SURFICIAL GEOLOGY ALONG THE ARKANSAS VALLEY FROM PONCA CITY NORTHWARD TO KIRK'S HILL TOP, NORTH-CENTRAL OKLAHOMA

By

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ABSTRACT

The main purpose of this investigation was to map the bedrock and Quaternary deposits of the Arkansas Valley from Ponca City nearly to the north end of Kaw Reservoir before the new reservoir covered up the geology. Both a surficial geologic map and an engineering soils map were made. Major emphasis is given to Quaternary geology, which has been studied very little in north-central Oklahoma and to the reconstruction of Quaternary geologic history.

The Pliocene Ogallala Formation may have overlain the study area but has been eroded away. It is probable that the huge intrenched meanders of the present-day Arkansas were superposed on the bedrock from a high-discharge stream (the ancestral Arkansas) flowing on the Ogallala.

Five alluvial deposits are present. In order of lower topographic position and decreasing age, they are the McCord Terrace Alluvium, the Ponca City Terrace Alluvium, the Uncas Terrace Alluvium, the Kaw City Terrace Alluvium, and the flood plain alluvium of the Arkansas River.

Deposits of Lake Blackwell I and Lake Blackwell II, which were produced when successive valley trains from the Rocky Mountains down the Arkansas Valley dammed the mouth of the valley of the Salt Fork of the Arkansas River, occur in the southwest part of the study area.

Eoilan deposits are not common in the study area because the deep, narrow Arkansas Valley generally restricted the sweep of wind across the

various alliuvial deposits. Colluvium is present on almost all hill-slopes.

There is local evidence that the climate of the study area changed repeatedly from humid to arid and back again during the Pleistocene Epoch.

Economic deposits in the study area include petroleum, limestone, and sand. Surface and ground water also are important resources in the study area.

INTRODUCTION

The study area was selected because of varied and interesting geology and because in the near future part of the area will be covered by water of the reservoir behind Kaw Dam which has been under construction since October, 1970. This large facility for hydroelectric power, irrigation, flood control, and recreation will be completed about June, 1976.

Scope and Purpose of Investigation

The purpose of this investigation is to describe bedrock and Quaternary deposits along the Arkansas Valley from just south of Ponca City northward to Kirk's Hill Top with emphasis on engineering geology. Because of the rapid development expected on both sides of Kaw Lake, this investigation is designed for use by laymen, politicians, engineers, planners, architects, and others as well as by geologists. Major emphasis also has been placed on the reconstruction of geologic history and especially on Quaternary history which never before has been studied in any detail in this part of Oklahoma.

Location of the Area

The thesis area is located along the Arkansas Valley in eastern Kay and western Osage Counties, and extends from immediately south of Ponca City northward up valley past Kaw Dam, Kaw City, Washunga, and Uncas to Kirk's Hill Top (see Plates 1 and 2 and Fig. 1). The investigation covers parts of T. 26 N., T. 27 N., and T. 28 N., R. 2 E., R. 3 E., R. 4 E., and R. 5 E. (see Fig. 1). The total area is approximately 150 square miles.

Previous Investigations

Although a number of geologic studies have been made in Kay and Osage Counties, they are mostly unpublished and are mostly subsurface investigations made in searching for oil and gas. Known subsurface studies are by Clark and Cooper (1930), Smith (1954), Querry (1957), and Bryan (1950). Surface mapping emphasizing bedrock has been done in Kay County by Noll (1955) and by Henry (1955). General geologic studies and drilling data related to Kaw Dam and Lake, are available in the Tulsa District Office of U.S. Army Corps. of Engineers.

Method of Investigation

Geologic mapping of the study area was accomplished in the field by camping out from the beginning of June to the beginning of August, 1974. The area was covered by car and by foot. Continual use was made of two sets of aerial photographs at a scale of about three in. to a mile. One set, taken in 1954, was provided by the Oklahoma Geological Survey, and the other, taken in 1966, was obtained from the Oklahoma State University Library. Bedrock investigations of the U.S. Army Corps. of Engineers for the Kaw Dam site and various sites around the reservoir were used. The thicknesses of all strata were measured or were taken from available report data. The three-points method, data from the Oklahoma Geological Survey, and Brunton compass measurements were used to determine dip and strike of strata. All available data and reports,

