone. Grains of sand can be seen in all phases except in the dense cap at the top and even here they are visible to the naked eye in some cases and can easily be seen in thin sections.

This lessening of the amount of sand in the denser portions of the limestone is caused by forcing of the crystals of calcite between the sand grains, thus making room for themselves by shoving the grains apart. That this process takes place is shown by the fact that the amount of sand decreases in direct proportion to the increase in density of the limestone. In the lower parts of the outcrops the rock is entirely sand, while in the hard cap the sand is only 10 percent. Microscopic examination of thin sections of the densest rock shows that the calcite has actually split grains of quartz.

From the foregoing it is evident that this cement is a concentration product of ascending ground waters. The calcium carbonate is contained in the waters which are continually rising, due to capillary action. On nearing the surface it is precipitated by the evaporation of the water. This process is illustrated at Nigger Springs on the Mesa de Maya, where a trail is cut through the talus deep enough to expose the sands of the Late Tertiary formation. At present there is a cemented layer two inches thick on the face of this cut, which has formed since the cut was made.

The cementing material is very soluble, as is shown by the many instances in which rootlets and twigs are found with a coating of it near the bottom of small banks of sand or cliffs of limestone. Where it has been crushed and used as road material, it dissolves and is reprecipitated after the first few rains, forming a hard surface much like concrete.

This ready solubility causes downward movement of the cement during rains. Wherever impervious layers are found in an outcrop, the cement tends to concentrate at their tops. The following section taken in the NW. 1/4 of sec. 30, T. 6 N., R. 8 E., will illustrate:

Section of Late Tertiary Formation, sec. 30, T. 6 N., R. 8 E.

Top—	Ft. In.
Gravel bed, heavy lime layer at base	8′ 0″
Sands, coarse and fine, lime layer at base, 3 or 4 small lime lenses higher up	10′ 0″
Clays, chocolate. Very thin lime layer at base	4′ 0″
Clays, chocolate; no lime layer at base, sand	3′ 0″
	25′ 0″

At the top of shale beds there is a layer of calcium carbonate a fraction of an inch thick, at the bottom of the conglomerate bed there is another layer, one to several inches thick. At the concrete crossing on Beaver River, near the NW. corner of sec. 19, T. 2, N. R. 4 E., cement can be seen to have worked its way down into the joints in the underlying Dakota sandstone. In but two instances was conglomerate found cemented, but in almost every gravel bed found at the surface, coatings of calcium carbonate on many of the pebbles indicated that it had been carried through this coarse material to lower parts of the formation.

This downward movement is evidently the cause of the very dense caps of limestone, for they are always at a place where erosion is rather active, as at the top of the stream bluffs. The bluffs of the Beaver and Cimarron valleys are thus topped along much of their courses, and the same phenomenon can be seen where small streams have cut into the surface of the plains. Away from these places the same concentration occurs, but the dense cap is not formed, the concretionary rubble being on top where excavations have exposed it.

Johnson[1] states that these lime beds represent various levels of the water table, having been deposited at such places as hard pans. A glance at the various elevations and different dips of the cap rocks in the cliffs of the lower end of the Beaver Valley, and the universal presence of the cement near the surface of the plains show that the present position of these beds is not caused by precipitation at the surface of a water table.

CONCLUSIONS ON LIME BEDS

A study of this cement in Cimarron County leads to the following conclusions:

1. It is a concentration product, precipitated near the surface by the evaporation of capillary ground water.
2. Room was made for the added material by the force of the recrystalizing calcite which shoved the sand grains apart.
3. During rains there is a downward transportation of cement. This is probably the cause of the dense concentrations in the cap rocks found in the cliffs along streams.
4. The cement was not deposited as hard-pan above water tables.

RELATIONS

The Late Tertiary formation lies unconformably on the Dakota and Purgatoire formations and probably, in the extreme eastern part of the county, on the red beds. It lies on the Dakota as far east as the east end of T. 5 N., R. 6 E., in the Cimarron Basin. Here the Dakota is abruptly cut off and to the east the Late Tertiary formation rests on the Purgatoire. It is not seen to rest on the red beds, but it is reported that the red beds appear in the channel of Cimarron River just across the line in Colorado, at which place the red beds must be directly overlain by the Late Tertiary beds because the base of the latter is near the bottom of the stream channel where it leaves Cimarron County.

[1]Johnson, W. D., The High Plains and Their Utilization; U. S. Geol. Survey; Twenty-first Annual Report, pt. 4 pp. 639-657, 1899-1900.

The patches of Dakota outcropping on the Beaver River at the concrete crossing, and on Currumpa and Cieneguilla creeks, are the tops of some of the hills formed by the post-Cretaceous erosion. These hills rise about 60 feet into the Late Tertiary which surrounds them.

The Late Tertiary formation is at the surface wherever it occurs except in the Mesa de Maya, where it is overlain by a basaltic flow.

AGE AND CORRELATION

This formation was followed 6 or 7 miles north of the State line and was found to connect with what Darton[1] mapped as the Nussbaum-Ogalalla formations, and which were designated as Nussbaum-Ogalalla-Arikaree on the geological map of Colorado published in 1813 by the geological survey of that state. The beds in Cimarron County have the same lithologic characters as the Nussbaum and Ogalalla of Colorado and the "Mortar Beds" of Kansas and on this basis could be correlated with those beds. If such is the true correlation the formation should be given the name Nussbaum which was proposed by Gilbert[2] for the part of the beds near Pueblo, Colorado, in 1897, as that name has priority. The correlation, however, is not sufficiently certain to warrant using this name for the beds in Cimarron County and therefore they have been designated simply as Late Tertiary formation.

That this formation is Tertiary is shown by its unconformable relation with the Comanchean and Cretaceous formations, and by the character of the materials. The uneven surface on which they rest is the result of the erosion which followed the withdrawal of the Cretaceous sea, and the movements which gave rise to the Rocky Mountains. The same erosion surface can be traced into New Mexico, and is visible in the unconformity between the Cretaceous formations and the Raton formation, known to be early Tertiary, in the region of Raton Mesa[3]. The crystalline materials, such as quartzite, schists, gneisses, and bits of feldspar, were derived from the cores of the Rocky Mountains, for there is no possible source of such material east of the mountains. This means that these materials were deposited after the close of the Mesozoic, for the site of the present Rocky Mountains was the seat of deposition during that era[4].

[1]Darton, N. H., Geology and Underground Waters of the Arkansas Valley in Eastern Colorado; U. S. Geol. Survey, Prof. Paper 52, Plate VI, 1906.

[2]Gilbert, T. K., U. S. Geol. Survey, Pueblo folio (No. 36), p. 4, 1897.

[3]Lee, W. T., Geology of the Raton Mesa and Other Regions in Colorado and New Mexico; U. S. Geol. Survey, Prof. Paper 101, pp. 55-56, 1917.

[4]Lee, W. T., Relation of the Cretaceous Formations to the Rocky Mountains in Colorado and New Mexico; U. S. Geol. Survey, Prof. Paper 95, p. 32, 1915.

That they are not early Tertiary is evidenced by the abundance and variety of the basalts in the gravels, which are little weathered in most cases, and many of which are vesicular. These basalts are from flows of Tertiary age in New Mexico and Colorado, probably late Eocene or Miocene, as that was the time of most extensive vulcanism in this part of the continent. Hills[1] places the flows in the region about Trinidad, Colorado in the late Eocene and Neocene. These basalts are older than those which form the cap of the Mesa de Maya for many of them are of a different composition, and pebbles of basalt were found in the gravels on the mesa below the basalt cap.

As no fossils have been found in these formations which would aid in placing it, its age must be judged entirely from its stratigraphic position and the evidence of the basalts. These two lines of evidence seem to place it in the Miocene or Pliocene, the latter being the more probable because of the abundance and variety of the basalts[2].

ORIGIN

The old notion of the origin of the vast sheet of Tertiary rock which lies on the Great Plains, and of which this formation is a part, was that it was deposited in a great lake which covered this part of the continent. The lake was postulated largely to account for the lime cement which is prominent wherever the rocks occur[3]. However, further study made it clear that the heterogeneous mixtures of gravels, sands, clays and limy sediments could not easily have been formed in a lake, and in 1896 Gilbert[4] suggested a stream origin for the formation in western Kansas. Haworth[5] in 1897, describing the Kansas Tertiary, ascribes a similar origin to them, and a little later Johnson[6], after a careful study of the Great Plains, described in detail the manner in which such a deposit would be found.

According to his description, a sheet of debris was spread in front of the Rocky Mountains during the Tertiary epoch, just

[1]Hills, R. C., U. S. Geol. Survey, Elmoro folio (No. 58), p. 2, 1899.

[2]Since the manuscript for this bulletin has been written, invertebrate fossils have been collected by Dr. John T. Lonsdale from Beaver County, Oklahoma, about 100 miles east of Cimarron County, in what appears to be the same formation. Miss Julia Gardner of the U. S. Geological Survey has identified the fossils as indicative of the age of the beds.

[3]King, C., Geological Explorations of the Fortieth Parallel; vol. 1, p. 451, 1878.

[4]Gilbert, G. K., The Underground Water of the Arkansas Valley in Eastern Colorado; U. S. Geol. Survey, 17th Ann. Rept., pt. 2, p. 575, 1895-1896.

[5]Haworth, E., Op. cit., pp. 251-284.

[6]Johnson, W. D., Op. cit., p. 643 et seq.

as similar debris is now being spread about the mountain ranges in the Great Basin. The streams flowing from the mountains deposited their loads on the slopes below the mountains, forming alluvial fans which finally met, making an aggraded slope composed of stream debris. The streams deployed more and more as they flowed away from the mountains and constantly aggraded their channels till they were forced out of them into new ones. This action went on till the surface of the Great Plains was covered with a great sheet of stream deposits long distances from the mountains.

The mountains to the west caused an arid or semi-arid climate in this region, so that the waters of the streams were evaporated, causing the precipitation of the salts carried in solution, a large part of which were loaded with lime. This lime was disseminated through the deposits when precipitated, but has been dissolved by ground water and reprecipitated near the surface when the water evaporated, as has been explained. (P. 66.)

TERTIARY IGNEOUS ROCKS

BASALT

The only igneous rock in the county is a basalt flow in the extreme northwestern part, capping the Mesa de Maya (Black Mesa), two miles north of Kenton. The remnant of the flow preserved on the mesa is a long, narrow tongue of lava half a mile, more or less, in width, and four miles long. It enters the county in the northwest quarter of sec. 6, T. 5 N., R. 1. E., runs east for half a mile and then turns into a northeasterly direction to the north line of sec. 33, T. 6 N., R. 1 E., ending about the middle of that line.

Its thickness was measured in the south side and again at Nigger Springs, which is on the north side of the Mesa on the State line. At the first place it was 50 feet thick and at the latter place 66 feet. Gould[1] gives a thickness of 100 feet for this part of the flow. The difference in these figures is due in part to the thickness of the flow in different places and in part to the fact that the contact of the flow with the underlying sediments is difficult to locate exactly, being covered by a thick talus.

