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GEOLOGY OF HARPER COUNTY, OKLAHOMA

by
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GEOLOGY OF HARPER COUNTY, OKLAHOMA

By Arthur J. Myers

Harper County, covering approximately 1075 square miles, is in northwestern Oklahoma. Aerial photographs were used in the field mapping of this semi-arid region. The bed rock consists of Permian and Cretaceous clastic and evaporite sediments approximately 535 feet thick, covered in the southwest by about 135 feet of Pliocene and Pleistocene continental deposits. The region is in the Plains Border of the High Plains Physiographic Province and most outcrops are bluff exposures.

In ascending order, the unfossiliferous Permian rocks consist of the Flowerpot shale, Blaine formation, Dog Creek shale, Whitehorse group, and Cloud Chief formation. The Flowerpot shale is a brownish red gypsiferous shale. The Blaine formation consists of four named massive gypsum members separated by red shale: (ascending) Medicine Lodge, Nescatunga, Shimer, and Haskew gypsums. The Dog Creek shale is a brownish red, even-bedded shale with thin beds of fine grained sandstone. The Whitehorse group includes the Marlow formation, which is an orange red, fine-grained, locally cross-bedded sandstone, and the overlying Rush Springs sandstone consisting of brownish red interbedded sandstone and

shale. The Cloud Chief formation is predominantly a maroon red shale with some gypsum and contains the resistant Day Creek dolomite at its base. The Cretaceous Kiowa shale outliers consist of yellow to gray to black shales, sandstones, and conglomerates with some fossiliferous beds. The Pliocene deposits include (ascending) the Laverne formation, buff, blue gray, and gray shales, sandstone, and conglomerates, and the Ogallala formation, pink, tan, and gray gravels, sands, and silts. The Pleistocene deposits are the Crooked Creek formation of the Meade group, which consists of tan to pink gravels, sands, and silts and the Pearlette volcanic ash lentil, post Crooked Creek dune sand, and gray to black clay and silt lake deposits. The Recent deposits are the terraces, alluvium, and dune deposits along recent streams.

During Permian time clastics and evaporites accumulated in marine embayments which covered western Oklahoma. Following this a period of erosion lasted during most of the Triassic and Jurassic periods. By Cretaceous time marine seas again covered the extreme western part of Oklahoma, and received clastic sediments from the west. Erosion again predominated during most of the Tertiary, but during the Pliocene two cycles of fluvial deposition by east flowing streams were separated by an intervening period of erosion. Later Pleistocene melt-water streams from the retreating Rock Mountain glaciers eroded channels in the pre-Pleistocene surface, but a cycle of fluvial deposition followed soon after. The last episode of Pleistocene

history involved the deposition of lacustrine sediments in shallow sink basins of local extent.

The Permian and Cretaceous rocks have a dip of 30 feet per mile to the south. The Tertiary and Quaternary deposits are essentially horizontal. Sink hole development has resulted in minor localized folding in all rocks.

Recent wide-spread drilling has shown a potential oil and gas supply but production is awaiting pipe-line facilities. Isolated sand and gravel deposits are used locally for road construction. The massive gypsum deposits of the Blaine formation may have economic possibilities. The volcanic ash deposits are small and would not permit large scale operation.

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I N T R O D U C T I O N

SCOPE AND PURPOSE OF THE WORK

This report presents the results of a detailed study of the Permian, Cretaceous, Tertiary, and Quaternary age rocks that crop out in Harper County, Oklahoma. The primary purposes of this investigation were: (1) to study in detail the character, distribution, and thickness of the rock formations and to prepare detailed geologic maps of surface rocks, (2) to correlate the formations with type localities, (3) to determine structure, and (4) to locate and describe mineral deposits of possible economic value.

LOCATION OF THE AREA

The area includes all of Harper County, which is in northwestern Oklahoma. The county is included in Townships 25 to 29 North and Ranges 20 to 26 West, and has an area of approximately 1075 square miles. Figure 1 shows the county outline and its relationship to other Oklahoma counties.

PREVIOUS INVESTIGATION

Prior to this investigation the geological reports have included Harper County as part of regional or stratigraphic



Figure 1. Location map.

studies. The principal reports relating to the geology of Harper County are as follows: Gould, C. N. (1905), Aurin, Firtz (1917), Clifton, R. L. (1926), Gould, C. N. and F. E. Lewis (1926), Greene, F. C. (1926), Bullard, F. M. (1928), Suffel, G. G. (1930), Evans, Noel (1931), Green, D. A. (1937), Norton, G. H. (1939), Taylor, D. W. and C. W. Hibbard (1955), and Schoff, S. L. (1956). Reports including the geography of Harper County are: Snider, L. C. (1917) and Fenneman, N. M. (1922). The following reports deal with the economic geology: Snider, L. C. (1913), Burwell, A. L. and W. E. Ham (1949), and Burwell, A. L. (1956).

PRESENT INVESTIGATION

The original investigation was aimed at mapping the Cenozoic deposits of Harper, Ellis, and Roger Mills counties for the Geologic Map of Oklahoma (1954). The field work was of a reconnaissance type and was completed during the summer of 1951.

Later the investigation was changed from reconnaissance to detailed study of sediments and mapping of only Harper County. Aerial photographs were obtained from the Department of Agriculture. Transparent cellulose acetate sheets were attached to alternate pictures in each line of flight.

Section lines were almost everywhere identifiable and the sections were numbered on the photographs. The photographs were studied stereoscopically and all possible strata and drainage systems were traced. The patterns of drainage, roads, and culture were transferred to a base map.

The field work was completed during the summer of 1955. Prior to each day's field mapping the photos of the area to be covered were stereoscopically studied. Formations were traced by walking along the outcrop and the units observed in the field were located on the acetate covers of the photos. The geology was then transferred to the base maps. Sections were measured at several places and fossils were collected.

ACKNOWLEDGMENTS

Financial support for the detailed mapping (1955) was made available through Dr. C. C. Branson, present director of the Oklahoma Geological Survey and for the reconnaissance mapping (1951) through Robert Dott, at that time director of the Oklahoma Geological Survey. The writer is indebted to Professors W. H. Burt, E. C. Stumm, C. W. Hibbard, K. K. Landes, and J. H. Zumberge for manuscript suggestions. Professor C. W. Hibbard spent several days in

the field with the writer, made many valuable suggestions, and identified the vertebrate fossils. Dwight Taylor identified the invertebrate fossils.

G E O G R A P H Y

Harper County lies in the northwest part of Oklahoma. It is approximately rectangular in shape with the northeast corner cut off by the Cimarron River, and is bounded by Clark and Comanche counties, Kansas on the north; Woods and Woodward counties on the east; Woodward and Ellis counties on the south; and Beaver County on the west. Harper County comprises all or parts of Tps. 25 to 29 N., and Rs. 20 to 26 W. and totals about 1075 square miles.

PHYSIOGRAPHY

The County is predominantly in the Plains Border section of the Great Plains province (Fenneman 1931, pp. 25-30). This section consists of a belt of steeper than normal escarpments or slopes formed on the eastern edge of the High Plains section of the Great Plains Province. The High Plains section is composed of Tertiary and Quaternary silts, sands, and gravels, which have a gentle eastward slope from the Rocky Mountains. With the removal of the Tertiary cover the rocks have been highly dissected but not reduced to the low relief which is characteristic of the Osage section of the Central Lowland province to the east.

Physiographically Harper County consists of two plains separated by a very distinct escarpment which faces north-eastward and crosses the county diagonally from 4 miles south of the northwest corner to the southeast corner. The escarpment dividing the two plains consists of a sharp slope dissected by V-shaped gullies and valleys; this belt of very rough broken land ranges from 1 to 3 miles in width. The sandy Tertiary and Quaternary sediments are generally the scarp former, but in some areas the Permian Day Creek dolomite and Rush Springs formation form the escarpment.

The upper plain which comprises the southwestern half of the county grades from a flat surface to rolling hills with gentle relief and the general slope descends to Beaver River which crosses diagonally the southwestern 1/4 of the county. The rocks are predominantly Pliocene Laverne and Ogallala formations, Pleistocene Crooked Creek formation and dune sand, and Recent dune sand and alluvium. The sandy character of the upper plain results in the absorption of water, and consequently there are very few streams to cause dissection of this area. This section consists of the part of the High Plains which has been only slightly eroded with a remnant of the High Plains remaining in the N 1/3 of T. 27 N., R. 26 W. and all of T. 28 N., R. 26 W. East of this

area in the S 1/2 of T. 28 N., R. 25 W., N 1/3 of T. 27 N., R. 25 W., and W 1/2 of T. 27 N., R. 24 W. the topography is moderately level but is more highly dissected. A narrow strip extending from the above described area to the southeast corner of the county is similarly eroded. Outliers of Cretaceous Kiowa shale have formed a few buttes in the south central part of this section. A belt of recent sand dunes north of the dry river bed of Beaver River has restricted erosion and checked the northward movement of the river resulting in the river channel apparently being shifted gradually southwestward. South of Beaver River the Pliocene Laverne formation has been moderately well dissected to a surface of low relief. The extension of the High Plains has been completely removed if it ever did cover this section. In some places the river has eroded its channel into Permian rocks, but no deep valleys have formed.

The Cimarron River has cut its bed approximately 400 feet lower than has Beaver River and as a result the northeastern plain is more highly dissected and has greater relief than the southwestern region. The rocks in this northeastern plain are Permian and form a heavier textured soil than the sandy soils of the southwestern section resulting in more runoff. The resistant beds of gypsum of the Blaine

formation are mainly responsible for the lower plain. Many intermittent streams flowing eastward have cut through the beds of gypsum forming a rough uneven topography, which in places has been rounded somewhat by leaching of the gypsums. Narrow steep sided valleys are common and some scarps are over 100 feet high such as along the Cimarron River. The roughest topography in the county is along Sleeping Bear Creek in the southeastern part of the county. This section of the lower plain is known as the gypsum hills. Buffalo Creek which is an east flowing tributary of the Cimarron River has been the main eroding agent in Harper County and has eroded the central part of the county to a surface which slopes gently toward Buffalo Creek. This surface is formed on the Dog Creek shale and Marlow formation. A series of small mesas and buttes whose cap rock is the Day Creek dolomite of the Cloud Chief gypsum form the divide between Buffalo Creek and the Cimarron River.

Sink basins formed in almost all formations are common throughout the county. Some of the most recent basins have only internal drainage, but many basins are an integrated part of the drainage system. Several basins are a mile or more in diameter; one such basin exists in sec. 27, T. 28 N., R. 24 W. and a larger basin has formed near the center

of T. 28 N., R. 25 W.

The landscape of Harper County is characteristic of a subhumid climate. The landforms are mesas, buttes, scarps, and canyons which have dolomite and/or gypsum at their tops. Further evidence of the subhumid climate is the formation of a lime enriched zone 2 to 4 feet below the surface in many of the soil profiles.

DRAINAGE

Harper County is drained by the Cimarron and Beaver Rivers. The Cimarron is a broad stream choked with sands and clays and in places has a broad salt flat. The Beaver is a moderately broad stream with many oxbows and meander scars on its floodplain.

The Cimarron River rises in New Mexico and flows across Oklahoma in an east-southeasterly direction. It enters Harper County 2 miles south of the northwest corner and 9 miles east of this corner flows into Kansas; this area is part of the Englewood basin. With a broad swing in Kansas the Cimarron River flows through the Ashland and Sitka basins and then forms the northeast boundary of Harper County.

The lower physiographic plain is drained by the Cimarron River and its tributaries. Buffalo Creek is the most

important tributary in Harper County and with its tributaries drains the central part of the county. Sleeping Bear and Sand Creeks, the major tributaries of Buffalo Creek, are the main scarp formers in the county, but small tributaries of the Cimarron have formed the scarps in northwestern Harper County. The mesas and buttes across the northern part of the county were formed by small north flowing tributaries of the Cimarron and small south flowing tributaries of Buffalo Creek.

The higher physiographic plain is drained by Beaver River and its tributaries. Beaver River heads in New Mexico and in Woodward County, Oklahoma it joins with Wolf Creek and becomes the North Canadian River. The North Canadian River, including the Beaver, roughly parallels the Cimarron River across the state and merges with the Canadian River east of Eufaula in McIntosh County, Oklahoma. Most of the tributaries are small northeast flowing intermittent streams, but Kiowa and Clear Creeks in Harper County are permanent streams fed by springs from Tertiary sands. Since there is a broad sand dune belt north of Beaver River there are practically no south flowing tributaries.

The large Englewood, Ashland, and Sitka basins have controlled the course of the Cimarron River and similarly the

course of minor streams in Harper County has been influenced by the large number of shallow sink basins.

CLIMATE

Harper County has a continental, temperate, subhumid climate (Blair 1942, pp. 184-190) typified by long hot summers and mild winters. The mean summer temperature is 80.5° with uncomfortably hot temperatures during the day and usually nights that are cool. July has the highest average temperature and the highest recorded temperature was 115° on August 13, 1936. Low humidity and the usual breeze make the temperature seem much lower than the thermometer indicates; however occasionally there are southerly hot dry winds of long duration. Winters are generally mild with a mean temperature of 37.5° , but occasionally there are short periods of severe cold rain or snow. January is the coldest month and the lowest recorded temperature is -17° on January 4, 1947. The average annual air temperature is 59.0° which is 1.6° below the average for the state.

From 1931 to 1955 the average number of days between the last killing frost in the spring and the first killing frost in the fall is 200 days. The last killing frost in the spring usually occurs early in April but has occurred as

early as March 19 and as late as May 3. The first frost in the fall is generally in late October or early November with the earliest on October 7 and the latest on November 16.

There are both regional and local storms in the county, which may produce intense rainfall over small areas. The average annual precipitation measured at Buffalo is 22.20 inches. Most of the rain falls in the period from April through September with the maximum amount in June and a lesser amount from October through March with the minimum monthly average in January. The maximum annual rainfall was 35.75 inches in 1941 and the minimum annual rainfall was 11.11 inches in 1954.

SOILS AND VEGETATION

Most of the soils in Harper County have a sandy texture because they were derived from siliceous formations. The soils developed under a coarse grass cover in a subhumid climate. A horizon of carbonate of lime has accumulated 2 to 4 feet below the surface as a result of the subhumid climate.

The heavier textured soils are red and were derived from Permian formations. The top soil is brown due to the presence of organic material. The heavier textured soils

support a heavy sod consisting of buffalo grass, blue grama, side-oats grama, bluestem, and also a scattered growth of pricklypear and various species of plants belonging to the Leguminosae and Compositae families. The smooth soils are well supplied with plant nutrients and are very productive. The soils erode rapidly where they slope and as a result are unsuited for agriculture.

The lighter textured soils were derived from Tertiary and Quaternary formations and have a top soil that is grayish brown. Vegetation consists of bluestem and Indian grass as well as sand sage. In some places the soils support small, thinly scattered post oak, blackjack oak, elm, hackberry, gum elastic (shittim wood), soapberry, and wild plum trees. Cottonwood, willow, elm, and persimmon trees and sumac shrubs grow along some of the larger streams. These uneroded soils are moderately productive; however, the eroded soils and very loose deep sandy soils are unsuited to the production of cultivated crops. The soils are subject to blowing and drifting in places where the vegetation has been removed.

In a subhumid climate the soil-moisture relationship is important to agriculture. The heavy subsoils are capable of retaining more moisture than the lighter subsoils which may

cause higher yields. Wheat is the most important crop and is grown on most of the cultivated soils.

POPULATION AND ECONOMIC DEVELOPMENT

The land included in Harper County was a part of the Louisiana Purchase. It was later included in the Cherokee Outlet, which was land set aside for the Cherokee Indian Nation. This land was bought from the Cherokee Nation and opened for settlement in 1893. Harper County, with its present boundaries, was part of the Oklahoma Territory which, combined with the Indian Territory, was admitted to the Union as a State in 1907.

In 1950 the population of Harper County was 5977, or approximately 5.6 persons per square mile. Buffalo which had a population of 1544 is the county seat. The population of other towns in the county in the same year was as follows: Laverne, 1269; Selman, 161; May, 143; and Rosston, 85.

The Wichita Falls and Forgan branch of the Missouri, Kansas, & Texas Railway crosses the southwestern part of Harper County with facilities at Laverne and May. Buffalo is served by a branch of the Atchison, Topeka & Santa Fe Railway from Waynoka in Woods County. Harper County is crossed by improved State highways 34 and 46 and Federal

highways 64, 270, 183, and 283. Local roads follow section lines except in the rougher areas.

Farming and stock raising are the chief industries of the county. Oil and gas are the main mineral resources, but most wells are shut-in awaiting pipe line facilities. Gravel pits are worked locally for highway construction.

HARPER COUNTY
MEAN TEMPERATURE

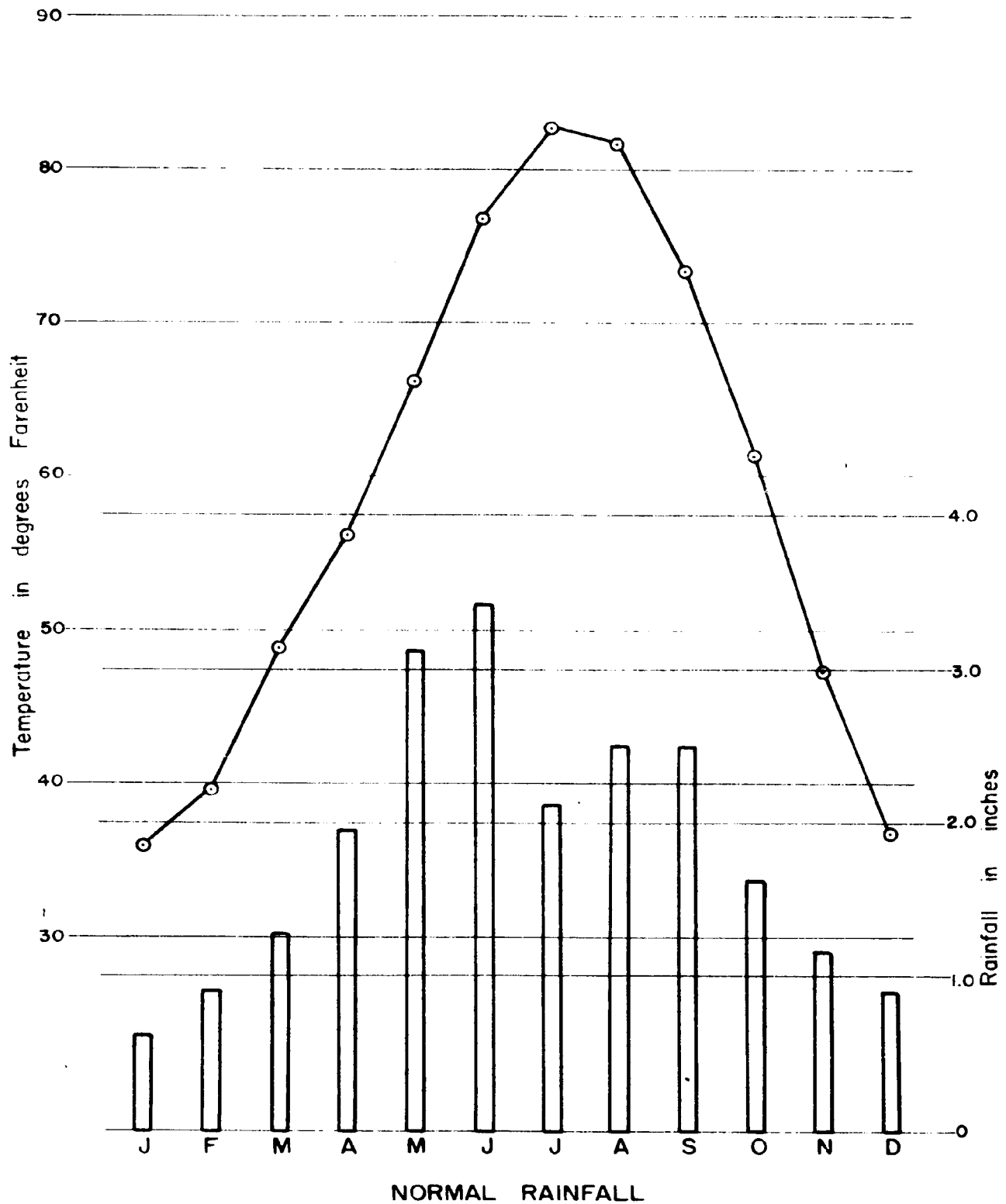


Figure 2

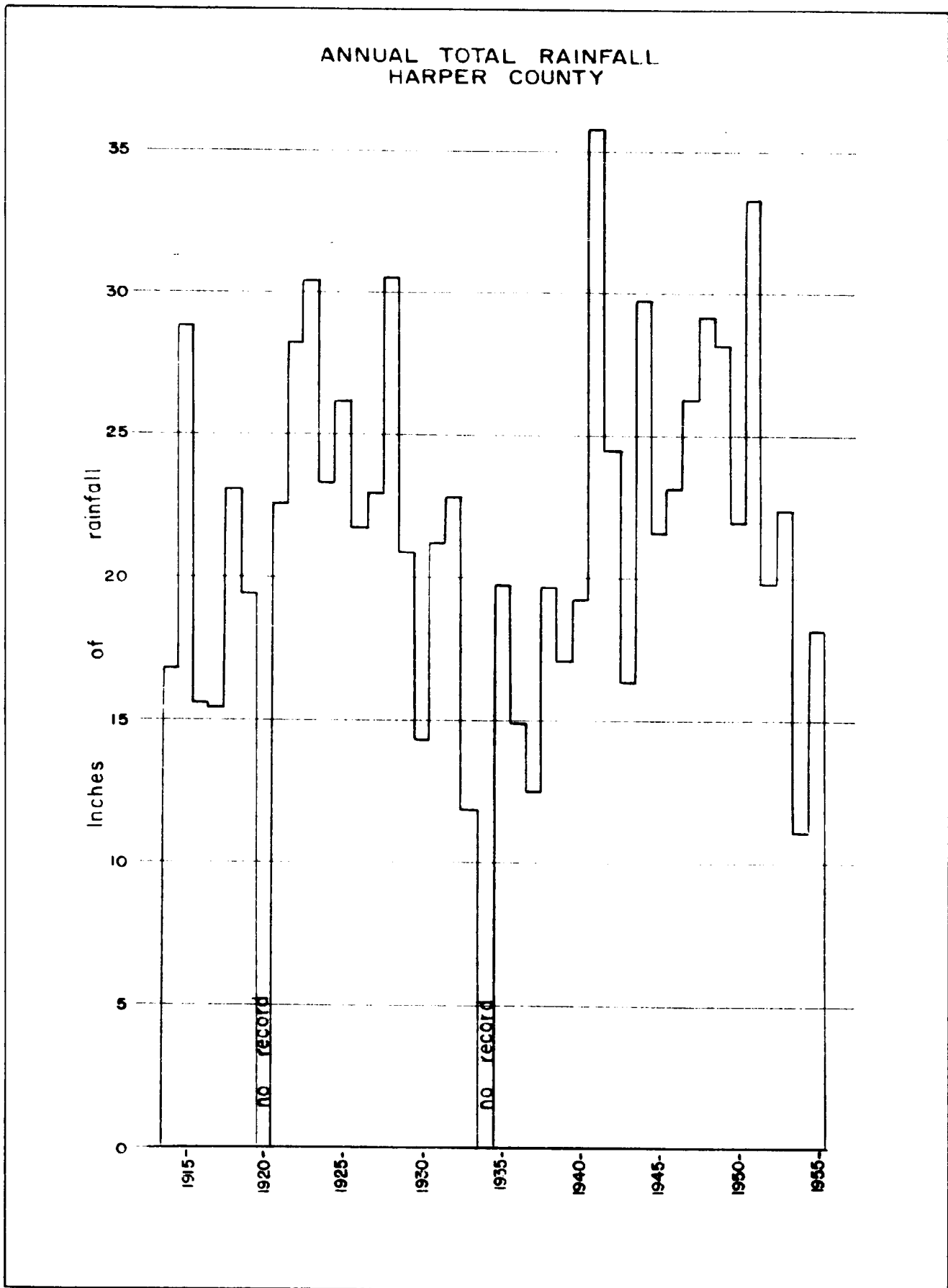


Figure 3

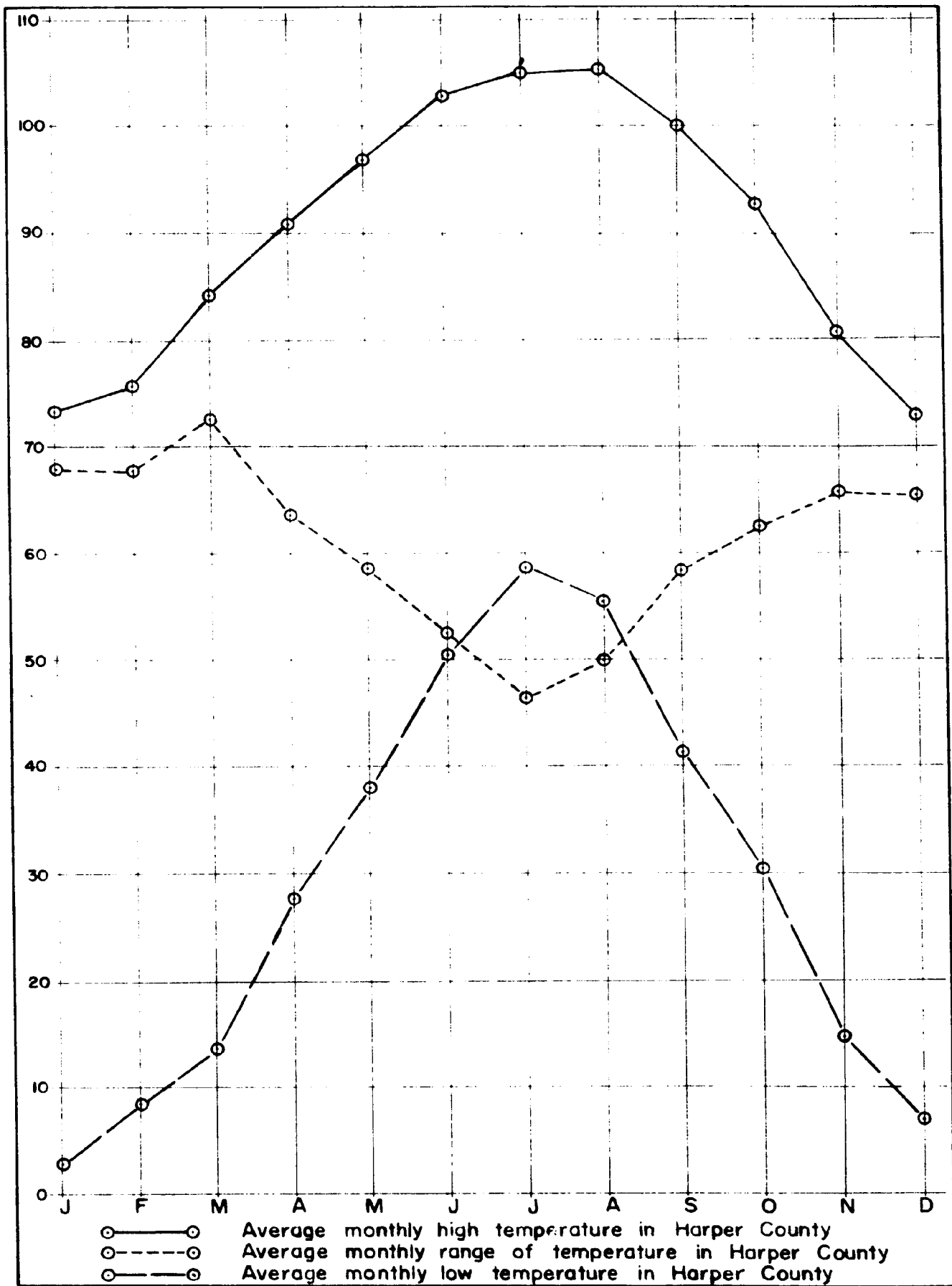


Figure 4

TABLE 1

CLIMATIC DATA FOR BUFFALO, HARPER COUNTY, OKLAHOMA
NORMAL MONTHLY, SEASONAL, AND ANNUAL TEMPERATURE AND PRECIPITATION

Month	Temperature			Precipitation			Snow average depth Inches
	Mean °F	Absolute maximum °F	Absolute maximum °F	Mean Inches	Total amount for the driest year (1954) Inches	Total amount for the wettest year (1941) Inches	
December	36.9	89	- 9	0.90	0.28	0.35	2.8
January	36.0	84	- 17	0.67	0.06	1.79	2.4
February	39.7	89	- 8	0.91	0.06	1.45	3.4
Winter	37.5	89	- 17	2.48	0.40	2.59	8.6
March	48.9	99	- 8	1.28	0.23	1.33	2.9
April	56.3	99	20	1.95	1.22	2.57	0.2
May	66.3	105	25	3.12	5.58	5.57	T
Spring	57.2	105	- 8	6.35	7.03	9.47	3.1
June	76.9	111	35	3.42	0.30	4.35	
July	82.8	114	46	2.12	0.56	1.31	
August	80.5	115	43	2.49	0.40	1.84	
Summer	80.5	115	35	8.03	1.26	7.50	
September	73.4	109	29	2.50	0.23	5.90	T
October	61.4	102	12	1.68	2.19	8.80	0.8
November	47.6	88	0	1.06	T	0.49	0.8
Fall	60.8	109	0	5.34	2.42	15.19	
Year	59.0	115	- 17	22.20	11.11	35.75	12.5

TABLE 2

CLIMATIC DATA FOR BUFFALO, HARPER COUNTY, OKLAHOMA
MONTHLY AND ANNUAL PRECIPITATION (INCHES)