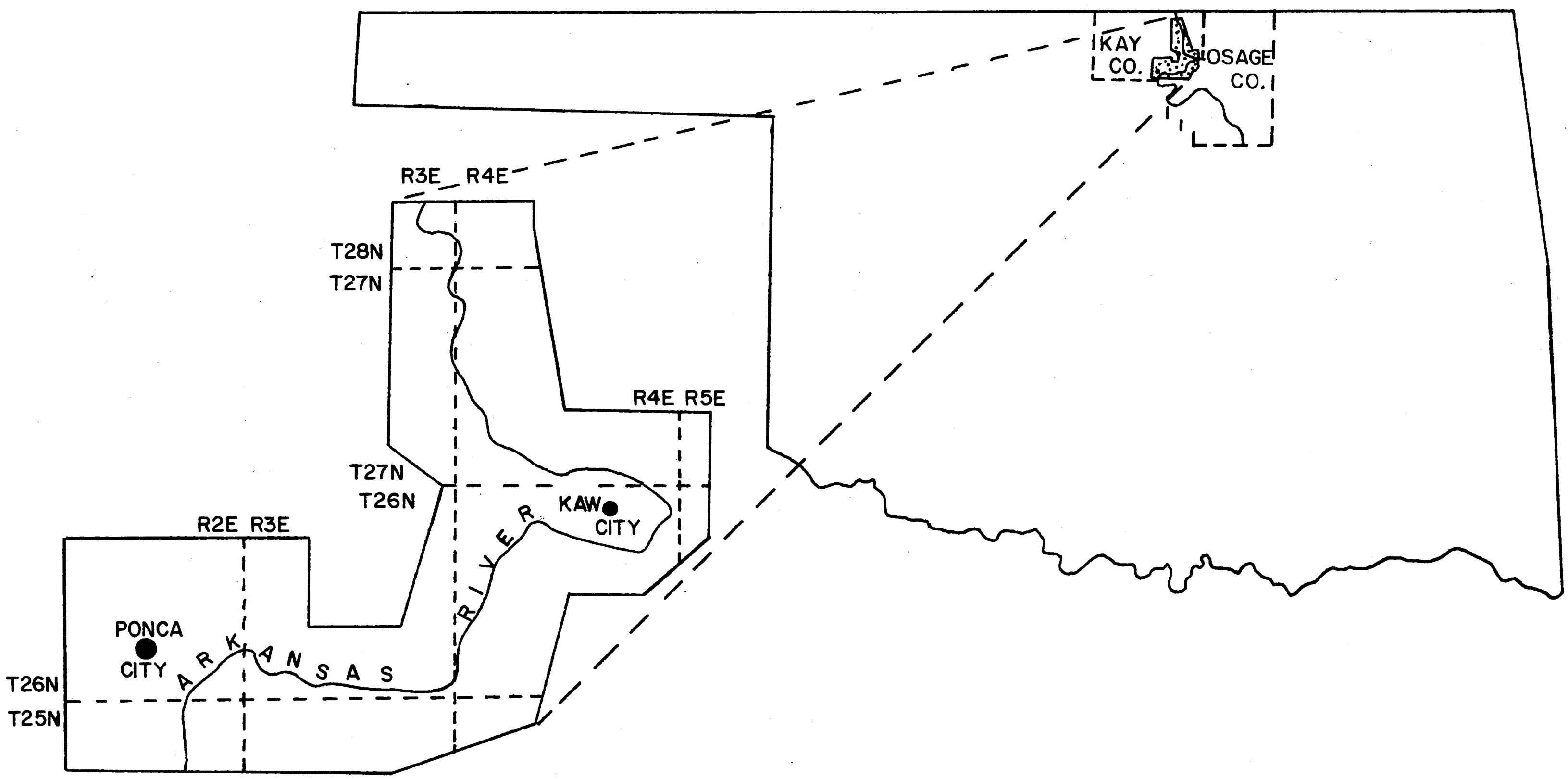

Fig. 1.--Location of the study area in north-central Oklahoma

both published and unpublished, were collected from the Oklahoma Geological Survey, the U.S. Soil Conservation Service, the Oklahoma Highway Department, the U.S. Army Corps. of Engineers (both at the Kaw Dam Office and at the Headquarters of the Tulsa District), and the municipalities of Kaw City, Ponca City, and Newkirk.

Population and History

According to the 1970 census the population of Osage County was 29,750 while Kay County had a total of 48,791. Ponca City, established in July, 1893, had a population of 25,940 or 53% of the entire county population (see Fig. 1). Although Newkirk, just to the north of Ponca City, is the county seat, it had a population of only 2173. Kaw City, situated in the center of the thesis area, had a population of 283.

Kaw City was established in 1902 by the Kaw City Townsite Company on a 480 acre site in a great bend of the Arkansas River (see Fig. 1). From the town's inception building progressed at a rapid rate with a population of about 300 by September, 1902. The railroad passed through town, and Kaw City was an important shipping point for both cattle and farm products. The oil boom in the vicinity doubled the city population in the early 1900's, but the boom started to fade in June, 1923 when a spring flood struck the city. The depression and World War II contributed to further decline, and the hotel closed its doors in 1952. A new town site was chosen two miles to the west of the original site in 1972 because the old site will be inundated by Kaw Reservoir. The new site like the old site will be surrounded on by three sides by the Arkansas River. The population at the new city location is about 150.

Washunga and Uncas with populations of 25 and 52 respectively will be covered by water on completion of Kaw Dam. These people and many of the residents of old Kaw City are moving to other towns in the vicinity such as Newkirk, Ponca City, Tonkawa, Blackwell, and Kirkdare because available housing is cheaper than building a new home above the flood-control pool of Kaw Reservoir.

Climate

Ponca City on the western edge of the thesis area and Kaw City on the eastern edge of the area twenty miles to the north have essentially the same climate (see Tables 1 and 2). The region is classed as having a temperature, subhumid climate (Holbrook, 1967, Thornthwaite, 1941). Warm moist air from the Gulf of Mexico and cold dry air from the Arctic produce high precipitation in the spring and occasional storms and tornadoes. Average annual rainfall distribution is 35% in summer, 30% in spring, 24% in fall, and 11% in winter. The average total annual rainfall is 32.11 in. in Ponca City. Summer daytime temperatures are often uncomfortably hot but the nights are generally cool. The average annual temperature at Ponca City is 60.9°F. The lowest recorded temperature in the area was -25°F. at White Eagle in February, 1905; the highest was 117°F at Newkirk in July, 1954. Other climatic data are shown in Tables 1 and 2.

Communication and Transportation

Major highways serving the study area are U.S. Highways 60, 77, and 177 and Oklahoma Highways 11 and 119. U.S. Highway 60 extends east-west through Ponca City. U.S. Highway 77 passes north-south through Newkirk and Ponca City. At Ponca City it turns sharply west on U.S.