The lower part of the flow is massive, very finely crystalline rock, with major joints which break it into 10 foot blocks, these

[1]Gould, C. N., Geology and Water Resources of Oklahoma; U. S. Geol. Survey, Water-Supply Paper, 148, p. 82. 1905.

blocks in some instances are broken by minor joints into 2 foot blocks. The joints have no persistent direction, and in most cases the faces of the blocks are conchoidal. In some portions of this part of the flow there are patches which have been jointed horizontally, the joints being ¼ inch to 3 inches apart, which makes the rock appear layered for areas of 10 to 30 square feet. The upper part of the flow is very black basalt, dense for the most part, but with much vesicular structure, especially near the top. Vesicles appear, at rare intervals, 25 feet from the bottom of the flow and increase in number until they make up a large part of the volume of the rock toward the top.

The rock is olivine basalt with ophitic texture. It is composed of about 45 percent labradorite, 45 percent augite, 7 percent magnetite and 1 percent olivine, a large part of which has been altered to iddingsite. The lower part of the flow is entirely crystaline. The labradorite laths average 0.2 mm. in length the augite crystals 0.1 to 0.2 mm. in diameter, the olivine 0.425 mm., and the magnetite 0.099 mm. The upper part of the flow is finer grained and contains considerable glass between the crystals, which can only be seen with the aid of the microscope. Calcite is found in thin sections from the upper part of the flow, partly filling the small vesicles. It is evidently the result of weathering of exposed portions of the flow. A chemical analysis of this rock made in the laboratories of the Oklahoma Geological Survey give the following result[1].

Analysis[1] *of Lava from Upper Part of Black Mesa, Cimarron County, Oklahoma.*

	Percent
SiO_2	50.96
Al_2O_3	17.54
Fe_2O_3	3.01
FeO	7.46
MgO	5.17
CaO	9.18
Na_2O	2.78
K_2O	0.54
H_2O-	0.48
H_2O+	0.38
TiO_2	1.31
ZrO_2	n.d.
CO_2	faint trace
P_2O_5	0.54
SO_3	00.00

[1]Analysis by A. C. Shead, chemist for the Oklahoma Geol. Survey.

	Percent
Cl	n.d.
F	n.d.
S	0.08
Cr_2O_3	0.04
V_2O_3	n.d.
NiO	00.00
MnO	0.15
BaO	00.00
SrO	00.00
Li_2O	00.00
	99.62

AGE

The sands and gravels of the Late Tertiary formation underlie the lava throughout its extent in Cimarron County. It is evident, therefore, that the eruption of this basalt took place after that formation had been deposited. It has been shown that the Late Tertiary formation is of either Miocene or Pliocene age, and therefore the flow must have occurred either very late in the Tertiary, probably in the Pliocene, or in the very early Quaternary. The flow must have occurred before late Pleistocene, for the valleys of the West Carrizo and its tributaries have cut through the basalt, forming several mesas in southern Colorado. The major part of the cutting of these valleys was done in Pleistocene time, as is evidenced by the presence of elephant bones in the flood plains (pp. 27 and 77). Therefore, the flow must have occurred after the beginning of the Pliocene and before the end of the Pleistocene. Since active erosion of the Great Plains began with the Pleistocene[1], and since all evidence points to the formation of this flow before erosion began, it would seem more probable that the lava was poured over this region in Pliocene time rather than later.

SOURCE OF LAVA

As shown in the section on the physiography of the mesa, its top is an essentially flat surface having an elevation of about 6,000 feet at its western end, which is some 50 miles to the northwest of Cimarron County, in Colorado. From this place it drops to an elevation of 4,900 feet at its eastern end in Cimarron County. Ten miles west of the east end of the mesa there are three spines of igneous rock which are known as the Bar Seven L Buttes or Piney Mountain. The surface slopes away from these spines in all directions, and at a distance it is plainly seen that

[1]Johnson, W. D., Op. cit., p. 631.

these are the highest parts of a great hill some 5 miles across at the base and roughly circular in outline. The rocks found on these slopes and in the spines are massive and vesicular, red and black basalts. The physiographic evidence and the character of the rocks suggest very strongly that these are the cores or vents in an old volcano or cinder cone which have been largely worn away. They are probably the vents from which the lava forming the cap of the Mesa de Maya was extruded.

RECENT DEPOSITS

Recent deposits have been formed by the two major streams and their larger tributaries, and by the work of the wind. The Cimarron and its larger tributaries have flood plains half a mile to a mile wide. Most of the alluvium is sandy, but some of it is loam and clay. The sandy material increases in proportion to the clay in the eastern part of the valley. Along Beaver River, for almost its entire length, the alluvium is composed largely of sand which is blown about by the wind whenever the water is low. This forms dunes, which makes it difficult to separate the stream deposits from wind-blown sand.

Areas of dune sand occur in several places. Most of the dunes are covered with vegetation and therefore are fixed, but others are almost bare of vegetation and the sand is in active movement. The dunes are all post-Tertiary, having been blown up from the sandy phases of the Late Tertiary formation. While there is a possibility that some of them were formed in Pleistocene time, it is certain that many of them are still forming and the probabilities are that they are all Recent and are so classed.

The largest area of dune sand is along Beaver River, for nearly its entire length in Cimarron County. This is an elongate area, 45 miles in length and varying from 1 to 7 miles in width. Though Beaver River flows through this area, only an extremely small part of the sand was furnished by the stream. A second large dune area is on the plains in a belt about 3 miles wide, running diagonally from the extreme southwest corner of T. 3 N., R. 3 E., to sec. 17, T. 4 N., R. 4 E., ending on the east side of Cold Springs Arroyo. A third large dune area lies in the northeastern part of the county near the place where Cimarron River leaves the county. It is continuous from secs. 14 and 23, T. 6 N., R. 7 E., eastward to sec. 13, T. 6 N., R. 8 E., except for the gap, about a mile wide, caused by Cimarron Valley. The eolian sands are white in some places, but in most they are brownish in color like the prevailing color of the sands in the underlying Late Tertiary formation from which they were derived.

A generalization might be made by saying that where recent deposits lie on Cretaceous and older formations, they contain clays, sands, and gravel beds in about the proportion found in most stream deposits, and where they lie on the Late Tertiary formation they are composed, for the most part, of sand worked over by the wind or by wind and surface water.

GEOLOGIC HISTORY

The geologic history of the region in which Cimarron County is situated is rather closely tied up with that of the Rocky Mountains. When sediments were being deposited on the site of these mountains, the region here described also received sediments, and when mountains were formed, the debris from their erosion was spread over this country. The folding of the mountains to the west is reflected here in slight undulations of strata. The mountains have always influenced the climate much as they do today.

THE TRIASSIC (PERMIAN?) PERIOD

According to Lee[1], mountains were folded on the present site of the Rocky Mountains at the close of Pennsylvanian time. On the east side of these mountains, which were probably as high as the present Rockies, there was an arid area to which debris from the mountains was washed and deposited, forming the red beds as they are found today. The deposition of red beds lasted through the Permian and perhaps the Triassic Period.

After the deposition of the red beds there was a slight folding in the region to the west, at the end of the Triassic or beginning of the Jurassic. This wrinkled the red beds into gentle folds a mile or less across, and from a few feet to 100 or 200 feet in height, with dips of $3\frac{1}{2}°$ to $6°$ on the flanks. These folds have not been noted in the county, but are plainly visible a few miles up the Cimarron Valley in New Mexico, and it is probable that the disturbances were felt here.

After this slight folding, came a period of erosion which beveled off the tops of the folds just formed, and caused the early Jurassic (Exeter) sandstone to be deposited over them unconformably[2]. This formation appears to be absent in Cimarron County, where erosion probably continued till the deposition of the Morrison beds in the western part of the county, and the Purgatoire in the eastern part.

[1]Lee, W. T., Early Mesozoic Physiography of the Southern Rocky Mountains; Smithsonian Miscellaneous Collections, vol. 69, No. 4, p. 5, 1918.

[2]Lee, W. T., Geology of the Raton Mesa and Other Regions in Colorado and New Mexico; U. S. Geol. Survey, Prof. Paper 101, p. 62, 1917.

COMANCHEAN PERIOD

By late Jurassic or early Comanchean time, the ancient Rocky Mountains had been beveled down to a peneplain, which extended from somewhere in southern Utah as far as the middle of Cimarron County and probably farther east. At the southwest edge of this area, there was a land mass which, though low, was supplying sediments to streams, which in turn were distributing them over the flat and marshy lowland. Here and there on the plain were lakes, and in these lakes limestones were deposited. Such was the physiography of this country at that time as described by Mook[1]. The stream deposits of late Juriassic or early Comanchean time, formed the Morrison beds which reached to the western part of Cimarron County, but probably not farther east than Range 4. In the meantime the eastern part of the county probably was suffering erosion. One of the lakes, postulated in Mook's description of the origin of the Morrison formation, must have covered the western end of the county, for there limestones are exposed.

Sediments were still contributed from the west to the area here described when a shallow sea crept in from the east or south. Some changes in the condition of the land to the west occurred, for instead of the fine material which the streams had been bringing, there appeared sand with feldspar and occasionally gravel. These were worked over on the sea shore to form the thick layers of white sandstone of the Purgatoire formation. The finer material was carried out to sea, forming the shale beds between the sandstones found farther east in the same formation. There probably was considerable oscillation of the shore line, due to the differing amounts of sediments furnished to the slowly sinking sea floor, or to diastrophic movements, as shown by the alternations of sand and shale, especially in the eastern part of the area. Finally the sea shore moved westward, at least as far as the Rocky Mountains, and the black shales with the characteristic Comanchean fauna were deposited. It was apparently not a deep sea, for there are layers of sandstone and sandy shale in its deposits. At a later stage, probably with the withdrawal of the sea, coal marshes and the so-called "fire clays" were formed in the extreme western part of the county.

CRETACEOUS PERIOD

In the early part of the Cretaceous period, sands which were

[1]Mook, C. C., Op. cit., pp. 295-348.

probably the result of a long continued weathering of older rocks, were reworked into the Dakota sandstone by the action of fresh water, assisted by the wind. In the Raton Mesa region, 70 miles west, there was a great thickness of Cretaceous marine sediments, and it is probable that the same sea covered Cimarron County and deposited sediments here also.

At the close of the Cretaceous period the sea withdrew and there occurred the great diastrophic movements which formed the present Rocky Mountains. The effects of these movements are to be seen in this area in the eastward tilting of all the older formations, and in the undulations and small folds later described (p. 77).

TERTIARY PERIODS

After the post-Cretaceous folding, sediments began accumulating near the newly formed mountains, but there was no deposition in the Cimarron County area till the latter part of the Tertiary. During the early Tertiary the country was eroded until all marine Cretaceous sediments were removed and a gently undulating surface was formed. This is shown by the hills of Dakota sandstone on the Currumpa and Cieneguilla creeks and Beaver River, and by the abruptness with which the overlying Late Tertiary cuts out the Dakota and Purgatoire formations in the eastern end of the Cimarron Valley.

By the Miocene or Pliocene period the wash from the mountains had reached the area here described, and great quantities of sand and gravel were deposited, filling the valleys and forming a sheet over the entire surface of the county. Streams from the mountains were partly or wholly evaporated in the arid or semi-arid climate which existed here at that time, and deposited lime carbonate which was later concentrated to cement parts of the formation.