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1891	1.40	-	2.05	0.20	0.60	14.00	-	-	6.60	-	-	-	-
1892	-	-	-	0.13	5.56	3.59	2.53	2.05	0.82	1.95	-	-	-
1893	-	-	-	-	-	2.31	1.43	12.55	2.04	0.68	-	-	-
1894	-	1.80	0.10	2.95	5.55	-	-	-	-	-	-	-	-
1895	-	3.00	0.20	1.50	4.05	-	-	-	-	-	-	-	-
1896	1.20	0.00	0.15	-	-	-	-	1.40	3.72	-	-	-	-
1907	-	-	0.21	1.29	1.15	3.80	4.18	2.91	1.10	2.95	0.55	2.24	-
1908	0.07	1.82	-	0.83	2.37	3.00	3.88	2.08	3.22	0.38	2.83	0.00	-
1909	-	-	1.02	0.78	-	-	-	-	-	-	-	-	-
1913	-	-	-	-	-	-	-	-	4.38	1.12	4.85	2.10	-
1914	0.10	0.40	0.90	1.20	4.68	1.82	3.45	2.60	0.75	0.28	T	0.65	16.83
1915	0.95	2.50	0.30	3.14	4.18	4.39	2.37	4.54	4.57	1.61	T	0.35	28.90
1916	0.75	T	0.10	2.32	2.81	5.83	0.00	0.92	1.02	0.68	0.45	0.65	15.53
1917	1.00	0.55	0.50	1.42	1.13	0.90	0.88	6.66	1.50	T	0.72	0.10	15.36
1918	0.85	0.11	1.51	2.67	4.23	2.60	1.53	0.65	2.48	1.64	0.40	4.48	23.15
1919	T	1.95	2.03	3.21	2.69	3.26	1.85	2.50	T	0.45	1.43	0.15	19.42
1920	0.70	T	1.00	-	2.62	1.72	3.27	3.11	2.46	3.93	1.65	1.75	-
1921	0.85	1.00	0.68	1.70	2.44	6.06	3.09	2.83	3.45	T	0.00	0.50	22.60
1922	0.83	1.40	8.56	1.42	3.83	1.58	2.53	0.70	4.20	0.92	2.24	0.00	28.25
1923	0.00	0.50	0.80	3.03	6.38	6.18	1.39	0.16	3.73	7.01	0.88	0.75	30.41
1924	0.00	T	3.57	3.92	0.85	1.22	2.96	3.94	2.83	2.42	0.40	1.15	23.26
1925	0.60	0.30	0.07	2.16	3.84	4.80	2.43	2.23	6.62	0.92	2.05	0.20	26.22
1926	1.15	0.40	2.10	1.15	2.98	2.94	2.82	2.35	2.29	1.79	0.50	1.10	21.75
1927	0.35	0.56	2.14	1.18	1.00	2.20	6.15	5.31	3.23	0.50	0.02	0.35	22.99
1928	0.00	3.57	1.55	1.72	3.50	5.63	1.72	2.40	0.93	3.58	4.15	1.77	30.52
1929	0.90	0.60	1.20	0.90	3.38	1.66	2.90	1.54	2.68	1.75	3.30	0.05	20.86
1930	0.80	0.00	0.00	2.39	1.34	1.64	2.99	0.29	1.40	1.82	1.30	0.20	14.17

TABLE 2 (Continued)

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1931	0.38	0.79	5.08	4.07	2.68	1.05	1.45	0.92	0.76	0.54	3.20	0.32	21.24
1932	1.26	0.37	0.68	3.18	2.80	7.73	0.38	3.04	2.02	0.24	0.25	0.89	22.84
1933	0.06	0.12	0.04	3.31	0.86	0.11	2.56	1.85	1.80	0.24	0.50	0.38	11.84
1934	-	-	-	-	-	-	0.46	0.18	3.55	0.53	1.27	0.60	-
1935	0.62	0.56	0.61	T	7.24	1.24	T	4.93	1.84	1.02	1.56	0.24	19.86
1936	0.90	T	T	0.59	0.42	2.08	T	0.03	4.07	1.88	0.00	0.89	14.96
1937	0.60	0.35	1.21	0.06	2.37	1.98	1.14	1.07	1.05	2.47	0.02	0.18	12.50
1938	T	1.50	1.28	3.79	5.24	4.15	0.78	1.50	0.45	0.18	0.07	0.75	19.69
1939	1.51	0.70	1.81	2.76	0.89	5.60	2.05	0.54	0.00	0.17	0.25	0.76	17.05
1940	0.85	1.36	0.10	1.43	2.92	1.17	2.51	4.40	1.31	0.19	2.41	0.62	19.27
1941	1.79	1.45	1.33	2.57	5.57	4.35	1.31	1.84	5.90	8.80	0.49	0.35	35.75
1942	0.80	0.98	1.48	3.85	1.65	1.38	1.36	2.51	2.87	5.84	0.24	1.01	23.97
1943	T	0.24	0.60	1.35	3.41	3.78	1.49	0.84	0.53	0.34	0.27	3.49	16.34
1944	0.87	1.40	1.35	4.36	5.94	0.64	4.80	3.43	1.54	2.18	1.68	1.57	29.76
1945	1.28	0.65	1.68	4.36	0.54	4.14	1.47	2.91	4.10	0.14	0.00	0.30	21.57
1946	0.70	2.11	1.15	0.76	4.30	4.12	0.28	1.63	1.40	3.41	2.47	0.77	23.10
1947	0.52	0.02	3.10	5.24	5.55	2.50	2.70	3.35	0.00	0.05	1.30	1.95	26.28
1948	0.39	2.79	1.21	1.20	0.85	6.53	5.30	6.08	2.08	1.61	0.73	0.40	29.17
1949	2.09	1.64	0.63	1.48	7.35	4.60	4.48	0.72	3.52	1.01	0.05	0.60	28.17
1950	T	0.45	0.04	0.42	2.07	3.27	9.17	3.04	2.51	0.79	0.22	T	21.98
1951	0.50	1.25	1.60	1.04	7.42	11.92	1.59	1.57	3.38	2.09	0.73	0.24	33.33
1952	0.28	0.52	1.76	5.10	3.40	0.24	1.29	4.42	0.25	0.00	1.32	1.25	19.83
1953	0.72	1.30	1.47	0.87	2.85	1.62	4.46	3.19	0.82	3.14	0.90	1.08	22.42
1954	0.06	0.06	0.23	1.22	5.58	0.30	0.56	0.40	0.23	2.19	T	0.28	11.11
1955	0.49	1.44	T	0.93	7.71	3.92	0.78	0.86	1.80	T	0.28	T	18.21
Normal	0.67	0.91	1.28	1.95	3.12	3.42	2.12	2.49	2.50	1.68	1.16	0.90	22.20

TABLE 3

CLIMATIC DATA FOR BUFFALO, HARPER COUNTY, OKLAHOMA
MONTHLY AND ANNUAL MEAN TEMPERATURE (F°)

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1931	40.8	-	44.6	53.6	60.6	80.6	-	79.6	82.0	68.2	50.0	-	-
1932	-	50.0	-	-	-	-	-	80.8	72.1	60.5	45.6	30.8	-
1933	43.0	36.0	50.8	58.2	69.2	83.8	85.2	80.0	78.4	62.4	51.0	-	-
1934	-	-	-	-	-	-	90.0	87.4	71.0	65.5	50.2	39.3	-
1935	41.2	44.3	56.8	56.5	62.6	74.4	86.0	82.9	71.0	61.6	44.2	37.8	55.9
1936	33.1	29.8	53.3	59.6	70.8	80.6	87.6	88.2	-	57.4	47.3	41.8	-
1937	25.8	39.0	44.4	58.5	70.8	77.4	86.3	86.4	74.6	60.3	45.2	36.5	58.5
1938	39.2	41.6	55.8	56.7	66.7	75.8	82.7	86.2	75.5	68.1	45.6	39.2	61.1
1939	41.9	35.6	50.4	59.4	70.5	79.1	84.2	81.6	77.8	64.0	46.3	43.0	61.2
1940	19.8	38.6	51.4	57.3	65.6	75.8	84.4	78.6	73.4	66.6	45.2	41.0	58.1
1941	37.2	38.8	44.6	58.6	69.2	73.4	80.3	81.0	73.4	62.0	48.8	41.5	59.1
1942	34.2	36.1	49.2	59.5	66.5	77.4	83.2	80.0	70.9	61.6	49.2	37.3	58.8
1943	37.6	45.7	43.0	62.6	64.0	78.8	83.9	88.6	71.9	58.6	46.0	31.4	59.3
1944	34.2	41.0	44.0	54.9	68.6	79.0	80.6	82.0	72.2	60.8	49.6	36.8	58.7
1945	37.6	39.6	-	55.2	-	73.0	81.4	82.4	74.0	61.3	49.1	33.7	-
1946	38.6	46.2	54.2	64.8	64.4	77.8	84.2	81.6	72.7	62.0	48.0	43.5	61.5
1947	36.4	37.3	44.5	56.4	64.4	75.5	80.4	84.3	77.4	68.6	42.6	36.5	58.7
1948	31.0	31.3	38.8	62.2	67.9	77.4	80.5	77.2	73.8	59.7	43.6	37.9	56.8
1949	25.5	36.1	44.9	54.7	65.9	75.2	80.5	75.5	65.9	59.5	50.5	35.2	55.8
1950	32.0	39.6	-	55.9	62.7	75.6	75.8	75.4	68.3	65.4	43.2	35.5	-
1951	33.7	37.7	43.1	54.5	65.9	70.7	81.4	81.7	68.5	58.8	41.4	36.2	56.1
1952	40.9	43.4	44.3	56.3	66.9	85.4	84.2	85.1	72.3	59.7	46.2	36.7	60.1
1953	44.6	45.3	53.5	57.7	67.2	-	79.1	79.5	76.2	63.8	48.8	39.7	-
1954	38.1	51.7	45.4	64.3	64.7	82.3	89.6	86.4	80.8	63.8	59.9	42.0	63.4
1955	37.7	38.2	49.9	65.6	70.6	74.7	85.6	83.0	76.2	64.9	46.6	39.9	61.1
Average	36.0	39.7	48.9	56.3	66.3	76.9	82.8	81.8	73.4	61.4	47.6	36.9	59.0

TABLE 4

CLIMATIC DATA FOR BUFFALO, HARPER COUNTY, OKLAHOMA
MONTHLY MAXIMUM AND MINIMUM TEMPERATURES (F°)

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug	Sept.	Oct.	Nov.	Dec.
1935	69 - 2	84 10	86 20	90 30	96 37	97 48	107 62	105 52	97 40	90 36	74 17	64 11
1939	69 20	65 4	83 14	92 31	102 42	105 53	108 59	105 51	108 36	95 31	80 13	83 5
1940	50 - 5	78 19	95 20	90 20	93 40	106 52	108 46	107 56	99 45	99 34	81 0	71 14
1941	64 15	68 18	84 18	84 31	94 49	100 50	101 56	102 61	100 40	93 31	82 16	74 20
1942	70 -12	69 - 1	82 24	93 32	98 34	102 46	103 55	103 54	96 34	91 29	84 15	68 10
1943	82 - 9	81 7	88 - 1	94 29	95 39	100 53	107 60	110 48	97 43	95 20	81 20	69 - 6
1944	66 0	77 7	77 18	82 30	94 34	106 52	103 60	107 55	98 43	88 33	86 14	65 11
1945	67 13	77 9	- -	84 20	- -	- -	- -	106 55	104 37	89 27	86 18	69 5
1946	79 9	78 16	97 24	97 34	94 33	104 49	108 60	109 53	97 40	87 33	78 24	78 6
1947	74 -17	76 12	83 11	88 32	95 38	104 43	105 58	105 65	109 45	98 34	72 15	69 8

TABLE 4 (Continued)

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1948	71 - 6	77 - 6	82 - 8	92 27	102 37	110 54	100 57	99 60	103 42	93 28	75 22	73 12
1949	66 - 1	69 8	76 20	85 27	- -	99 56	100 62	100 57	89 36	91 27	80 20	67 5
1950	71 -	71 7	- 8	93 24	92 30	107 48	98 53	98 47	90 47	94 39	88 10	75 0
1951	72 - 1	87 -13	86 15	92 27	95 36	96 44	106 57	109 59	106 39	95 30	76 12	77 1
1952	74 7	76 18	86 8	91 22	98 36	107 58	106 52	110 62	99 42	95 26	88 11	69 5
1953	75 8	75 12	90 25	98 25	105 34	- -	110 50	106 57	104 46	92 33	78 13	71 11
1954	77 21	89 17	85 9	96 28	93 29	105 50	114 64	109 59	104 42	102 27	82 19	83 7
1955	69 9	74 8	88 8	98 32	93 51	96 49	104 63	106 53	100 49	95 29	84 9	89 6
Average High	73.6	76.3	86.1	91.5	96.5	103.1	105.1	105.6	100.3	92.9	80.8	73.0
Average Range	68.1	67.8	72.8	63.8	58.5	52.7	46.4	50.0	58.6	62.6	65.9	65.7
Average Low	2.8	8.5	13.6	27.8	38.1	50.4	57.5	55.6	41.6	30.4	14.9	7.3

TABLE 5
CLIMATIC DATA FOR BUFFALO, HARPER COUNTY, OKLAHOMA
TEMPERATURE EXTREMES AND DATES OF KILLING FROSTS

Year	Maximum temperature	Date	Minimum temperature	Date	Last killing frost	First killing frost	Length of growing season
1931	-	-	9	3-31	4-3	10-29	209
1932	-	-	- 9	12-12	-	10-26	-
1933	112	7-9	-12	2-8	4-16	10-9	176
1934	112	7-31	-	-	-	10-28	-
1935	107	7-11	- 2	1-21	4-13	11-1	202
1936	115	8-13	- 6	2-8	4-22	10-26	187
1937	111	8-11	- 1	1-9	4-9	11-16	221
1938	105	8-10	2	1-31	4-9	10-23	197
1939	108	7-21	4	2-10	4-19	11-2	197
1940	108	7-27	- 5	1-8	4-13	11-6	207
1941	102	8-17	15	1-7	3-27	11-6	224
1942	103	7-17	-12	1-15	3-31	10-26	209
1943	110	8-2	- 9	1-19	4-20	10-25	188
1944	107	8-4	0	1-8	4-18	11-16	212
1945	-	-	-	-	4-5	10-22	200
1946	109	8-7	6	12-30	3-19	11-10	236
1947	109	9-3	-17	1-4	4-15	11-5	204
1948	110	6-18	- 8	3-11	4-26	10-17	174
1949	100	7-7	- 1	1-30	4-5	10-25	203
1950	107	6-26	0	1-4	5-1	11-3	186
1951	109	8-7	- 1	1-30	4-5	10-25	203
1952	110	8-16	5	12-25	4-14	10-7	176
1953	-	-	8	1-16	4-20	11-7	201
1954	114	7-12	3	1-21	5-3	10-27	177
1955	106	8-24	6	12-9	4-7	10-24	200

S T R A T I G R A P H Y

I N T R O D U C T I O N

The stratigraphy of Harper County includes Quaternary, Tertiary, Cretaceous, and Permian rock units. About 400 feet of Permian strata crop out in the county. The sequence includes rocks ranging in age from the upper part of the Flowerpot shale of lower Guadalupian age to the lower part of the Cloud Chief formation of lower Ochoan age. Subdivisions of the Guadalupian and Ochoan series in Harper County are:

Ochoan series

Cloud Chief formation

Guadalupian series

Whitehorse group

Rush Springs sandstone

Marlow formation

El Reno group

Dog Creek shale

Blaine formation

Haskew gypsum member

Shiner gypsum member

Nescatunga gypsum member

Medicine Lodge gypsum member

Flowerpot shale

The Permian rocks consist largely of shales, gypsums, and sandstones and have a gentle southerly dip. The oldest rocks in the area crop out in the eastern part of the county, which is the topographic low; younger Permian rocks crop out to the west, which is topographically higher.

A few Cretaceous outliers with a total thickness of about 60 feet of shale and sandstone crop out in south-central Harper County. The rock is the Kiowa shale of Comanche age.

In the southwestern half of Harper County the Permian and Cretaceous rocks are covered by Cenozoic sediments, which consist of approximately 30 feet of Pliocene and 70 feet of Pleistocene strata. These deposits are predominantly alluvial sand and gravels with a 13 foot bed of volcanic ash. Subdivisions of the Cenozoic in Harper County are:

Recent

sand dunes

alluvium

terrace

Pleistocene

lake deposits

sand dunes

Meade group

Crooked Creek formation

Pearlette ash member

Pliocene

Ogallala formation

Laverne formation

The Anadarko Basin of western Oklahoma was a deep geosyncline filled with sediments of Pennsylvanian and Permian age. Harper County is on the north flank of the basin and the surface rocks are Permian offshore deposits and evaporites. The Cenozoic rocks of Harper County are predominantly floodplain deposits of eastward flowing streams from the Rocky Mountains with some lake basin deposits.

T H E G E O L O G I C M A P

Two geologic maps were prepared; one to show the bedrock (pre-Tertiary) geology and one to show the surficial (Cenozoic) deposits. The bedrock geology includes the Permian and Cretaceous deposits and consists of seven formations. Except for the gypsum members of the Blaine formation and the Day Creek dolomite of the Cloud Chief formation

no units could be traced. Only in the southeastern part of the county was it possible to separate the two members of the Whitehorse group. Eight Cenozoic formations were mapped. The Pearlette ash of the Crooked Creek formation was the only recognizable unit and it crops out only in one area.

Figure 5. Correlation chart of Permian strata.
(in back pocket)

P E R M I A N S Y S T E M

Most of the exposed bedrock in Harper County belongs to the upper part of the Permian system, which is divided into the Guadalupian series and the Ochoan series. Figure 5 is a correlation chart of the Permian system.

GUADALUPEAN SERIES

As used in this report the Guadalupian series includes the El Reno group and the Whitehorse group. Newell (1940) stated that the fossil evidence suggested that the Whitehorse be included in the Guadalupian.

E l R e n o G r o u p

The El Reno group includes the strata from the base of the Flowerpot shale to the base of the Marlow formation and includes the following formations (ascending): Flowerpot shale, Blaine formation, and Dog Creek shale. The maximum measured thickness in Harper County is 200 feet. The base of the Flowerpot shale lies outside the area covered in this report, but is considered unconformable with the underlying Hennessey shale. The upper contact is unconformable with the overlying Whitehorse group.

Flowerpot Shale Formation

The name Flowerpot shale is applied to the strata lying above the Hennessey shale and below the Blaine formation. At its type locality near Flower Pot Mound in Kansas, it is a somewhat variegated brownish red gypsiferous shale cut by veins of selenite gypsum. Only the uppermost 60 feet of the formation, which crops out in the bluffs along the Cimarron River and Buffalo Creek, is exposed in the area covered by this report.

Original description: The Flowerpot shale was named by F. W. Cragin and he designated the type locality as Flower Pot Mound in Barber County, Kansas. Cragin (1896, p. 25) described the Flowerpot shale as follows:

. . . . in canyon walls. . . ., the satin-spar forms a network with irregular rhomboidal meshes, warped plates traversing the clay in all directions, sometimes is spacious sublenzitic compartments subject to partition in various directions by intersecting veins. The seams vary from mere paper-seams to plates several inches in thickness.

A noticeable and picturesque feature of the Flowerpot clays is the manner in which their outcrops are carved by the elements. They are, in fact, a theater of rapid erosion, and many weird spectacles present themselves in their relief forms they are frequently cut into rather steeply sloped faces having that peculiar pattern of sculpture that is best designated as cone and gully erosion.

Other descriptions: Norton (1939, p. 1792), Moore

1951, p. 39), and Swineford (1955, p. 66) described the Flowerpot shale as reddish brown gypsiferous shale and silty shale, cut by intersecting veins of selenite. A few thin beds of sandstone and siltstone, and locally a thin lenticular dolomite, were noted. Measured thickness ranges from 170 to 190 feet in Kansas.

History of usage: Cragin used the term Flowerpot to describe the formation below the Blaine gypsum and above the Cedar Hills in the type locality. In Oklahoma, Gould (1905, p. 39) used the term Enid formation to describe all the beds below the lowermost gypsum of the Blaine. Evans (1931, p. 408) discarded Gould's Enid formation and followed Cragin's **original** usage, which now prevails.

Distribution: The Flowerpot shale crops out in a belt from Barber County, Kansas, into central Woods County, Oklahoma. It is also exposed in the bluffs on the south side of the Cimarron River from the Kansas state line southeastward through Woodward County into Canadian County. In Major County the exposures become more extensive and form a belt 10 to 12 miles wide in Blaine, Kingfisher, and Canadian counties. In Harper County it is the lowermost exposed formation and crops out in the bluffs along the Cimarron River and Buffalo Creek.

Character and thickness: The Flowerpot shale conformably underlies the Blaine formation and consists of reddish brown gypsiferous shale and silty shale, with a few thin beds of sandstone and siltstone. Intersecting veins of selenite and satin spar gypsum cut through the formation and vari-colored fragments cover eroded slopes. Only the uppermost 60 feet of the formation crops out in Harper County.

Age, correlation, and fossils: According to Davis (1955, p. 51) the Flowerpot shale is the basal formation of the El Reno group in Oklahoma. It is placed in the Nipewalla group of the Leonardian series in Kansas, and can be correlated with the basal part of the Double Mountain formation of Texas. The Duncan sandstone correlates with the lower part of the Flowerpot shale, and the Chickasha formation of Stephens and Grady counties with the middle and upper portions. No fossils are known from this formation in Harper County.

Blaine Formation

The Blaine formation in Harper County consists of four named gypsum members, interbedded with red shales and some dolomite, which lie above the Flowerpot shale and below the Dog Creek shale. As used in this report, the named gypsum

beds (in ascending order) are Medicine Lodge, Nescatunga, Shimer, and Haskew, and are separated by unnamed red shales. The lower three beds of gypsum rest on thin beds of dolomite. Gould (1902) defined the Blaine formation, but did not trace the gypsum members from Cragin's locality in Kansas.

Original description: C. N. Gould (1905, p. 44-52) named the Blaine formation for outcrops along Salt Creek (Henquent's Canyon) in northern Blaine County, Oklahoma, and designated that area as his type locality. He described the Blaine formation as follows:

The Blaine division consists of red shales with interbedded strata of gypsum and dolomite. . . . The characteristic which justifies its recognition as a division is the abundance of gypsum contained in it and its extent and limits are well defined accordingly. . . . The Blaine division consists of five members, three ledges of massive gypsum, and two more or less arenaceous and argillaceous dolomite, interstratified with red shale. . . . The Ferguson gypsum member is the lowermost of the heavy gypsum ledges in the Redbeds of this region. It varies in color from almost pure white to a dirty brown according to the purity of the mineral. . . . Above the Ferguson is a stratum of red shale. . . . Upon this in its turn rests a ledge of arenaceous dolomite named the Magpie dolomite which usually varies in thickness from one to three feet, but in places as on West Creek, Woods County, thickens locally to ten or twelve feet. . . . The Medicine Lodge gypsum rests upon the Magpie and in many places completely covers it. . . . The Altona dolomite is the next notable member

above the Medicine Lodge gypsum from which it is separated by a stratum of shale -- the Jenkins clay of Cragin. It is an arenaceous dolomite which differs in neither lithological character, areal extent or relation to the superjacent gypsum from the Magpie. . . . Resting upon the Altona dolomite is a third gypsum ledge to which Professor Cragin gave the name Shimer gypsum from a township in Barber County, Kansas, where the rock was first studied. . . . The thickness of the Blaine division varies considerably with the locality. An average thickness will approximate 75 feet.

Other descriptions: Snider (1913, p. 119) stated that in northwestern Oklahoma north of the Glass Mountains there are three beds of gypsum in the Blaine. He did not say whether Cragin's Medicine Lodge or Gould's Ferguson was the lowest bed. Miser (1926) mapped the Blaine formation to include all beds from the top of the Chickasha formation to the base of the Dog Creek shale. This modified the definition of the Blaine gypsum so as to include beds above the Shimer gypsum and below the Ferguson gypsum and to discard the Greer formation. Clifton (1930, p. 166) stated that in southeastern Harper County there were four distinct gypsum beds separated by shale and that field evidence indicated that the name Blaine should be dropped and a new name adopted to include the Blaine and Dog Creek beds. According to Sellards (1933, p. 178) the Blaine formation as used in Texas included at least part of the underlying Chickasha and

part or all of the overlying Dog Creek of Oklahoma. The top member is the Childress dolomite and gypsum and the Auanah gypsum is near the base. Evans' (1931, p. 409-412) description of the Blaine formation included four gypsum members separated by beds of shale.

Medicine Lodge gypsum member

Original description: The Medicine Lodge gypsum member was first described by Cragin and named for Medicine Lodge River and the town of Medicine Lodge, Barber County, Kansas. Cragin (1896, p. 32) gave the thickness of the Medicine Lodge gypsum as varying between 12 and 30 feet and described it as follows:

In minor parts, the Medicine Lodge gypsum is nearly pure white; in others it is suffused with leaden-gray or dusky-brown shades; most commonly it is grayish-white mottled with feebly defined dark spots.

Other descriptions: At the type locality of the Blaine formation Muir (1934) mentioned a two inch bed of dolomite, oolitic and granular in part, which grades into the Medicine Lodge gypsum which is 6 feet thick. A series of red shales, 33 feet thick, overlies the gypsum. Evans (1931, p. 410), studying the Medicine Lodge in Harper County, reported a gray to almost black dolomite bed, one foot or less thick, underlying 25 to 30 feet of gypsum. Moore (1951, p. 39)

stated that in Kansas the Medicine Lodge gypsum averages 20 feet thick and is underlain by a bed of oolitic dolomite ranging in thickness from 6 inches to 1 foot.

Nescatunga gypsum member

Original description: Norton (1939, p. 1797) named the Nescatunga gypsum member for the exposures along Nescatunga Creek in Comanche County, Kansas, and stated:

The Nescatunga gypsum bed is well exposed along the lower reaches of Nescatunga Creek where it is 8 feet thick and separated from the overlying and underlying gypsums by red shale beds of nearly the same thickness. Two miles west, near Liberty School, the member has thinned to 2 feet although protected by several feet of cover. In this area no dolomite occurs at the base of the bed although it is reported present in Oklahoma.

Other descriptions: Evans (1931, p. 410) described the Nescatunga (his Shimer) gypsum in Harper County as a 13 feet thick bed of gypsum overlying a thin dolomite bed and separated from the Medicine Lodge gypsum by approximately 20 feet of red shale. Muir (1934, p. 1302) described the Nescatunga gypsum member (his Shimer) at the type locality of the Blaine formation as a bed 18 feet thick consisting of a lower 5 foot gypsum bed, a middle 5 foot anhydrite bed, and an upper 8 foot gypsum bed. The anhydrite is lenticular and in places absent, but the thickness of the bed remains

the same. At the base is a light gray, granular, laminated soft dolomite. Above the Nescatunga gypsum member is 35 feet of red gypsiferous shales.

Shimer gypsum member

Original description: The Shimer gypsum member was named by Cragin. Shimer Township, T. 33, 34, 35 S., R. 17 W., Comanche County, Kansas, was designated as the type locality. Cragin (1896, p. 27) described the Shimer gypsum member as follows:

The upper gypsum, or Shimer, is less constantly developed (than the Medicine Lodge gypsum) as a distinct bed of massive gypsum, not appearing at all on the valley of the Medicine Lodge river, so far as observed.

He gave the thickness of the Shimer gypsum as varying from 0 to 10 feet and separated from the Medicine Lodge by 7 to 10 feet of red clay, which is the Jenkins clay (named after the former Jenkins postoffice, near Cave Creek).

Other descriptions: Evans (1931, p. 411) described the Shimer gypsum (his Lovedale) as a 13 foot bed of gypsum overlying a 1 to 2 foot dolomite bed. It is separated from the underlying Nescatunga (his Shimer) by 7 feet of red shale. He suggested a possible correlation of this gypsum member with the Mangum dolomite on the south side of the Anadarko Basin. Norton (1939, p. 1797), Moore (1951, p. 39),

and Swineford (1955, p. 68) reported that the Shimer gypsum in Kansas is a 24 foot gypsum bed overlying a 6 to 18 inch dolomite bed and that the thickness is reduced in many places by solution and erosion.

Haskew gypsum member

Original description: Evans (1931, p. 411) named the Haskew gypsum member for exposures in Harper and Woodward counties, Oklahoma, and described this member as follows:

The Haskew gypsum bed commonly differs from the lower three in several particulars. It does not ordinarily have a dolomite bed at its base, although a very impure sandy dolomite has been observed in a few places. This member has a maximum thickness, in Harper and northern Woodward counties, of about 4 feet, and is separated from the Lovedale gypsum by 4 feet of red shale. The clusters of interlocking crystals on the surface of this bed are commonly much smaller than those of the other three beds. Also this bed has considerably more reddish color than the other three.

Other descriptions: Moore (1951, p. 38), described the Haskew gypsum member in Kansas as a 1 foot gypsum bed, which in many places has been removed by solution. It is underlain by 5 feet of red shale.

History of usage: Gould named the Blaine formation for the interbedded gypsum and shale. The base of the formation is the Ferguson gypsum member which Gould considered the equivalent of Cragin's upper Flowerpot formation. Cragin

applied the name Medicine Lodge gypsum to the lowermost massive gypsum in Kansas. Gould considered this the second bed in Blaine County, but in other areas the Medicine Lodge gypsum is considered the basal member. Norton considered that the gypsum beds in the Blaine formation in Oklahoma have been misnamed and miscorrelated with Cragin's original beds. This was partly due to the fact that Cragin did not name the gypsum lentil in the "Jenkins clay" and that Evans applied Cragin's term "Shimer gypsum" to this lentil. Norton, therefore, named the gypsum in the Jenkins clay, the Nescatunga, and threw out Evans' Lovedale which he considered was Cragin's original Shimer gypsum. The Shimer gypsum was named by Cragin for the second gypsum in Kansas, and Gould, Evans, and Muir followed this usage in Oklahoma. Norton showed that the Shimer is the third gypsum since Cragin had missed one bed. The Haskew gypsum is the uppermost member of the Blaine and was named by Evans for exposures in Harper County. The following correlation chart (after Norton, 1939) shows the historical relationship of the named gypsum beds in the Blaine formation.