Table 1.--Temperature and precipitation in the study area

Month	Temperature				Precipitation				
			Two years in 10 will have at least 4 days with			One year in 10 will have			
	Average daily maximum	Average daily minimum	Maximum temperature equal to or higher than	Minimum temperature equal to or lower than	Average total	Less than	More than	Days with snow cover of 1 inch or more	Average depth of snow on days with snow cover
	°F.	°F.	°F.	°F.	Inches	Inches	Inches	Number	Inches
January	47.8	26.4	67	8	1.04	0.1	2.5	2	2
February	53.2	29.8	73	12	1.23	.3	2.2	1	2
March	61.8	36.3	79	19	1.92	.3	3.7	1	2
April	73.0	48.0	86	32	3.13	.6	7.1	(2)	7
May	81.1	57.3	92	44	4.71	1.0	10.5	0	---
June	90.8	66.7	101	55	4.43	1.9	8.3	0	---
July	96.0	71.0	105	62	3.60	.2	9.1	0	---
August	95.9	70.4	107	61	3.09	.7	5.9	0	---
September	87.7	62.1	100	47	3.52	.5	7.6	0	---
October	76.5	51.3	91	36	2.41	.1	6.4	0	---
November	60.5	37.3	76	21	1.70	(3)	4.0	(2)	1
December	50.6	29.7	67	14	1.33	.1	2.8	1	3
Year	72.9	48.9	107	1	32.11	43.2	21.2	5	3

Table 2.--Probabilities of last freezing temperatures in spring and first in fall in the study area

Probability	Dates for Given Probability and at Temperature Levels Shown				
	16°F	20°F	24°F	28°F	32°F
Spring:					
1 Year in 10, later than	March 21	April 1	April 8	April 10	April 27
2 Years in 10, later than	March 13	March 24	April 2	April 5	April 21
5 Years in 10, later than	February 27	March 11	March 20	March 27	April 10
Fall:					
1 Year in 10, earlier than	November 22	November 8	November 4	October 23	October 17
2 Years in 10, earlier than	November 29	November 16	November 9	October 29	October 21
5 Years in 10, earlier than	December 14	November 30	November 19	November 8	October 29

Highway 60 and then turns south again at Tonkawa west of the study area. U.S. Highway 177 enters the area from the south and turns sharply west of Ponca City on U.S. 60. It turns north again two miles east of Tonkawa outside the study area. Oklahoma Highway 11 enters the area in the west from Blackwell, turns south on U.S. Highway 177 and then leaves the area to the east on U.S. 60. Oklahoma Highway 119 connects Kaw City with U.S. Highway 177, just north of Ponca City and runs eastward from Kaw City across the Arkansas River to north-central Osage County. County roads, most of them of crushed rock or gravel and dirt, are quite numerous and give access to most of the area. Most follow section lines.

Railroad tracks of the Atchison, Topeka, and Santa Fe Railroad and of the Chicago, Rock Island, and Pacific Railroad radiate north, south, east, and west from Ponca City. Unfortunately the Atchison, Topeka, and Santa Fe Railroad line which extended northwest-southeast across the area to serve Kaw City and vicinity was abandoned when the Kaw Dam Project was started.

GEOMORPHOLOGY

Kay and Osage Counties, Oklahoma, are situated on the Osage Plain of the Central Lowland Province (Hunt, 1966). Average elevation is approximately 1,000 ft. above sea level and the maximum relief is nearly 300 ft. in the northern part of the area. The lowest elevation is 910 along the Arkansas River in the southwest part of the area, just south of Ponca City. The highest elevation is in the north at an elevation of 1,270 ft. The most abrupt differences in elevation occur in the northern part of the area where within a mile the relief is 300 ft. from the top of the Mervine anticlinal fold down to the Arkansas River on its east flank. The topography is partly smooth and rolling suggesting topography developed in a humid climate. A rather angular, step-like topography developed in alternating limestones and shales, however, strongly suggests that relicts of topography developed in an arid climate remain. The many cuestas in the area are capped by limestones. Limestones are the most resistant rocks in the area. Shales are soft and form relatively gentle slopes.

The area is well drained by gullies, creeks, and river valleys that vary in shape and size (see Plate 1). The dominant stream pattern is dendritic.

The major perennial stream in the area is the Arkansas River with a gradient varying from two ft. per mi. to seven ft. per mi. The seven ft. per mi. gradient occurs in sec. 12 and 13, T. 27 N., R. 3 E. where the river is flowing on the Wreford Limestone on the upthrown side of the

Mervine Fault (see Plates 1, 3, and 4). The steep gradient is thought to be caused by the need for high energy in cutting through this resistant rock.

The Arkansas River runs across the Mervine fault axis at an angle of about 30° instead of along the fault as might be expected. Many of the tributaries of the Arkansas River appear to be controlled by fractures in the bedrock, but this has not been studied quantitatively.

McCord Terrace

Four river terraces are recognized in the study area. Although no geomorphic map is included herein, the distribution of flat surfaces on terrace alluvium on the surficial geologic map (Plate 1) combined with the longitudinal profiles of the terraces (Plate 4) and the cross sections (Plate 3) show the distribution of terraces adequately.

The McCord Terrace is the oldest and highest terrace found in the area. The surface of the terrace is much dissected by erosion in the northern part of the area (see Plates 1 and 4). In the southern part of the study area, the terrace is mostly well preserved, especially just southeast of Ponca City.

Ponca City Terrace

The Ponca City terrace is the second highest and second oldest in the area. Its surface varies in elevation from 985 ft. in the south to 1110 ft. in the north (see Plates 1 and 4). It has been largely destroyed by erosion in the middle part of the study area on the east side of Arkansas River, while on the west side it is still preserved.

Plain of Lake Blackwell II

In the southwest corner of the study area is the smooth, relatively flat lake plain produced when the valley train partially filled the Arkansas Valley in Ponca City time damming the mouth of the Salt Fork of the Arkansas.*

Uncas Terrace

The Uncas Terrace is the third highest and third oldest terrace in the study area and is mostly well preserved (see Plates 1 and 4). The surfaces are almost flat.

Kaw City Terrace

Kaw City Terrace is the lowest and youngest terrace in the area. In the northern and southern ends of the area the surface has been completely destroyed by lateral migration of the Arkansas River. The total area occupied by this terrace is very small.