Shortly after the deposition of the Late Tertiary formation ceased, and before erosion had begun to wear away the surface thus formed, a volcano, now known as Piney Mountain, some 50 miles to the northwest of the county in Colorado, sent out a flow of basaltic lava which flowed into the extreme northwestern edge of the county covering several square miles. The date of this eruption is not definitely fixed, but it was sometime during the Pliecene. This was part of the closing outbursts of Tertiary vulcanism throughout the Rocky Mountain region.

PLEISTOCENE AND RECENT

The entire history following the time of the basalt flow has been one of erosion. The streams had not taken their present courses at the time of the lava flow, but must have begun to flow in these channels shortly afterward. Before the Pleistocene period had passed, there must have been a considerable valley carved by West Carrizo Creek, for the bones of an elephant were found in the flood plain deposits of that stream just north of the Colorado line. The relatively greater amount of erosion during the Pleistocene than since, was due to the fact that the climate of the region to the west, and possibly of this region, was more moist during that period than now. This sent larger volumes of water down the streams and carved the valleys to their present size. With the close of the Pleistocene period the climate became more arid, and the streams eroded their valleys less. Since that period the surface changes have not been great. The wind has blown the sands into dunes and the basins have been developed or enlarged by the downward percolation of surface waters and by wind erosion. The present configuration of the surface, therefore, is the result of erosion which has taken place in a very short time, geologically speaking.

STRUCTURE

The formations of this region have suffered little folding since their deposition, but nevertheless the same forces which developed the Rocky Mountains made themselves felt here, tilting the beds and developing relatively small arches and troughs. These structures are only visible in areas where formations older than the Late Tertiary outcrop, namely in the basin of Cimarron River, and in the small patches on Beaver River and its tributaries. So far as geologists have been able to observe the Late Tertiary formation shows no effects of diastrophism.

The general dip of all formations is toward the east, the beds pitching at about the same rate as the surface of the plains (18 to 20 feet to the mile). On this dip, there are imposed a series of undulations. The exact nature of these folds could not be determined, because of the lack of accurate elevations. So far as could be determined, they are roughly parallel to the direction of the Rocky Mountains, running in a north-south direction across the county. A sharp east dip at the western edge of Kenton is the first one noticeable in travelling down the Cimarron Valley. A dip of about the same magnitude is seen in the western side of West Carrizo Valley. This dip carries the Morrison beds below the surface, and they do not reappear until the valley of Gillenas Creek is reached, where they are to be seen on its western side. They are carried below the surface again by an east dip, which carries the formations down 100 feet or so in a distance of 2 or 3 miles, to the bottom of a shallow syncline with its lowest part less than one-half a mile east of the mouth of Gillenas Creek. The base of the Dakota sandstone at that place is not more than 100 feet above the level of the Cimarron River. There is little or no rise in the base of the Dakota for 4 miles down stream, but from that point it pitches east again until it is but a few feet above the river, half a mile west of the Clark Ranch house near the center of sec. 33, T. 6 N., R. 4 E. Then it gradually rises from 200 feet until it reaches the center of Range 5, where the dip changes to east again and can be followed for 4 or 5 miles before it is covered by the Late Tertiary formation, which blots out all trace of the underlying structure.

In the cross section down the Cimarron Valley there are three major synclines with their axes at the eastern boundary of Range 1, a little east of the mouth of Gillenas Creek, and at a point half a mile west of the Clark Ranch house in sec. 33, T. 6 N., R. 4 E., respectively, with corresponding anticlines between them. The shape of the folds can not easily be worked out by reconnaissance methods, because of the narrowness of the canyons, which makes it impossible to see very far from any one place. Therefore, the shape of these structures is somewhat in doubt, but it is probable that they extend in a north-south direction across the county, since they are the result of the pressure which came with the folding of the Rocky Mountains.

The largest of these structures in the county will be described a little more in detail, because there have been attempts to prospect it for oil. The Purgatoire limestone bed rises from the bottom of the Cimarron Valley at the Sloan crossing near the middle of the west line of sec. 11 T. 5 N., R. 4 E., and can be traced over most of Tps. 5 and 6 N., R. 5 E., and as far east as secs. 19, 30, and 31, T. 5 N., R. 6 E. With this marker it is possible to work out the structure indicated on the accompanying map. This structure is a dome-shaped anticline which covers practically all of T. 5 N., R. 5 E. The highest part of the dome is in the northwest quarter of sec. 22, and from this point the rocks dip in all directions. Toward the west there is a slope of about 30 to 50 feet to the mile from the top of the dome to the Sloan crossing, 5 miles to the west. There is a drop of 100 feet from the top of the dome to the cliffs on the north side of Cimarron River, a distance of some 3 miles, while to the east there is an abrupt drop of 120 feet in a little less than 2 miles. On the southern side of the anticline there is a drop of about 50 feet in the first mile. The slope then changes, rising toward the south until the bluffs of the Cimarron Valley are reached and the structure is lost under the Late Tertiary formation. In general, this structure is a dome with its top 150 to 200 feet above its base on all sides except the south, where it is only some 50 feet.

This dome is apparently only one feature of a folded zone running north and south, for there is a decided westerly dip to be seen the entire length of Ute Canyon, extending south across the valley of the Cimarron to the bluffs on its southern side. East of the dome there are a number of small folds with dips of 5° to 10°, which are apparently a part of a crumpled zone. In secs. 35 and 36, T. 5 N., R. 5 E., a great number of steep dips, ranging up to 7°, covering areas 200 feet to a quarter of a mile in length, are seen in the banks of the streams.

In the wrinkled zone east of the main fold and directly north of the dips just described, there is an elongated dome covering the major part of secs. 35 and 36, T. 6 N., R. 5 E. It is indicated by several low, parallel ridges which are made by the upturned sandstone layers of the Purgatoire formation. In the center of the structure, shales and soft sandstones are exposed, covering an area of about one square mile. The sandstone layers forming the rims of this structure dip at angles of 6° to 7° to the west and south, and less to the north and east, making a symmetrical fold.

The outcrop of the Dakota and Purgatoire formations on Currumpa Creek appears to be the top of an anticline, the crest of which is half a mile west of the Wilson crossing at about the middle of the north line of sec. 23. T. 2 N., R. 1 E. The reverse, or west dip as traced on the black shales of the Purgatoire formation amounts to 40 feet to the mile in a direction N. 45° W. The eastern dip is somewhat less than this, amounting to about 36 feet to the mile. The stream valley has been cut at right angles to the axis of the anticline, and the narrowness of the outcrop north and south prevents the rest of the structure from being seen.

Anticlines are probably present at two other localities, being indicated by abnormal dips. One such is seen in the red beds on the east side of a small tributary of Cimarron River in sec. 9, T. 5 N., R. 6 E., where the beds are tilted to the north at an angle of about 10°. The dips to the east and south could not be seen because of the flattening out of the surface, which does not expose cliffs of sufficient size. A second locality is in sec. 11, T. 4 N., R. 1 E., where a north dip of about the same magnitude is to be seen in sandstones and shales of the Purgatoire formation in a tributary of South Carrizo Creek. These may be only local dips, but it is possible that they are parts of larger anticlines covering several square miles.

ECONOMIC GEOLOGY

OIL AND GAS

It has been proved that two conditions are necessary for the accumulation of oil and gas in commercial quantities. (1) There must be a considerable body of shales in which the oil originates, with associated sandstones which act as reservoirs for the oil after it is formed; and (2) there must be some sort of trap into which the oil and gas can migrate and be caught in sufficient quantities to pay for its extraction.

A study of the formations outcropping on the surface in Cimarron County, shows that there is little hope of expecting oil in commercial quantities from any of them, even where they are under cover. The only formation which contains carbonaceous shales is the Purgatoire, and it is possible that these shales might furnish a little oil and gas. Some gas is evidently furnished by them, for water wells on the plains which reach to about their horizon, frequently are reported to have the water level raised and lowered with no respect to rainfall, the change in level being accompanied by a bubbling and rumbling in the wells caused by gas which escapes through the water. However, there are no beds of these black shales in the Purgatoire formation in Cimarron County large enough to furnish sufficient oil or gas to be commercially valuable. Neither the Morrison beds nor the red beds contain oil-bearing shales, so that if oil and gas are found in the county it must be from formations beneath the red beds. It is not definitely known what formations lie below them, for the nearest outcrop of the base of these beds is in the Rocky Mountains, some 180 miles to the west[1], and the next nearest some 300 miles to the east in central Oklahoma. In both these places Pennsylvanian rocks are exposed, and it is possible that they may extend underneath the surface between these two widely separated limits. McCoy[2] thinks that the Upper Pennsylvanian sea covered this area and deposited marine rocks corresponding to the Magdalena series in New Mexico. In the Texas Panhandle, some

[1]Lee, W. T., Op. cit., p. 39.
[2]McCoy, A. W., A Short Sketch of the Paleogeography and Historical Geology of the Mid-Continent Oil District and Its Importance to Petroleum Geology; Am. Assoc. Petroleum Geologists, Bull. vol. 5, No. 5, Plate IV, 1921.

70 miles south of Cimarron County, a series of limestones with some dark shales and sandstones is found beneath the red beds. In a well near Channing, Texas, these beds are over 1,500 feet thick. A well in Carson County reports drilling through oil shale at a depth of 3,100 feet[1]. The age of these rocks is unknown, because no fossils have yet been found in them, but they resemble the marine Permian of southwest Texas[2]. In a well drilled near Liberal, Kansas, 60 miles east of Cimarron County, blue shales are reported at a depth of 1,935 feet, which in that region is just below the red beds. It is not unreasonable to suppose that rocks similar to those found at these two places are present under the red beds of Cimarron County, and as there has been production of oil and gas at both these places, it is quite probable that these rocks contain similar products in this county.

The traps which collect oil and gas are in most cases folds in the strata. Where strata are slightly folded and the oil-bearing sand is below the level of the ground water surface, as is the case in this area, oil will work its way upward in the reservoir rocks, and lodge at the crests of the folds, forming a "pool." The location of certain of these folds in Cimarron County has been given (p. 77). The structure showing on the surface may not be the same as that at the depth of the oil-bearing rocks, for, as has been pointed out, there is a small angular unconformity between the top of the red beds and the overlying rocks in the exposures in the upper Cimarron Valley in New Mexico.

Two wells have been drilled in the county, both in the Cimarron Valley, one in the western end almost south of Kenton, and the other north of Boise City. The first well mentioned was drilled by the Segregated Oil and Gas Company of Oklahoma City, in the center of sec. 22, T. 4 N., R. 1 E. The log of the well was not available, but from a reliable source it was learned that the well was drilled to a depth of 2,037 feet, at which depth a light flow of gas was struck that blew itself out in three days. From an examination of the sludge and by comparing the depth with the thickness of known formations through which the well was drilled, it appears probable that this gas came from somewhere about the base of the red beds. It is stated financial difficulties prevented the completion of the well. The second well was drilled by the Empire Gas and Fuel Company in the SW. corner of the NW. ¼ of sec. 22, T. 5 N., R. 5 E. This well was located on the anticline already described (p. 78), and drilled to a depth of 1,580 feet when legal difficulties compelled the company to stop drill-

[1]The Oil and Gas Jour., vol. 20, No. 45, p. 5, April 6, 1922.
[2]Pratt, W. E., personal communication.

ing. No show of oil or gas was found here, but the depth of the well was hardly sufficient to be a test of the structure for even though the top of the hole was but a short distance above the top of the red beds, it is probable that the well did not go through this formation. The log of the well as far as drilled is given on page 30.