Cragin(1896)	Gould(1905)	Evans(1931)	Norton(1939)
		Haskew	Haskew
Shimer	Shimer	Lovedale	Shimer
Jenkins clay	Medicine Lodge	Shimer	Nescatunga
Medicine Lodge	Ferguson	Medicine Lodge	Medicine Lodge

Distribution: The Blaine formation has been traced from southwestern Kansas across western Oklahoma into the Texas panhandle and central northern Texas. Exposures in Oklahoma are in northwestern Woods, eastern Harper, eastern Woodward, Major, Blaine, and Canadian counties. The Blaine formation in Harper County crops out as a band ranging from 1 to 4 miles wide. From the Kansas border south it forms a scarp along the west side of the Cimarron River. Outcrops extend about 14 miles upstream along Buffalo Creek and 6 to 8 miles up its principal tributaries which are Sand Creek and Sleeping Bear Creek.

On the geologic map, the base and the top of the Blaine formation are on the Medicine Lodge gypsum scarp and the Haskew gypsum scarp, respectively. The position of the Nescatunga and Shimer gypsum scarps within the formation are shown.

Character and thickness: The Blaine formation in Harper County has a total thickness of 90 feet; this includes massive gypsum beds, thin dolomite beds, and brownish red shale beds. Good exposures of the gypsum members of the Blaine formation occur along Sleeping Bear Creek in T. 26 N., R. 20 W. showing the relationship between the members. Most of the gypsum members are relatively well exposed along the lower half of Buffalo Creek. The two lower members are visible along the Cimarron River in T. 27 N., R. 20 W. and the southernmost sections in T. 28 N., R. 20 W.

The lowermost member of the Blaine formation is the Medicine Lodge gypsum member, which is a massive white-gray crystalline gypsum with a gray one foot dolomite bed at its base. It has a thickness of 25 to 30 feet. Good exposures of this member are in the NE 1/4 sec. 14 and the SE 1/4 sec. 24, T. 27 N., R. 20 W.

The Nescatunga gypsum member is separated from the Medicine Lodge gypsum member by 20 feet of red shale. This member consists of 13 feet of massive gypsum and is underlain by a gray dolomite. The dolomite upon weathering has a pitted surface. Good exposures of this gypsum member can be found in the NE 1/4 sec. 19, T. 27 N., R. 20 W. and in all the northeast quarter of T. 26 N., R. 21 W.

Overlying the Nescatunga gypsum member is the Shimer gypsum member; seven feet of red shale separate the two members. The Shimer is a massive gypsum 13 feet thick. At the base of the Shimer is a gray dolomite bed 1 to 2 feet thick, which commonly appears pitted and clinker-like as a result of weathering. The weathering is more pronounced than in the dolomite at the base of the Nescatunga. In many places much of the gypsum has been removed by solution. The Shimer gypsum member outcrops are well exposed in the NE 1/4 sec. 31, T. 27 N., R. 20 W. and in the NE 1/4 sec. 23, T. 26 N., R. 21 W.

The Haskew gypsum member, the topmost member of the formation, consists of 4 feet of gypsum underlain by 4 feet of brownish red shale. In a few places the gypsum has been removed by leaching. Outcrops of this member are visible in the NW 1/4 sec. 15, T. 25 N., R. 20 W.

In many localities in Harper County much of the gypsum has been removed by solution and in some areas only the dolomite at the base of the gypsums remains. In the northeastern part of the County along the Cimarron River all of the gypsum has been removed. To the south only the two lowermost gypsum members are present and only in the southeastern part of the County are all four gypsum members present. Since solution has had such a great effect on these

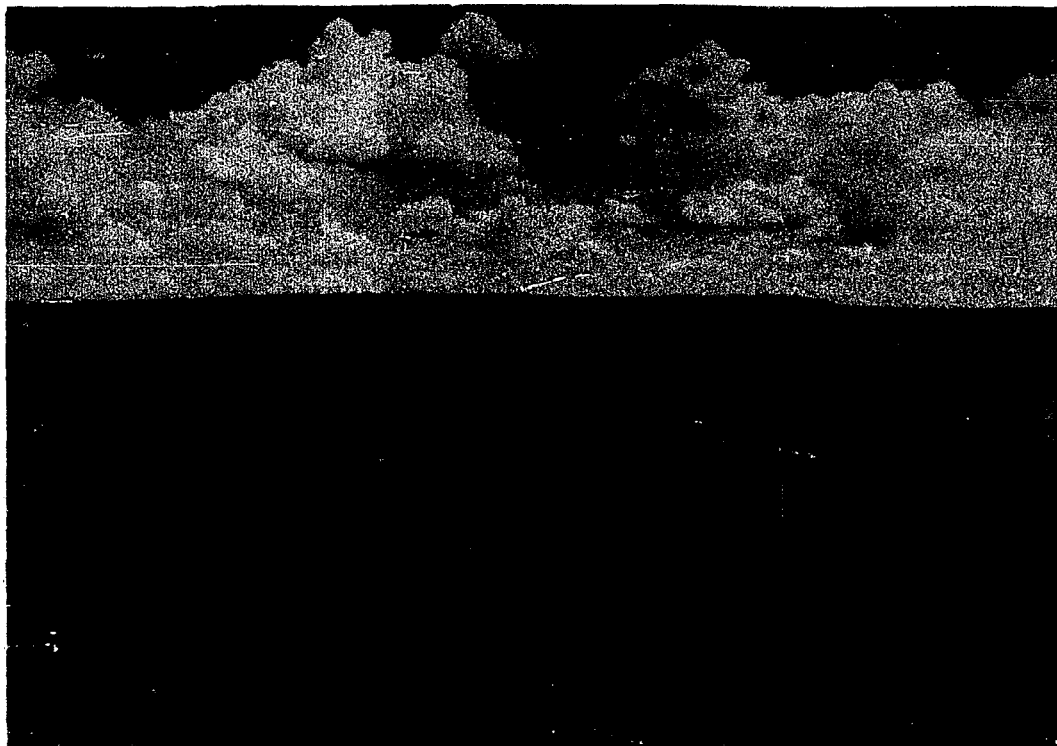


Figure 6. Outcrop of the Blaine formation showing (ascending order) the Medicine Lodge gypsum, the Nescatunga gypsum, and the Shimer gypsum. SE $\frac{1}{4}$ section 29, T. 27 N., R. 20 W.



Figure 7. Closeup of the Nescatunga gypsum member showing the total thickness. SE $\frac{1}{4}$ section 29, T. 27 N., R. 20 W.

evaporites and since the lowermost members are more intact than the upper members it appears that in the past there have been larger streams than are in existence at the present time. It is possible that the Pleistocene streams which flowed across this county could have removed the gypsum.

Age, correlation, and fossils: The Blaine formation is generally regarded as of middle Permian age and is the uppermost formation assigned to the El Reno group and is equivalent to beds of the same name in Kansas and Texas. No fossils have been found in Harper County.

Dog Creek Shale

The Dog Creek shale conformably overlies the Blaine formation and is unconformable below the Whitehorse formation. In Harper County it is a reddish-buff gypsiferous shale with thin beds of red sandstone and gypsum, and has a thickness of 25 to 50 feet.

Original description: Cragin (1896, p. 39-40) named the Dog Creek shale, designated the area along Dog Creek in western Barber County, Kansas, as the type locality, and gave the following description:

The lowest member, or Dog Creek terrane, of the Kiger consists of some thirty feet, or locally of a less or greater thickness, of dull-red argillaceous shales, with laminae of gypsum in the

basal part and one or two ledges of unevenly lithified dolomite in the upper. The color of these shales resembles that which prevails in most of the terranes of the Salt Fork division below, more than that of the Kiger terranes above the Dog Creek. The dolomite varies from light-gray to dark-gray, and clay-impregnated portions may partake of the red color of the including shales. In lithological character, it varies from solid stone which serves a fair purpose as a building-stone for the rougher uses, to that which is so contaminated with clay as to be soft and worthless. It is often cellular or cancellated. A dark and cellular variety occurs at the top of a remnantal mound of the Dog Creek at the highest point of the range of lofty tables that forms the eastern front-line of the Gypsum hills southwest of Medicine Lodge, this mound being the most easterly outlier of the Dog Creek formation in Kansas.

In Oklahoma, it is seen on the bluffs of the Cimarron river in the immediate vicinity of the Great Salt Plain.

Other descriptions: Gould (1924), p. 334) stated that the Dog Creek becomes thicker in Oklahoma than it is at the type locality as described by Cragin. In Woodward County the Dog Creek is 225 feet thick. In Blaine County, where its entire thickness cannot be measured at any one place, it may be as much as 400 to 500 feet thick. Clifton (1930, p. 166) gave the maximum thickness in Harper County as 25 feet. The dolomite within the formation in Woods County, Oklahoma, is replaced by two beds of gypsum in southeastern Harper County, or at least by beds occupying the stratigraphic position of the Dog Creek. Therefore, he believed

that the Dog Creek shale should be classified and correlated as a part of the Blaine formation in Kansas and Oklahoma.

Evans (1931, p. 412) described the Dog Creek shale in Harper County as 50 feet of gypsiferous red shale with a few thin beds of poorly cemented red sandstone and thin beds of gypsum near the base. Norton (1939, p. 1799) stated that the Dog Creek at the type locality is 53 feet of shale with several layers of dolomite and dolomitic sandstone. On Cave Creek the Dog Creek is only 23 feet thick, and in Oklahoma has been reduced to 14 feet. The topmost member is a one foot gypsum bed which is commonly absent due to solution.

History of usage: The use of the term Dog Creek shale has followed Cragin's original work.

Distribution: The Dog Creek shale crops out as a thin band in Barber and Comanche counties, Kansas, and continues as a thin band into Woods County, Oklahoma. In Harper County it crops out as a belt west of the Cimarron River and extends southeastward through northeastern Woodward County where it forms a scarp along the north side of the North Canadian River. The band continues along the North Canadian River through Major, Blaine, and Canadian counties. It crosses the North Canadian River in the vicinity of El Reno and is exposed in bluffs along the South Canadian River west of Union

City and in the hills of northwestern Grady County west of Minco. The formation crops out on the south side of the Anadarko Basin near Mountain View in Kiowa County and as a thin band continues west into Beckham County; thence south as a wide band through western Greer, western Jackson, and eastern Harmon counties.

In Harper County the Dog Creek shale forms a band generally $1/4$ to $1/2$ mile wide, but may be as much as 3 miles wide. In the northeastern corner it is a few miles west of the Cimarron River and continues south as a band to the northeast corner of T. 27 N., R. 20 W.; then it swings west parallel to Buffalo Creek. It crosses the creek in the vicinity of Buffalo and then continues southeast to the southeast corner of the county. The belt is within a few miles of Buffalo Creek except where north flowing tributaries of Buffalo Creek cause the band to swing several miles to the south.

Character and thickness: The Dog Creek shale is commonly grouped with the Blaine formation since often it is not possible to differentiate the beds. However, in Harper County the Dog Creek shales are the deposits between the uppermost gypsum of the Blaine formation and the basal beds of the Whitehorse group.

The formation consists predominantly of reddish buff

shale or silty shale beds. Also present are thin beds of fine grained sandstone which are poorly cemented, and thin beds of dolomite, dolomitic and gypsiferous sandstone, and gypsum. At the top of the formation is a one inch gray dolomitic sandstone. The average thickness of the Dog Creek shale is 50 feet.

Age, correlation, and fossils: The Dog Creek shale is the uppermost formation in the El Reno group, Leonardian series of the Permian, and is the equivalent of beds of the same name in Kansas and Texas. No fossils have been found in Harper County.

W h i t e h o r s e G r o u p

The Whitehorse group in Harper County consists of the upper Permian rocks unconformable above the Dog Creek shale of the El Reno group and unconformable below the Cloud Chief formation. In the northeast quarter and western half of the county the rocks are mapped as Whitehorse group undifferentiated. In the southeast quarter two members are mapped. These are the Marlow formation at the base which is a soft, fine-grained, poorly cemented sandstone and the overlying Rush Springs sandstone which consists of interbedded sandstone, shales, and gypsum. Unconformities both above and below limit the Whitehorse group.

Original description: The Whitehorse group was named by Gould (1905, pp. 55-56) for exposures in the vicinity of Whitehorse Springs, Woods County, Oklahoma. The beds were also described (under the name Red Bluff sandstone) by Cragin (1896, p. 40) and Gould quoted Cragin's description of the Red Bluff sandstone as his description of the Whitehorse sandstone.

This formation consists of some 175 or 200 feet of light-red sandstone and shales. * * * Viewed as a whole it is very irregularly stratified, being in some cases considerably inclined, in others curved, and this oblique and irregular bedding, being on a much larger scale than that of ordinary cross beddings, at first glance gives the impression of dips, anticlines, synclines, etc., that have been produced by lateral pressure, the dips, however, being in various directions. * * * The Red Bluff beds exhibit the most intense coloration of any of the rocks of the series. When the outcrops are wet with recent rains their vividness of color is still greater, and the contrasts of their almost vermilion redness with other colors of the landscape is most striking. Spots and streaks of bluish or greenish gray sometimes occur in these rocks, but not to nearly so great an extent as in the lower beds. The sandstones of the Red Bluffs are generally too friable for building stone, but in some instances selected portions have proved hard enough for such use and are fairly durable.

Other descriptions: Reeves (1921, p. 51) described the Whitehorse sandstone as a friable reddish-brown cross-bedded to regular-bedded sandstone which weathers rapidly. Clifton (1930, p. 167) stated that the Whitehorse sandstone consists of a series of depositional units which include horizons of

massive fine-grained sandstone, shale beds, sandy shale beds, at least 5 gypsum or gypsiferous beds or lenses, and 5 or more fossiliferous lagoonal or shoreline or channel sand deposits. Evans (1931, p. 414) stated that the Whitehorse group consists of soft, poorly cemented, fine-grained reddish buff sand, red to maroon shale, and a few white to reddish crystalline gypsum beds. The total thickness is approximately 250 feet; the lower 100 feet is sand with one or two nonpersistent gypsum beds and the upper 150 feet contains a considerable amount of shale and 6 or 7 beds of reddish white crystalline gypsum.

Marlow Formation

Original description: Sawyer (1924, pp. 314-315) proposed restricting the name Whitehorse sandstone to the upper part of the Whitehorse, and named the lower part the Marlow formation. He (1929, p. 11) renamed his restricted Whitehorse sandstone the Rush Springs member of the Whitehorse and called the lower part the Marlow member. Sawyer's original description for outcrops in southwestern Oklahoma follows:

The Marlow formation consists of brick-red shales and even-bedded brick-red sandstone with bands of fine white sand and sandy gypsums. The entire formation is gypsiferous, many of the shales containing veins of satin-spar and the sandstones more or less gypsum. A thin layer of

almost pure gypsum about 1 foot thick is found at the top of this formation. The thickness of the Marlow formation is about 120 feet.

Other descriptions: Green (1936, p. 1470) stated that the Marlow is definitely an overlapping contact. The evidence is more easily recognized on the south side of the basin.

Rush Springs Sandstone

Original description: Sawyer (1929, p. 11) considered the Wichita Mountains region of southwestern Oklahoma his type locality and described the Rush Springs as follows:

The Rush Springs member consists almost entirely of red cross-bedded sandstone and has little or no shale or gypsum in this area.

Other descriptions: Evans (1931, p. 414-417) stated that the Whitehorse formation of Harper County consists of approximately 250 feet of reddish buff sand, red to maroon shale, and a few white to reddish crystalline gypsum beds. He further stated that it is not possible to separate the Marlow member from the Rush Springs member in northwestern Oklahoma and together they constitute the lower 100 feet or more of the Whitehorse. Green (1936, p. 1472-1473) believed that there is an unconformity at the top of the Rush Springs, therefore, the Cloud Chief should be included in the

Quartermaster formation. Norton (1939, p. 1802) wrote that the Whitehorse conformably overlies the Dog Creek although many have suggested an unconformity because of the variable thickness of the Dog Creek. In Kansas (Norton 1939, p. 1803 and Moore 1951, pp. 37-38) the Whitehorse can be divided into four characteristic members: the Marlow, the Relay Creek dolomite, an even-bedded sandstone, and an upper shale member. The Marlow sandstone member is a red, fine-grained, locally shaly or silty cross-bedded sandstone which is about 110 feet thick. The Relay Creek dolomite and sandstone member consists of two dolomite beds ranging in thickness from a few inches to about 1 foot separated by red and white fine sandstone which is locally cross-bedded. The thickness is about 22 feet. The even-bedded member is a maroon very fine sandstone and shaly siltstone, mostly even-bedded but locally cross-bedded in the upper part, with a thickness of about 100 feet. The upper shale member consists of about 38 feet of predominantly brick red or maroon silty shale, siltstone, and a minor amount of very fine sandstone with a zone of dolomitic beds in the basal part and a zone of gray green sandy shale in the upper part.

History of usage: Gould (1905, p. 55) proposed the name Whitehorse for exposures in Woods County, Oklahoma.

Sawyer (1924, p. 315-316) restricted the name Whitehorse to the upper part of the formation and named the lower part the Marlow formation. Later Sawyer (1929, p. 11) divided the Whitehorse into two members; the Marlow member being the basal one and the Rush Springs member the upper one. Evans (1931, p. 420) added the Cloud Chief gypsum as the top member of the Whitehorse with a middle Rush Springs member and a basal Marlow member. Green (1936, pp. 1471-1473 and 1937, pp. 1525-1529) restricted the Whitehorse to Sawyer's original two members with the Cloud Chief grouped with the Quartermaster.

Distribution: The Whitehorse group crops out on both sides of the Anadarko basin. On the north flank it is a belt 10 to 20 miles wide through Woods, Harper, Woodward, Dewey, Blaine, Custer, and Washita Counties, Oklahoma, and Clark, Comanche, and Barber Counties, Kansas. The formation noses in Caddo and southwestern Grady Counties becoming very extensive at the surface. The south flank is a belt 2 to 3 miles wide through southern Washita and Beckham Counties with an isolated exposure in west central Harmon County.

In the western third, central, and south central part of Harper County the Whitehorse is buried beneath Tertiary and Quaternary deposits. Surface exposures at the Kansas

state line are practically the width of the county but near the center of the county are about 8 miles wide; this belt continues diagonally to the southeastern corner of Harper County. Another area of Whitehorse exposures is south of Beaver River in the southwestern part of the county.

Character and thickness: The Whitehorse group consists of approximately 200 feet of reddish sandstone, siltstone, shale, and minor quantities of white to reddish gypsum beds. In the southeast quarter of Harper County the Marlow member is composed of 65 feet of soft, light-red, fine-grained, commonly cross-bedded, and generally poorly cemented sandstone with a few non-persistent gypsum beds. The Relay Creek dolomite which is near the top of the Marlow is essentially absent in Harper County. It was either not deposited or has been destroyed, but a few gullies contain a 1/8th inch dolomite bed. The Rush Springs sandstone is composed of about 140 feet of well bedded, red, fine-grained sandstone and siltstone with reddish brown shales and beds of gypsum. The Marlow erodes into low rolling hills whereas the Rush Springs forms a more rugged topography. Good exposures are located in the NW 1/4 sec. 17, T. 25 N., R. 20 W. In the northern half of the county it is impossible to separate the two members and in the western part the beds

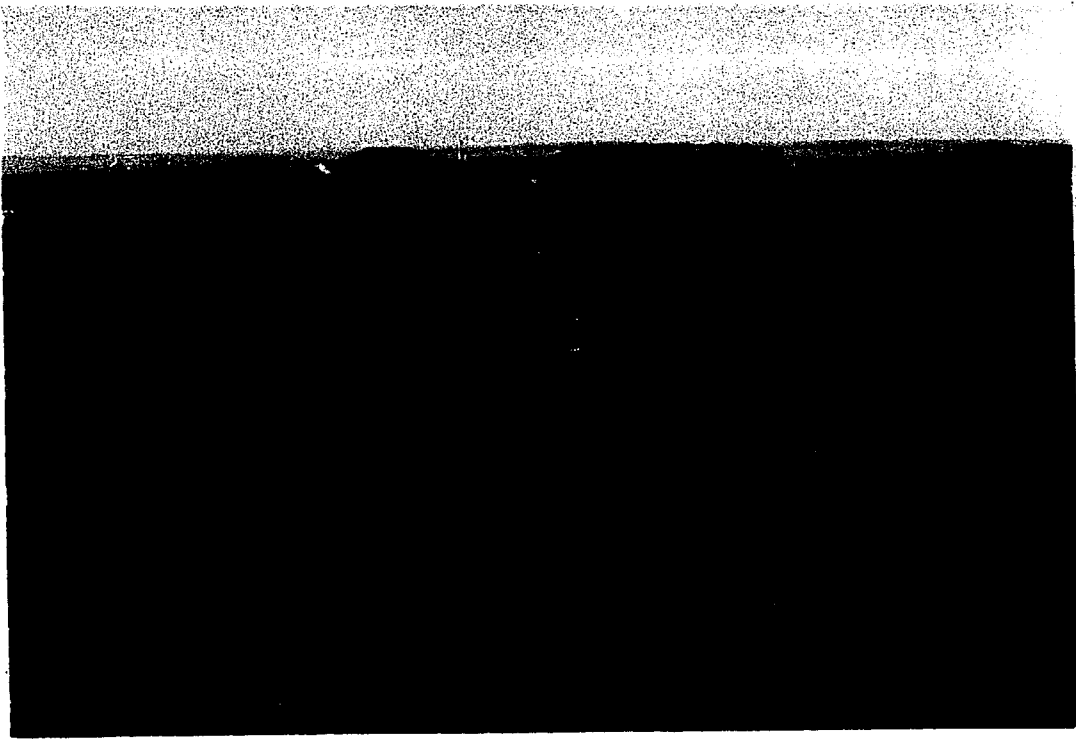


Figure 8. Typical Rush Springs topography.
Section 8, T. 25 N., R. 20 W.



Figure 9. Outcrop of Rush Springs sandstone.
Section 11, T. 25 N., R. 21 W.

are buried below later deposits. The beds in sec. 1, T. 28 N., R. 26 W. are wholly or partly Rush Springs, but since the Marlow cannot be distinguished the rocks are mapped as Whitehorse undifferentiated.

Age, correlation, and fossils: In northwestern Oklahoma the Whitehorse group consists of the Marlow formation at the base and the overlying Rush Springs sandstone and belongs to the Guadalupian series of the Permian. It can be correlated with the Whitehorse of the Cimarron group of Kansas and with the Whitehorse group of Texas. No fossils have been found in the Whitehorse in the area of this report.

OCHOAN SERIES

The Ochoan series consists of the uppermost Permian strata. In Harper County the Cloud Chief formation is the only group present and overlies unconformably the Whitehorse group and is overlain by Cretaceous and Cenozoic rocks.

C l o u d C h i e f F o r m a t i o n

In Harper County the name Cloud Chief formation is applied to the dolomite, red shale, and gypsum overlying the Whitehorse group. The formation crops out in outliers and only the lowermost 25 feet is present. The Day Creek dolomite, a 2 foot dolomite with drusey quartz, is the basal

member and is overlain by irregular impure gypsum interbedded with gypsiferous shale.

Original description: The Cloud Chief formation was named by Gould (1924, pp. 324-341) for outcrops near the town of Cloud Chief in Washita County, Oklahoma, and was described as follows:

The Cloud Chief formation consists of ledges of massive gypsum imbedded in red shales. The gypsums vary much, both in number and thickness. In some places, as for instance near Cement, there are, according to Reeves, two beds separated by 15 to 20 feet of gypsiferous shale. The upper bed here varies in thickness up to 85 feet, but the average thickness of the two beds in this region is perhaps not more than 5 feet. In other localities three or more gypsums, separated by clay shales, outcrop on the surface.

Other descriptions: Gould (1925, p. 95) described the Cloud Chief gypsum as a massive white or pinkish gypsum, usually irregularly bedded with interstratified red clay shales. The thickness varies up to 115 feet. Green (1936, pp. 1473-1475) stated that the Cloud Chief formation consists of a sandstone in which the gypsum facies occur as lenses. The formation has a maximum thickness of 300 feet. Well logs at the type locality show that the basal gypsum is 100 feet thick. The greatest problem is in the correlation of the dolomites.

Day Creek Dolomite

Original description: The Day Creek dolomite was named by Cragin (1896, p. 44) from exposures at the head of Day Creek in Clark County, Kansas, and described as follows:

The Day Creek dolomite is a persistent stratum of dolomite, varying from less than a foot to five feet or more in thickness * * * It is a true dolomite, containing with the carbonate of lime an equal or even greater percentage of carbonate of magnesia. The stone is nearly white in fresh fracture, weathers gray, and often has a streaked and gnarly grain crudely resembling that of fossil wood. It is more or less cellular and in places, cancellated. Irregular nodules of limonite are here and there imbedded in it.

Other descriptions: Gould (1924, p. 337) wrote that the thickness varies up to 5 feet and occasionally there are two distinct ledges of dolomite 2 to 4 feet thick which are separated by red shales. Clifton (1930, p. 170) stated that there are wide lateral variations in the mineral content of the Day Creek. In the shoreward areas both calcite and dolomite are present with chert or flint as an important secondary constituent. Basin-ward the dolomite gives way to gypsum and the chert content decreases or entirely disappears. Evans (1931, pp. 425-426) wrote that the Day Creek dolomite is a 2 foot thick, hard, light gray limestone or dolomitic limestone, which commonly contains aggregates of

smoky or reddish chert. Merritt and Hamm (unpublished Oklahoma Geological Survey report, 1942) described an outcrop of the Day Creek dolomite in the SW 1/4 sec. 18, T. 28 N., R. 22 W. as a 2½ foot thick ledge of white, dense, crenulated dolomite with strongers and irregular masses of bluish botryoidal chalcedony. Thin section study showed that considerable quartz is present in three forms: (1) euhedral, 0.25 to 0.4 mm. long, partially replaced by calcite; (2) anhedral in cavities associated with secondary calcite, with which it seems to be at least in part contemporaneous; and (3) chalcedonic silica replacing carbonate and euhedral quartz.

History of usage: Gould and Lewis (1926, p. 24) suggested that the Day Creek dolomite might well be considered the basal part of Gould's Cloud Chief. Sawyer (1929, p. 12) stated that the Cloud Chief overlies the Whitehorse and underlies the Quartermaster and that Cragin's Day Creek has been applied to the Weatherford dolomite, the Greenfield dolomite, and the Quartermaster dolomite. Clifton (1930, p. 172) believed that the Cloud Chief as a formation name should be dropped and that a new formation name be adopted to include beds from the base of the Day Creek to the base of the Quartermaster. It would include the Day Creek, the

Hackberry, the Big Basin, and the beds overlying the Big Basin to the base of the Quartermaster. Evans (1931, p. 420) stated that the Cloud Chief is a member of the Whitehorse formation. The base is a double gypsum bed and the top underlies the Day Creek. Buckstaff in the discussion of Evans' paper did not believe that Evans had proved his interpretation of the stratigraphic relationship. Sellards (1933, p. 179-180) placed the Cloud Chief above the Whitehorse and below the Quartermaster. Green (1936, p. 1473) included the Cloud Chief as the basal member of the Quartermaster formation. Miser (1954) stated that in northwestern Oklahoma the Day Creek is the basal member of the Cloud Chief.

Distribution: The Cloud Chief formation occurs as isolated outliers in north-central, central, and southeastern Harper County. The outcrops are generally less than a mile wide and form the divides between the Cimarron River and Buffalo Creek and between Buffalo Creek and Beaver River.

Character and thickness: The Cloud Chief formation is predominantly a dark maroon shale with one or two thin gypsum beds and the Day Creek dolomite at its base. The Day Creek consists of a single bed of pale-gray to pink dense fine-grained dolomite with a thickness of about $2\frac{1}{2}$ feet. In

many localities the member contains chert nodules and finely disseminated chert which is commonly blue to purple in color. Over much of Harper County the Cloud Chief formation is the uppermost rock and most of it has been removed by erosion. Its presence is due to the resistant basal Day Creek dolomite which has prevented its entire removal. The maximum thickness is 30 feet.

Age, correlation, and fossils: The Cloud Chief formation is in the Ochoan series of the Permian and can be correlated with the Taloga formation and Day Creek dolomite of Kansas. No fossils have been found in Harper County.

C R E T A C E O U S S Y S T E M

COMANCHE SERIES

K i o w a S h a l e

The name Kiowa shale is applied in Harper County to the Cretaceous sandstones and shales unconformably overlying the Cloud Chief formation. This formation consists of black to yellow resistant sandstones and thin white somewhat chalky limestones. It crops out as widely scattered outliers and is overlain by Quaternary sand dunes. The maximum observed thickness is 52 feet.

Original description: The Kiowa shale was named by Cragin (1895, p. 70) for outcrops in Kiowa County, Kansas, and was described as follows:

The designation, Kiowa shales, is proposed for the inferiorly dark colored and superiorly light colored shales that outcrop in several of the counties of southwestern Kansas, resting upon the Cheyenne sandstone in their eastern and upon the "Red Beds" in their middle and western exposures, and being overlaid by brown sandstone of middle Cretaceous age, or Tertiary, or Pleistocene deposits according to the locality.