Flood Plain of the Arkansas River

In the study area the Arkansas River is a meandering stream flowing southward in a broad flood plain. This broad plain may be due to huge amounts of water flowing from melting glaciers in the Rocky Mountains at the end of the Wisconsin glaciation which eroded away most of the younger terraces. When the high discharge of water was reduced, the

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*A similar lake plain was produced by deposition in Lake Blackwell I when the McCord Alluvium dammed the mouth of the Salt Fork of the Arkansas, but this older surface has been completely dissected by erosion.

deposition of alluvium occurred and the flood plain began to be developed. Erosion and deposition near the bank change continually depending on the amount of flow of the water in the river.

Sand Dunes

The only sand dunes mapped in the study area are on the Ponca City Terrace near the east end of Kaw Dam. Although eolian activity was widespread in north-central Oklahoma during the Quaternary (see Meyer, 1975, and Blair, 1975), there is remarkably little evidence of wind action in the study area. This is thought to be because the Arkansas Valley was too deep and narrow in most places for the prevailing southwest wind to get an unimpeded sweep across the alluvial deposits that repeatedly supplied an available source of eolian materials. The one deposit mapped (see above) is at the northeast end of a northeast-southwest trending segment of the Arkansas Valley where the prevailing southwest wind could blow effectively.

STRATIGRAPHY

All unconsolidated deposits (of Quaternary age) rest directly on bedrock of the Permian Period which is approximately 200 million years older. Based on this major unconformity and differences in cementation the stratigraphy of the study area is divided into two parts: bedrock stratigraphy and stratigraphy of unconsolidated deposits.

Bedrock Stratigraphy

The bedrock exposed in the thesis area is of early Permian age of which the oldest rocks are exposed in the eastern and northeastern parts of the area while the youngest crops out in the southwest part. These Permian rocks are underlain by all five series of the Pennsylvanian System. The Pennsylvanian rocks consist of numerous beds of drab-colored limestone from inches thick to more than 15 ft. thick interbedded with drab to red-colored shales (Clark and Cooper, 1930). The stratigraphic sequence of Permian rocks exposed in the area consists mostly of evenly stratified, fairly persistent beds. All strata are shallow marine or near-marine in origin. The thickness of the Permian Systems is about 1600 ft. (Clark and Cooper, 1930) in the southern part of the study area. The oldest unit dropping out in the area is the Crouse Limestone and the youngest is the Herington Limestone (see Plate 1).

Crouse Limestone

The Crouse Limestone, the oldest surface unit in the study area, is

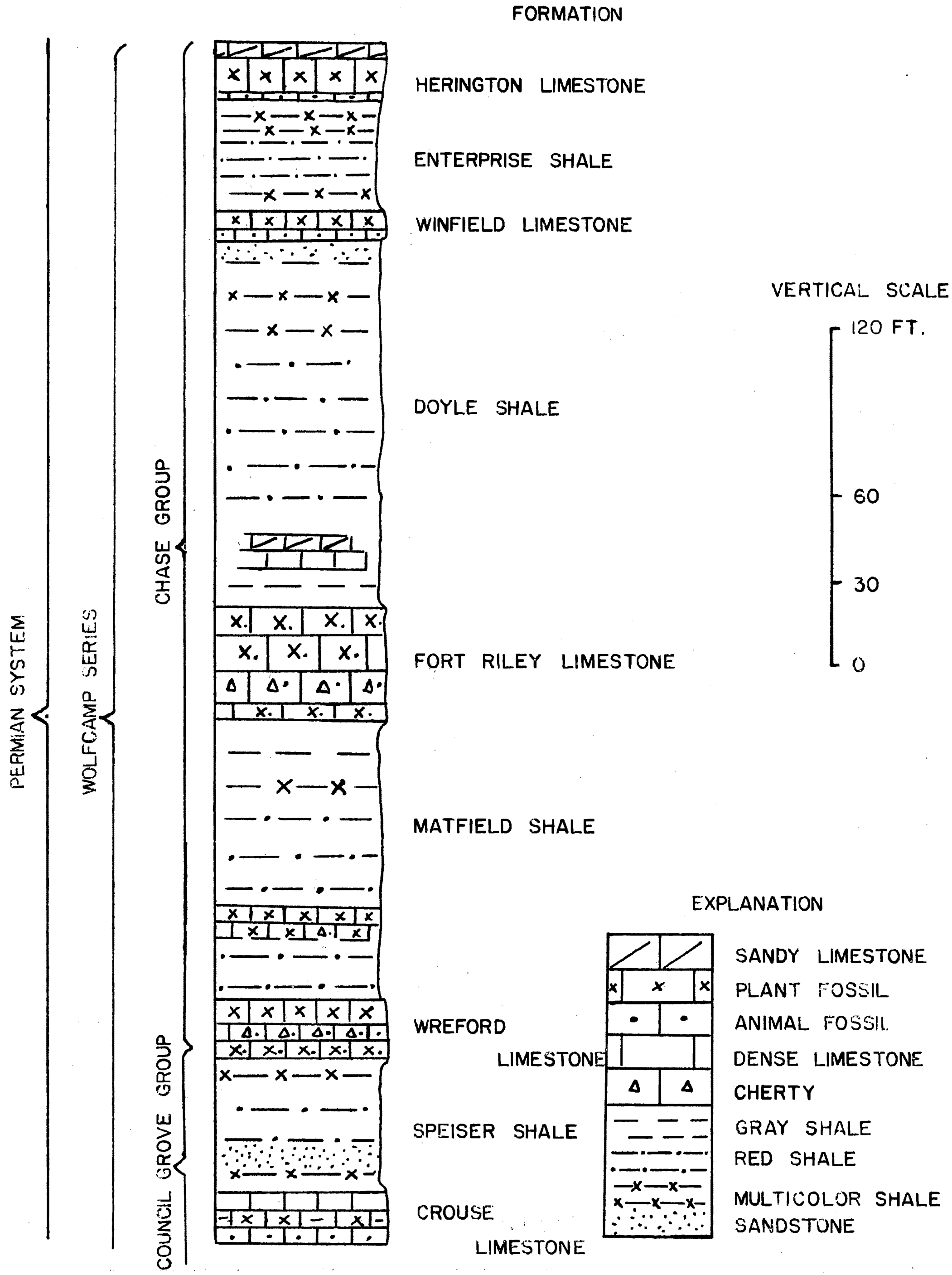


Fig. 6.--Bedrock stratigraphic column in the Ponca City area, north-central Oklahoma (modified from Noll, 1955)