The nearest production at present, is 54 miles to the east, 4 miles west of Liberal, Kansas. A good flow of gas was struck some 2,500 feet below the top of the red beds. The Amarillo gas field is 70 miles south of Cimarron County. In both the above places the gas and oil come from sands immediately below the red beds. From the slight showing of gas in the Segregated Company's well and the proximity of production to the east and south, the outlook for oil and gas in Cimarron County would seem favorable.

It is very expensive to test new areas such as this by wildcat drilling without geological aid and the more detailed the available geological information the better the chances of finding any pools of oil or gas which exist. The rock structure capable of producing oil and gas can be worked out by the ordinary methods where the Dakota sandstone and older formations are at the surface. This limits such prospecting almost exclusively to the Cimarron Basin. This does not mean that the possibility of the existence of oil and gas under the other parts of the county is not as good as in the Cimarron Basin, but it does mean that this is the only region in which the geologist can work intelligently from surface indications. The rest of the county is covered by Tertiary rocks which so far as observed do not give traceable beds, on which to determine statistics and which are separated from the underlying Dakota sandstone by a great unconformity.

Since one gas well has been successfully completed in Texas County this report should contain a section covering the future possibilities for oil and gas in the area. There has been production of oil and gas to the north, south and east of Texas County so naturally the possibility of the location of oil and gas pools in the area covered by this report is a topic of great interest.

The gas well which was drilled in the county was in the NW. ¼ of the SW. ¼ of sec. 4, T. 1 N., R. 12 E., and was developed by the Home Development Company, a local company, with headquarters at Texhoma. Drilling was started November 15, 1922 and completed December 3, 1922. The initial production of the well was estimated as 25-30,000,000 cubic feet of wet gas. No commercial use has ever been made of the gas obtained.

The depth of this well was 3,040 feet. The well log as reported to the Corporation Commission is given below with the addition of lines showing the approximate boundaries between geologic formations.

Home Development Company, Well No. 1,
NW. 1-4, SW. 1-4, sec. 4, T. 1 N., R. 12 E.

Formation	Top	Bottom	Age
Sandy soil	0	15	
Sand and gravel	15	174	Tertiary
Hard sand	174	200	
Red rock	200	315	Permian red beds
Sandy shale	315	355	
Red shale	355	400	
Lime shale	400	420	
Flint rock	420	425	
White lime	425	433	
Red brake	435	480	
Red sand	480	510	
Red shale	510	600	
Sandy shale	600	640	
Red shale	640	700	
Red water sand	700	760	
Red shale	760	775	
Gyp rock	775	800	
Red brake	800	825	
Hard lime	825	860	
Red shale	860	875	
Salt rock	875	900	
Red shale	900	910	
Red sand	910	930	
Salt rock	930	985	
Red shale	985	1,000	
Soft sand	1,000	1,025	
Hard red sand	1,025	1,100	
Soft red sand	1,100	1,220	
Red shale	1,220	1,280	
Red sand	1,280	1,300	
Red shale	1,300	1,400	
Red sand	1,400	1,425	
Red shale	1,425	1,450	
Red sand	1,450	1,467	
Red shale	1,467	1,500	
White lime	1,500	1,525	
Sandy lime	1,525	1,575	
Salt rock	1,575	1,650	
Gyp rock	1,650	1,655	
Black lime	1,655	1,670	
Red shale	1,670	1,700	
Red sand	1,700	1,740	
Red shale	1,740	1,750	
Broken sand	1,750	1,800	
Lime shale	1,800	1,825	
Red mud or shale	1,825	1,860	

Formation	Top	Bottom	Age
Broken sandy	1,860	1,880	
Sandy hard lime	1,880	1,910	
Red shale	1,910	1,950	
Red shale	1,950	2,125	
Red cave	2,125	2,160	
Sandy shale	2,160	2,180	
Hard lime	2,180	2,190	
Blue shale	2,190	2,200	
Sandy shale	2,200	2,210	
Red shale	2,210	2,220	
Hard lime	2,220	2,240	
Red cave	2,240	2,250	
Lime hard	2,250	2,260	
Shale red	2,260	2,270	
Lime hard	2,270	2,275	Permian red beds
Blue shale	2,275	2,280	Pennsylvanian?
Lime white hard	2,280	2,290	
Blue shale	2,290	2,300	
Lime dark	2,300	2,310	
Blue shale	2,310	2,340	
Lime and shale	2,340	2,400	
Blue shale	2,400	2,450	
Lime hard	2,450	2,475	
Blue shale	2,475	2,500	
Black lime hard	2,500	2,520	
Blue shale	2,520	2,545	
Lime shale	2,545	2,555	
Red shale	2,555	2,560	
Lime white	2,560	2,570	
Red shale	2,570	2,580	
Lime white hard	2,580	2,590	
Blue shale	2,590	2,620	
Lime broken	2,620	2,630	
Blue shale	2,630	2,670	
Lime black	2,670	2,695	
Gas sand	2,695	2,707	
Lime ...	2,707	2,720	
Blue shale broken	2,720	2,735	
Red shale	2,735	2,740	
Lime hard	2,740	2,750	
Water sand	2,750	2,760	
Lime hard	2,760	2,775	
Shale red	2,775	2,780	
Shale blue	2,780	2,800	
Lime shale	2,800	2,825	
Soft sand no water	2,825	2,850	
Blue shale	2,850	2,875	
Black and white lime	2,875	2,900	
Red shale	2,900	2,925	
Lime white	2,925	2,950	
Red and blue shale	2,950	2,980	
Lime white	2,980	2,990	
Red shale	2,990	3,020	
Red cave	3,020	3,040	Total depth

As can be seen from this corrected log the well was started in Tertiary sand and gravel, penetrated the Permian red beds and encountered gas sand several hundred feet down in the Pennsylvanian formations at a depth of 2,700 feet.

In modern oil field practice the location of drilling sites is largely a matter of the geologic structure of the rocks of the region. Certain structural conditions of the rocks favor the occurrence of oil and gas, while their absence often absolutely prohibits its accumulation. In Oklahoma it has been found that the commonest structure containing oil or gas is an anticline or dome, that is where the rocks have been folded into underground domes or ridges. Under such conditions oil and gas, if present in the rocks, migrate into and accumulate within these structures. Such structures therefore, become favored locations for drilling operations.

The main producing horizon of Oklahoma evidently lies in the Pennsylvanian rocks which immediately underlie the Permian red beds. The gas well of Texas County is believed to secure production from the Pennsylvanian.

Any test wells drilled in Cimarron County should be located on the crests of the larger anticlines already described. (Page 77). Tests made on the plains will be wildcat tests, but there would appear to be the best chance of finding oil or gas in a north-south strip in Range 5, for it is there that the change in the Purgatoire formation appears to have made a zone of weakness, which would tend to be deformed just as it has been where exposed in the Cimarron Valley, in T. 5 N., R. 5 E.

The depth of a test well will depend on its location stratigraphically. If it is in the bottom of the Cimarron Valley, but little more than the red beds will have to be penetrated before possible oil bearing rocks will be encountered, while if it is drilled on the plains, the entire thickness of the Purgatoire, the Dakota, and the Late Tertiary formation will have to be added to that of the red beds. As the red beds are about 2,000 feet thick, the test well would have to be more than that depth in the bottom of the Cimarron Valley, and probably more than 3,100 feet if drilled on the plains.

Water for drilling purposes can be had in abundance from some of the springs in the tributaries of the Cimarron River, or by drilling wells to a depth of from 100 to 200 feet. The water in the large streams is not suitable as it is very alkaline and tends to make scale in the boilers. Fuel would have to be brought in from outside, unless the lignite seams described below are opened. This coal does not have a high fuel value, and wood is very scarce, so that it has been cheaper in the case of wells already drilled, to haul coal and oil from the railroad.

COAL

Thin beds of lignitic coal are found in the top of the Purgatoire formation in the extreme western end of the county at the heads of Tesesquite and South Carrizo creeks, tributaries of the Cimarron. At the first place, the coal is exposed in two drifts, located in secs. 19 and 20, T. 4 N., R. 1 E., which were driven some years ago during a boom of what was to be the town of Mineral. These mines were never worked commercially nor for local consumption. The largest of the two drifts is near the center of sec. 19, T. 4 N., R. 1 E., and the following section was exposed at this place:

Section of Coal Beds, Cimarron County

	Ft. In.
Top—	
Sandstone	3′ 0″
Shale, soft, black	6″
Coal, blocky bone	6″
"Soapstone" fire clay mixed with carbonaceous material	2′ 6″
Coal, lignitic	1′ 6″
Fire clay	To bottom

Two samples from this drift were analyzed in the laboratories of the Oklahoma Geological Survey. A sample taken across the entire 5-foot face of carbonaceous material between the fire clay and the overlying sandstone gave the following results[1]:

Lignite, Cimarron County, Oklahoma

	Percent
Moisture	8.65
Volatile combustible matter	22.40
Fixed carbon	15.04
Ash	53.91
	100.00
Sulphur	0.50
Heating value in B. T. U., 2,710 per pound	

A second sample which contained only the pure lignite from the 1½-foot seam above the fire clay anaylzed as follows[1]:

Lignite, Cimarron County, Oklahoma

	Percent
Moisture	12.64
Volatile combustible matter	31.25
Fixed carbon	35.34
Ash	20.77
	100.00
Sulphur	0.55
Heating value in B. T. U., 7,550 per pound	

[1]A. C. Shead, chemist.

A second exposure of coal at the same horizon is to be found in the NW. ¼ of sec. 5, T. 3 N., R. 1 E., in the bed of South Carrizo Creek. It has been worked by stripping and is used locally. The coal seam is 18 inches thick, and can be traced for more than a quarter of a mile along the stream bed, being lost under the cover of rock debris washed over the outcrops both above and below the exposure. The following section was taken in a stream cut, a few hundred feet up stream from the Will Baker Ranch house:

PLATE XVII.

COAL SEAM IN THE TOP OF THE PURGATOIRE FORMATION, SOUTH CARRIZO CREEK, SEC. 5, T. 3 N., R. 1 E.

Section of Lignite Bed, Cimarron County, Oklahoma

	Ft. In.
Top—	
Massive sandstone	1′ 2″
Shale, gray, sandy	10″
Sandstone, thin bedded, gray, medium-grained	1′ 4″
Lignite	1′ 6″

Top—	Ft. In.
Shale, sandy, some black in color, grading into sandstone below	7"
Sandstone	To bottom

A sample of this lignite was analyzed in the laboratory of the Oklahoma Survey, giving the following[1]:

Anaylsis of Lignite, Cimarron County, Oklahoma

	Percent
Moisture	11.35
Volatile combustible matter	30.09
Fixed carbon	40.58
Ash	17.98
	100.00
Sulphur	0.40
Heating value in B. T. U., 8,500 per pound	

From the above it can be seen that while these coals are not first class lignites, they run better than the low grades of lignite in heating value. The low moisture content is partly the result of loss of water after the sample was taken. The sulphur content is low, while the ash is high.