The Kiowa shales are a locally modified northern extension of part of Hill's Comanche series, cut off from the main part by erosion. They are named for the place of their typical occurrence, Kiowa County, Kansas. The fossils

of the shales are chiefly those which, in Texas, are common in the Fredericksburg division (Comanche series).

Other description: Bullard (1928, p. 56) gave the following description of the Kiowa shale in Harper County, Oklahoma:

The Kiowa shale consists typically of thinly laminated black shale grading into a yellowish clay in the upper part. The black shale of the lower portion of the Kiowa is especially characteristic consisting of very thinly laminated, paper-like shale. The upper portion contains more lime and has a distinctly yellow color, standing out in marked contrast to the lower portion. There are numerous thin layers of soft yellowish sandstone, particularly in the upper part. The formation contains throughout thin limestone layers, almost a fossil coquina consisting of fragments of oyster shells. Fossils are exceptionally abundant, occurring in the limy and sandy layers through the formation. The black shale rarely contains fossils.

History of usage: Marcou (1858, p. 17) applied Neocomian age to the fossiliferous beds in western Oklahoma because the fossils were characteristic of beds of Neocomian age in Europe. Gould (1905, p. 78) stated that the outliers in western Oklahoma are remnants of the Comanche beds which extend from Texas to Kansas. Bullard (1928, p. 73-74) correlated the outliers in Harper County with those of the Kiowa of Kansas.

Distribution: The Cretaceous outliers of western Oklahoma extend from the Avilla Hills on the Kansas line southward to within a few miles of the Wichita Mountains. Small isolated outcrops occur in Harper County in secs. 6 and 24, T. 26 N., R. 23 W. A disconnected series of outliers extends from sec. 17, T. 25 N., R. 23 W. in an easterly direction to secs. 11 and 12, T. 25 N., R. 21 W.

Thickness and character: The Kiowa shale consists of gray to black thinly laminated shale grading into a yellow clay interbedded with yellow sandstone and sandy conglomerate. The basal portions contain many fragments of the Permian red beds. Pebbles of the conglomerate are black iron-stained sandstone grading in size up to a foot in diameter. Fossils are exceptionally abundant, occurring in both limy and sandy layers and in places forming a limy coquina. Selenite gypsum crystals are abundant in some of the black shales.

Outcrops occur on the divide between Buffalo Creek and Beaver River. A prominent north facing escarpment with the Kiowa shale exposed on the crest is formed by the Day Creek dolomite overlying the soft easily eroded Whitehorse formation. Recent dune sand from Beaver River covers the southern edge of these southward dipping beds.

In Harper County erosion has removed most of the once extensive Kiowa shale, leaving a few isolated outliers. The maximum measured thickness is 52 feet located in sec. 14, T. 25 N., R. 22 W.

Age, correlation, and fossils: According to Bullard (1928, p. 73) the outliers in Harper County are correlative directly with the Comanchean Kiowa shale of Kansas. There are two important fossiliferous horizons common to the two main areas, a Cyprimeria zone and a Gryphea corrugata zone. Other fossils are Exogyra texana, Trigonia sp., Turritella sp., Oxytropidoceras belknapi, and Gryphea navia.

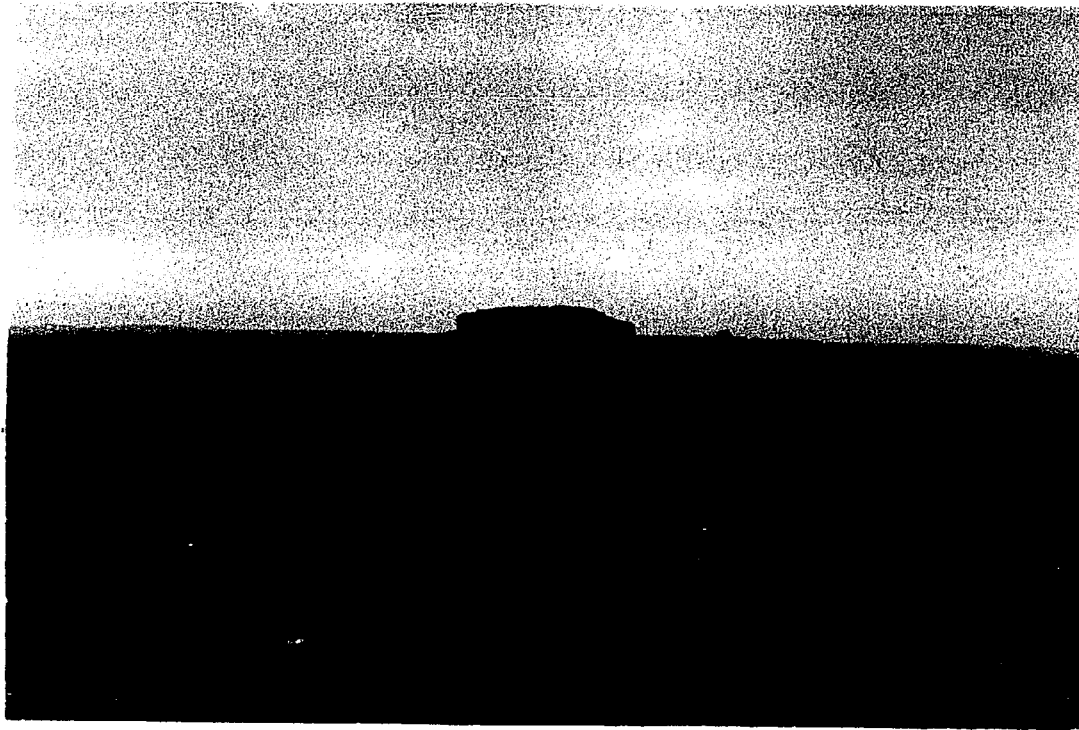


Figure 10. Cretaceous outlier of Kiowa shale. Section 7, T. 25 N., R. 21 W.

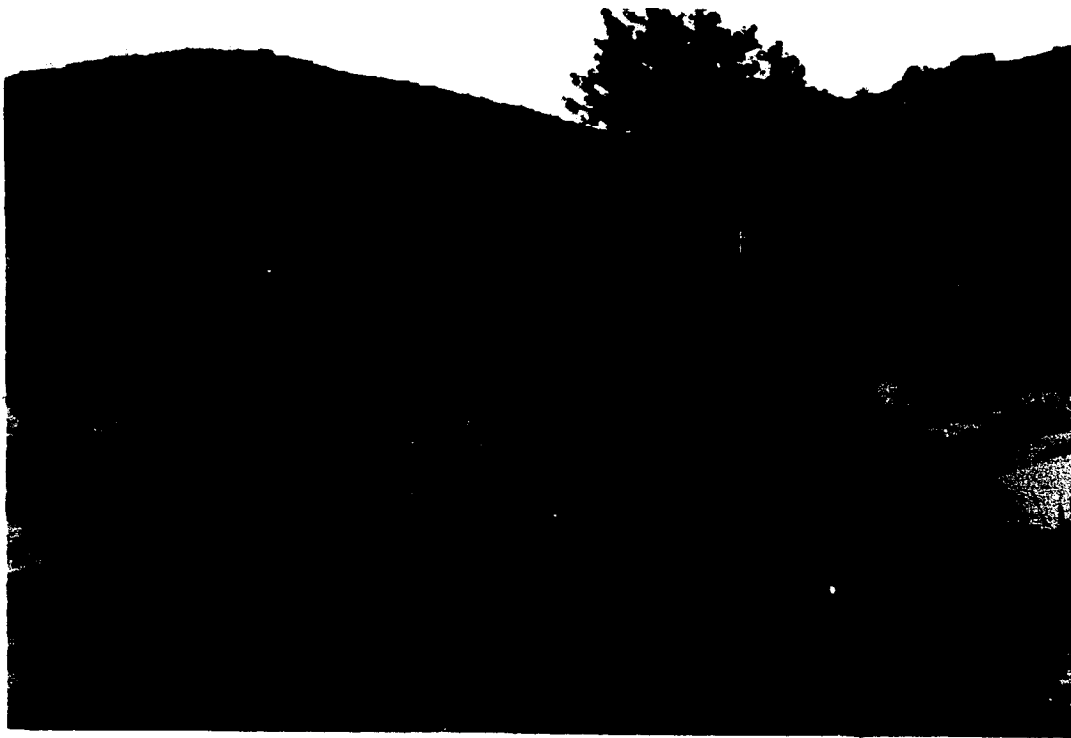


Figure 11. Closeup of Kiowa shale.
Section 7, T. 25 N., R. 21 W.

T E R T I A R Y S Y S T E M

PLIOCENE SERIES

Only rocks of the Pliocene series of the Tertiary system are present in Harper County, Oklahoma. As used in this report the Pliocene series includes the Laverne formation and the Ogallala formation.

L a v e r n e F o r m a t i o n

The Laverne formation consists of resistant interbedded limestones, shales, sandstones, and conglomerates. In Harper County it is unconformable above the Whitehorse formation and is covered in a few places by Pleistocene outwash and dune sand deposits. Its exposed thickness in Harper County varies from 0 to 35 feet, but is known to be as thick as 500 feet in the subsurface on the Stevens - Seward county line in Kansas.

Original description: The Laverne formation was named by Waite and it is assumed that the type locality is in the vicinity of Laverne in Harper County, Oklahoma. The original manuscript has been lost, but Gould and Lonsdale (1926, p. 33) gave the following description of the Laverne formation which is an excerpt from Waite's manuscript:

The limestone of this formation varies from a pure white to a buff-colored limestone that has a conchoidal fracture. This member is prolific with fossils. Mollusca occur in great abundance. Bones and teeth are very often found. A great many leaves of many varieties are found in the buff-colored limestone.

Other descriptions: Smith (1940, pp. 37-38), Frye and Hibbard (1941, p. 398), Frye (1942, pp. 94-97), and Byrne and McLaughlin (1948, pp. 68-72) have described the Laverne formation in Kansas as dipping beds of gray, fine grained, thin-bedded sandstone, chalky sandstone, sandstone containing conglomerate, blue gray to tan even-bedded shale, and tan soft silty limestone which typically contains a thin bed of gray dense limestone at the top. Schoff (1956, p. 3) gave the following description of the Laverne formation:

The formation consists of sand, gravel, caliche, limestone, silt, and clay, most of which are not readily distinguishable lithologically from other Tertiary beds. Beds are gray, blue-gray, tan, yellow, pink, maroon, light green, and white. The distinctive beds in the formation are soft, massive, sandy chalk (or chalky sandstone), hard fossiliferous gray to white limestone, hard carbonaceous limestone, and coaly shale, but all exposures do not include such distinctive beds. No bed or group of beds is sufficiently persistent laterally to serve as a stratigraphic marker within the formation, and no subdivisions of the formation have been proposed.

History of usage: Gould and Lonsdale (1926, p. 33) followed Waite's usage. Gould (1927, p. 238) declared the

name obsolete, but later workers brought it back.

Distribution: The Laverne formation crops out in northwestern Ellis, southwestern Harper, eastern Beaver, and southwestern Texas counties, Oklahoma, and in Meade and Seward counties, Kansas. Younger rocks probably cover it in much of Seward, Haskell, Stevens, and Grant counties, Kansas, and in western Beaver County, Oklahoma. Surface exposures of the Laverne formation in Harper are located in the southern half of T. 26 N., R. 26 W., all of T. 25 N., R. 26 W., and most of the southern and western three-quarters of T. 25 N., R. 25 W.

Character and thickness: The basal part of the Laverne formation is a coarse conglomerate containing an abundance of black iron-stained pebbles. The conglomerate is not continuous and was probably early basin fillings. Most of the exposures in Harper County consist of interbedded gray to blue-gray sandy chalk, blue-gray to tan shales, gray fine grained thin-bedded sandstone, and massive tan to pink coarse grained sandstone. The rock is well indurated and resistant to erosion. The thickness varies from 0 to 35 feet.

One of the peculiarities of the Laverne formation is that it generally has a dip, up to as much as 15 degrees.

Within one section isolated outcrops frequently dip in different directions. On aerial photographs in many places the Laverne formation is seen as rings, averaging 300 to 400 feet across. Field examination showed the rings to be small structural basins with a resistant limy sandstone forming the rims. The basins are the result of subsidence following the dissolving of the salt and gypsum from the underlying Permian beds. Good examples are in the SW $\frac{1}{4}$ section 16 and SW $\frac{1}{4}$ section 36, T. 25 N., R. 25 N. The basins explain the wide variations in dip in local areas.

According to Frye and Schoff (1942) the Meade basin was formed by fault movement during late Pliocene time (post Laverne, pre Ogallala) causing a deep seated solution of salt and gypsum. Water flowed down the fault, eastward through the Permian beds, and then issued forth as springs along the Cimarron River and Salt Fork of the Arkansas River. As a result of this solution there was subsidence of overlying beds forming the structural basins in the Laverne formation. The process continues today at a much slower rate forming sinkholes and structural basins in the overlying rocks.

In no place is the Ogallala in contact with the Laverne formation. Byrne and McLaughlin (1948, p. 72) suggested



Figure 13. The light colored rock forms the resistant rim of a sink developed in Laverne formation. Automobile is within the sink. SE $\frac{1}{4}$ section 36, T. 25 N., R. 25 N.



Figure 14. Closeup of the Laverne formation.
NW $\frac{1}{4}$ section 23, T. 26 N., R. 26 W.

that either the resistant Laverne formed hills over which the Ogallala was not deposited or that post-Ogallala erosion has removed the latter. The unconformity above the Laverne formation is the greatest break in the sedimentation record of the Pliocene and Pleistocene as horizontal Pleistocene beds rest on the Laverne which has dips as great as 15 degrees.

Age, correlation, and fossils: The Laverne formation is considered by most workers to be early Pliocene in age; however, it is possible that it might be late Miocene at least in the lower part. Schoff (1956, p. 4) stated that it correlates approximately with the Valentine formation of the Ogallala group, but that the U. S. Geological Survey has not accepted the Valentine formation.

The Laverne formation in Oklahoma is the equivalent of the Laverne formation in Kansas.

Chaney and Elias (1938, pp. 1-72) have described the flora and have included a chapter by Hesse describing the vertebrates. Hibbard (personal communication, 1956) has identified horse teeth from the SW $\frac{1}{4}$ sec. 10, T. 25 N., R. 26 W. as typical Laverne horses as reported by Hesse (1936).

O g a l l a l a F o r m a t i o n

The Ogallala formation in Harper County includes sand, silt, and gravel of middle Pliocene age. It unconformably overlies late Permian beds and is overlain by Pleistocene and Recent material.

Original description: Darton (1899, p. 734) named the Ogallala formation, designated the type locality as near Ogallala station in western Nebraska, and gave the following description:

Extending from Kansas and Colorado far into Nebraska, there is a calcareous formation of late Tertiary age to which I wish to apply the distinctive Name Ogalalla [now spelled Ogallala] formation * * * In its typical development the Ogalalla formation is a calcareous grit or soft limestone containing a greater or less amount of intermixed clay and sand, with pebbles of various kinds sprinkled through it locally, and a basal bed of conglomerate at many localities * * * The pebbles it contains comprise many crystalline rocks, which appear to have come from the Rocky Mountains * * * The general thickness of the Ogalalla formation varies from 150 to 300 feet, the greater amount being along the Wyoming line in the northwestern corner of Kimball County.

Other descriptions: Elias (1931, 1942, and 1948) stated that the Ogallala formation at the type locality is poorly sorted, always somewhat pinkish, and the "mortar beds" form prominent escarpments. The upper limit is a

persistent hard algal limestone precipitated largely by the agency of Chlorellopsis bradleyi which was probably deposited along the shores of lakes on the flat fluviatile sediments. Except for the uppermost part, fossil herbaceous seeds provide a means for zoning. Lugn (1939, pp. 1260-1263) assigned the rank of group to the Ogallala of Nebraska with four formations (in ascending order): Valentine, Ash Hollow, Sidney, and Kimball. He described the Valentine formation as more or less unconsolidated fine gray sands, 175 to 225 feet thick. The Ash Hollow, the typical "mortar beds," consist of layers of gravel and sand, silt, and fine sandy clay, with some beds of volcanic ash, all more or less indurated into hard caliche beds. The thickness varies from 100 to 150 feet. The Sidney gravel, 15 to 50 feet thick, ranges from fine to medium river sand to pebbles and cobbles, the coarse material generally having a dark coating of mineral and clay. The Kimball formation ranges in thickness from 25 to 50 feet and consists of silt, clay, and fine sand, partly cemented with caliche, with one or two algal limestone beds at the top. In Kansas, according to Frye, Leonard, and Swineford (1956, pp. 51-64), the Valentine member of the Ogallala formation is composed predominantly of fine to medium, relatively well-sorted, gray to greenish

gray feldspathic sand, containing disseminated calcium carbonate and tubules and irregular concretions of opal.

Thickness ranges from 30 to 100 feet. The Ash Hollow member is generally a fine to coarse feldspathic sand, 35 to 200 feet thick, locally with zones of gravel, silt, clay, and volcanic ash. The texture is more uniform than the Valentine member and the color is pink to tan. The Kimball member, except for the basal Sidney gravel lentil, is an ash gray to reddish tan to red-brown feldspathic, richly calcareous, medium to fine sand and silt. The calcium carbonate content increases upward and the upper part is a relatively soft impure limestone locally capped by an "Algal limestone" bed.

History of usage: Elias (1931) and Hesse (1935) proposed a type section at the Feldt ranch (SE $\frac{1}{4}$ sec. 33, T. 14 N., R. 38 W.) approximately two miles east of the town of Ogallala, Nebraska. Lugn (1938, 1939) assigned the rank of group to the Ogallala and divided it into four formations. Moore, Frye, and Jewett (1944) and Moore and others (1951) have classed the Ogallala as a formation in Kansas with three members.

Distribution: The surface of the Ogallala formation forms the High Plains which extends from Texas to South

Dakota, with the exception of Seward and Meade counties, Kansas, and eastern Beaver and northwestern Harper counties, Oklahoma, where early Pleistocene overlies the Ogallala. Outcrops of the Ogallala formation in Harper County form a discontinuous belt from a point about 4 miles south of the northwestern corner to the west central part of the county. In the northwest the formation crops out as a belt about 1/16th of a mile wide overlain by Pleistocene deposits. In the west central part of the county exposures are as much as a mile wide since the younger rocks have been removed by erosion.

Thickness and character: In Harper County the Ogallala formation consists of beds of moderately well-sorted to poorly-sorted sand and gravel, some of which are partially cemented by calcium carbonate. In some areas such as in sec. 18, T. 28 N., R. 22 W. the beds are dark colored and contain an abundance of Cretaceous oyster shells, material probably derived from the Kiowa shale and possibly the Dakota sandstone. More commonly the beds are buff to pinkish arkosic sands with small pebbles of red Permian sandstone. Some layers are well indurated while others are loose sand, locally cross-bedded. Good exposures are in sec. 1, T. 27 N., R. 26 W., and sec. 34, T. 27 N., R. 24 W.

The thickness ranges from 0 to 35 feet.

Age, correlation, and fossils: The Ogallala formation of the High Plains consists of non-marine rocks, Neogene in age (Miocene and Pliocene); however, in Harper County the Ogallala is middle (Hemphillian) Pliocene. Although no continuous beds exist, except for the "Algal limestone," the formation is distinctive from beds above and below and can be traced as a unit. The Ogallala of Harper County can be correlated with rocks of the same name in Texas, Kansas, Nebraska, and South Dakota. Fossil molluccan assemblages, fossil seeds, and other flora have been described in Kansas (Elias 1931, pp. 132-163, and 1942, pp. 9-122 and Frye, Leonard, and Swineford 1956, pp. 28-47) and in Nebraska (Lugn 1939, pp. 1258-1263).



Figure 15. Basal Ogallala gravels.
Section 18, T. 28 N., R. 22 W.



Figure 16. Resistant ledge of the Ogallala formation. NE $\frac{1}{4}$ section 34, T. 27 N., R. 24 W.

Q U A T E R N A R Y S Y S T E M

PLEISTOCENE SERIES

The rocks which were deposited during the glacial and interglacial stages make up the Pleistocene series. These deposits in Harper County are non-glacial and include the Meade group, dune sand, and lake deposits.

M e a d e G r o u p

In Harper County the Meade group includes the fluvial gravels, sands, and silts and volcanic ash that lie above the Pliocene Ogallala formation or above the Permian Rush Springs sandstone or Whitehorse group where the Ogallala is missing. The thickness varies from 0 to 70 feet.

In the mid-continent area the group has been divided into two formations: the Ballard formation below and the Crooked Creek formation above. The Ballard formation has not been recognized in Harper County, but the Crooked Creek formation containing the Pearlette ash lentil is present.

Original description: The Meade formation was named by Cragin (1896, p. 33) for exposures in the immediate vicinity of the old Vanhem post office (NW $\frac{1}{4}$ sec. 13, T. 30 S., R. 23 W.) in Clark County, Kansas. The original description read:

These gravels are mostly unconsolidated, but frequently contain hard ledges in Meade County and elsewhere. They are generally 10 to 30 or 40 feet in thickness and frequently grade into the Pearlette.

Other descriptions: McLaughlin (1946, p. 123) described the Meade formation as a thick deposit of coarse sand and gravel at the base, overlain by red silt and sand which contain abundant nodules of caliche and lenticular beds of volcanic ash.

History of usage: Cragin (1896, p. 53) gave the name "Meade gravels" to sands and gravels laid down in deep and broad valleys near Meade Center, Meade County, Kansas. Frye and Hibbard (1941, p. 411) redefined the Meade formation to include Cragin's Meade gravels and Pearlette ash, Smith's Odee formation, Smith's Equus niobrarensis bed, Smith's Jones Ranch beds, and all other beds of Pleistocene age above the Rexroad member of the Ogallala formation and below the Kingsdown silt, and designated the Pleistocene beds along Crooked Creek valley in sec. 21, T. 33 S., R. 28 W. as the type locality. McLaughlin (1946, p. 123) defined the Meade formation in the same manner as Frye and Hibbard except that he removed the Jones Ranch beds and placed them in the Kingsdown silt. Hibbard (1949, p. 66) restricted the Meade formation to include only the original deposits

designated by Cragin as the "Meade gravels" in the area of the old Vanhem postoffice and the overlying silts and caliche exposed on a tributary of Spring Creek, west of Crooked Creek. He gave the name Crooked Creek formation to the overlying beds below the Kingsdown silt. Frye, Swineford and Leonard (1948, p. 521) restricted the Meade formation to the Pleistocene strata overlying the Ogallala formation in NW $\frac{1}{4}$ sec. 21, T. 33 S., R. 28 W., Meade County, Kansas. This is the type locality of Hibbard's Crooked Creek formation. They introduced the term Blanco formation for the strata which Hibbard had assigned to the Meade formation and the underlying Rexroad formation. At a conference held in Lawrence, Kansas, in June, 1956, the name Meade formation was abandoned. As the Meade formation in many reports included deposits ranging in age from Nebraskan to Yarmouth, and, as it is desirable to divide the Pleistocene into upper and lower Pleistocene for mapping, the name Meade was elevated to group status to include all deposits from the base of the Pleistocene to the top of the Yarmouth sediments. The Meade group in northwestern Oklahoma and southwestern Kansas consists of the Ballard and Crooked Creek formations, the latter the Meade formation of Frye, Swineford, and Leonard (1948) and Frye and Leonard (1952).

The name Ballard formation was proposed to replace the Meade formation of Hibbard (1949 and 1956) and the equivalent part of Frye and Leonard's (1952) Blanco formation. The name Angell member was also proposed to replace the name Meade gravels member of Hibbard's (1949 and 1956) classification.

Distribution: Outcrops of the Meade group are found in Clark, Meade, Seward, Grant, Haskell, and Stevens counties, Kansas, and Beaver and Harper Counties, Oklahoma. The deposits in Harper County crop out as a thin discontinuous belt from the northwestern to the southeastern corner of the county. At this time it is not possible to assign a formational name to the sands and gravels in T. 25 N., R. 20 and 21 W., and so they are mapped as belonging to the Meade group undifferentiated. The beds in the northwestern part of the county belong to the Crooked Creek formation; this dating is made possible by the presence of the Pearlette ash.

Character and thickness: The Meade group consists of deposits of silt, sand, gravel, and volcanic ash. In T. 25 N., R. 20 and 21 W. the beds are mapped as Meade group undifferentiated since there are no known fossils or volcanic ash. The basal portion is coarse grained and well cemented while the upper part is more silty with a few pebbles and contains some consolidated beds, 2 to 5 feet thick. The

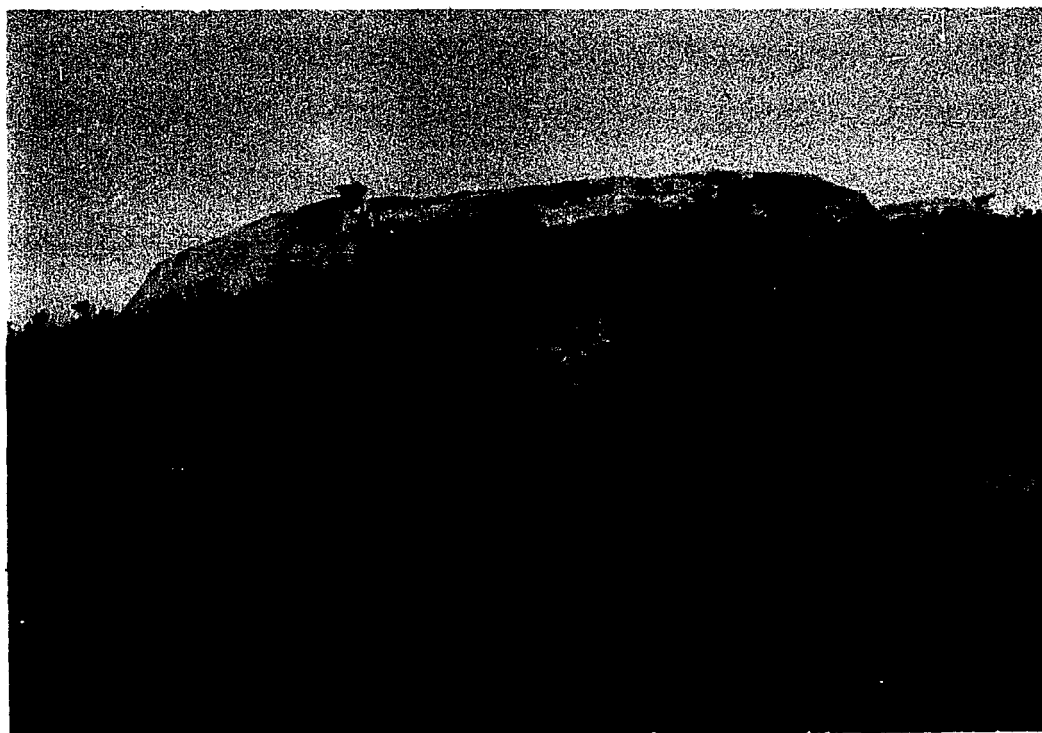


Figure 17. Outcrop of a massive resistant bed of the Meade group. Section 33, T. 25 N., R. 20 W.

sands are generally tan in color whereas the colors of the silt beds range from buff to tan and gray to black. The maximum thickness is 70 feet.

The bank of a Pleistocene stream channel eroded into the Permian Rush Spring sandstone and subsequently refilled is visible in the NE $\frac{1}{4}$ sec. 33, T. 25 N., R. 20 W. Within the old channel are boulders of red sandstone up to one foot in diameter. Pebbles are commonly a black iron-stained sandstone and reworked Cretaceous oyster shells are abundant.

Crooked Creek Formation

The name Crooked Creek formation is applied in Harper County to the gravels, sand, silt, and the Pearlette volcanic ash lentils which unconformably overlie the Ogallala formation and the Whitehorse group and are generally blanketed by post Crooked Creek sand dunes. In Kansas two named members are described: the basal Stump Arroyo member and the Pearlette ash member; but in Harper County the Pearlette ash is the only recognizable unit. The maximum thickness of the formation is 60 feet.

Original description: Hibbard (1949, p. 71) named the Crooked Creek formation and gave the following description of the type locality in S $\frac{1}{2}$ sec. 16, W $\frac{1}{2}$ sec. 15 and N $\frac{1}{2}$ sec.

21, T. 33 S., R. 28 W. on the east side of Crooked Creek,
Meade County, Kansas:

Silt, sand and some clay, tan to buff brown massive. Contains sand and some caliche. The surface at the top of bluff is covered with a rubble of caliche 14.8 feet.

Silt, sandy, gray to tan 5.4 feet.

Clay, with some silt and sand, light gray, massive. Breaks with a conchoidal fracture when dry 4.5 feet.

Silt, clay, and some sand, gray massive, containing a few calcareous nodules (Borchers fauna) 6.4 feet.

Pearlette Ash member. Volcanic ash, pearl-gray, lenticular, somewhat impure 7.1 feet.

Clay, silt and some sand, tan gray and brown gray, massive. Cudahy fauna occurs in top 12 inches and base of ash 9.5 feet.

Sand, silt and coarse gravel, brown, contains abundant nodules. Grades upward into red-brown to reddish sandy silt 8.8 feet.

Stump Arroyo member. Sand coarse, reddish to light tan, and well sorted, containing white quartz pebbles, grading upward into finer more poorly sorted sand, calcareous nodules at top 10.1 feet.

Pearlette Ash Member

The Pearlette formation was named by Cragin (1896, pp. 53-54) from the old postoffice of Pearlette, Meade County, Kansas. He described it as a "wide horizon of white to brownish (rarely greenish) volcanic ash. The ash attains a thickness of 13 feet in a bed southwest of Meade Center,

considerably less in Clark and the many other counties of Kansas (especially western Kansas), Nebraska, etc., in which the ash has been found." Hibbard (1949, p. 71) considered the Pearlette formation of Cragin of member rank in the Crooked Creek formation. At the Pleistocene Conference in Lawrence, Kansas, June 28-29, it was recommended that the Pearlette volcanic ash member be reduced in rank to lentil.