exposed in the east and northeastern parts of the area (see Plate 1). Rocks of this formation are grayish-white (where fresh) to creamy (where weathered), thin-bedded limestone interbedded with various thicknesses of tan to brown calcareous shale. The limestone is fine-grained, fossiliferous, and porous with some jointing. Fossils collected by the author in S½, sec. 6, T. 26 N., R. 5 E. were productid brachiopods in coral mud showing that the environment of deposition was a quiet, low energy, near-shore environment, possibly a biostrome or stable shelf environment. Thickness is approximately 20 ft.

Speiser Shale

In this area the Speiser Shale overlies the Crouse Limestone. The rocks consist of a non-fossiliferous maroon shale grading upward to gray and tan near top. Layers or lenses of rust-brown calcareous, thick-bedded medium to fine-grained, crossbedded quartz sandstone occur occasionally just below the overlying Wreford Limestone. This sandstone is found in the northern part of the area in the south portion of T. 28 N., R. 5 E. and the northeast portion of T. 26 N, R. 5 E. The total thickness is 38 - 60 ft.

Wreford Limestone

The Wreford Limestone is extensively exposed all over the northern and northeastern parts of the area at elevations of about 1030 to 1040 ft. in the northern part and of about 1100 ft. east of Kaw City (see Plate 1). The unit consists of two gray to buff massive-bedded limestone units 3-8 ft. thick, which are medium-grained and fossiliferous and are separated by a brown to yellow shale. A massive brown chert bed approximately two ft. thick is found in the lower limestone unit. Total thickness of the Wreford Limestone is 10-20 ft. Calcareous mud (calcilutite), a few sand grains, large shark's teeth, and wood fragments indicate that the environment of deposition was near-shore but that the water was deep enough for sharks to swim. Badly fractured bryozoans may indicate a protected lagoon environment or an area of protected near-shore.

Matfield Shale

The Matfield Shale consists of two thick maroon shale members grading upward to gray and tan. They are separated by a thin fossiliferous limestone, occasionally with lenses of reddish-brown medium to fine-grained crossbedded sandstone. Total thickness is 50-100 ft.

Fort Riley Limestone

The Fort Riley Limestone which crops out over a large area in the north-central part of the study area, consists of two mostly gray, fine-grained, massive-bedded, fossiliferous limestone units 10-15 ft. thick separated by a shale approximately one ft. thick. A 1-8 ft. nodular chert layer occurs in the lower limestone unit. Total thickness is 20-25 ft. The environment of deposition of this formation is thought to be one of high energy deposition at the bottom, because of the occurrence of clastic material and fossil fragments. The presence of echinoderm coquina, echinoid spines, and brachiopod fragments show that this unit was deposited in a moderately shallow, warm, clear water, near-shore marine environment.

Doyle Shale

The Doyle Shale (see Plate 1) is a dark-brown to light-gray calcareous, slabby, friable, thick-bedded shale with thin-bedded fossiliferous limestone interbeds in the middle and lower parts. Thickness is 100-130 ft.

Winfield Limestone

This formation crops out extensively over 30% of the area. The thickness is 10 ft. in sec. 25, T. 26 N., R. 3 E. The unit is buff to light-gray when fresh, dirty-gray to light-brown where weathered, fine- to medium grained, fossiliferous, and massive-bedded. Some small scale pitting occurs on weathered surfaces. Where fresh, the limestone is massive, moderately dense, and hard with some joints. It is good for engineering uses (see Table 5). The environment of deposition was similar to that of the Fort Riley Limestone.

Enterprise Shale

The Enterprise Shale crops out in a relatively narrow band in most places, forming a fairly steep slope capped by the Herington Limestone. This unit is gray to maroon in the lower part grading upward to tan or olive-drab. It is sandy and friable in the lower part becoming calcareous in upper part with thin-bedded fossiliferous limestone interbeds. The total thickness is approximately 40 ft.

Herington Limestone

The Herington Limestone is the uppermost and youngest bedrock unit in the area. It is exposed extensively in the southwest corner of the thesis area from Ponca City to the vicinity of Kaw Dam. It is at an elevation of about 1020 ft. at Ponca City and gets higher to the east. The unit thickens westward. In general, the Herington Limestone is tan to buff at the bottom, grading upward to gray. The unit is fine-grained, fossiliferous, and massive-bedded in the upper approximately eight ft. and thin bedded below with a honeycombed zone about 18 in. thick at the base. The Herington is hard and competent where fresh. The thickness is approximately 20 ft. This unit is somewhat argillaceous and fine-grained suggesting a low-energy stable shelf environment of deposition, specifically a relatively clear-water environment with calcareous ooze on the bottom, which was being reworked by scavengers.