The extent and general character of the beds could not be determined, for it was impossible to trace them for any considerable distance. It is probable, however, that they are lenses of a rather limited extent. This possibility, together with the thinness of the seams, and the rather inferior quality, does not make a coal that could be profitably worked on a large scale, but because of the dwindling supply of wood and the expense of hauling other fuel from the railroad, these beds may be valuable for local purposes.

COPPER

There has been much prospecting for copper around the foot of the Mesa de Maya (Black Mesa) and the neighboring buttes, especially in a light green sandstone which forms the base of the Purgatoire formation. There are tiny pellets and stringers of black copper sulphide running through this rock, and the association of these with the green color has led to the belief that the green color is due to the presence of copper in quantity. Under the microscope, however, it can be seen that the color is due to an abundance of chloritic minerals, which contain no copper. A few miles up the Cimarron River in New Mexico there is a small copper mine from which copper can be produced, when

[1]A. C. Shead, chemist.

its price is very high, and there is also a similar mine in Colorado on West Carrizo Creek, a few miles beyond the county line. Both of these and the copper found in Cimarron County are very near the mesa, and it is probable that the magmatic waters from the basalt flow, percolating through the underlying rocks, deposited the copper. The anaylsis of the basalt (p. 87), does not show copper, but special tests for small amounts of that element were not made. However, almost all basalts, show small amounts of copper, and from the similarity in location and the absence of other igneous phenomena in the region, the natural conclusion is that this basalt furnished the copper of these veins.. The prospecting has been confined to the white sands, because it is here that the black sulphides show most conspicuously, and also because, as stated above, the greenish color of much of this sand is mistaken for a copper color. Because of the nature of the source of the copper, large deposits are not to be expected. Though many analyses have been made of samples from prospects in the county, none have shown copper in workable amounts.

BUILDING STONE

Throughout the greater part of Cimarron County there is no stone suitable for building material. In the valley of Cimarron River, however, in the northwestern part of the county, three separate formations contain stone suitable for this use.

The Cretaceous sandstones of both the Purgatoire and the Dakota formations, have had extensive local use for buildings. Many farm houses, barns and corrals in this part of the county are constructed of the native stone. It is usually brown or gray in color, and, breaking evenly along joint planes, forms blocks which can be laid up into structures without dressing. Not only have a considerable number of the farm structures in the region been built of the Cretaceous sandstones, but in many cases these sandstones have been hauled for considerable distances south of the Plains and used for buildings.

The lava of the Black Mesa is also suitable for building stone, but on account of its limited areal extent comparatively few buildings have been built of this material. The lava usually weathers into irregularly shaped blocks and because of the hard, tenaceous character of the rock which makes dressing difficult, it can not be used as economically as the Cretaceous sandstones, although it makes an excellent coarse filler to be used in concrete work.

AGRICULTURE

From data prepared by W. E. Baker, County Agent of Cimarron County, Oklahoma.

CLIMATE

Cimarron County, occupying the extreme western end of the Oklahoma Panhandle, has a semi-arid climate. The mean annual temperature for this part of the state is 59.5° F., and the average rainfall is 15 inches. During the summer the temperature seldom rises above 100° F., and since the average altitude of the county is about 4,000 feet above sea level, the summers are pleasant, and summer nights are extremely cool even after the warmest days. Summer winds prevail from the south and southwest, blowing continuously throughout the season.

The average winter temperature ranges from 5° to 40° above zero except at times when blizzards sweep over the county from the northwest bringing with them heavy drifting snow and ice. The lowest temperature for winter is usually 10° F. although during the severe blizzards the drop in temperature has been as low as 18° F. below zero. The high altitude of the region rarifies the atmosphere so that the cold is not so intense as in regions of higher humidity.

Rainfall, though limited in amount over a yearly period, is distributed equally throughout the seasons. The snows of the winter provide much needed moisture for wheat growing and the spring planting. Summer rains, though infrequent, are very precipitous, filling the small creeks and sinkholes. Spring and fall rains are light and continue for only a few hours.

SOILS

The soil is a Tertiary silt with a 10 percent mixture of fine sand which produces a rich sandy loam. This type of soil is very fertile under proper cultivation and moisture conditions.

The agricultural lands are divided into two classes, tight land which has only a minor portion of fine sand, and sandy loam. The tight land is best adapted to the production of small grains and the sandy loam to the cultivation of row crops and gardens.

PLANT LIFE

The flora of Cimarron County is similar to that of all the country typical of the western plains region. A heavy growth of buffalo grass is found on the prairies; trees of the more common varieties grow along the river valleys; small shrubs and plants of semi-arid type grow everwhere.

Altitude and climatic conditions in Cimarron County influence the time of planting to a considerable extent. Wheat, which is one of the leading commercial crops, should be planted in September, and will do best on the tight silt lands. Under proper tillage an average yield of 40 bushels to the acre is not uncommon. Oats and barley planted in either March or early April are excellent feed crops. Corn should be planted about the middle of May.

Grain sorghums are the most extensively cultivated crops in this county, and are valuable for domestic use as well as for exportation. These grains should be planted during the month of June in a sandy loam soil. The varieties produced are: standard and dwarf red maize, golden and white maize, several types of kafir, hagari and a few hybrids. Cane is raised largely as a seed and forage crop.

Broom corn which is planted during June, is rapidly becoming a staple commercial crop for the county since it is adaptable to the prevailing warm dry climate.

Alfalfa and sudan grass are excellent hay and pasture crops. Alfalfa is grown principally along the lowlands of the Cimarron River where it can be readily irrigated. The method used is flood irrigation, controlled by dams at the water flow and diverted into ditches by the use of gates. Two yields of alfalfa can be harvested each summer, the first for hay and the second usually for seed. Alfalfa seed produced in Cimarron County is rated among the best on the market in the United States.

A number of smaller products are cultivated such as Mexican pinto beans, which make large yields; Japanese hulless rice popcorn, which commands a good market; and garden produce from irrigated regions. Fruit production is in its infancy, although some profitable orchards of apples, cherries and plums are to be found in the sub-irrigated lowlands. In irrigated regions grapes are proving very profitable.

ANIMAL LIFE

The natural growth of buffalo grass which made No-Man's Land so attractive to the big ranchman in the early days is still the mainstay of the cattle industry. High grade Hereford cattle range over the big pastures of Cimarron County and are sent to the markets each year. Practically every farmer owns several head of marketable livestock. Sheep raising is rapidly making a market place on the farms, and it is recommended that every farmer should own at least a small flock. The poultry industry is becoming one of the most popular of enterprises.

CONCLUSION

Cimarron County, the youngest in development in the State of Oklahoma, is now getting its first railroad. This means that a commercial market for its produce will be available so that it will be given an opportunity to rank among the counties of the State.

According to records from the office of the county agent, there were under cultivation in 1921:

37,000 acres of wheat averaging 15 bushels per acre
4,665 acres of field corn averaging 25 bushels per acre
7,000 acres of broom corn averaging 1 bale to 3 acres
22,085 acres of maize and kafir
1,160 acres of alfalfa

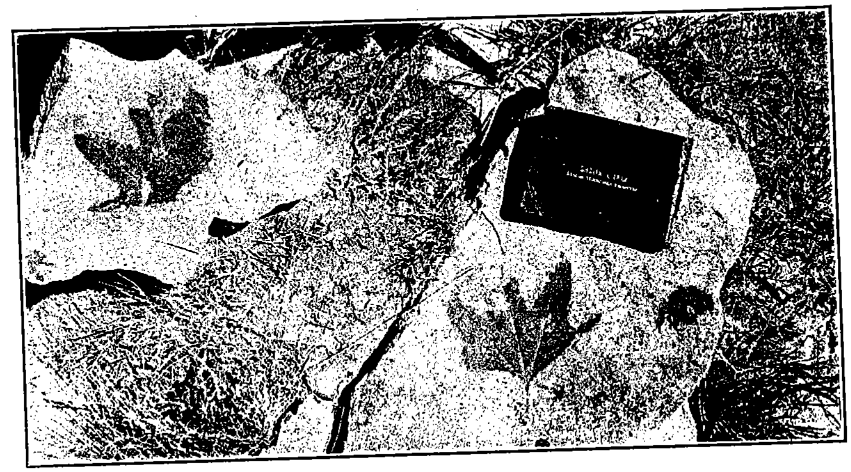
This makes a total of nearly 72,000 acres under cultivation besides 15,000 acres of new land which was broken during the year.

DAKOTA SANDSTONE PLANTS FROM CIMARRON COUNTY, OKLAHOMA

By A. C. NOE'.

The fossils described in this report were collected by Dr. E. P. Rothrock in Cimarron County, Oklahoma, and were given

PLATE XVIII.



DAKOTA SANDSTONE BLOCKS SHOWING LEAF IMPRESSIONS.

to the author for their determination and description. The locality in which they were found is described on page 56 under Age and Correlation.

Plates 19 to 24 show how the plant impressions are found. The matrix is a fine-grained sandstone, varying in color from pink to dark red, in which the finer veination of the leaves does not always appear clearly. This sandstone is famous for its fossil flora which can be found throughout the deposits of the Dakota formation in North America. All the plants described in this paper belong to the angiosperms. One of them is a monocotyledon; the remainder are dicotyledons. No gymnosperm came from this place, to the author's knowledge. Among the number of fossils only a few were selected either because they allowed a clear determination, or, as in the case of the stems and seeds, because they were worthy of being recorded.

LIST OF FIGURED SPECIES

Angiosperms

Monocotyledons

Alismophyllum victor-masoni (Ward) Berry	Plate	XIX, figure 1

Dicotyledons

Salix flexuosa, Newberry	Plate	XIX, figure 2
Quercus groenlandica, Heer	Plate	XX, figure 1
Platanus guillelmae, Goeppert	Plate	XXI, figure 2
Sterculia snowii, Lesquereux	Plate	XXII,
	Plate	XXIV, figure 2
Sterculia mucronata, Lesquereux	Plate	XXIII, figure 1
Unidentified Branches	Plate	XXI, figure 1
	Plate	XXIII, figure 2
	Plate	XXIV, figure 1
Unidentified Seeds	Plate	XX, figure 2

Alismophyllum victor-masoni
(Ward) Berry, Pl. XIX, fig. 1.

The specimen closely resembles the species described by Berry from the Patapsco formation of white House Bluff in Virginia[1]. Since the lateral margins are enrolled, the auricles appear more pointed than they probably were. The similarity between this fossil and the recent genus, *Sagittaria*, is striking. Very little is known about fossil *Alismaceae*, but, to judge from the appearance of the impression, it seems advisable to place our fossil in Berry's species.

Salix flexuosa, Newberry
Plate XIX, Figure 2.