Distribution: Exposures of the Crooked Creek formation crop out in Comanche, Clark, Meade, and Seward Counties, Kansas, and Beaver and Harper Counties, Oklahoma. In Harper County outcrops of the formation form a continuous belt, 1/2 to 3 miles wide, across T. 28 N., R. 24, 25, and 26 W., and T. 27 N., R. 24 W.

Character and thickness: The Crooked Creek formation in Harper County is composed of volcanic ash, clay, sand, and gravel. Some of the sands and gravels are unconsolidated while others are cemented by calcium carbonate to form resistant beds, which are in part cross-bedded. The interstratified clay and sands are thin-bedded and range in color from white to blue-gray to tan. Some of the gravels have a pink cast due to the presence of feldspar pebbles. Nodules of caliche are abundant at various horizons, particularly at the top of sandstone beds and in the clay. The Pearlette

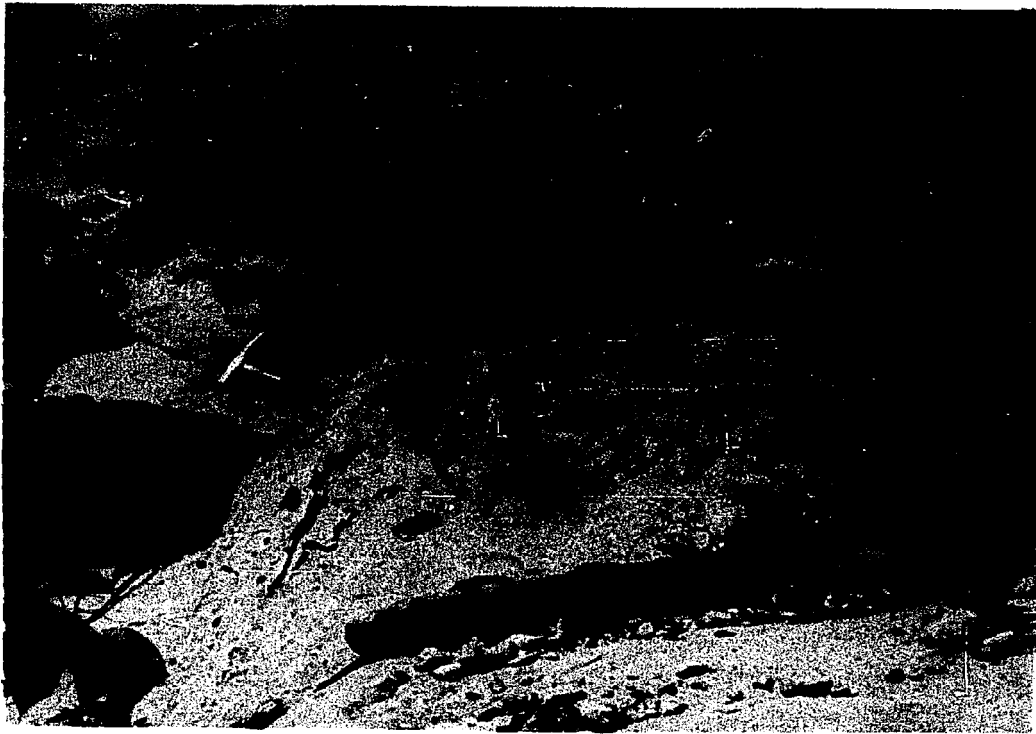


Figure 18. Closeup of the Crooked Creek formation showing cross-bedded resistant bed. NW $\frac{1}{4}$ section 10, T. 28 N., R. 26 W.

volcanic ash forms a 13 foot lenticular bed in the NW $\frac{1}{4}$ sec. 10, T. 28 N., R. 26 W., but is absent elsewhere in the county. The thickness of the formation varies from 0 to 70 feet.

Age, correlation, and fossils: The Crooked Creek formation is Pleistocene in age and is the equivalent of the Kansan-Yarmouth of the glaciated area. Hibbard (1949, pp. 73-77) has described the Cudahy and Borchers faunas from deposits in Kansas. No fossils have been found in Harper County.

D u n e S a n d

The upper Pleistocene sand dunes consist of well sorted, medium to fine grained sand which has been deposited by the wind. The sand of the post Crooked Creek dunes was probably derived from the alluvium of the Crooked Creek and later Pleistocene streams and buries some of the Crooked Creek formation. These dunes cover an area 6 to 8 miles wide south of the exposures of the Crooked Creek formation in northwestern Harper County.

L a k e D e p o s i t s

Twenty small isolated silt and clay deposits, unconformable above various Permian beds and also above the

Pleistocene Crooked Creek formation have been mapped in Harper County.

These upper Pleistocene deposits average 500 feet in diameter and 8 to 15 feet thick. They are composed predominantly of gray silt and clay which is more or less homogeneous throughout its thickness, but in places grades into a black silt. The material was derived locally and deposited in fresh water lakes which were probably small shallow sink-hole depressions.

Mollusk shells were found in all deposits and a few scutes of an extinct armadillo were found in the NW $\frac{1}{4}$ sec. 13, T. 28 N., R. 22 W. Taylor and Hibbard (1955, pp. 1-23) described the Bar M local fauna from the deposits in NW $\frac{1}{4}$ sec. 13, T. 28 N., R. 22 W. and SE corner sec. 14, T. 26 N., R. 23 W. in Harper County and considered it of Illinoian age. They tentatively correlated the Bar M local fauna with the Berends fauna which was found in the adjacent township in Beaver County. The isolated deposits of clay, silt, and re-worked ash are present in sec. 5 and 6, T. 5 N., R. 28 ECM. of Beaver County, Oklahoma. These beds were laid down in a large sink or series of sinks and are approximately the age of basin deposits in Meade County, Kansas, which are considered to belong to the base of the Kingsdown formation and

probably Illinoian in age. Mengel (1952) described a white pelican, Rinker and Hibbard (1952) a beaver and associated vertebrates. Taylor (1954) proposed the name Berends fauna for the vertebrates and mollusks from these deposits. Smith (1954) described the fish fauna and Starrett (1956) described some new mammals and compiled a complete list of the mammals of the Berends fauna.

Taylor (1954, p. 8) and Smith (1954, p. 288) postulated that the Berends local fauna existed at a time of cool moist climate. Taylor and Hibbard (1955, pp. 6-7) stated that the Bar M local fauna indicated a climate with summers like those of North Dakota, and with winters no colder and perhaps warmer than those of northern Kansas.

Taylor (personal communication) considered the mollusks from Dobey Spring, sec. 10, T. 27 N., R. 24 W. to be the same age as the Berends fauna. Hibbard (personal communication) has identified the mammals and found the muskrat is more advanced than the Ondatra from the Berends fauna.

Probably the Berends is early Illinoian and the Dobey Spring is late Illinoian or early Wisconsin.

Since these deposits are not continuous and the faunal assemblages are comparable it is difficult to correlate and assign all of them to particular glacial or interglacial

stages. It is possible that all the basin deposits were laid down at about the same time, but each basin is different and presents its own problems; however, because of the similarity in the sediments and faunal assemblages, all of these deposits in Harper County are tentatively assigned to the Illinoian stage.

RECENT SERIES

Terraces, alluvium, and dune sand have been deposited in Recent time since the retreat of the Wisconsin glacier.

T e r r a c e a n d A l l u v i u m

Alluvium consisting of the gravel, sand, and silt or clay deposited by streams in Recent geologic time underlies the floodplains of present streams. It is generally thickest near the middle of a valley, and usually is thicker along major streams than along small creeks.

Terrace deposits also consist of material laid down by streams in late geologic time, but are somewhat older than alluvium. Since the time of deposition the streams have cut to a lower level. The terrace deposits are adjacent to and topographically higher than present streams and their alluvium. A large terrace is present in T. 26 N., R. 25 W. and represents material deposited by the Beaver River. The

thickness of the sand and gravel in this terrace is 97 feet as shown by driller's logs on file with the Ground Water Branch of the U.S.G.S. in Norman, Oklahoma. Much of this material is probably alluvium filling a large sinkhole basin.

D u n e S a n d

Recent sand dunes consist of well sorted, medium to fine grained sand derived from the alluvium of the present day streams, and border the north sides of the Cimarron River, Beaver River, and part of Buffalo Creek. The dunes along Beaver River form a band 2 to 8 miles wide and overlap the earlier Pleistocene dunes, as well as Crooked Creek, Meade, Ogallala, Whitehorse, Rush Springs, and Kiowa rocks. Those along Buffalo Creek average one mile wide and cover the Whitehorse and Dog Creek formations. North of the Cimarron River in the northwest corner there are dunes on the floodplain. The major portion of this belt of dunes is in Kansas. Two small isolated deposits of dune sand are located north of Sand Creek and an unnamed creek in the southwestern part of Harper County.

G E O L O G I C H I S T O R Y

PERMIAN AND CRETACEOUS HISTORY

The interpretation of the geologic history of the Permian is based primarily on "The Rhythm of the Permian Seas" by J. M. Hills (1942). The Cretaceous history follows the work of Bullard (1928).

Hills (1942, p. 230) makes a distinction between seas of different salinities as reflected by the chemical composition of their sediments. Marine seas are those where there are deposits of black to gray sands and shales, gray limestones, and brown to buff dolomites. Saline seas include areas where there are evaporite sediments which include anhydrite, halite, and potash salts. Brackish seas are the near-shore areas exemplified by clastics, most of them red. The boundaries between the phases are rather arbitrary because the exact point of transition is difficult to pick.

A recent classification of seas is based upon chlorinity and salinity. Redeke's original classification was related to the chlorinity and Valikangas amended this work and set up a classification based on salinity and chlorinity. Hedgpeth's (1951, p. 50) classification is based upon the

TABLE 6
CLASSIFICATION OF SEAS

Redeke (1922, 1933)	Valikangas (1933)	Hedgpeth (1951)
Cl. o/oo	S. o/oo (Cl. o/oo)	
		<u>Fresh water</u>
Less than 0.1	Less than 0.5(p.2)	("Infrahaline")
		<u>Brackish water</u>
0.1 -- 1.0	0.5(p.2) -- 3.0(2.0)	Oligohaline
		Mesohaline
1.0 -- 5.5	3.0(2.0 -- 8.0(10.0)	alpha (Redeke); meiomesohaline (V ^ä likangas)
5.5 -- 10.0	8.0(10.0) -- 16.5	beta (Redeke); pleiomesohaline (V ^ä likangas)
10.0 -- 17.0	16.5 -- 30.0	Polyhaline
		<u>Marine water</u>
More than 17.0	More than 30.0	("Ultrahaline")

Modified after Hedgpeth (1951, p. 50)

chlorinity and salinity of the water and is presented in tabular form with Redeke's and Välikangas's classification in Table 6.

The most extensive neritic sea of Wolfcampian time had extended across western Texas and western Oklahoma into Kansas between the ancestral Rockies in New Mexico and the mountains occupying the site of the former Llanoria, Ouachita, and Marathon geosynclines. The Amarillo Mountains in the Texas Panhandle and the Wichita Mountains in southwestern Oklahoma were elongate islands athward this sea. Figure 19 shows the lower Permian Wolfcampian sea.

There was a gradual southward retreat of the shallow neritic sea until by late Hennessey time, it was restricted to southwestern Texas. A saline sea extended across the Texas and Oklahoma Panhandles with a brackish sea bordering it to the east. Figure 20 shows the outline of the middle Permian upper Leonardian-lower Guadalupian sea. In Oklahoma and Kansas the lands were apparently low and the fine-grained Salt Plain and Hennessey formations were deposited. The Wichita uplift on the south of this basin and the Ouachita uplift to the southeast were the source for much of the clastic sediments of the Hennessey and Garber formations. The Duncan-Chickasha wedge of clastics which are near-shore

and deltaic brackish sea sediments were derived partly from the Arbuckle uplift and possibly partly from the Wichita and Ouachita uplifts. North and west in the saline sea the Duncan-Chickasha sediments graded into the Flowerpot shale.

Following the deposition of the Flowerpot shale there was a comparatively rapid change in marine conditions with deposition of the basal Blaine gypsum in the marginal saline sea. The middle Permian Guadalupian marine sea with its shoreward saline and brackish portions is shown on map (Figure 21). The lands to the east must have been low because only fine clastic sediments were deposited close to shore. The Wichita uplift and the ancestral Rockies remained elevated and were the source of considerable relatively coarse material on the west side of the basin. Uplifts in the Arbuckle Mountains are related to the fluctuations of the seas resulting in the interbedding of dolomite, gypsum, and shale in the Blaine formation. As the marine sea withdrew, the Dog Creek formation consisting of shales, gypsum, and sand with dolomite stringers was deposited. Conditions were similar to those of Blaine time because in some areas the two formations are so similar that it is not possible to differentiate them.

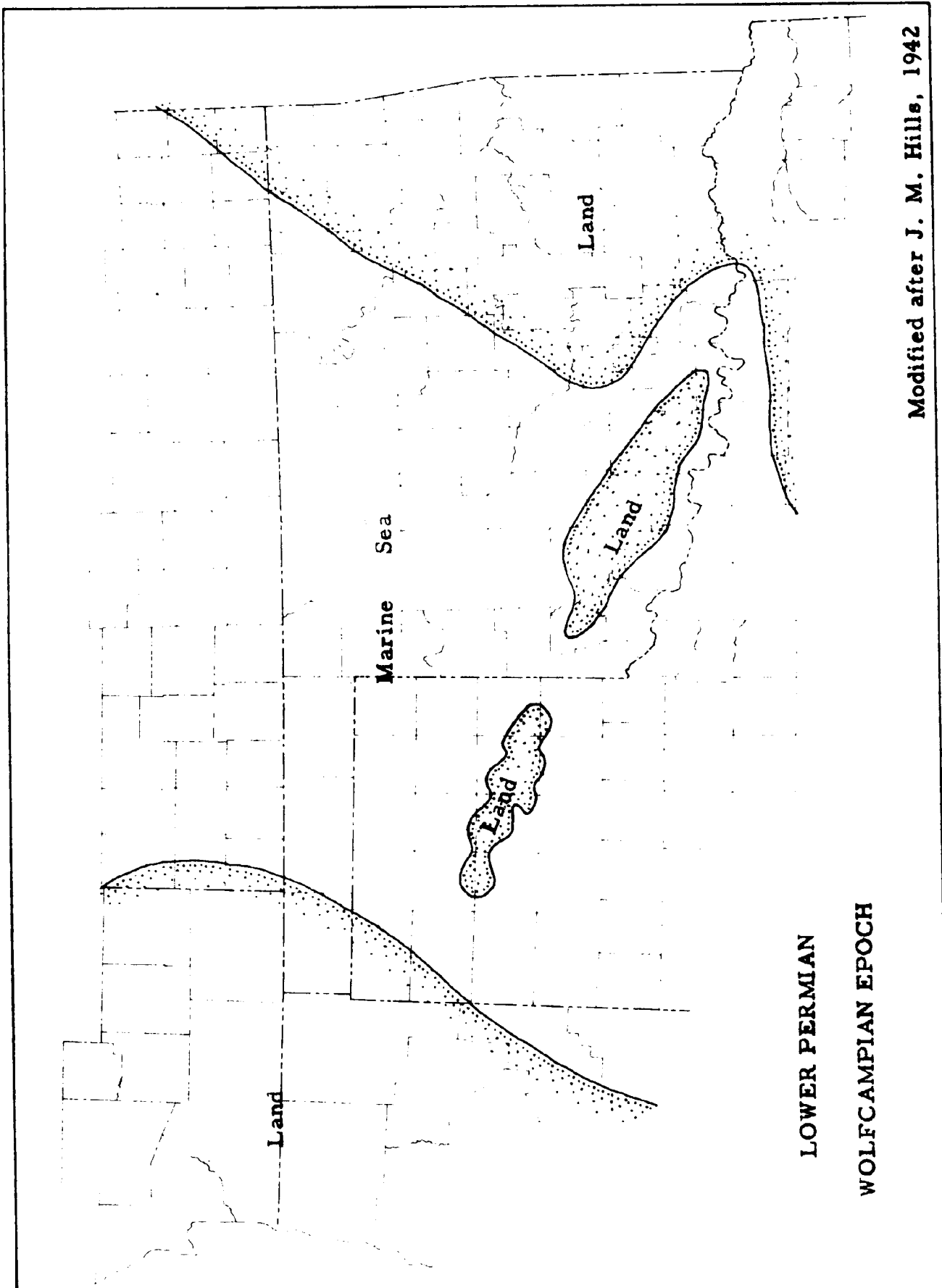


Figure 19

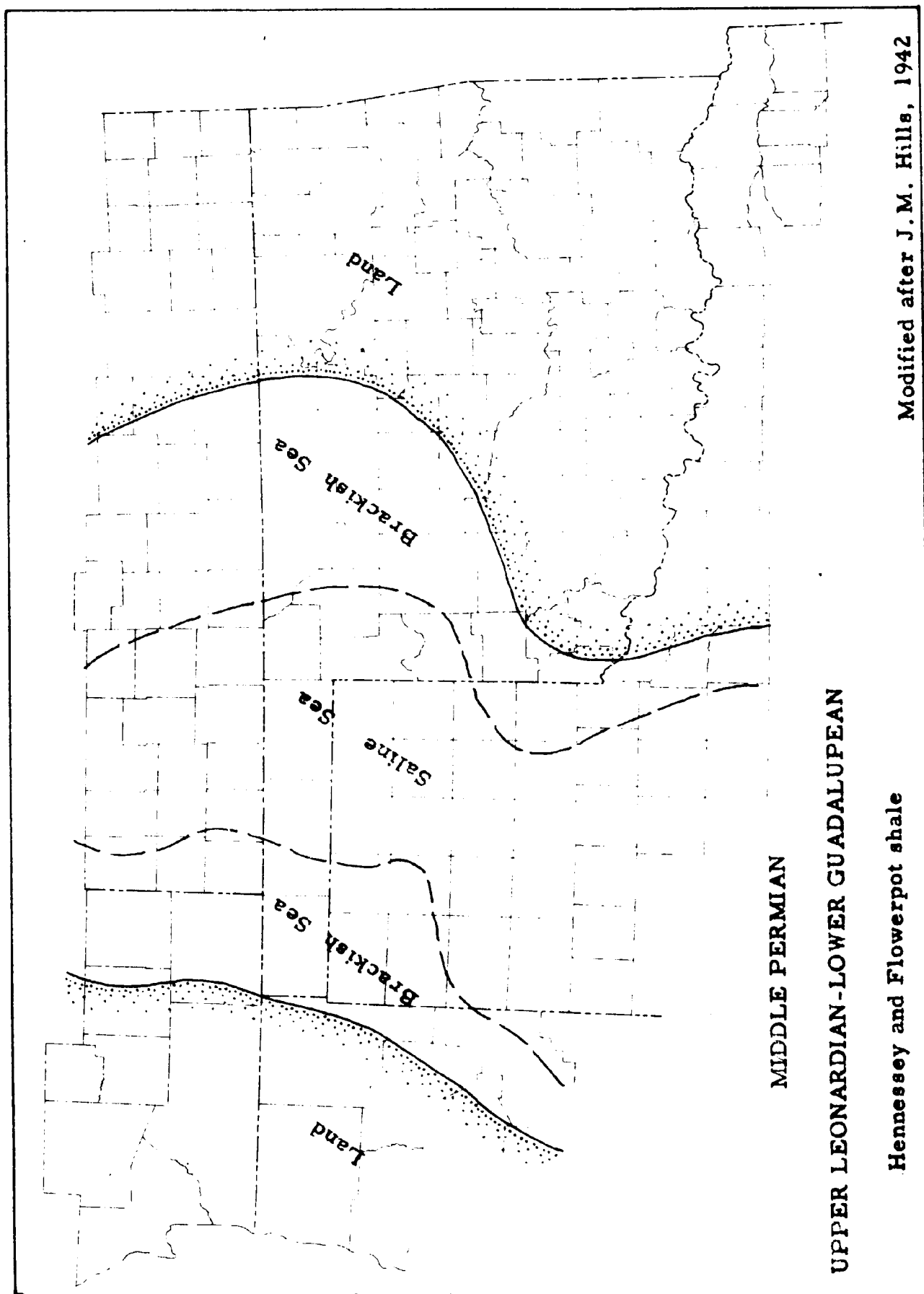


Figure 20

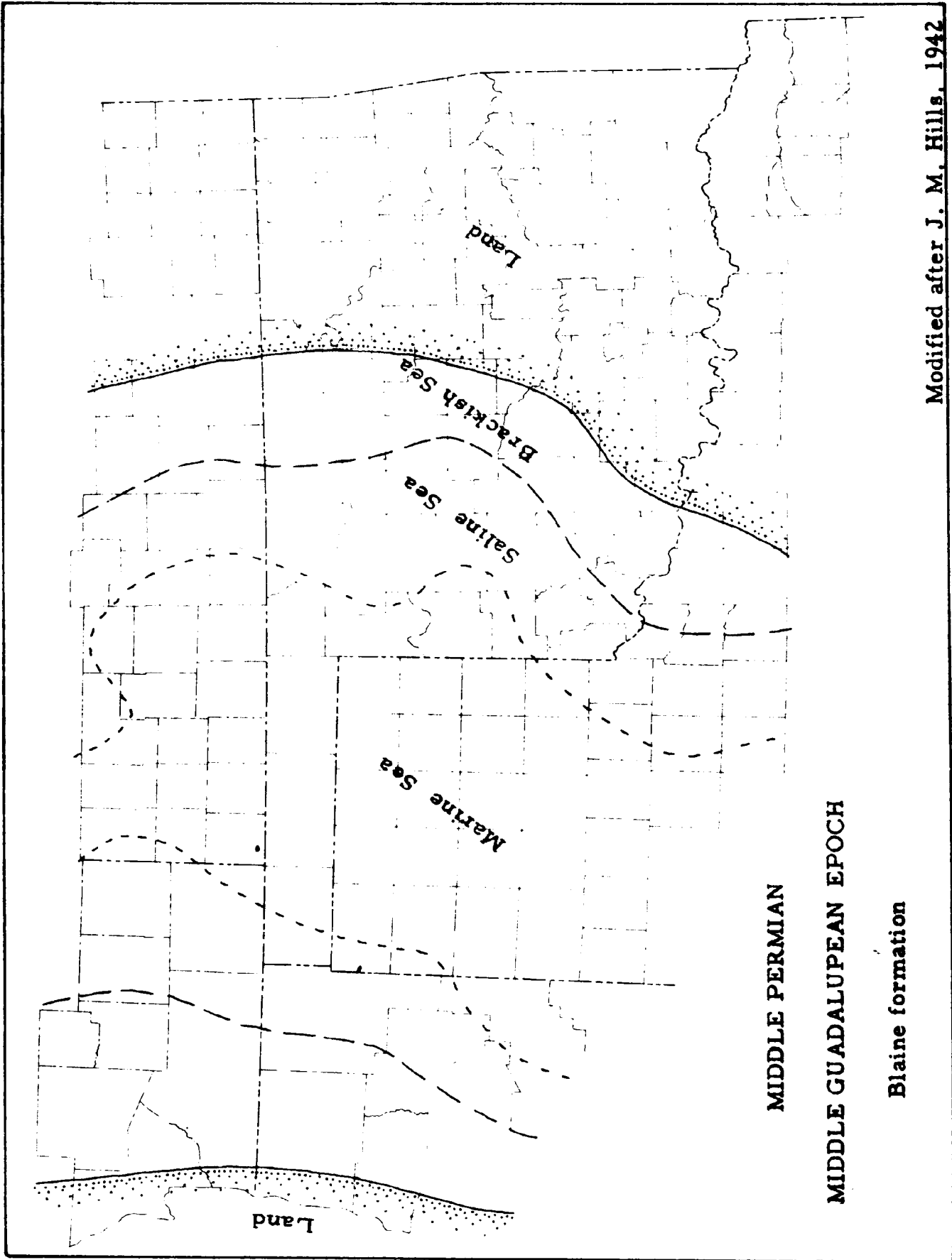
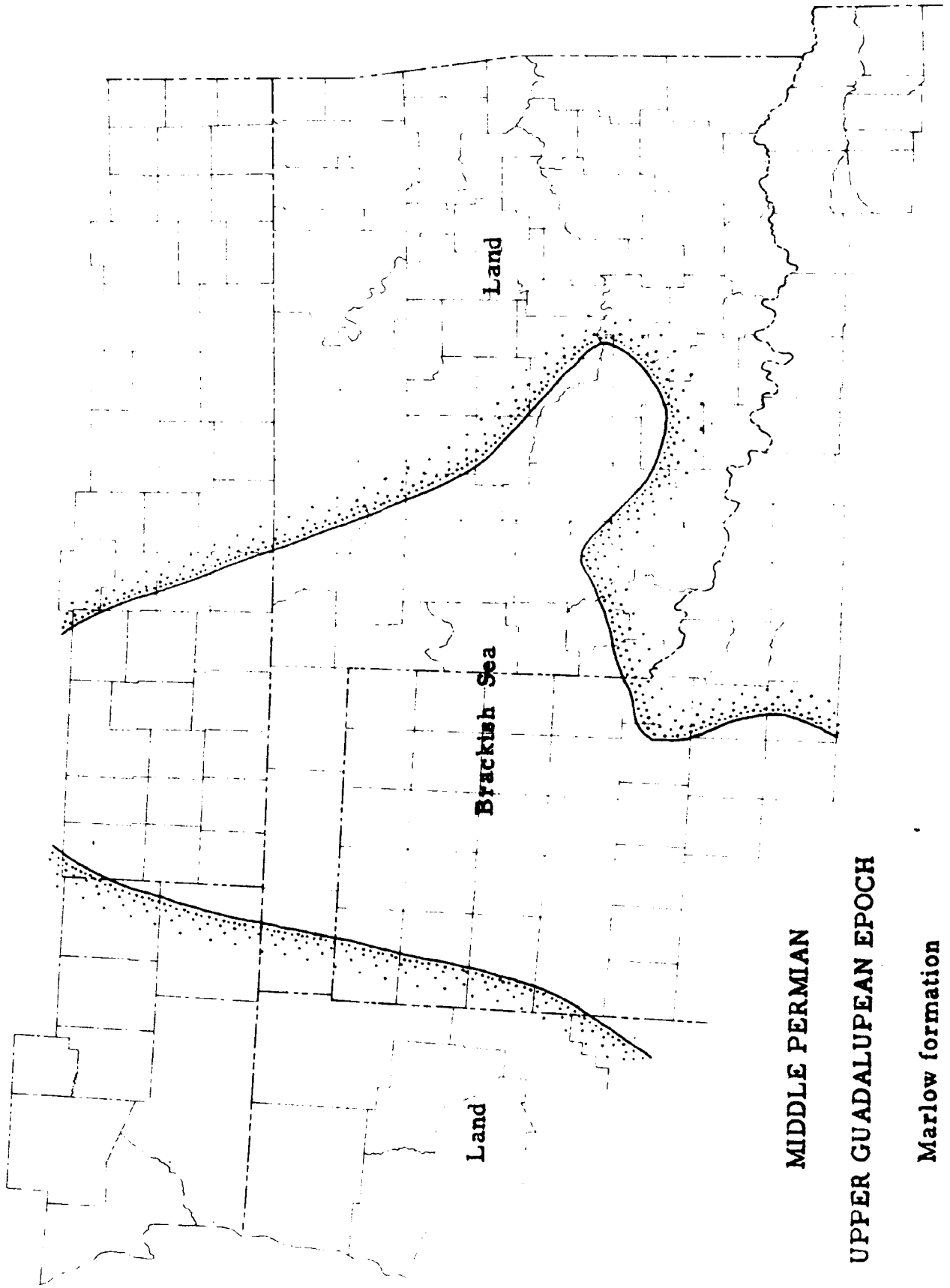


Figure 21

The Whitehorse sediments were deposited in an oscillating sea which formed shallow depositional basins. Some were shallow arms of the sea, some were lagoons, and some were lakes. As a result the Whitehorse formation consists of a series of depositional units of sandstones and shales with gypsum lenses. The Verden sandstone is believed to have been a calcareous barrier beach probably closing the mouth of a bay.

The Marlow formation was deposited in a quiet nearly isolated branch of the sea, surrounded by low deeply weathered lands from which enough fresh water drained to keep the salinity of the water below the evaporite-depositing point. Thin beds of fine clays and sands were deposited at this time. The middle Permian upper Guadalupian Marlow sea occupied the Anadarko basin and probably joined the main Permian basin by a shallow connection (Figure 22). The Marlow sands were derived from the Wichita-Red River uplifts to the south. Streams transported the major portion of these sands, but some was probably wind transported. A retreat of the sea to the main Permian basin and the Delaware basin due presumably to the uplift of the sea floor resulted in a sharp change in sedimentation. The former sea floor was covered with a complex of shifting subaqueous sand and



Modified after J. M. Hills, 1942.

Figure 22

sand dunes which formed the Rush Springs sandstone. Clay and gypsum formed in short-lived saline lagoons which eventually became shallow ponds and small lakes in the Permian desert.

In late Permian time this low topography was once again flooded by a neritic sea. As the sea retreated the water became more saline with the deposition of the Day Creek dolomite and Cloud Chief gypsum. Fluctuations of the climate caused shales to be interbedded with gypsum beds.

During most of the Triassic western Oklahoma was undergoing erosion. The non-marine Dockum red beds were deposited in upper Triassic lower Norian time. This formation is present today in Cimarron and Texas Counties in the Oklahoma Panhandle. If the rocks were laid down in Harper County, subsequent erosion has removed them.

Erosion of western Oklahoma continued through most of the Jurassic. The middle upper Jurassic Kimmeridgian non-marine Exeter sandstone and Morrison formation crop out in Cimarron County, Oklahoma. If these beds were present they were eroded before the Cretaceous seas covered Harper County because the Cretaceous Kiowa shale is unconformable above the Permian Cloud Chief formation.