Stratigraphy of Unconsolidated Deposits

Unconsolidated materials (soils in the parlance of the engineer) are the geological materials that easily can be separated by gentle means in water (Means and Parcher, 1963). Surficial deposits in north-central Oklahoma were deposited by "normal" stream action and by melt-waters from Rocky Mountain glaciers at various times during the Quaternary along the Arkansas Valley itself. Some of the unconsolidated surficial materials were blown from the flood plain and deposited in adjacent areas as loess and eolian sand (Hunt, 1966; Ruhe, 1970). Wind-blown accumulations from one in. to ten ft. thick can be found on the east side of Arkansas Valley, sec. 29, T. 26 N., R. 4 E. Other unconsolidated deposits have been produced by gravity movements (especially by colluviation) and by Man who is perhaps the most important agent of erosion and transportation operating in the study area today (see Plate 1).

McCord Terrace Alluvium

The McCord Terrace Alluvium is the highest and oldest terrace alluvium in the study area (see Plates 1 and 3). It is much eroded in the northern part of the area but is remarkably well preserved in the southern part of the area where three facies are recognized: Otm-1, the sandy facies consists of light-gray fine, well-sorted quartz sand on the surface grading downward to dark-brown medium to coarse sand and gravelly sand. Thickness is over 80 ft. Otm-2, the silty facies, consists of light-brown sandy silty clay to clayey silty sand at the surface. Thickness is over 80 ft. Otm-3, the clayey facies, consists of brown clay at the surface. The sandy facies is interpreted as a valley train deposit related to a melting ice cap in the Rocky Mountains, the upper part of which probably was reworked by "normal" stream action. The silty and clayey facies are interpreted as facies of a backswamp deposit of the Arkansas deposited after the flood plain was stablized in late McCord time. It is probable that both the silty and sandy facies grade into the sandy facies with depth. All three facies are highly weathered in the upper part. North of the Ponca City area all of the McCord is the sandy facies, (Qtm-1).

Deposits of Lake Blackwell I

All of the deposits of Lake Blackwell I recognized so far are a dark-gray to black silty clay, apparently deposited in relatively quiet water.

Ponca City Terrace Alluvium

The Ponca City Terrace Alluvium, the second highest and second oldest terrace deposit recognized in the area, is mostly brown to dark-brown clayey fine sand to sandy clay at the surface, generally grading downward to sand and silty sand with irregular lenses and layers of silt and clay. This deposit generally is highly weathered in the upper part. Thickness is 20-60 ft. This deposit is interpreted as a valley train deposit the upper part of which has been reworked by "normal" stream action.

Deposits of Lake Blackwell II

The deposits of Lake Blackwell II, which was formed in the Salt Fork Valley when the mouth of the Salt Fork was dammed by the Ponca City Alluvium facies, are divided into two facies: a silty clay facies (Ql-2) and a sandy, silty clay facies (Ql-3). The silty clay facies is thought to have been deposited in relatively quiet water of the lake, the detritus coming from the Salt Fork and the surounding terrain. The sandy, silty clay facies is interpreted as basic silty clay facies material modified by sand spilling into the lake from the Arkansas River as it flowed past on top of the "dam" or that washed off the "dam" (i.e., off the surface of Ponca City alluvium).

Dune Sand

Dune sand has been mapped in only one place in the study area, sec. 29, T. 26 N., R. 42, on the east side of Arkansas River (see Plate 1). It consists of white to light-gray fine, well-sorted quartz sand. Thickness is up to 10 ft.

Uncas Terrace Alluvium

The Uncas Terrace Alluvium, the third highest and third oldest terrace deposit in the area, is well preserved along the eastern side of the Arkansas Valley. It is typically brownish-yellow silty very fine sand. Thickness ranges from 20 to 40 ft. This deposit is interpreted as a valley train deposit the upper part of which has been reworked by "normal" stream action.

Kaw City Terrace Alluvium

The Kaw City Terrace Alluvium is the lowest and youngest terrace deposit in the area. This deposit typically is light-brown to gray mostly fine sand and silt. Thickness ranges from 5 to 40 ft. This deposit also is interpreted as a valley train deposit the upper part of which has been reworked by "normal" stream action.

Colluvium

Colluvium is a general term applied to loose and incoherent deposits, usually at the foot of a slope or cliff and brought there chiefly by gravity (Weller, 1960). Colluvium in the thesis area typically is a mixture of limestone fragments and material derived from decomposed sandy shale transported by gravity (and sheetwash) from upslope. On steeper slopes the colluvium usually contains more and larger limestone fragments than on gentler slopes. These fragments range from a few inches to many feet in diameter. In any event, the size of limestone fragments decreases downslope away from the source of the limestone. Indeed, in many places virtually no limestone fragments are present. Two colluvial facies have been mapped. Qtc-1 is gray to grayish-brown angular cobble-to boulder-sized fragments of limestone mixed with sandy silty clay derived from shale. Qtc-2 is a reddish-brown sandy silty clay with occasional gravel-sized angular fragments of limestone. The thickness of colluvium ranges from less than one foot to many feet.

Flood Plain Alluvium

Flood plain alluvium is the unconsolidated material composed of sand or silt or clay or a combination of them (and sometimes including gravel-sized material) occurring beneath the flood plains of the Arkansas River and its tributaries. This material has been rather recently deposited by running water. The coarser material is deposited along the channel and finer deposit further away. In the thesis area flood plain alluvium is exposed along Wolf Creek, Cat Creek, Possum Creek, Coon Creek, Fishhook Creek, Sweetwater Creek, Bear Creek, Sarge Creek, and Charley Creek with major accumulations along both sides of the Arkansas River (see Fig. 7).

Artificial Fill

Artificial fill is any material emplaced by Man. This includes man-made materials such as brick, cast iron, cement or concrete fragments, lumber, and other material as well as local crushed rock or unconsolidated material. Most of the artificial fill deposits in the study area are engineering fills constructed of unconsolidated materials "borrowed" from nearby. Two limestone quarries are still active in the middle of the area in SE ¼, sec. 22 and NE ¼ sec. 27, T. 27 N., R. 3 E. (see Fig. 7). Sand and gravel pits are open elsewhere near the construction sites (Fig. 7). A newly opened sand pit is in the NW ¼, sec. 3, T. 25 N., R. 3 E. in Osage County near Ponca City.