This specimen resembles *Salix protaefolia linearifolia* Lesquereaux[2]. The secondaries are not visible on the specimen and the texture seems to be thick.

Quercus groenlandica, Heer
Plate XX, Figure 1.

Our specimen shows a striking similarity with the species pictured by Heer[3]. Also Newberry's figures in the U. S. Geological Survey Monograph 35, 1898, Plate LIV, figures 1, 2, closely resemble our fossil; and so we can assume identity of species be-

[1]Maryland Geological Survey. Lower Cretaceous, Baltimore, 1911, p. 453.

[2]U. S. Geological Survey, Monograph 17, 1892, p. 49, Plate LXIV, figures 1-3.

[3]Heer Flora Fossils Artica, Vol. 1, 1896, p. 108, Plate X, figures 3, 4; Plate XLVII, figure 1.

tween our Dakota sandstone fossil and the Tertiary species described by Heer and Newberry, instead of establishing a new species, although no similar leaf from the Dakota sandstone formation has been described.

Platanus quillelmae, Goeppert
Plate XXI, Figure 2.

The fossil in question is probably a *Platanus* and resembles the Tertiary species which Lesquereux has pictured[1] There is again the choice between establishing a new species on the basis of a single impression or of using a Tertiary species name for a Cretaceous fossil. I am inclined to take the second choice and to avoid piling up new species on too slender grounds.

Sterculia snowii, Lesquereux
Plate XXII;XXIV, Figure 2.

This seems to be a very common Dakota sandstone species to which, without question, the fossil pictured on Plates 22 and 24 of this report belong.

Sterculia mucronata, Lesquereux
Plate XXIII, Figure 1.

The fossil agrees with the description and illustration by L. Lesquereux[2].

Unidentified Stems (Pls. XXI, Fig.1; XXIII, 2; XXIV, 1)
and Seeds (Pl. XX, Fig. 2)

These are impressions of branches of dicotyledonous plants. Inasmuch as no connection with any species can be established, the giving of names seems out of place. Nevertheless, it is worth while recording these fossils, because similar branches might sometime be found associated with leaves and a later determination would be possible.

Also the seed impressions (Pl. XX, Fig. 2(which belonged to an angiospermic and probably dicotyledonous plant must be left unidentified, but are reproduced here for the same reasons as were the stems,—namely, as a record for later and more advantageous circumstances when in some related flora such a seed associated with leaves might be found.

[1]Report, U. S. Geol. Survey, Terri, Vol. 7, 1897, Plate XXV, figure 3.

[2]U. S. Geol. Survey, Monograph 17, 1891 (1892), p. 182, Plate XXX, figures 1-4.

PLATE XIX

FIGURE 1. ALISMOPHYLLUM VICTOR-MASONI (WARD), BERRY.

LOCALITY: Sec. 33, T. 6 N., R. 4 E.

SIZE: x-⅓.

FIGURE 2. SALIX FLEXUOSA, NEWBERRY.

LOCALITY: Sec. 33, T. 6 N., R. 4 E.

SIZE: x-½.

PLATE XIX

PLATE XX

FIGURE 1. QUERCUS GROENLANDICA, HEER.

LOCALITY: Sec. 15, T. 4 N., R. 1 E.

SIZE: x-⅓.

FIGURE 2. IMPRESSION OF UNIDENTIFIED SEEDS.

LOCALITY: Sec. 19, T. 5 N., R. 5 E.

SIZE: x-⅓.

PLATE XX

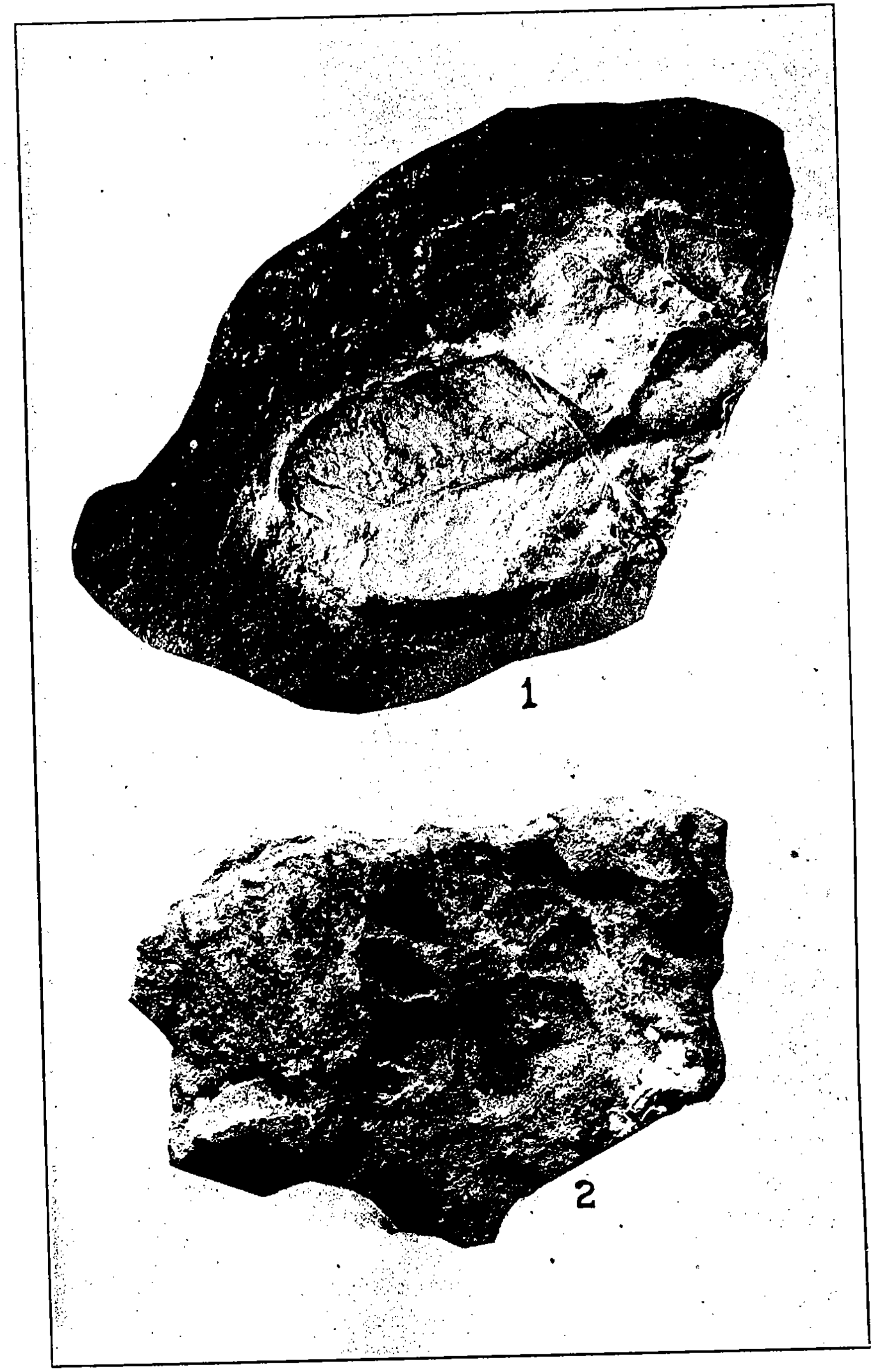


PLATE XXI

FIGURE 1. UNIDENTIFIED HERBACEOUS STEM.

LOCALITY: Sec. 32, T. 6 N., R. 3 E.

SIZE: x-3-5.

FIGURE 2. PLATANUS GUILLELMAE, GOEPPERT.

LOCALITY: Sec. 33, T. 6 N., R. 3 E.

SIZE: x-½.

PLATE XXI

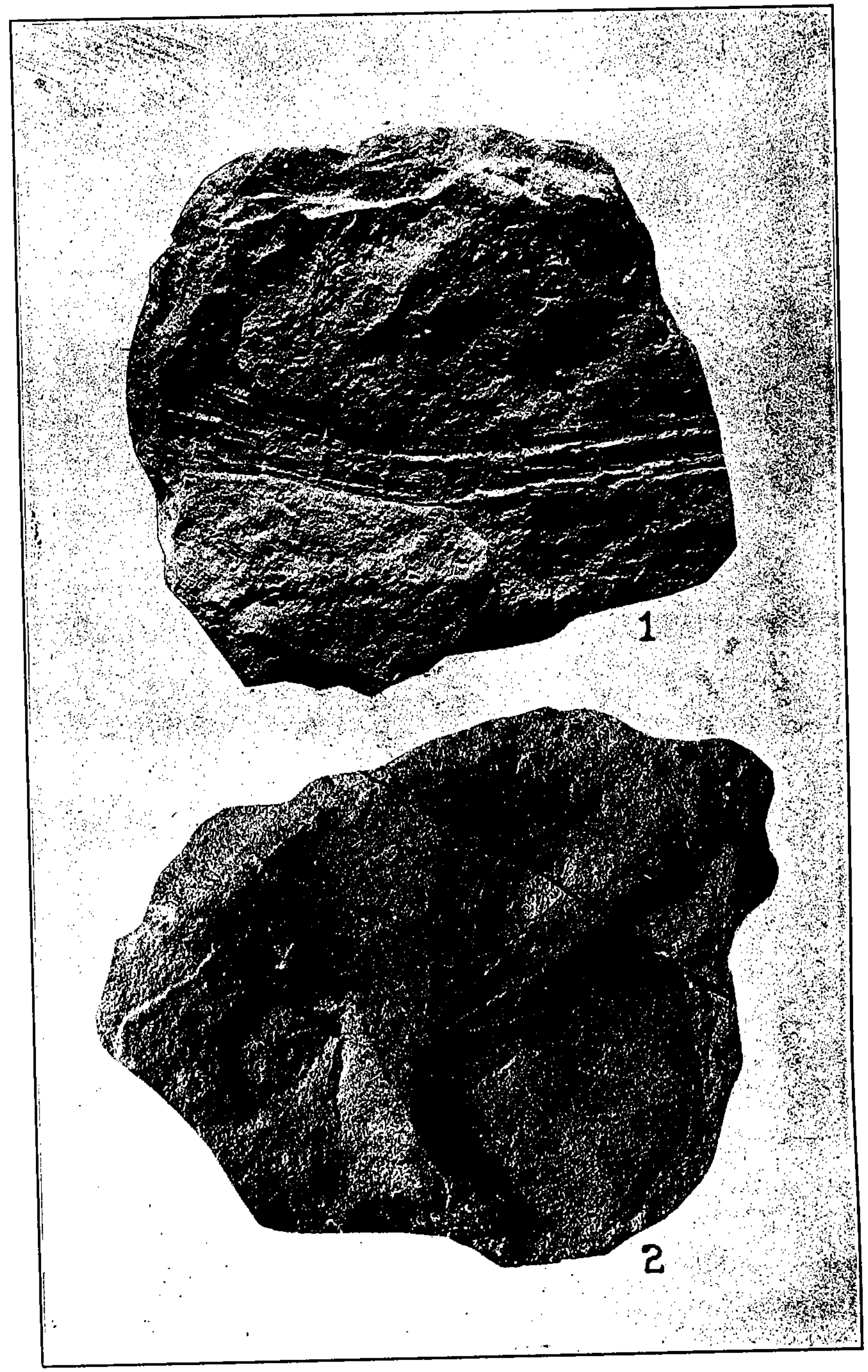


PLATE XXII

FIGURE 1. STERCULIA SNOWII, LESQUEREUX.