The last great flood of the interior of the continent

occurred during early Cretaceous time. The Trinity sea overlapped the Ouachita and Arbuckle Mountains, but it is not known whether the sea extended north of the mountains. If Cretaceous deposits were laid down to the north, they have been removed by erosion. During this time there was vigorous erosion with the deposition of conglomerate and coarse sand near shore and finer sediments farther from shore. By Fredericksburg time the land masses had been reduced to areas of low relief and the deposition of limestone predominated.

The lower Cretaceous late Comanchean Washita sea had expanded as a great embayment around the western end of the Wichita Mountains into western Oklahoma and southern Kansas, across the Texas Panhandle into eastern New Mexico and Colorado, and as far north as central Wyoming (Figure 23). The land masses which furnished most of the sediments to this great interior sea were to the north and west. In this shallow embayment oysters grew in abundance and in some areas formed shell beds as much as three feet thick. The size of the shells indicated that life conditions were exceedingly favorable for oysters. Sandstones, sandy conglomerates, and shell beds composed of broken shells, which are interbedded with shale and clay, show that the bottom was within reach

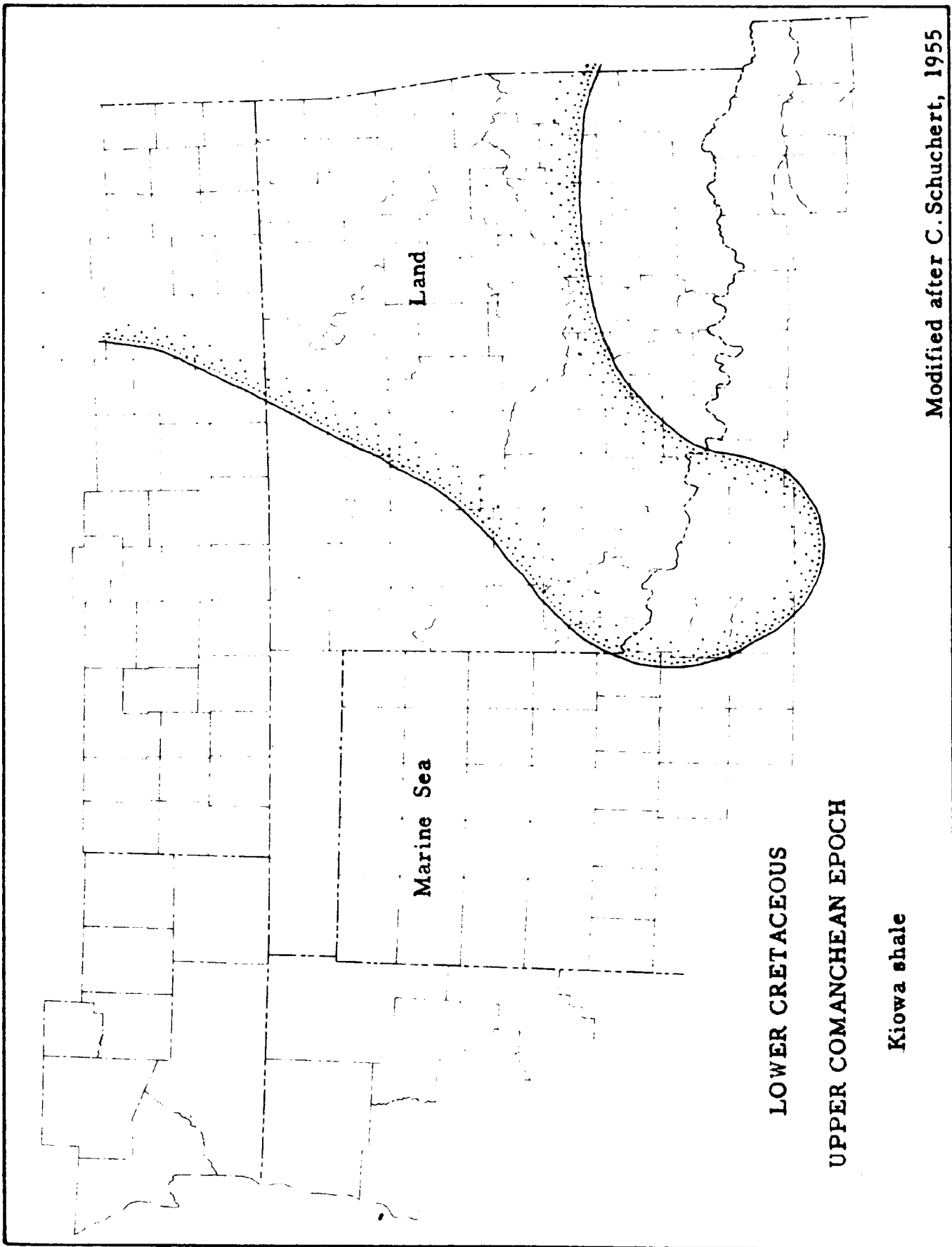


Figure 23

of currents and wave action of an occasional violent storm. The great embayment covering western Oklahoma was of short duration. For most of Washita time the sea slowly retreated to the south with many minor oscillations, but at the close of the epoch withdrew entirely from this region.

The upper Cretaceous Cenomanian-Turonian sea extended from the Gulf of Mexico to the Arctic ocean. The Dakota sandstone, Graneros shale, Greenhorn limestone and Carlile shale were deposited in this sea and outcrops of the Dakota sandstone, Graneros shale, and Greenhorn limestone are present in Cimarron County, Oklahoma. The Niobrara formation was deposited in the upper Cretaceous Coniacian-Santonian (Niobrarian) sea which was a broad embayment from the Gulf of Mexico into Canada. The sea probably covered the Oklahoma Panhandle and may have covered at least the western part of Harper County. The upper Cretaceous Campanian-Maestrichtian sea was a more restricted embayment in which the Pierre shale, Fox Hills sandstone, and Hell Creek formation were deposited. The sea extended from the Gulf of Mexico into southern Canada and probably covered the Oklahoma Panhandle. If any beds of upper Cretaceous age were deposited in Harper County subsequent erosion has removed them.

The Laramide revolution at the close of the Cretaceous caused renewed uplift and folding along the Wichita-Amarillo axis resulting in a series of gentle folds in the Cretaceous and underlying Paleozoic rocks.

TERTIARY AND QUATERNARY HISTORY

During most of Tertiary time Harper County was an area of erosion; however, by late Miocene or early Pliocene time aggrading streams from the Rocky Mountains began to deposit the Laverne formation on a surface of considerable relief. Byrne and McLaughlin (1948, p. 72) reported that test holes indicate the thickness of the Laverne may be in excess of 500 feet. Coarse material was deposited in the lower areas and consists in part of material that was derived locally. Later deposition smoothed the surface and on the floodplains formed some calcareous and diatomaceous lake deposits, which were also interbedded with sands and silts.

The Laverne formation was moderately folded and the folded beds then truncated by erosion (Frye and Schoff, 1942, p. 36). The axis of the fold strikes north-south in north central Beaver County, Oklahoma and southwestern Meade County, Kansas.

The Laverne formation was more resistant to erosion

than the underlying Permian rocks and formed highs while valleys developed in the Permian beds. In middle Pliocene time the streams from the Rocky mountains were once again aggrading streams in northwestern Oklahoma. Deposition of the Ogallala formation took place on the eroded surface, first filling in the lowest part of the valleys. As the valleys filled there was lateral overlapping until the whole surface became a coalescing alluvial plain surrounding the Laverne hills. During this time small ponds were probably common, formed in part by unequal deposition and in part by sinkhole development. These channel and floodplain deposits grade from moderately well sorted gravel to poorly sorted sandy silt and are variable in thickness because of the unevenness of the land surface on which they were deposited. Caliche deposits are common and extensive and indicate that during part of the time an arid climate existed.

The Meade basin of southwestern Kansas was formed by fault movement during Pliocene time. The lower part of the Ogallala formation was cut by the Crooked Creek and Fowler faults during middle Pliocene time. The oldest sinkhole fillings are Pleistocene, whereas the sinks were formed in post middle Pliocene. The sinks are on the upthrow side of the faults, but down dip of the beds and down gradient of

surface streams.

According to Frye and Schoff (1942, p. 38) ground water under hydrostatic pressure moved down the fault to the deep seated soluble Permian beds, then eastward through sandstones and possibly anhydrite, dissolving salt and gypsum, and emerged as salt springs to the east. Sinks formed as a result of the subsidence of surface deposits in places where the underlying beds had been removed by solution. This action which must have been prevalent over a large area has resulted in the Laverne formation generally having erratic dips. Further evidence for the subsidence is the presence of small structural basins 200 to 1000 feet in diameter. As the sinks developed and possibly because of renewed uplift, erosion began.

According to Hibbard (personal communication) the hydrostatic pressure has resulted in upward movement of water through soluble beds. Salt water springs have formed in areas where a sink has broken through to bed rock. Also drilling in area has hit artesian salt water, some wells had a strong flow. Sinks are not common in areas where there is a good cover of Cretaceous shale and clay, but have generally formed where there is exposed Permian or Ogallala overlying Permian without intervening Cretaceous clay and

shale. The Cretaceous has sealed off downward movement of ground water, but circulation takes place where this cover is removed. In section 7, T. 25 N., R. 21 W. sink hole development is reflected in Cretaceous cover where Cretaceous overlies Permian. In some areas the Cretaceous probably stops the formation of sinks, but in other areas lateral movement of ground water may form sinks under a Cretaceous cover.

A period of erosion followed removing any Ogallala that may have been deposited on the Laverne formation. Since the Ogallala and Laverne are not in contact Byrne and McLaughlin (1948, p. 72) suggested that either the resistant Laverne formed highs over which Ogallala was not deposited or that post-Ogallala erosion has removed the latter. The writer believes that it is probably a combination of the two processes.

During the Nebraskan glacial stage of the Pleistocene the melt water streams from the Rocky Mountain glaciers eroded large channels into the older rocks. As the glaciers retreated the competence of the streams was reduced causing deposition of the Ballard formation of the Meade group. Coarse sands and gravels were first deposited and later the finer sands and sandy silts practically filled the channels

and may even have spread out forming floodplain deposits. Sinkhole development continued during this time and some of the deposits are probably fillings of these sinks. The sediments deposited in channels eroded into the Permian in southeastern Harper County may belong to this sequence.

With the advance of the Kansas glaciers in the Rocky Mountains the melt water streams eroded channels into the Pliocene Ogallala and Permian Whitehorse rocks in Harper County. Sinkhole development continued. As the glaciers retreated the Crooked Creek formation was deposited filling the channels, spreading out as a floodplain, and filling sinks. The bedding of the Crooked Creek formation indicates frequent periodic floodings. A wide spread ash fall was carried into local ponds forming the Pearlette Ash lentil of the Crooked Creek formation. At the close of this time the streams were nearly in equilibrium and the Crooked Creek formation had filled the stream channels to the level of the high plains. North winds during late Kansan and Yarmouth time formed sand dunes to the south of the Crooked Creek stream channels.

Late Pleistocene time has been predominantly a period of erosion with sinks continuing to form. During Illinoian time many of the sinks contained ponds which were filled

with material washed into them from the surrounding land. These lake deposits represent a range of time as not all the basins were formed and filled at the same time.

Some large basins such as the Ashland and Englewood of Clark County, Kansas were formed by the coalescing of several small sinks. The Cimarron River developed its channel in these sinks in either Illinoian and/or Wisconsin time. Subsequent erosion has connected many of the smaller localized sinks with the main rivers. The Cimarron and Beaver Rivers eroded deep channels into the Permian rocks and then partially filled them and the sink basins with later sediments. The terrace deposit of the Beaver River in T. 26 N., R. 25 W. is, in part, probably a sink basin filling as are both the Englewood and Ashland basins.

Extensive late Pleistocene and Recent sand dunes have formed on the north sides of Beaver River and Cimarron River.

S T R U C T U R A L G E O L O G Y

Harper County is on the north flank of the Anadarko Basin, which is situated in western Oklahoma, the Panhandles of Oklahoma and Texas, northeastern New Mexico, southeastern Colorado, and southwestern Kansas. It is an asymmetrical basin delimited on the south by the Wichita-Amarillo Mountains, on the north by the Central Kansas Uplift, on the east by the Nemaha Ridge, and on the west by the Sierra Grande-Las Animas Arch (Figure 24). The beds of the north flank dip away from the Central Kansas Uplift and Sierra Grande-Las Animas Arch at approximately 10 feet per mile into the basin. The surface rocks exhibit many minor folds which resulted from sink-hole development. No faults are known in the county. On the truncated Mississippian the Pennsylvanian rocks in Harper County dip south approximately 60 feet per mile.

According to Beebe (1956, p. 120) the Anadarko Basin is a typical zeugogeosyncline with an unstable mobile belt along the steeply-dipping north flank of the Arbuckle-Wichita-Buried Amarillo Mountains, with a deep trough immediately in front of these mountains, a less complex and more gently

dipping north limb, a hingeline on the north flank shown by accelerated dip in the lower Permian and Pennsylvanian, and finally, a broad platform or "shelf" represented by the flanks of the Central Kansas Uplift. The principal axis of the basin is parallel to and north of the Wichita-Buried Amarillo Mountains, and branches into several lesser arms.

The following discussion of the origin of the Anadarko Basin is based upon the work of Wheeler (1955, pp. 22-25). The stable interior of North America was flooded by a northwest invading sea from the Ouachita geosyncline. This Southern Oklahoma embayment reached the Midcontinent region in upper Cambrian time depositing a basal clastic (Regan sandstone) on the pre-Cambrian basement rocks. The region must have sagged considerably in late Cambrian and Ordovician time as evidenced by 6000 feet of Cambro-Ordovician Arbuckle limestone. The marginal sections are thinner, reveal numerous unconformities, and the carbonate rocks tend to be dolomitized and leached by subaerial erosion. By mid-Ordovician time the seas had spread farther into the continental interior and had encountered eolian sand which was redeposited alternately with green clay shales and magnesium limestones (Simpson group). Deposition continued basinward without significant change to early Devonian time; the Viola

limestone, Sylvan shale, and Hunton group were formed during this interval. In mid-Devonian time the entire area between and including the Central Kansas and Ozark Uplifts were differentially elevated. As a result of this tilting the early rocks (Hunton to Arbuckle) were bevelled off to the north and are missing in most northern Oklahoma counties. The truncation evidently reduced the midcontinent region approximately to base level. Subsidence recommenced in late Devonian time and by Mississippian time had advanced northwestward toward the Hugoton embayment. The overlapping Woodford formation was deposited in the basin followed by the argillaceous Caney-Mayes shale and Springer shale.

The first episode of true mountain building commenced along the axis of the southern Oklahoma basin in late Morrow (early Pennsylvanian) time and culminated in late Atoka (early Pennsylvanian) time. The tectonic features formed were the Oklahoma City Uplift, which is the southern segment of the Nemaha Ridge; the Arbuckle Mountains with the Ardmore Basin on the south, and the Wichita-Amarillo Mountain system with the Anadarko Basin on the north. The Wichita-Amarillo Mountain geanticlinal belt formed a mobile borderland with the accumulation of a thick section of sediments in the shallow water of the basin adjacent to the

borderland. Further uplifts moved basinward resulting in subsequent sedimentation moving forelandward. The orogenic forces caused folding (locally overturned) and faulting (locally high angle thrusting).

Erosion must have exposed broad expanses of Pre-Cambrian granite as a great abundance of coarse conglomerate with granite pebbles was deposited around the flanks of the Wichita and Arbuckle Mountains. Granite was carried into the Deese sea which flooded the subsiding Anadarko Basin and even more arkosic sandstone was deposited during Hoxbar time. The sea was slowly advancing northward over the broad expanse of Cambro-Ordovician to Mississippian limestones and reworked the residual limestone debris. Late Pennsylvanian mountain building affected the same axis rejuvenating many of the old domes and faults and creating new ones.

By early Permian time the orogenic belt had been fairly well stabilized by compression and consequent folding. In middle Permian time the Permian Basin of west Texas began to form which changed the direction of tilt in the northwestern part of the basin to the southwest. The basin, more restricted in area than before, subsided slightly with the accumulation of the middle Permian marine deposits that

grade upward into increasingly evaporitic non-marine sediments and red beds of the upper Permian.

At the end of the Triassic there was further tilting of the northwestern part of the basin, but because of the lack of sedimentary record its influence on the basin is unknown. The structure of the northern portion of the northwestern Anadarko Basin was further complicated by northeast tilting during the Laramide Revolution.

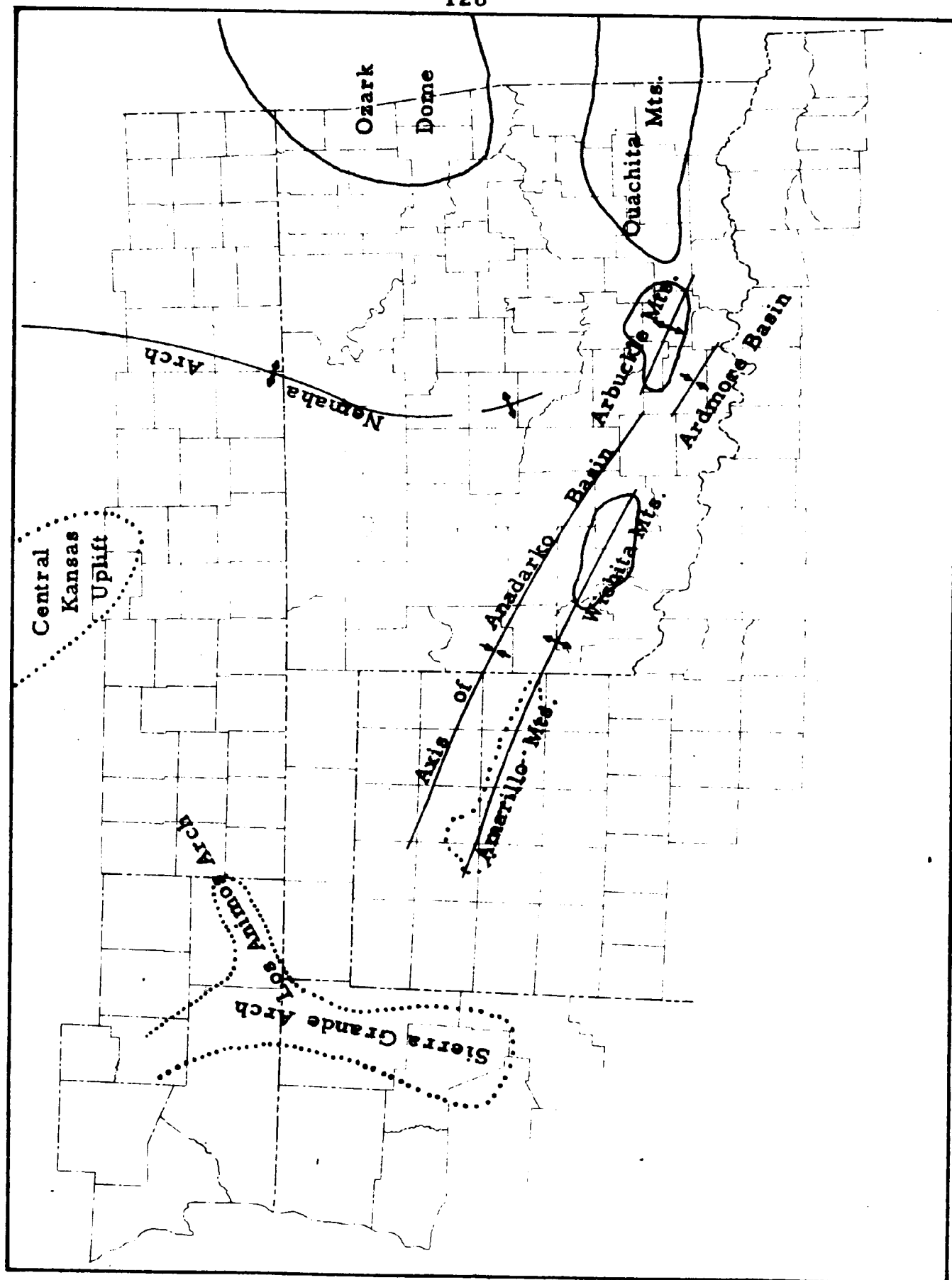


Figure 24. Structural features in Oklahoma and adjacent states.

PALEOZOIC CORRELATION CHART

Midcontinent		U. S. Standard		
Quartermaster		Ochoan	Permian	
Whitehorse		Guadalupean		
El Reno Clearfork Wichita		Leonardian		
Pontotoc	Wolfcamp	Wolfcampian		
	Cisco	Virgilian		
Hoxbar or Canyon		Missourian	Pennsylvanian	
Deese or Strawn		Desmoinesian		
Upper Dornick Hills or Atoka		Atokan		
Lower Dornick Hills		Morrowan		
Springer				
Chester	Caney	Chesterian		Mississippian
Boone		Meramecian		
		Osagean		
Woodford		Kinderhookian		
Hunton	Oriskanian		Devonian	
	Helderbergian			
		Niagaran		Silurian
		Albion		
Sylvan		Cincinnatian	Ordovician	
Viola		Trentonian		
Simpson	Blackriverian			
	Chazyan			
Arbuckle	Canadian			
	Croixan		Cambrian	

M I N E R A L R E S O U R C E S

OIL AND GAS

A total of 44 tests for oil and gas have been drilled in Harper County as of September, 1956; of these, twenty-six have been dry and eighteen are gas and gas distillate wells. Thirteen of these potential producers have been completed during this calendar year.

According to records which are now available, the earliest test for oil was drilled in 1921 by the Buffalo-St. Louis Company on the Tucker land ($N\frac{1}{2}$ $SE\frac{1}{4}$ $SE\frac{1}{4}$ sec. 9, T. 27 N., R. 22 W.) east of Buffalo. It was abandoned as dry at a total depth of 4,070 feet. Apparently no further drilling was done until 1930 when Sinclair Oil and Gas Company drilled their No. 1 Howell (center of $SW\frac{1}{4}$ sec. 14, T. 26 N., R. 24 W.) to a depth of 8,589 feet, the deepest test in the state at that time. This test penetrated some 3,000 feet of Permian, nearly 4,000 feet of Pennsylvanian and 1,600 feet of Mississippian sediments. The well completed in June, 1930, tested 11.1 million cubic feet of gas per day and 65 barrels of gasoline which was piped 4 miles to a loading rack and shipped by tank car. Production was from "Tonkawa" sand

of early Virgilian age at a depth of 5,350 to 5,400 feet.

No more than five tests, all deeper than 7,500 feet, were drilled between 1930 and 1947. The next discovery was made by the J. M. Huber Corporation in September of 1947 in their No. 1 Hieronymus (center of NW $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 3, T. 26 N., R. 24 W.). Production is also from the "Tonkawa" sand and consists of gas and gas distillate. This well is 2 miles north of the No. 1 Howell well.

In March, 1952, Sunray Oil Corporation completed their No. 1 Wolfe (center NW $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 4, T. 25 N., R. 25 W.) with an initial production of 47 barrels of distillate and 5.2 million cubic feet of gas per day in a sand at 7,190 to 7,230 feet in the Morrow series at the base of the Pennsylvanian. This Morrow discovery opened the South Laverne field and sparked leasing and seismic exploration activity in Harper County, which culminated in drilling exploration in 1955 and 1956, with the result that gas and gas distillate production has been found in three additional zones: "Hoover" sand of Virgilian age at approximately 4,150 to 4,200 feet, and two deeper horizons in rocks of Chester-Mississippian age, one of which also contains oil.

At the present time all but one of the wells are shut-in awaiting pipe line facilities. The original discovery

well, Sinclair's No. 1 Howell, has been the source of supply of gas for the towns of Laverne and Buffalo these many years. The accumulative production of this well as of May 1, 1956 was 11,800 barrels of distillate and 1,520 million cubic feet of gas. Lack of market, type of petroleum product, and depth of production have been the main reasons for slow exploration in Harper County.

VOLCANIC ASH

There are two small deposits of volcanic ash in Harper County. At the present time neither is being worked, but there has been production from the deposit in sec. 10, T. 28 N., R. 26 W. The thickness of this deposit ranges from 1 to 15 feet with an estimated area of 25 acres. The average thickness of the overburden is 3 to 8 feet. The deposit in secs. 28 and 33, T. 26 N., R. 26 W. ranges from 1 to 5 feet thick, with an estimate of 10,000 cubic yards. Overburden is 1 to 2 feet thick. An analysis of the ash shows it to be a volcanic glass with a trace of carbonate and anisotropic and feldspar grains (Burwell 1949, p. 45).

The ash was probably carried by the wind from volcanoes in north-central New Mexico to its present site. The deposits are associated with high river terraces and show

evidence of deposition in quiet water, suggesting they were formed as the ash settled from the air into lakes on the flood plains of rivers, with some additional concentration of ash by local run-off into lakes. A fresh water molluscan fauna at the base of some deposits supports the idea of lacustrine deposition. The ash in sec. 10, T. 28 N., R. 26 W. has been correlated with the Pleistocene Pearlette ash lentil of the Crooked Creek formation of Kansas.

GYPSUM

An all-time high tonnage and value of gypsum was recorded in Oklahoma in 1954 with all production from the Blaine formation in Blaine County. Ample reserves of gypsum in workable ledges crop out in Harper County along the Cimarron River and Buffalo Creek. The gypsum is in the Blaine formation and consists of 4 beds which are 25, 13, 13, and 4 feet thick separated by beds of shale.

SAND AND GRAVEL

Sand and gravel has been quarried at several places in Harper County for local use in highway construction. Practically all of the production is from the basal Laverne and basal Ogallala formations.

WATER RESOURCES

In Harper County the Cenozoic deposits are the best sources of ground water. The yield from wells in southwestern and northwestern Harper County ranges from 500 to 1,000 gallons per minute. A belt north of Beaver River yields 50 to 500 gallons per minute. Wells in the Permian yield from 0 to 50 gallons per minute and the water often contains a large concentration of dissolved gypsum.

Springs are common along the contact of the porous Cenozoic rocks and the underlying Permian. One of the largest is Doby Springs (sec. 10, T. 27 N., R. 24 W.) which is the source of water for Buffalo. Laverne, which is located on a Pleistocene terrace deposit, obtains its water from wells drilled into the terrace.

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Figure 26. Composite section of rocks exposed in
Harper County, Oklahoma. (in back pocket)

M E A S U R E D S E C T I O N S

Upper part of the Flowerpot shale and lower part of the Blaine formation in the SE $\frac{1}{4}$ sec. 24, T. 27 N., R. 20 W.

	Feet
Blaine formation	
6. Gypsum (Nescatunga), massive, white	10.0+
5. Dolomite, hard, dense, gray	0.8
4. Shale, red	20.0
3. Gypsum (Medicine Lodge), massive, white	27.0
2. Dolomite, shaly, black	1.0
Flowerpot shale	
1. Shale, gypsiferous, reddish brown	85.0
	<u>143.8</u>

Lower part of the Blaine formation in the NE $\frac{1}{4}$ sec. 29, T. 27 N., R. 20 W.

Blaine formation	
6. Dolomite, dense, gray, pitted and clinker-like as a result of weathering, overlying gypsum removed by solution	1.0
5. Shale, red	9.5
4. Gypsum (Nescatunga), massive, white	11.0
3. Dolomite, dense gray	0.8
2. Shale, red	11.0
1. Gypsum (Medicine Lodge), massive, white	15.0+
	<u>48.3</u>

Upper part of the Blaine formation in the NW $\frac{1}{4}$ sec. 15, T. 25 N., R. 20 W.

Blaine formation	
7. Gypsum (Haskew), massive, pink	3.8
6. Shale, red	4.0
5. Gypsum (Shimer), massive, white	13.0
4. Dolomite, dense, gray	1.5
3. Shale, red	7.0
2. Gypsum (Nescatunga), massive, white	13.0
1. Dolomite, dense, gray	0.7
	<u>43.0</u>

Dog Creek shale in the SE $\frac{1}{4}$ sec. 10, T. 25 N., R. 20 W.

Dog Creek shale

6. Sandstone, fine grained, a $\frac{1}{2}$ inch gray dolomitic bed at top	15.2
5. Clay shale, silty, red	6.6
4. Siltstone, light red	4.5
3. Clay shale, reddish brown	13.0
2. Siltstone, light reddish brown	2.5
1. Clay shale, brownish red	9.0
Blaine formation	<u>50.8</u>

Whitehorse group in the NW $\frac{1}{4}$ sec. 17, T. 25 N., R. 20 W.

Cloud Chief formation

17. Dolomite (Day Creek member), siliceous, white	1.8
---	-----

Rush Springs sandstone

16. Sandstone and shales, thin bedded, red	50.0
15. Sandstone, resistant, red	7.0
14. Shale, red	6.2
13. Sandstone, resistant, red	5.0
12. Shale, red	10.0
11. Sandstone, fine grained, red	2.5
10. Shale, red	13.8
9. Sandstone, resistant, red	5.0
8. Shale, red	15.0
7. Sandstone, resistant, red	6.3
6. Shale, gray	0.5
5. Shale, red	14.5

Marlow formation

4. Sandstone, fine grained, interbedded gypsum, orange red	27.0
3. Sandstone, medium grained, red	4.0
2. Sandstone, fine grained, orange red	6.0
1. Sandstone, cut by $\frac{1}{2}$ inch intersection gypsum stringers, orange red	22.0

Dog Creek shale

196.6

Whitehorse group in the NW $\frac{1}{4}$ sec. 23, T. 25 N., R. 22 W.