Fig. 7--Typical clay drape within sandy alluvium. Sandy alluvium is underlain by several feet of sandy silt alluvium. NE¼, sec. 1, T. 26 N., R. 4 E.

PEDOLOGIC SOILS

The study of soils from the standpoint of their morphology and genesis is the science of pedology. This type of study is most important for agriculture, and its classification is influenced by 5 principal genetic factors (Spangler, 1960; and Barnes, 1948): climate, vegetation, parent material, slope, and age. A difference in kind or degree of any of these factors will result in a different soil. Pedologists deal with shallow soil materials generally those not more than five ft. below the surface. Soils in the study area have been mapped for the Kay County Soil Report (Culver, 1967) and for the Osage County Soil Report which will be published soon by the Soil Conservation Service. These soil maps were used to aid in geological mapping and especially in constructing the map showing the unified classification, and engineering classification (see Appendix 1) of surficial soils (Plate 2).

STRUCTURAL GEOLOGY

The study area is located between the Ozark and Nemaha uplifts. The surface bedrock is sedimentary rock of early Permian age, which is underlain by sandstone, shale, and limestone of Pennsylvanian age. The regional dip of the area is not more than 50 ft. per mile (or less than 1° westward. There are, however, local reversals where anticlines and synclines occur. The strike is approximately N. 10° E. (Bryan, 1950; Clark and Cooper, 1930; Eardley, 1962; Querry, 1957; and Smith, 1954).

The Mervine anticline and the associated Mervine Fault are the most outstanding structural features in the area. The asymmetrical Mervine anticline is just west of and parallel to the fault (see Plate 1 and Fig. 4 on Plate 3). The anticline is a broad fold that appears in profile as a cuesta trending northeast-southwest. The western and eastern limbs dip about 2°, N. 65° W. in the NE¼ sec. 10, T. 27 N., R. 3 E., and 6° S 70° E in the NE½, sec. 11, T. 27 N., R. 3 E., respectively at the southern end of the fold the dip is about 3°, S. 40° E. (SE½, Sec. 15, T. 27 N. R. 3 E.). The Mervine anticline is believed to be the same trend as the Ponca City anticline farther southwest and as the Dexter and Beaumont anticlines farther northeast in Kansas (Clark and Cooper, 1930).

The Mervine anticline is on the downthrown side or west of the Mervine fault. On the upthrown side of the fault the rocks are dipping about $1\frac{1}{2}^{\circ}$, S. 80° E. in the SW¼, sec. 1, T. 27 N., R. 3 E. (see Plate 1 and Fig. 4 of Plate 3). Joints and fractures are common in all limestone units in the area having an effect upon ground-water movement and the shear strength of rocks.

GEOLOGIC HISTORY

At the end of Precambrian time in north-central Oklahoma erosion of igneous and metamorphic rocks gave way to deposition in warm shallow seas. This deposition was interrupted only briefly until Mississippian time. Major regional uncomformities affecting the study area were produced in early Mississippian Hunton time and in post-Mississippian pre-Pennsylvanian time. In Pennsylvanian time the sea repeatedly advanced and retreated across the area producing thin cyclic sequences of sandstone, limestone, and shale often with coal beds. In early Permian time the environment of deposition was continuously marine or near-marine, and it is probable that sea level was alternately rising and falling so that the strand line was migrating landward and seaward not far away. At any rate, the early Permian rocks that crop out in the study area are alternating limestones and shales (see Fig. 6). The total thickness of post-Cambrian rock in the study area is approximately 2,000 ft. (Clark and Cooper, 1930; Beckwith, 1930). The boundary between the Pennsylvanian and the Permian in north-central Okalhoma is not marked by a physical break but is based upon interpretation of the fossil record. Indeed, the exact position of the boundary is the subject of some controversy (Clark and Cooper, 1930; Schuchert, 1941; Hussey, 1947; Clark and Stearn, 1960).

It is possible that equivalents of Mesozoic and/or Cenozoic rocks found today farther west were deposited in the area, but, if so, they have been destroyed by later erosion.

All of the sedimentary rocks in the area were tilted gently (about 1^{o}) to the west, probably in late Permian time during uplift of the Ozark Mountains (Hussey, 1947). It is probable that the Mervine fault and the Mervine anticline were produced at this time. All of the Permian rock units at the surface in the study area subseqeuntly have been truncated by post-Permian erosion. Unquestionably some hundreds of feet of younger Permian rocks also were eroded from the area during this time.

During late Tertiary time vast High-Plains-type of alluvial-plain deposits were laid down as a thick apron from the Rocky Mountains outward in all directions. These included the Pliocene Ogallala Formation which extended eastward across Oklahoma and probably all the way to the Gulf of Mexico which was much farther inland than it is today. This episode of erosion and deposition caused the Rocky Mountains to be "almost buried in their own debris" and the formation of great coalescing alluvial plains, the only large remnant of which is the present-day High Plains. The Ogallala in Oklahoma was several hundred feet thick in places and included detritus from clay- to cobble-size. During the Quaternary much of the world was subjected to a period of intense erosion (Thornbury, 1969). In north-central Oklahoma the Ogallala was eroded away by essentially the same streams that deposited it, streams that had changed from anastomosing, aggrading streams to meandering, degrading streams, undoubtedly in response to changes in climate.

As the Ogallala was being eroded away the pebble- and cobble-sized material lagged behind on the evolving erosional landscape because it was too heavy to be moved readily by the available running water. With time all rock types except quartz and quartzites were destroyed by chemical weathering, so that today only iron-oxide-stained quartz and quartzite pebbles and cobbles survive in some places on the uplands south of the thesis area (see Meyer, 1975 and Blair, 1975).