LOCALITY: Sec. 16, T. 6 N., R. 2 E.

SIZE: x-⅝.

PLATE XXII

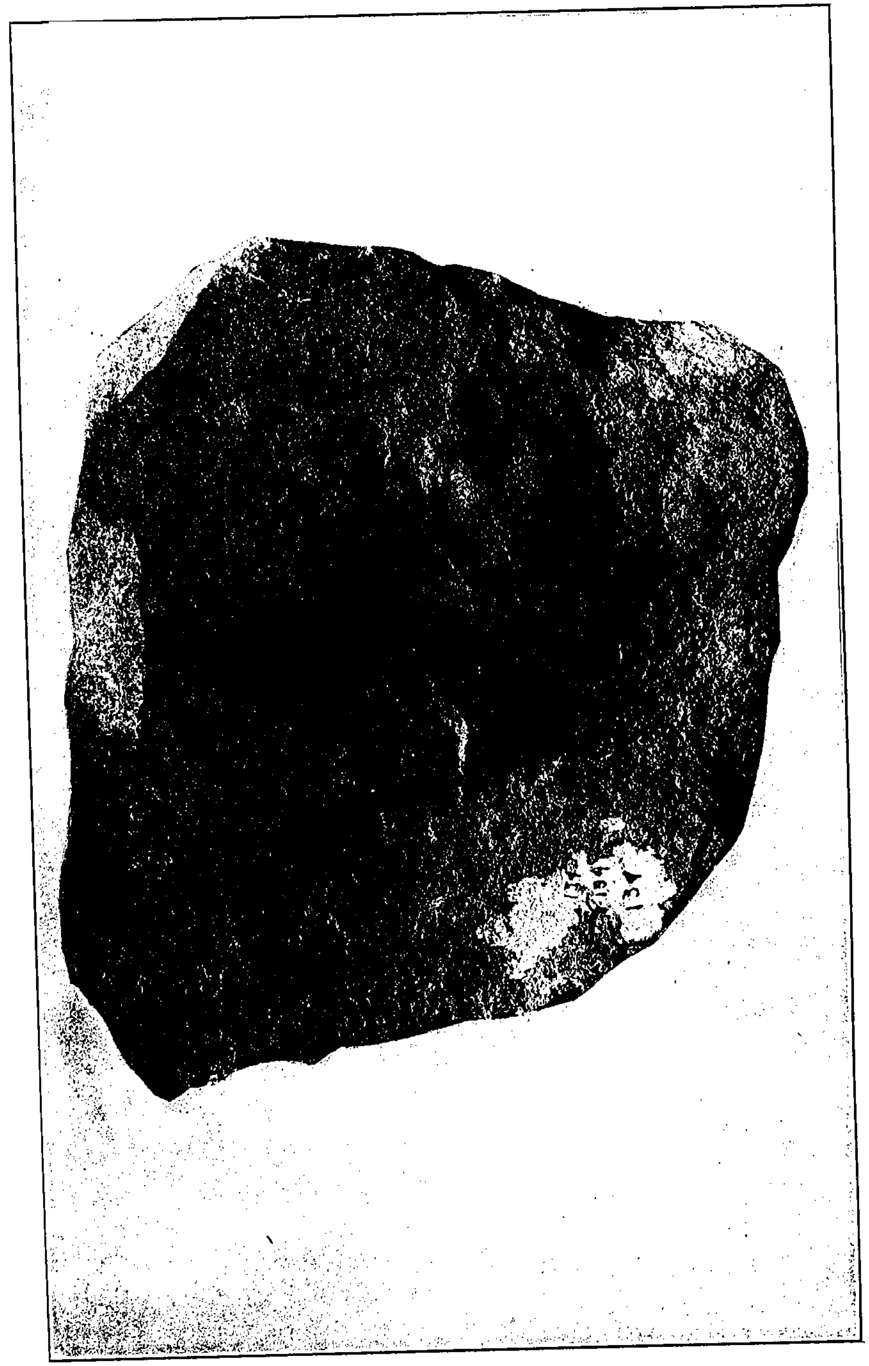


PLATE XXIII

FIGURE 1. STERCULIA MUCRONATA, LESQUEREUX.

LOCALITY: Sec. 15, T. 4 N., R. 1 E.

SIZE: x-¾.

FIGURE 2. UNIDENTIFIED TREE BRANCH.

LOCALITY: Sec. 15, T. 4 N., R. 1 E.

SIZE: x-⅓.

PLATE XXIII

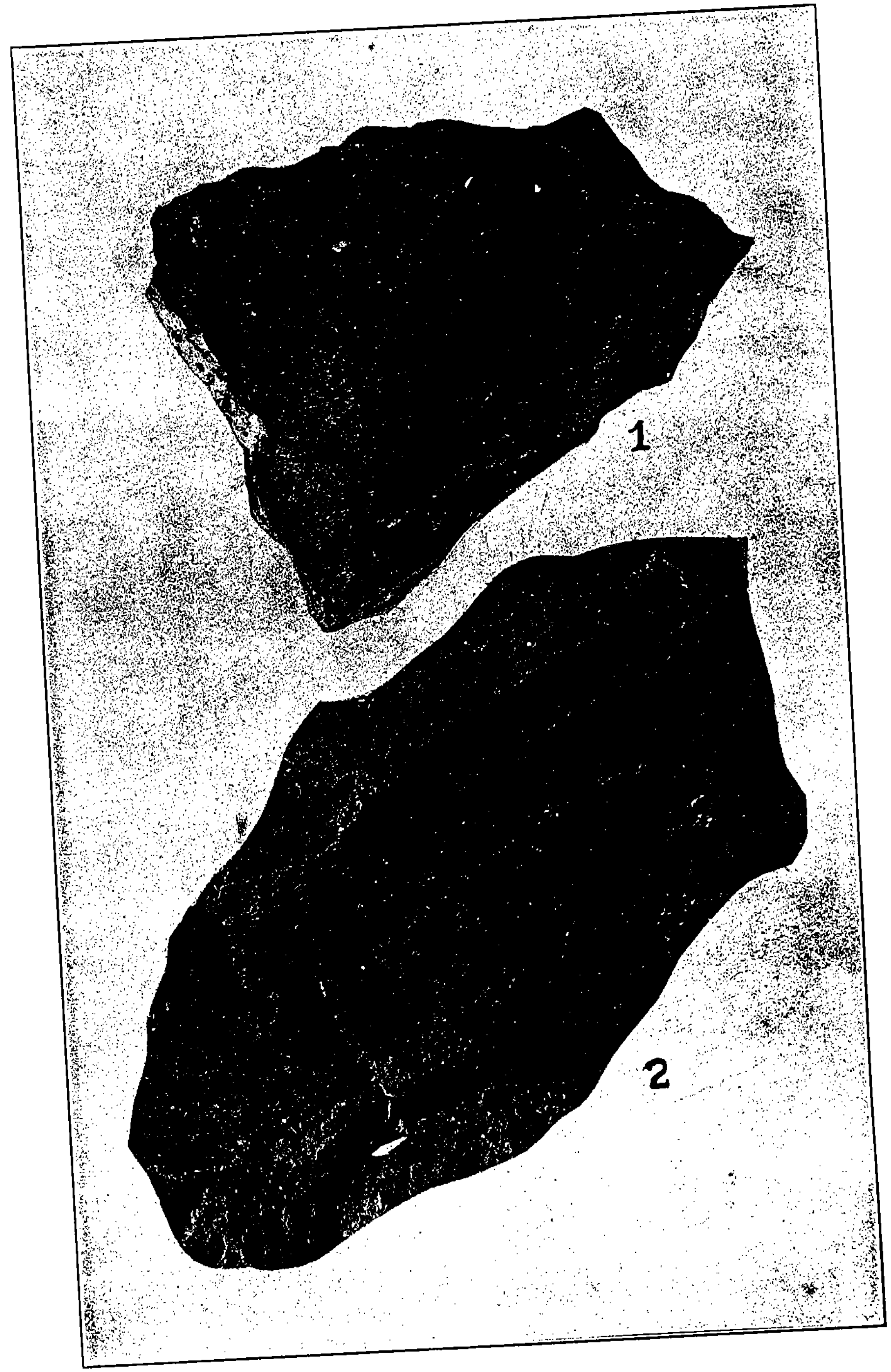


PLATE XXIV

FIGURE 1. UNIDENTIFIED TREE BRANCH.

LOCALITY: Sec. 14, T. 4 N., R. 1 E.

SIZE: x-½.

FIGURE 2. STERCULIA SNOWII, LESQUEREUX.

LOCALITY: Sec. 15, T. 4 N., R. 1 E.

SIZE: x-⅓.

PLATE XXIV

PUBLICATIONS OF THE OKLAHOMA GEOLOGICAL SURVEY

The work of the Oklahoma Geological Survey is made available to the public by means of bulletins, circulars and maps.

The following shows the status of the various publications:

(**Publications which are out of print,** but may be consulted in many public libraries.)

Bulletin No. 1—Preliminary Report on the Mineral Resources of Oklahoma.
Bulletin No. 2—Rock Asphalt, Asphaltite, Petroleum and Natural Gas in Oklahoma.
Bulletin No. 3—Geology and Mineral Resources of the Arbuckle Mountains.
Bulletin No. 5—Structural Materials of Oklahoma.
Bulletin No. 6—Director's Report and Brief Chapters on Twenty Oklahoma Minerals.
Bulletin No. 7—Clay and Clay Industries of Oklahoma.
Bulletin No. 8—Road Materials and Road Conditions in Oklahoma.
Bulletin No. 9—Lead and Zinc in Oklahoma.
Bulletin No. 10—Glass Sands in Oklahoma.
Bulletin No. 15—Director's Biennial Report to the Governor with Mineral Production of Oklahoma from 1901 to 1911.
Bulletin No. 16—Ponca City Oil and Gas Field.
Bulletin No. 17—Geology of East-central Oklahoma.
Bulletin No. 18—Report on Cushing oil field.
Bulletin No. 19—Petroleum and Natural Gas in Oklahoma by Counties. Pt. I & II.
Bulletin No. 21—Neva Limestone in Northern Oklahoma.
Bulletin No. 23—The Geology and Economic Value of the Wapanucka Limestone.
Bulletin No. 24—Geology of a Portion of Northeastern Oklahoma.
Bulletin No. 25—Bibliography of Oklahoma Geology.
Bulletin No. 27—Geography of Oklahoma.
Bulletin No. 30—Geology of the Red Beds of Oklahoma.
Circular No. 1—Origin, Scope and Purpose of the Oklahoma Geological Survey.
Circular No. 2—Brief Statement of the Geological History of Oklahoma.
Circular No. 3—Oklahoma Among the Southern States.
Circular No. 4—Trees and Shrubs of Oklahoma.
Circular No. 5—Rock Asphalts of Oklahoma and Their Use in Paving.
Circular No. 7—Correlation of Oil Sands of Oklahoma.
Circular No. 8—Methods and Costs of Drilling Oil and Gas Wells.