Rush Springs sandstone

15.	Shale, gypsiferous, red	8.0+
14.	Shale, thin beds of gypsum, gray	1.0
13.	Shale, red	8.0
12.	Sandstone, coarse grained, red	1.0
11.	Shale, red	3.0
10.	Sandstone, resistant, tan-gray	0.5
9.	Shale, gray	2.0
8.	Shale, red	4.6
7.	Sandstone, resistant, red	3.0
6.	Shale, red	5.5
5.	Shale, gray	2.0
4.	Shale, red	8.5
3.	Dolomite, gray	0.2
2.	Shale, red	1.0
1.	Dolomite, gray	0.3
		<u>48.6</u>

Upper part of the Whitehorse group and the lower part of the Ogallala in the SE $\frac{1}{4}$ sec. 1, T. 28 N., R. 26 W.

Ogallala formation

19.	Sandstone, red sandstone pebbles, tan	6-10.0
Whitehorse group, undifferentiated		
18.	Sandstone, shaly, gypsiferous, red	17.0
17.	Sandstone, red	1.0
16.	Shale, sandy, slightly gypsiferous, red	25.0
15.	Sandstone, red	1.7
14.	Shale, gray	0.7
13.	Shale, red	16.0
12.	Sandstone, thin-bedded near top, red	6.2
11.	Shale, sandy, red	16.4
10.	Sandstone, red	2.0
9.	Shale, red	5.0
8.	Sandstone, massive, red	5.6
7.	Shale, red	6.0
6.	Sandstone, red	8.5
5.	Shale, gray	5.0
4.	Gypsum, white	0.1
3.	Shale, red	5.2
2.	Shale, gray	0.3
1.	Sandstone, red	14.0
		<u>145.7</u>

Lower part of the Cloud Chief formation and part of the Crooked Creek formation in the SE $\frac{1}{4}$ sec. 18, T. 26 N., R. 23 W.

Crooked Creek formation

- | | |
|------------------------------------|------|
| 5. Sand and gravel, unconsolidated | 7.0+ |
| 4. Conglomerate, cross-bedded | 1.0 |

Cloud Chief formation

- | | |
|--------------------------------------|------------|
| 3. Gypsum, white | 0.8 |
| 2. Shale, maroon | 15.0 |
| 1. Dolomite, siliceous, bluish white | <u>1.2</u> |
| | 25.0 |

Lower part of the Cloud Chief formation and part of the Crooked Creek formation in the NW $\frac{1}{4}$ sec. 25, T. 28 N., R. 24 W.

Crooked Creek formation

- | | |
|--|-------|
| 4. Sand and gravel, unconsolidated, caliche nodules | 10.0+ |
| 3. Conglomerate, black iron stained pebbles up to 12" x 4", abundant oyster shells | 1-3.0 |

Cloud Chief formation

- | | |
|---------------------------------------|--------------|
| 2. Shale, maroon | 14.0 |
| 1. Dolomite, siliceous, bluish purple | <u>1-2.0</u> |
| | 29.0 |

Kiowa shale in the SE $\frac{1}{4}$ sec. 14, T. 25 N., R. 22 W.

Kiowa shale

- | | |
|---|------|
| 10. Shale, shell horizon at top, gray to yellow | 8.5 |
| 9. Shale, sandy, yellow | 0.6 |
| 8. Shale, blue-black grading to yellow | 22.0 |
| 7. Shale, sandy, yellow | 4.8 |
| 6. Sandstone, breaks into large blocks, yellow | 1.8 |
| 5. Sandstone, erodes readily, yellow | 1.5 |
| 4. Shale, grades from yellow to black | 6.0 |
| 3. Sand, pebbly, yellow | 5.6 |
| 2. Shale, sandy, gray grading to black | 10.0 |
| 1. Shale, sandy, gray green | 0.8 |

Permian

61.6

Laverne formation in SW $\frac{1}{4}$ sec. 23, T. 26 N., R. 26 W.

Laverne formation

8. Sandstone, gray	0.8
7. Shale, gray	0.2
6. Sandstone, gray	0.3
5. Shale, snail horizon, gray	1.0
4. Sandstone, gray	0.5
3. Shale, gray	1.1
2. Shale, thin bedded, gray	1.3
1. Shale, sandy, snail horizon, gray	<u>2.1</u>
	7.3

Crooked Creek formation in the NE $\frac{1}{4}$ of the NW $\frac{1}{4}$ sec. 10, T. 28 N., R. 26 W.

Crooked Creek formation

7. Clay, sandy, caliche pebbles, gray	18.0+
6. Sandstone, brown caliche pebbles at top, light gray	3.6
5. Sandstone, white	3.0
4. Sandstone, erodes unevenly, buff	23.0
3. Sandstone, resistant, erodes evenly, buff	7.8
2. Sandstone, poorly consolidated, caliche at top, white	4.0

Ogallala formation

1. Sandstone, pink sandstone pebbles, white	1.1
---	-----

Whitehorse group

 60.5
Crooked Creek formation in the SW $\frac{1}{4}$ of the NW $\frac{1}{4}$ sec. 10, T. 28 N., R. 26 W.

Crooked Creek formation

7. Overburden	4-6.0
6. Volcanic ash, gray	13.0
5. Clay, caliche pebbles	23.0
4. Gravel, pink feldspar pebbles give it a pink cast	12.0
3. Conglomerate, cross-bedded, resistant	4.0
2. Gravel	15.0

Ogallala formation

1. Sandstone, small pebbles of pink sandstone, buff

3.5

Whitehorse group

76.5

Crooked Creek formation in the SE $\frac{1}{4}$ sec. 17, T. 28 N., R. 25 W.

Crooked Creek formation

2. Gravel, pink feldspar pebbles, tan pebbles, bone fragments

14.0+

Ogallala formation

1. Sandstone, buff

5.0

Whitehorse group

19.0

Meade group undifferentiated in the NW $\frac{1}{4}$ sec. 29, T. 25 N., R. 20 W.

Meade group, undifferentiated

7. Shale, gray

8.0

6. Shale, tan

1.4

5. Shale, buff

13.0

4. Shale, banded gray and tan

14.0

3. Shale, buff

4.0

2. Shale, black grading into gray

5.0

1. Shale, buff

15.0

70.4

CRAGIN 1896 Kansas		CRAGIN 1897 Northwestern Oklahoma		GOULD 1902 Oklahoma	GOULD 1905 Oklahoma	REEVES 1921 Caddo county Oklahoma	SAWYER 1924 West of Carnegie and East El Reno		GOULD 1924 Southwestern Oklahoma	GOULD 1926 Kansas Oklahoma Texas			
Kiger division	Big Basin sandstone	One Horse gypsum		Quartermaster formation	Quartermaster formation	Quartermaster formation	Quartermaster fm.		Quartermaster formation	Big Basin ss	Quartermaster fm.	Red sandy shales	
		Old Crow gypsum											
	Hackberry shale	Taloga formation		Greer formation	Greer formation	Greer formation	Cyril gypsum	Cyril gypsum	Cloud Chief formation	Hackberry shale	Cloud Chief fm. (Greer)	Gypsiferous red shale	
	Day Creek dolomite												
	Red Bluff formation	Day Creek dolomite		Day Creek dolomite mem.	Day Creek dolomite mem.	Limestone = Day Creek dol	Day Creek dolomite	Day Creek dolomite	Day Creek formation	Day Creek dol.	Day Creek dol.		
		Red Bluff formation		Red Bluff formation	Whitehorse sandstone member	Whitehorse sandstone	Whitehorse ss.	Whitehorse ss.	Whitehorse formation	Whitehorse fm. (Red Bluff ss)	Whitehorse fm.	Whitehorse fm. (Lake-Trammel)	
	Dog Creek shale	Stoney Hills shale	Chapman member Amphitheatre member	Dog Creek shale	Dog Creek shale member	Dog Creek shale	Dog Creek shale		Dog Creek formation	Dog Creek shale	Dog Creek shale	Gypsiferous red shale	
	Salt Fork division	Cave Creek gypsum	Shimer gypsum		Shimer gypsum	Shimer gypsum member	Blaine formation	Blaine formation	Duncan sandstone	Collingsworth gypsum	Blaine formation (Cave Creek)	Blaine formation	Blaine formation (Esokta, Greer)
			Altana dol.										
		Jenkins clay	Medicine Lodge gyp	Medicine Lodge gyp mem.									
			Maggie dol.										
			Medicine Lodge gypsum	Ferguson gypsum	Ferguson gypsum mem.				Haystack gypsum				
Flowerpot shale		Glass Mountain formation	Flowerpot shale	Flowerpot shale	Enid formation	Enid formation	Enid formation	Undifferentiated shale and sandstone	Chickasha formation	Flowerpot shale	Chickasha fm.	Gypsiferous red shale	
Cedar Hill sandstone			Cedar Hill ss.	Cedar Hill sandstone						Cedar Hill ss.			
Salt Plain measure		Kingfisher formation	Salt Plain measure	Salt Plain measure						Salt Plain measure			
Harper sandstone			Harper sandstone	Harper sandstone						Harper sandstone			
									Duncan sandstone			San Angelo ss.	
									Wellington shale	Duncan ss.	Schazo sh.		
									Marion sandstone		Vale sandstone		

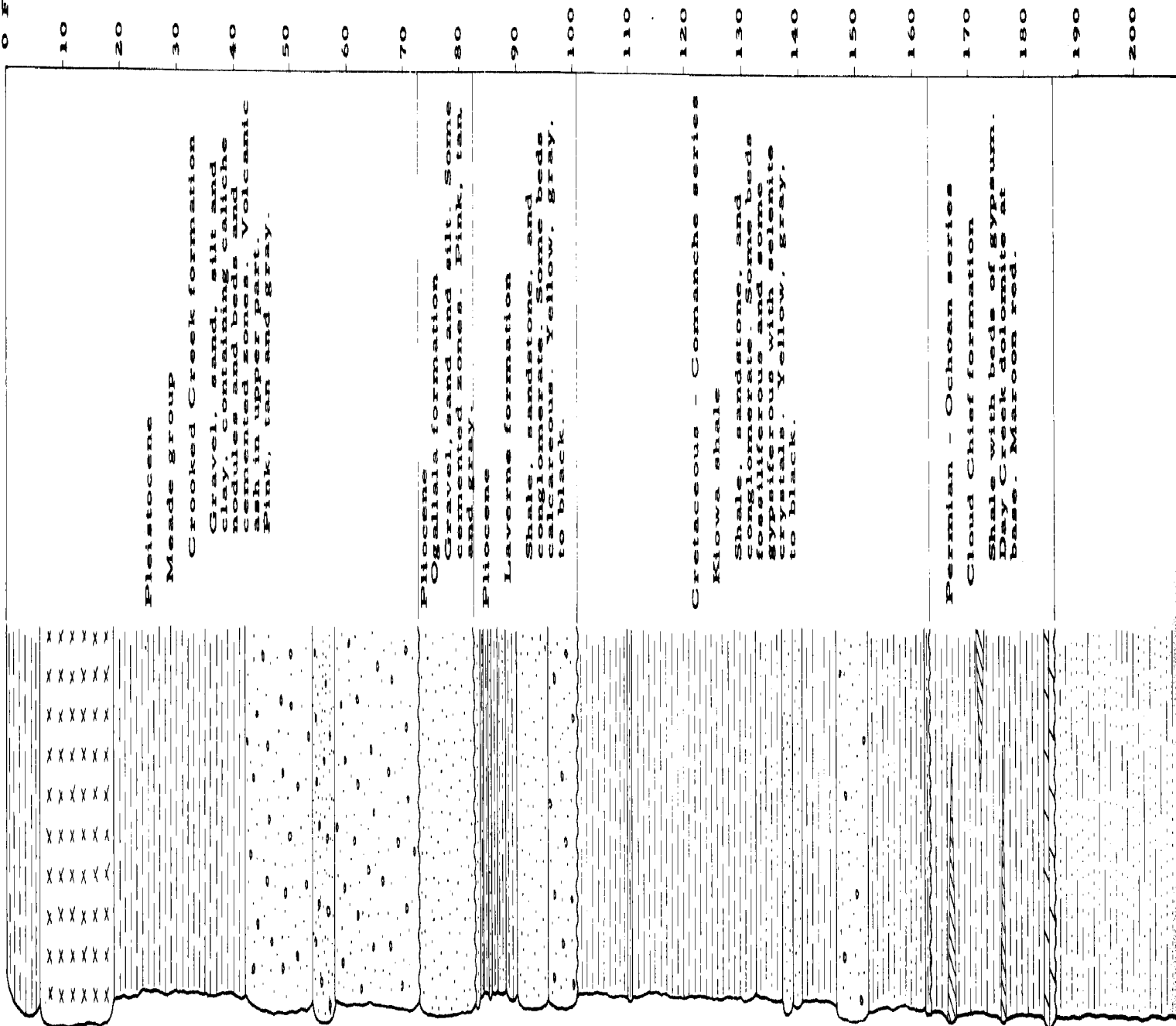
Figure 5. Correlation chart of Permian strata.

[illegible]

30 homo	EVANS 1931 Northwestern Oklahoma	GREEN 1936 West-central Oklahoma	GREEN 1937 Western Oklahoma	BROWN 1937 Grady, Stephens, Comanche cos, Okla	SCHWEER 1937 Western Oklahoma	NORTON 1939 Kansas	MOORE 1951 Kansas	DAVIS 1955 Grady and Stephens cos, Okla	This Report Harper county Oklahoma
Quartermaster formation	Elk City sandstone	Quartermaster formation	Quartermaster formation		NW SE	Big Basin formation		Cloud Chief formation	Cloud Chief formation
Day Creek dolomite	Doxey shale								
Cloud Chief member	Cloud Chief member				Cloud Chief formation				
Whitehorse formation	Weatherford dol	Rush Springs fm	Cloud Chief formation	Rush Springs member	Weatherford dol	Day Creek dolomite	Day Creek dolomite	Day Creek dolomite	Day Creek dolomite
Rush Springs member	U. Relay Creek dol	Relay Creek dol	Rush Springs ss	Relay Creek dol	Rush Springs sandstone	Relay Creek dolomite	Upper shale member	Rush Springs ss	Whitehorse undifferentiated or Marlow missing
Marlow member	Marlow formation	Marlow formation	Marlow formation	Marlow member	Marlow formation	Marlow sandstone	Marlow sandstone	Marlow formation	Rush Springs ss
Dog Creek formation	Dog Creek shale	Dog Creek - Blaine formation	Dog Creek and Blaine formations	Haskew gypsum	Dog Creek shale	Dog Creek shale	Dog Creek shale	Dog Creek shale and Blaine gypsum undif.	Dog Creek shale
Haskew gypsum	Haskew gypsum	Lovedale gypsum	Lovedale gypsum	Lovedale gypsum	Haskew gypsum	Haskew gypsum	Haskew gypsum	absent	Haskew gypsum
unnamed shale	unnamed shale	unnamed shale	unnamed shale	unnamed shale	Lovedale gypsum	Shimer gypsum	Shimer gypsum	absent	unnamed shale
Lovedale gypsum dolomite	Shimer gypsum	Shimer gypsum	Shimer gypsum	Shimer gypsum	Shimer gypsum	Nescatunga gypsum	Nescatunga gypsum	absent	Shimer gypsum dolomite
unnamed shale	Alabaster gyp	Alabaster gypsum	Alabaster gypsum	Alabaster gypsum	Medicine Lodge gypsum	Medicine Lodge gypsum	Medicine Lodge gypsum	absent	unnamed shale
Shimer gypsum dolomite	Medicine Lodge gypsum	Medicine Lodge gypsum	Medicine Lodge gypsum	Medicine Lodge gypsum	Medicine Lodge gypsum	Medicine Lodge gypsum	Medicine Lodge gypsum	absent	Nescatunga gypsum dolomite
unnamed shale	Flowerpot shale	Flowerpot shale	Flowerpot shale	Chickasha formation	Flowerpot shale	Flowerpot shale	Flowerpot shale	Flowerpot shale	unnamed shale
Medicine Lodge gypsum	Duncan sandstone	Duncan sandstone	Duncan sandstone	Duncan sandstone formation	Cedar Hills sandstone	Cedar Hills sandstone	Cedar Hills sandstone	Chickasha formation	Medicine Lodge gypsum dolomite
Flowerpot shale	Hennessey shale	Hennessey shale	Hennessey shale	Hennessey shale	Salt Plain formation	Salt Plain formation	Salt Plain formation	Duncan sandstone	Flowerpot shale
Harper sandstone					Harper sandstone	Harper sandstone	Harper sandstone		

COMPOSITE SECTION OF ROCKS EXPOSED IN HARPER COUNTY, OKLAHOMA

0 FEET



220

230

240

250

260

270

280

290

300

310

320

330

340

350

360

370

380

390

400

410

420

430

Permian - Guadalupean series

Whitehorse group

Rush Springs sandstone

Shale and sandstone. Some beds massive and resistant to erosion. Upper part is thin-bedded sandstone and shades of gray. Lower beds of gypsuum. Brownish red.

Permian-Guadalupean series

Whitehorse group

Marlow formation

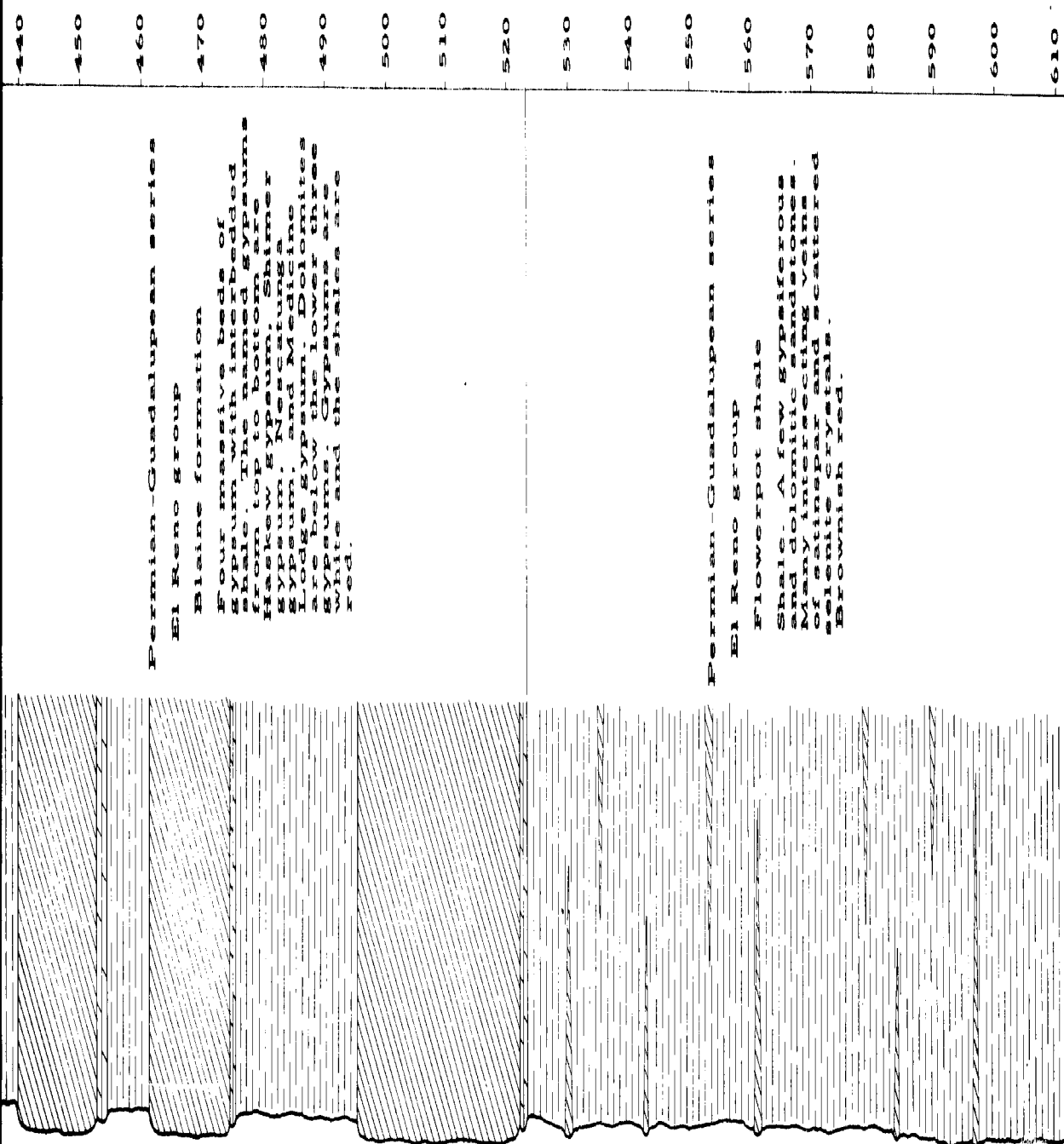
Fine-grained sandstone. Locally cross-bedded. Orange red.

Permian-Guadalupean series

El Reno group

Dog Creek shale

Mostly even-bedded shale. Some thin beds of fine sandstone, dolomitic siltstone, and gypsuum. Brownish red.



Permian-Guadalupean series
El Reno group

Blaine formation

Four massive beds of gypsum with interbedded sandstone. The beds range from top to bottom are Haskew gypsum, Shimer gypsum, Nescaunga Lodge gypsum, and Medicine Hat gypsum. Dolomite is present in the lower part of the Haskew gypsum. The white and the shales are red.

Permian-Guadalupean series
El Reno group

Flowerpot shale

Shale. A few gypsiferous and dolomitic sandstones. The sandstones are of a fine grain and scattered selenite crystals. Brownish red.

EXPLANATION

- Conglomerate
- Sandstone
- Shale
- Siltstone
- Sandy shale
- Thin-bedded sandstone and shale
- Dolomite
- Gypsum
- Volcanic ash

GEOLOGIC MAP (PRE-TERTIARY) OF HARPER COUNTY OKLAHOMA

by

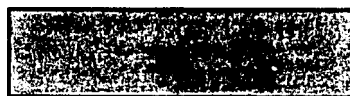
Arthur J. Myers

1956



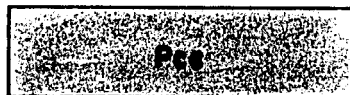
Scale in miles

EXPLANATION



KIOWA SHALE

Yellow, light gray, dark gray to black shale and yellow coarse conglomeratic sandstone; fossils abundant at some horizons, 0-52 feet thick.

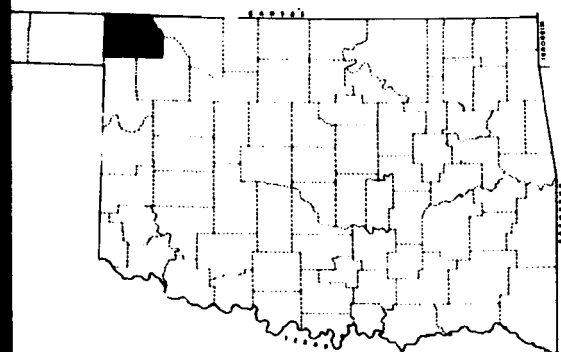


CLOUD CHIEF FORMATION

CRETACEOUS

COMANCHE SERIES

SERIES



R 26 W

R 25 W

R 24 W

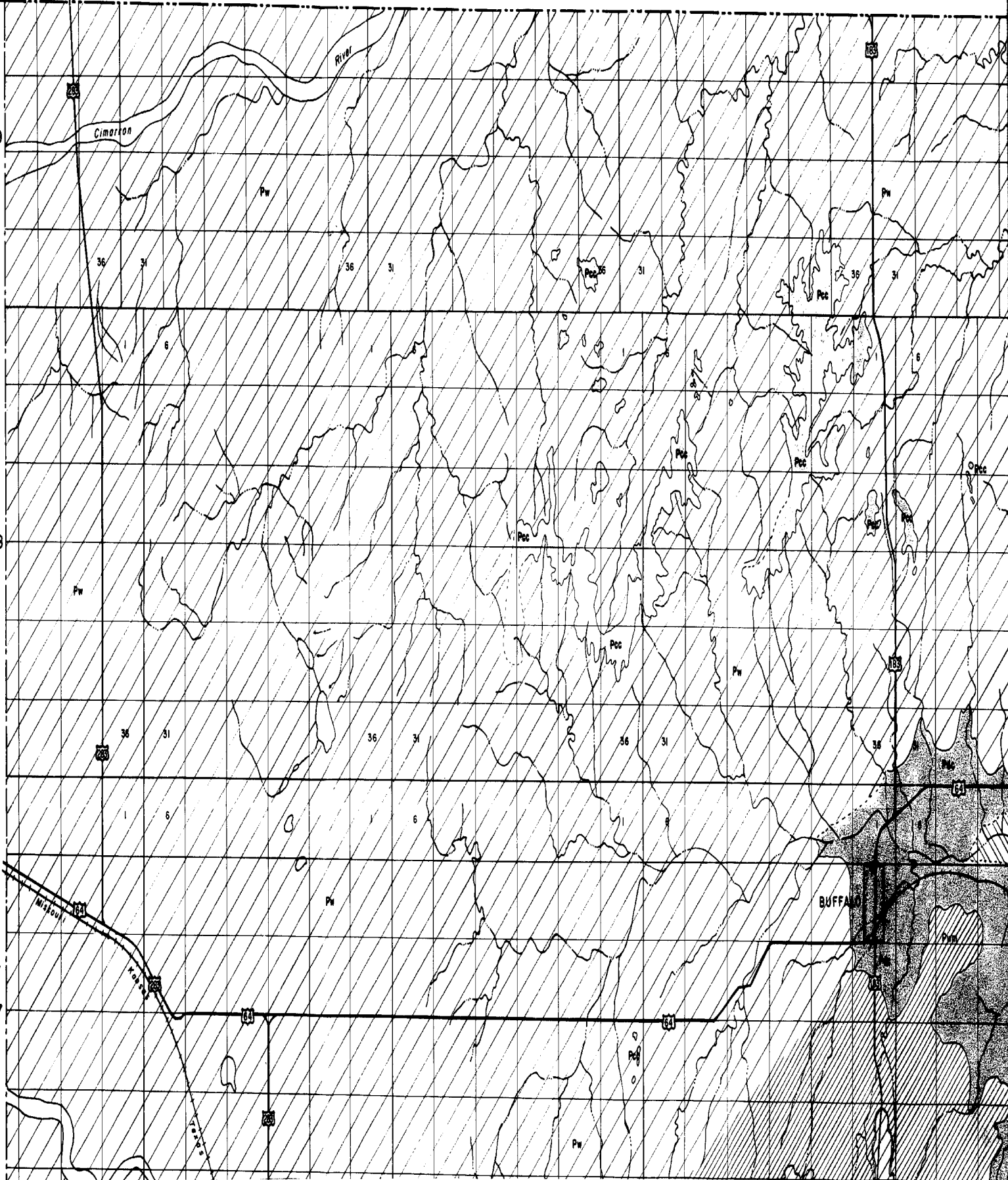
R 23 W

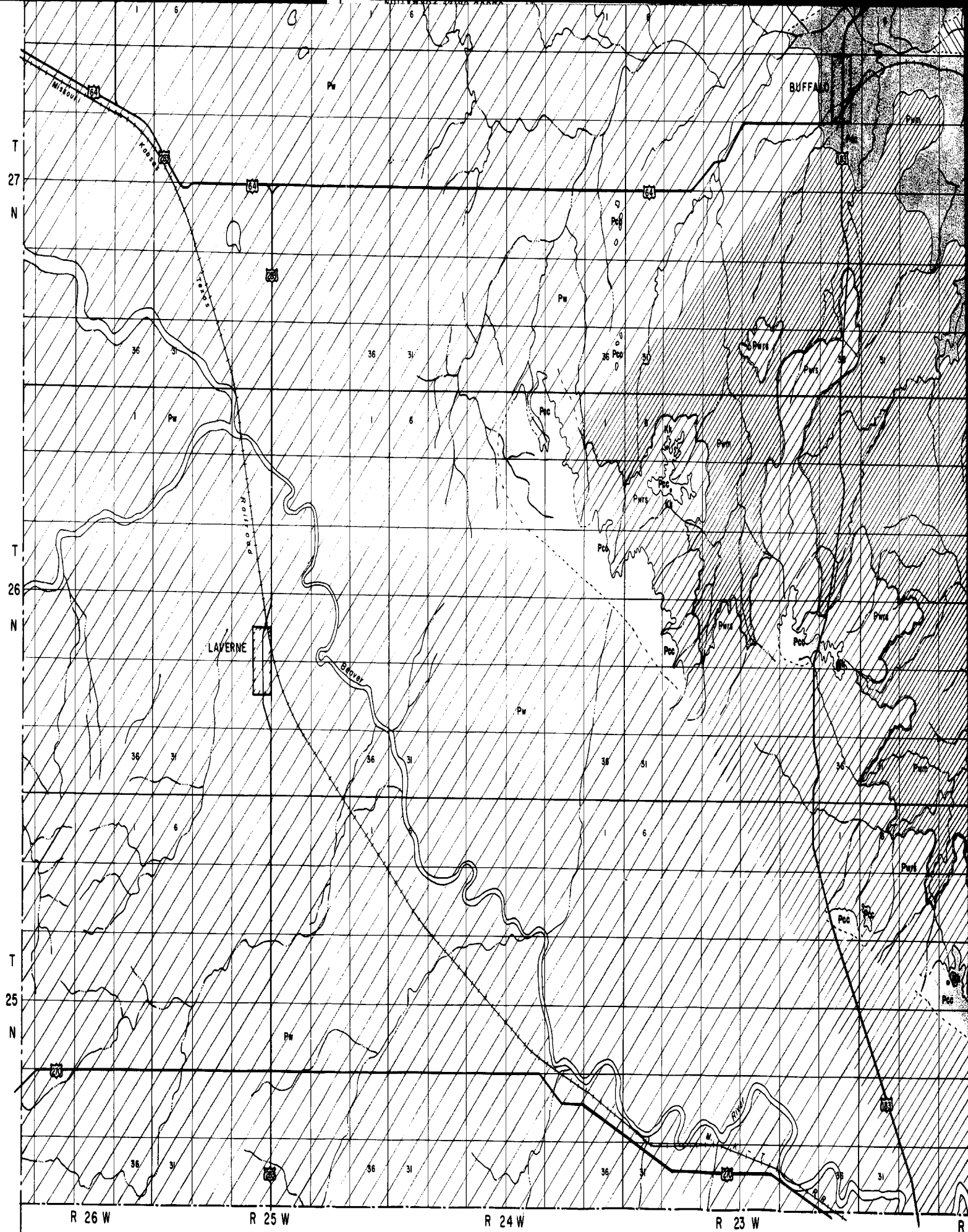
R 22

T
29
N

T
28
N

T
27
N





R 22 W

R 21 W

GEOLOGIC MAP (PRE-TERTIARY)

OF

HARPER COUNTY

OKLAHOMA

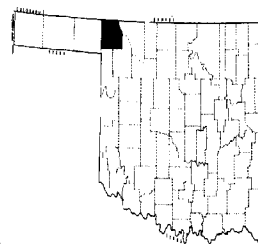
by

Arthur J. Myers

1956



Scale in miles



EXPLANATION



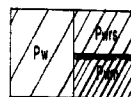
KIOWA SHALE

Yellow, light gray, dark gray to black shale and yellow coarse conglomeratic sandstone; fossils abundant at some horizons, 0-52 feet thick.