List of Available Publications October, 1925

(These publications may be secured from the Oklahoma Geological Survey, Norman, Oklahoma. The law requires that they be sold, and the price of each is attached. Please send stamps for postage.)

Bulletin No. 11—Gypsum and Salt of Oklahoma, by L. C. Snider $1.00 .10

Bulletin No. 13—Volcanic Ash in Oklahoma, by Frank Buttram	1.00	.05
Bulletin No. 20—Granites of Oklahoma, by C. H. Taylor	1.00	.10
Bulletin No. 22—Director's Biennial Report for 1913-14.		
Bulletin No. 26—Lime Resources and Industries of Oklahoma, by John Cullen	.75	.05
Bulletin No. 28—Tripoli Deposits of Oklahoma, by E. S. Perry	.50	.05
Bulletin No. 29—Travertine Deposits of Oklahoma, by W. H. Emig	.50	.05
Bulletin No. 32—Geology of Southern Ouachita Mountains of Oklahoma, Pt. I and II, by C. W. Honess	1.00	.10
Bulletin No. 33—Geology of Love County, by Fred M. Bullard	.50	.05
Bulletin No. 34—Geology of Cimarron County, by E. P. Rothrock	.50	.07
Bulletin No. 35—Index to the Geological Formations of Oklahoma, by Chas. N. Gould, to accompany Miser's colored geologic map.	.50	.07
Circular No. 6—Animal and Plant Life in Oklahoma, by C. W. Shannon	.25	.05
Circular No. 10—A Siluro-Devonian Oil Horizon in Southern Oklahoma, by Geo. D. Morgan	.25	.05
Circular No. 11—Arkose of the Northern Arbuckle Area, by Geo. D. Morgan	.10	.02
Circular No. 12—Stratigraphic Position of the Franks and Seminole Conglomerates of Oklahoma, by Geo. D. Morgan	.25	.05

A large number of base and geologic maps of various areas of Oklahoma are available.

Publications in Preparation, October, 1925

(To be issued during the coming biennium.)

Petroleum and Natural Gas in Oklahoma. Revision of Bulletin 19, to be reissued as two bulletins. Special chapters are now being prepared by a number of Oklahoma geologists.

Geology of Texas County, by Gould and Lonsdale.

Geology of Beaver County, by Gould and Lonsdale.

Coal Resources of Oklahoma, by C. W. Shannon, et al.

The Papoose Oil Feld, by John R. Bunn.

Geological Map of Oklahoma, by H. D. Miser, co-operative work with Oklahoma geologists and U. S. Geological Survey.

Physical and Chemical Analysis of Oklahoma Minerals, by A. C. Shead.

Geology of Marshall County, by Fred M. Bullard.

Geology of Craig County, by D. W. Ohern.

Geology of Nowata County, by D. W. Ohern.

Geology of Washington County, by D. W. Ohern.

Asphalt in Oklahoma (Circular No. 5 to be revised).

Underground Methods and Equipment for Producing Oil in Oklahoma, by H. C. George.

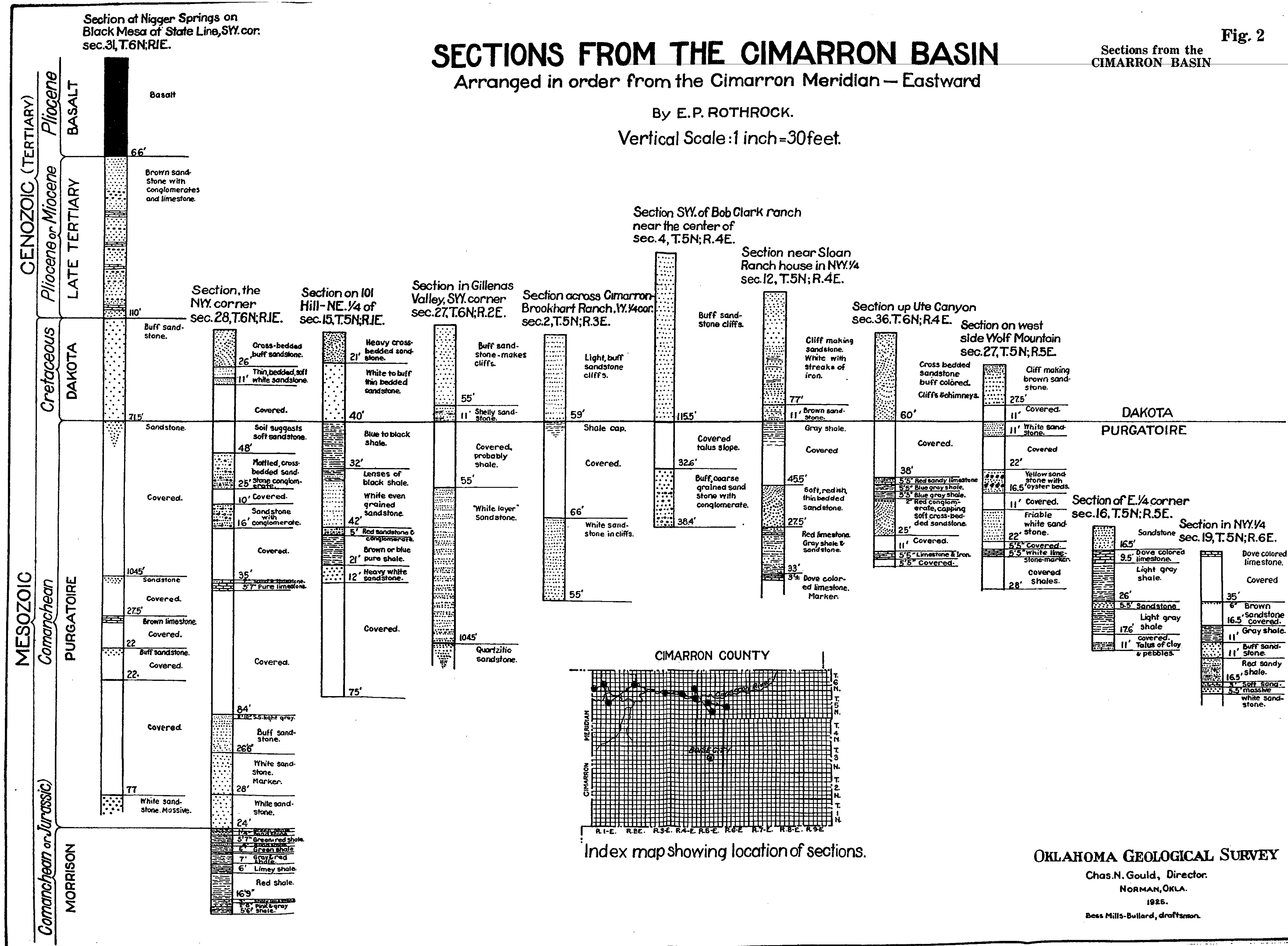


Fig. 2
Sections from the CIMARRON BASIN
SECTIONS FROM THE CIMARRON BASIN
Arranged in order from the Cimarron Meridian — Eastward
By E. P. ROTHROCK.
Vertical Scale: 1 inch = 30 feet.
CENOZOIC (TERTIARY)
MESOZOIC
Pliocene
Pliocene or Miocene
Cretaceous
Comanchean
Comanchean or Jurassic
BASALT
LATE TERTIARY
DAKOTA
PURGATOIRE
MORRISON
Section at Nigger Springs on Black Mesa at State Line, SW. cor. sec. 31, T.6N; R.1E.
Basalt
Brown sandstone with conglomerates and limestone.
Buff sandstone.
Sandstone.
Covered.
Sandstone
Covered.
Brown limestone.
Covered.
Buff sandstone.
Covered.
Covered.
White sandstone. Massive.
Section, the NW. corner sec. 28, T.6N; R.1E.
Cross-bedded buff sandstone.
Thin, bedded, soft white sandstone.
Covered.
Soil suggests soft sandstone.
Mottled, cross-bedded sandstone conglomerate.
Covered.
Sandstone with conglomerate.
Covered.
5'7" Pure limestone.
Covered.
Buff sandstone.
White sandstone. Marker.
White sandstone.
Green shale
Limey shale.
Red shale.
Section on 101 Hill - NE. 1/4 of sec. 15, T.5N; R.1E.
Heavy cross-bedded sandstone.
White to buff thin bedded sandstone.
Blue to black shale.
Lenses of black shale.
White even grained sandstone.
Red sandstone & conglomerate.
Brown or blue pure shale.
Heavy white sandstone.
Covered.
Section in Gillenas Valley, SW. corner sec. 27, T.6N; R.2E.
Buff sandstone - makes cliffs.
Shelly sandstone.
Covered, probably shale.
"White layer" sandstone.
Quartzitic sandstone.
Section across Cimarron - Brookhart Ranch, W. 1/4 cor. sec. 2, T.5N; R.3E.
Light, buff sandstone cliffs.
Shale cap.
Covered.
White sandstone in cliffs.
Section SW. of Bob Clark ranch near the center of sec. 4, T.5N; R.4E.
Buff sandstone cliffs.
Covered talus slope.
Buff, coarse grained sand stone with conglomerate.
Section near Sloan Ranch house in NW. 1/4 sec. 12, T.5N; R.4E.
Cliff making sandstone. White with streaks of iron.
Brown sandstone.
Gray shale.
Covered
Soft, redish, thin bedded sandstone.
Red limestone.
Gray shale & sandstone.
Dove colored limestone. Marker.
Section up Ute Canyon sec. 36, T.6N; R.4E.
Cross bedded sandstone buff colored. Cliffs & chimneys.
Covered.
Red sandy limestone
Blue gray shale.
Red conglomerate, capping soft cross-bedded sandstone.
Covered.
Limestone & Iron.
Covered.
Section on west side Wolf Mountain sec. 27, T.5N; R.5E.
Cliff making brown sandstone.
Covered.
White sandstone.
Covered
Yellow sandstone with oyster beds.
Covered.
Friable white sandstone.
Covered.
White limestone-marker.
Covered shales.
DAKOTA
PURGATOIRE
Section of E. 1/4 corner sec. 16, T.5N; R.5E.
Sandstone
Dove colored limestone.
Light gray shale.
Sandstone
Light gray shale
covered. Talus of clay & pebbles.
Section in NW. 1/4 sec. 19, T.5N; R.6E.
Dove colored limestone.
Covered
Brown Sandstone
Covered.
Gray shale.
Buff sandstone.
Red sandy shale.
Soft sandstone.
massive white sandstone.
CIMARRON COUNTY
CIMARRON MERIDIAN
BOISE CITY
R.1E. R.2E. R.3E. R.4E. R.5E. R.6E. R.7E. R.8E. R.9E.
T.6N. T.5N. T.4N. T.3N. T.2N. T.1N.
Index map showing location of sections.
OKLAHOMA GEOLOGICAL SURVEY
Chas. N. Gould, Director.
NORMAN, OKLA.
1925.
Bess Mills-Bullard, draftsman.