CLOUD CHIEF FORMATION

Red clay shale with thin beds of gypsum, 0-35 feet thick. Day Creek dolomite member at base, 2 to 3 feet thick, gray, buff and lavender, dense, massive and siliceous.



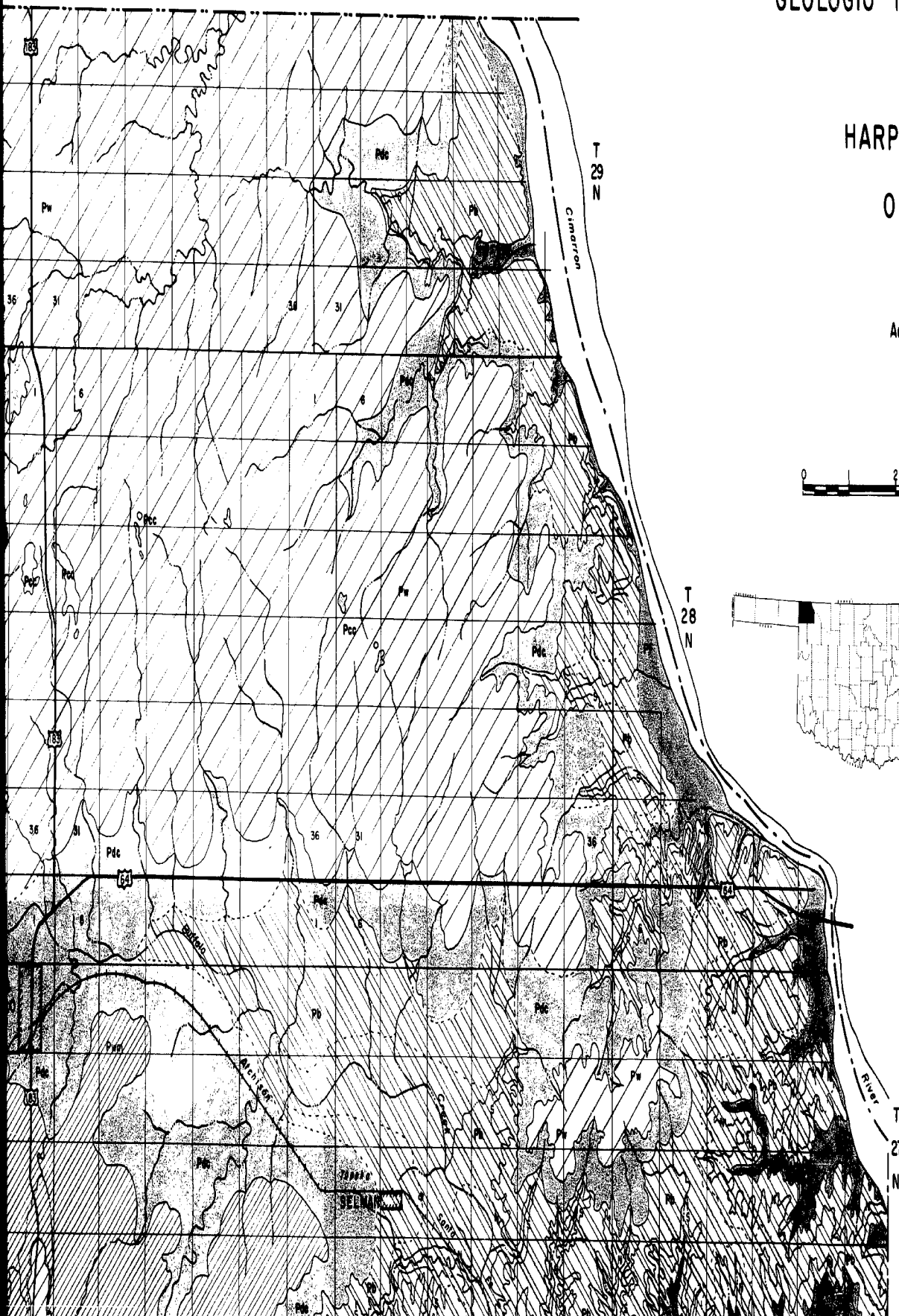
WHITEHORSE GROUP

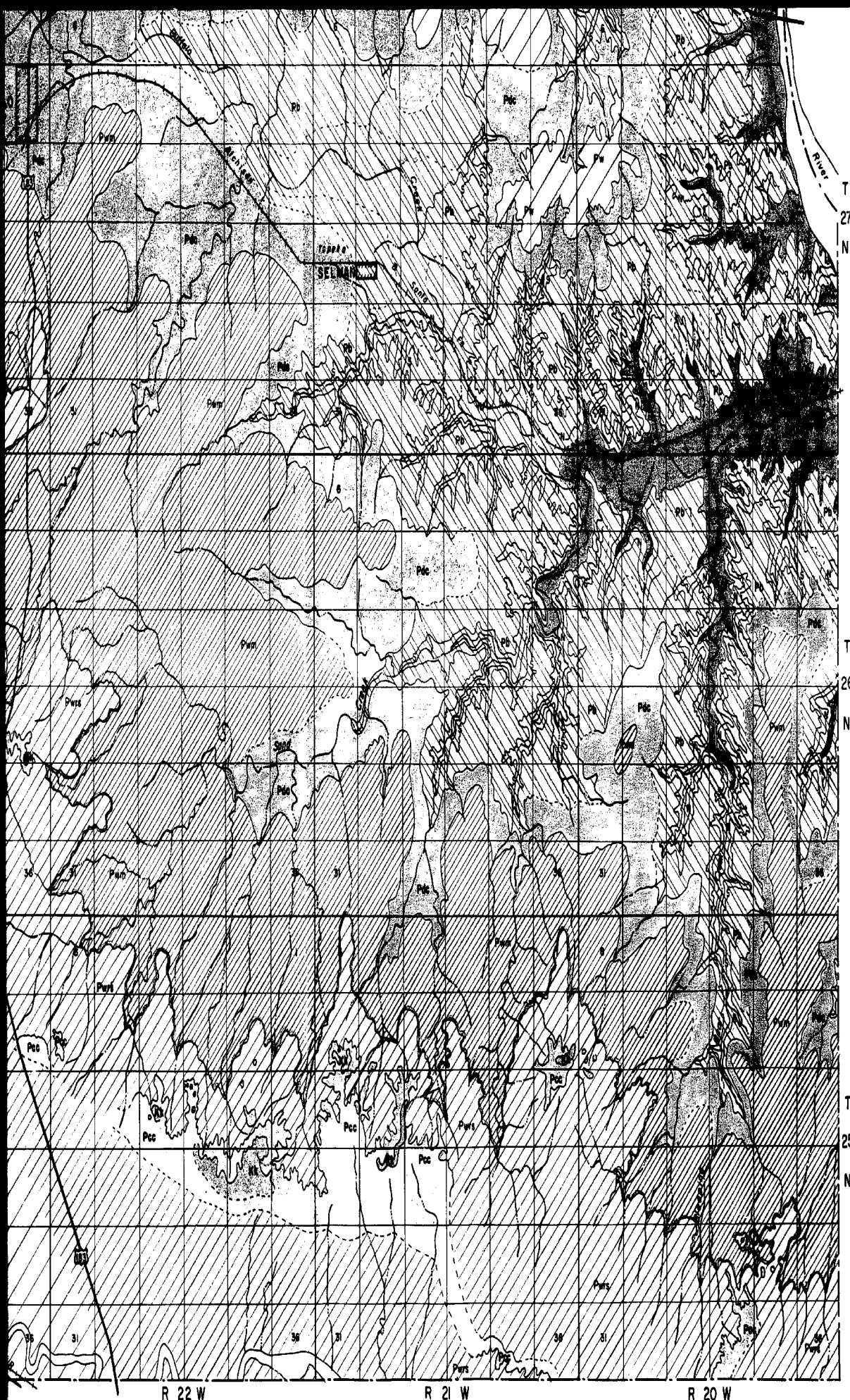
In north half and southwest part of county, Whitehorse Group, undifferentiated (Pw), orange-red and brownish red cross-bedded sandstone, siltstone and shale with a few gypsum lenses; 250 feet thick. In southeast area, the group is divided into Rush Springs sandstone (Pwrs)

CRETACEOUS
COMANCHE SERIES

OCHOAN SERIES

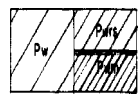
KESWICK SERIES





OCHOANS
 WHITEHORSE GROUP
 PERMIAN
 GROUP
 GUADALUPEAN
 SELMA

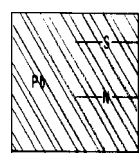
Red clay shale with thin beds of gypsum, 0-35 feet thick. Day Creek dolomite member at base, 2 to 3 feet thick, gray, buff and lavender, dense, massive and siliceous.



WHITEHORSE GROUP
 In north half and southwest part of county, Whitehorse Group, undifferentiated (Pw), orange-red and brownish red cross-bedded sandstone, siltstone and shale with a few gypsum lenses; 250 feet thick. In southeast area, the group is divided into Rush Springs sandstone (Pws) above and Marlow formation (Pwm) below. Rush Springs is red, fine-grained sandstone and reddish brown silty shale with gypsum, locally cross-bedded, 150 feet thick. Marlow formation is orange-red, soft massive sandstone, locally clayey, silty and cross-bedded, 100 feet thick.



DOG CREEK SHALE
 Brownish red even-bedded silty shale, containing thin beds of fine sandstone, dolomitic siltstone and gypsum; 50 feet thick.



BLAINE FORMATION
 Massive gypsum beds interstratified with red shales; 90 feet thick. Contains in descending order the following stratigraphic units:
Haskew gypsum member, 4 feet thick; underlain by red shale, 4 feet;
Shimer gypsum member (S), 13 feet with gray dolomite (1-2 feet) at base; underlain by red shale, 7 feet;
Neocatunga gypsum member (N), 13 feet with gray dolomite (0.5-1 foot) at base, underlain by red shale, 20 feet;
Medicine Lodge gypsum member, 25 to 30 feet thick, with (0.5 to 1 foot) gray to black dolomite bed at base.



FLOWERPOT SHALE
 Brownish red silty shale, 60 feet thick; containing a few gypsiferous and dolomitic sandstones, many intersecting veins of satinspar and scattered selenite crystals.

+---+ Railroad
 [H] Federal Highway
 --- Formation contact
 (Dashed line: indefinite or covered)

SURFICIAL DEPOSITS (CENOZOIC) OF HARPER COUNTY OKLAHOMA

by

Arthur J. Myers

1956



Scale in miles

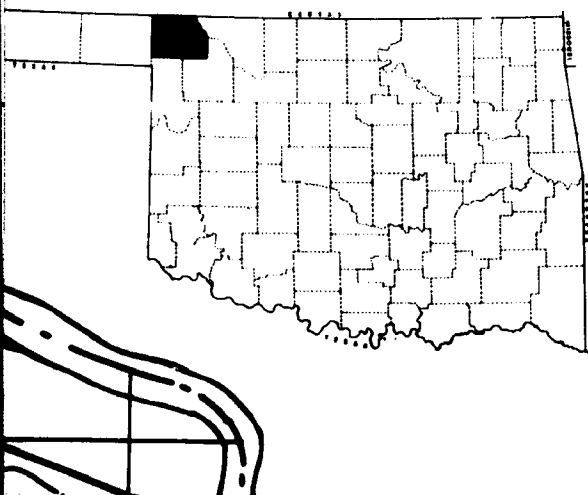
EXPLANATION

Qrs

DUNE SAND

Gray to tan, well-sorted
eolian sand, predominantly
quartz, along north side of
streams.

Qal



R 26 W

R 25 W

R 24 W

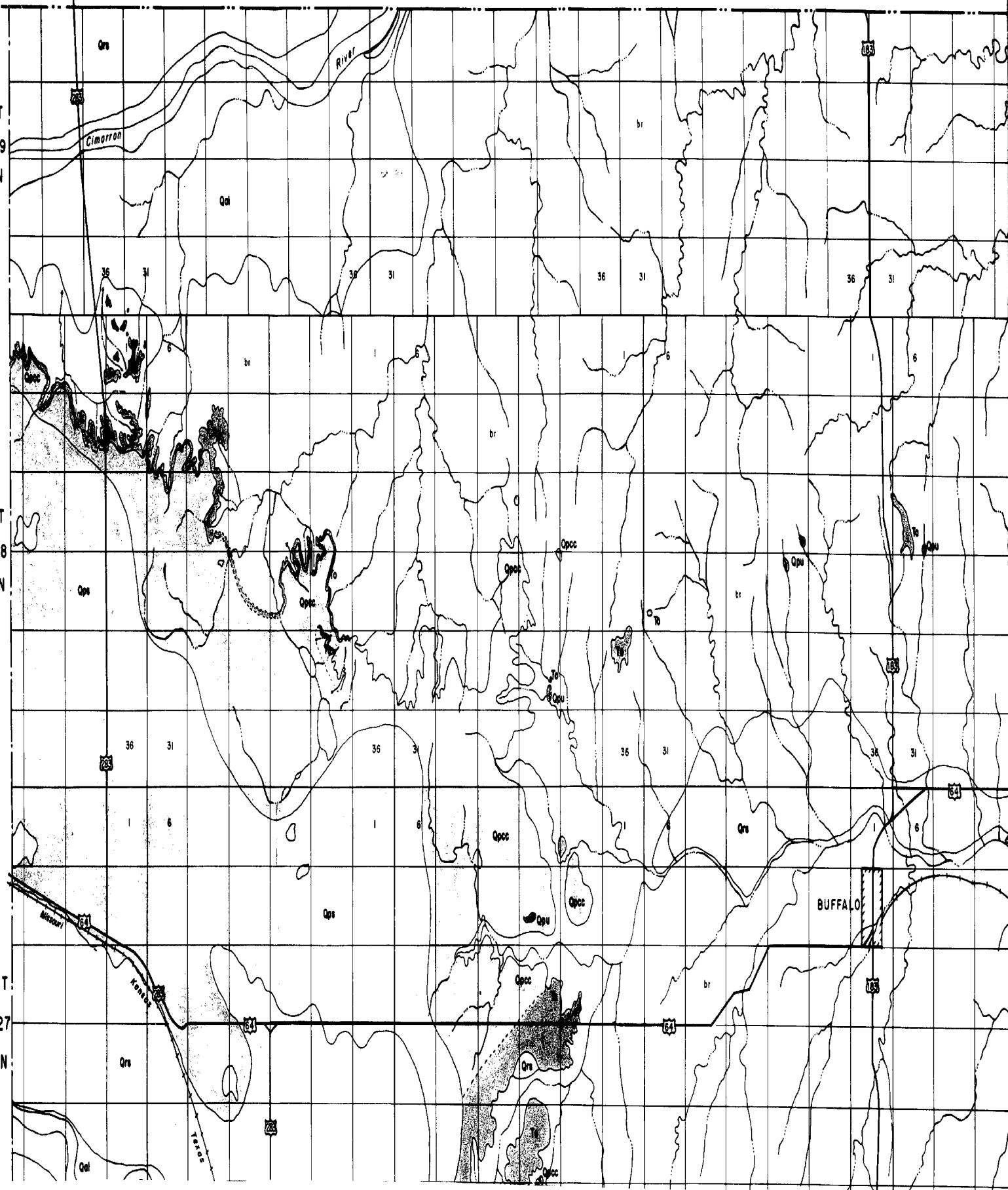
R 23 W

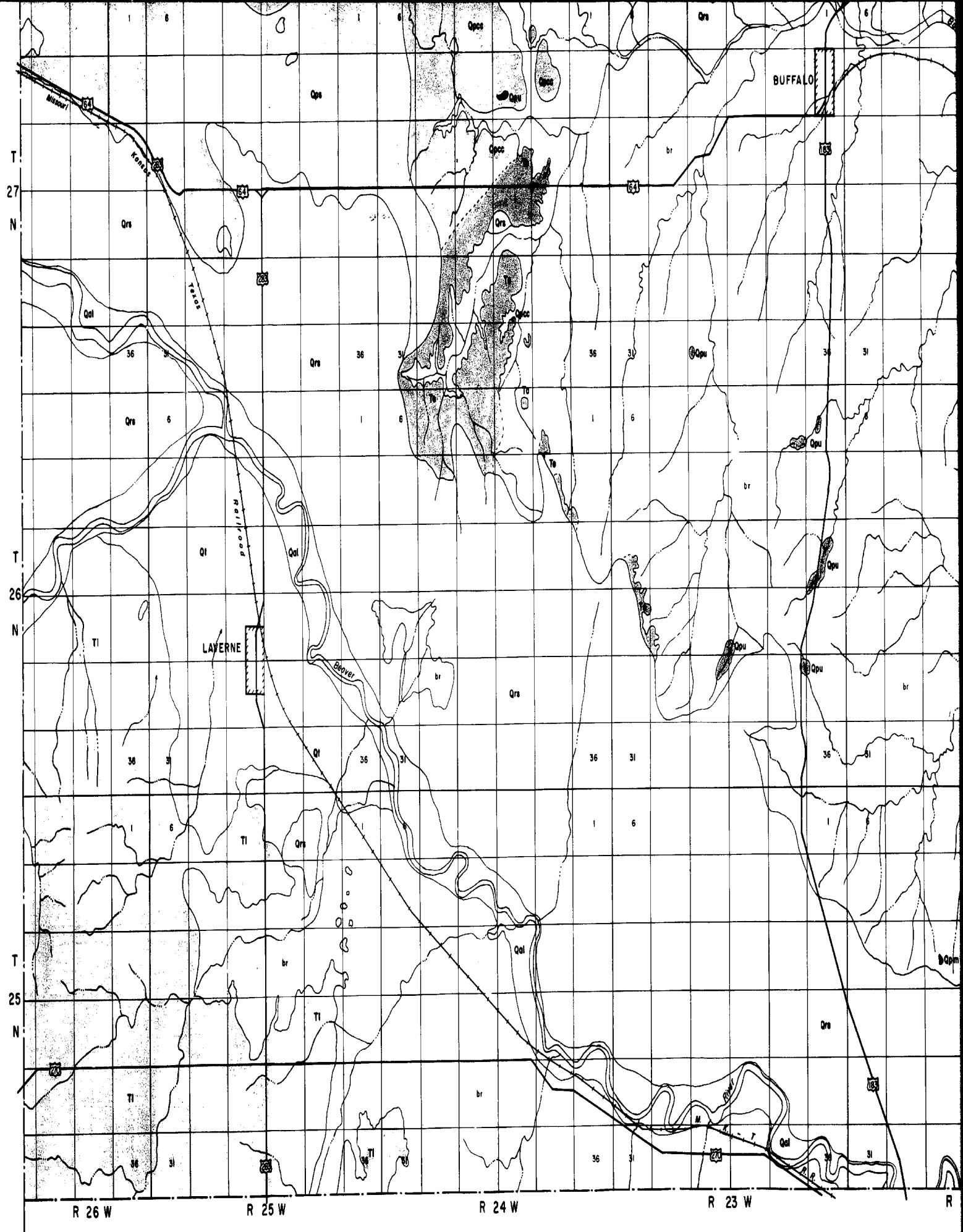
R 22

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29
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27
N





R 22 W

R 21 W

SURFICIAL DEPOSITS (CENOZOIC)

OF

HARPER COUNTY

OKLAHOMA

by

Arthur J. Myers

1956



Scale in miles

EXPLANATION

Qrs

DUNE SAND

Gray to tan, well-sorted
eolian sand, predominantly
quartz, along north side of
streams.

Qal

ALLUVIUM

Gray to tan gravel, sand,
silt and clay underlying
present flood plains.

Qt

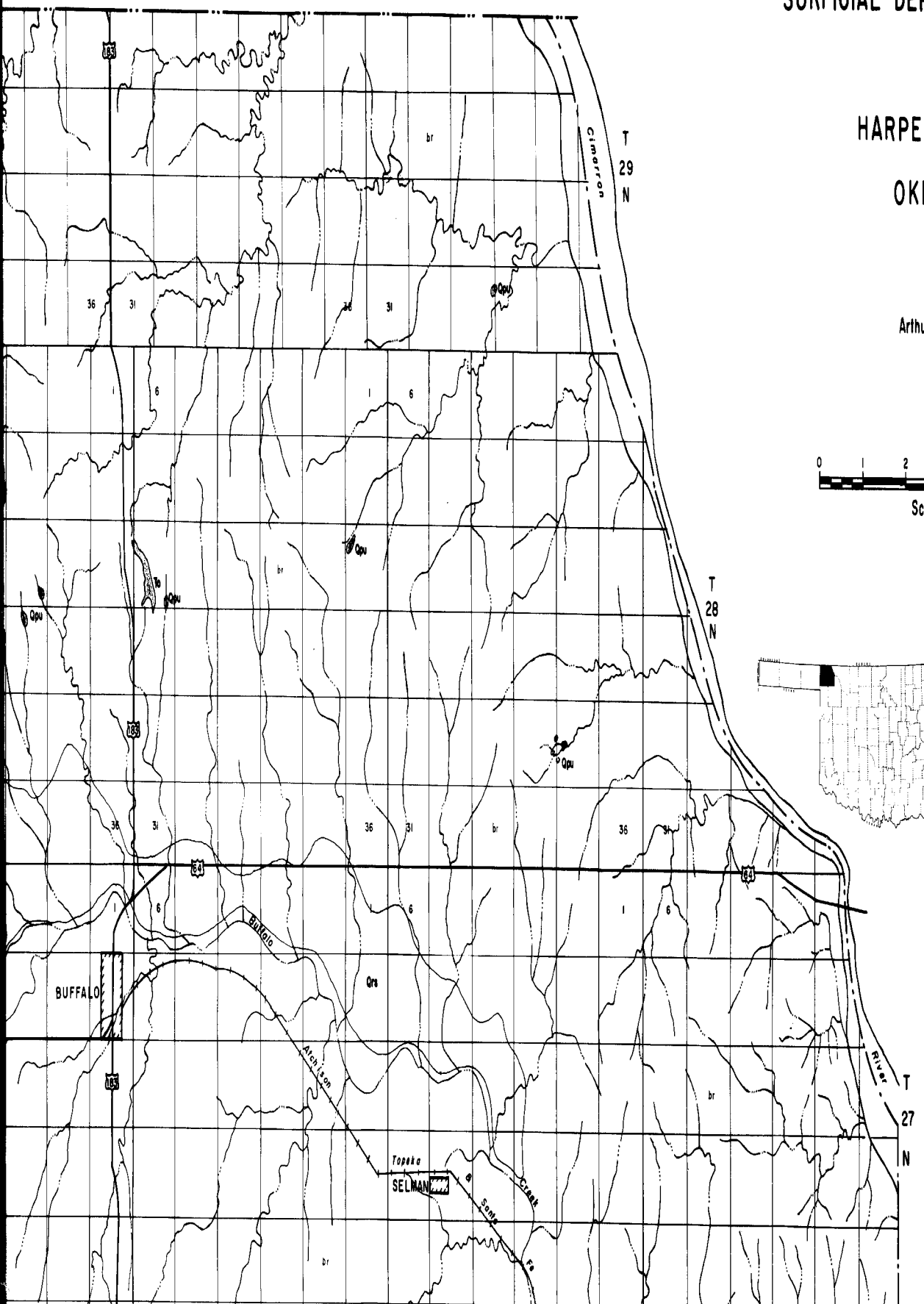
TERRACE

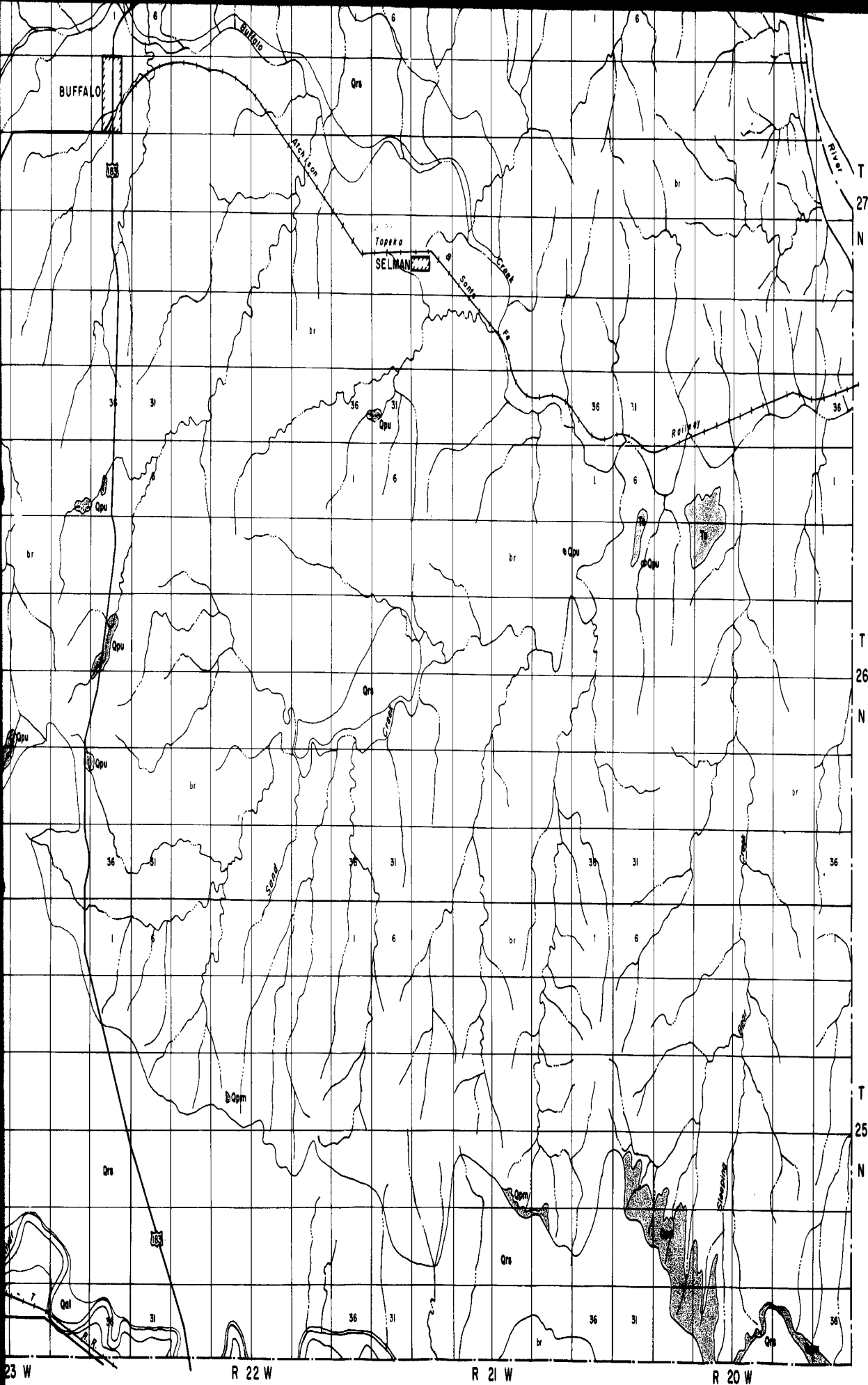
Gray and light tan gravel,
sand, silt and clay.

Qla

LAKE DEPOSITS

Gray clay with small fossils,
probably Illinoian stage;
0-17 feet thick.





ALLUVIUM
Gray to tan gravel, sand, silt and clay underlying present flood plains.

Qr

TERRACE
Gray and light tan gravel, sand, silt and clay.

Qpu

LAKE DEPOSITS
Gray clay with small fossils, probably Illinoian stage; 0-17 feet thick.

Qpm

DUNE SAND
Gray to tan well-sorted eolian sand.

Qpc

MEADE GROUP

In southeastern corner, Meade Group, undifferentiated, (Qpm), gravel, sand, and silt, locally cross-bedded, 0-70 feet thick. In northwestern quarter of county, Crooked Creek formation (Qpc), gravel, sand, silt, volcanic ash (Pearlette member), 0-70 feet thick.

To

OGALLALA FORMATION
Arkosic gravel, sand and silt, locally cemented with calcium carbonate, massive to cross-bedded; 0-35 feet thick.

br

LAVERNE FORMATION
Gray to white gravel, sand, silt, clay, caliche and limestone; 0-30 feet thick on surface.

br

BEDROCK
Pre-Tertiary bed rock.

----- Railway
 Federal Highway
 --- Formation contact
 (Dashed line: indefinite or covered)