The early(?) Quaternary Arkansas River was a much larger stream than the present day Arkansas so that, as it cut down through the Ogallala, its great meanders (reflecting its very high discharge) were superposed on the underlying bedrock, producing huge intrenched meanders (see Plate 1). These are particularly well developed in the south end of the study area and for some fifty miles downstream along the Arkansas Valley. The intrenched meanders have been preserved here because the bedrock is more resistant to lateral erosion than it is north of the study area where the relatively small present-day Arkansas has been able to cut a wide flood plain.

By some time in the early Quaternary (possibly in Nebraskan time) the Arkansas had cut deeply into the bedrock and then was filled into a depth of at least 80 ft. by the McCord Formation (see Plate 1 and Fig. 3 on Plate 3) damming the mount of the Salt Fork of the Arkansas River just south of the study area and producing a huge lake, Lake Blackwell I, the eastern end of which extends into the southwest part of the map area. Locally derived black clayey sediments were deposited in this lake. Later (perhaps during Aftonian time) a well-developed flood plain, the remnants of which are the McCord Terrace, was established on top of thick McCord Terrace Alluvium.

Rejuvenation of the Arkansas (perhaps during the Kansan glaciation) and infilling of the Arkansas Valley by Ponca City Alluvium caused the Valley of the Salt Fork of the Arkansas to be dammed again but at a lower level, producing Lake Blackwell II. Again, black clayey sediments were deposited in most of the lake, but near the Arkansas Valley spillage of sand from the Arkansas or wash from the Ponca City Formation caused a sandy clay facies to be developed in the eastern end of the lake. A period of quasiequilibrium (perhaps early in the Yarmouthian interglaciation) produced a flood plain, the remnants of which are the Ponca City Terrace. Either during active valley train formation or during a following arid period sand dunes were deposited near the east end of recently-constructed Kaw Dam (Plate 1) by the prevailing southwesterly winds.

Rejuvenation and infilling by Uncas Alluvium (perhaps during the Illinoian glaciation) produced the Uncas Formation. Quasiequilibrium (perhaps during early Sangamonian time) produced a flood plain the remnants of which are the Uncas Terrace.

Further rejuvenation and infilling by Kaw City Alluvium (perhaps during the Wisconsian glaciation) produced the Kaw City Formation. Quasiequilibrium (perhaps during one of the substages of the Wisconsin) produced a flood plain, remnants of which are the small, low Kaw City Terrace.

Further rejuvenation and infilling (perhaps at the end of the Wisconsin glaciation) and quasiequilibrium (probably during the early Holocene) produced the present-day flood plain.

Finally, Man with his clearing of vegetation, cultivation, and construction of all kinds has had a radical effect upon the landscape so that today Man probably is the most important agent of erosion, transportation, and deposition operating in north-central Oklahoma.

These periodic episodes (rejuvenation, followed by infilling with alluvium, achievement of quasiequilibrium, and the establishment of a well-developed flood plain) probably reflect, in part, climatic changes from humid to arid and back again in the study area during the glaciations and interglaciations of the Pleistocene, but they probably reflect even more the effects of meltwater from the icecaps that covered the Rocky Mountains periodically during this time.

Radical local climatic changes probably are reflected in the angular cuesta topography in the area (i.e., the sharp angular topography is a relict of an arid climate in an area that today has a humid climate). The fact that limestones are resistant cap rocks strongly supports this hypothesis. Other evidence that the climate of north-central Oklahoma probably has changed repeatedly from humid to arid and back again in the southern U.S.A. is recorded by Garner (1975, p. 35-38).

The extensive deposits of colluvium in the study area (see Plate 1) almost certainly reflect periods of humid climate. Whether colluvial deposits could have survived from one humid period to the next is uncertain, but the angular topography suggests that at least some of the arid periods were long and severe enough to cause arid-land erosion with attendant destruction of surface soil and colluvium.

ECONOMIC GEOLOGY

Mineral resources of economic importance in Kay and Osage Counties are petroleum, natural gas (gas and liquid forms), limestone, sand, and gravel. Production values are shown in Table 3.

Table 3.--Total value of economic minerals in Kay and Osage Counties, Oklahoma (in thousands of dollars).*

County/Year	1970	1971	1972
Kay	15,921	15,383	15,243
Osage	45,766	43,581	43,845

*From U.S. Bureau of Mines Mineral Yearbooks, 1971 and 1972.

Petroleum and Natural Gas

Oil activity in north-central Oklahoma dates back to 1885 when Foucett drilled on Boggy River. Marland, a Pennsylvania oil operator, discovered the first north-central Oklahoma oil field near Ponca City in December, 1907 (Clark and Cooper, 1930; Barnes, 1939). Oil activity increased in this area in early 1918 when the Mervine oil field and others were discovered and the western part of the Osage Indian Reservation was opened for leasing.

In 1972 11 more wells were drilled in Kay County than the previous year, while two more were drilled in Osage County. See Table 4 for summary of wells drilled in 192.

Table 4.--Oil and gas wells drilled in 1972

County	Oil Wells	Gas Wells	Dry Wells	Total Wells
Kay	35	3	27	65
Osage	107	9	57	173

*From U.S. Bureau of Mines Mineral Yearbook, Oklahoma 1972.

Approximately 20% of the total proved oil and gas fields in both Kay and Osage Counties are in the study area (see Fig. 8). Of these the Ponca Oil Field has been the biggest producer in the area, and it still produces to the present day.

The sub-surface geologic structure of the area contains numerous reservoirs which are mostly of Pennsylvanian and Ordovician age. They are primarily elongate parallel folded structures which trend almost northeast-southwest. They become more pronounced with depth (Bryan, 1950; Clark and Cooper, 1930; Querry, 1957; and Smith, 1954). The average depth of producing reservoirs in the area is 3,000 ft.

Construction Materials

In the past the Herington limestone has been quarried in several

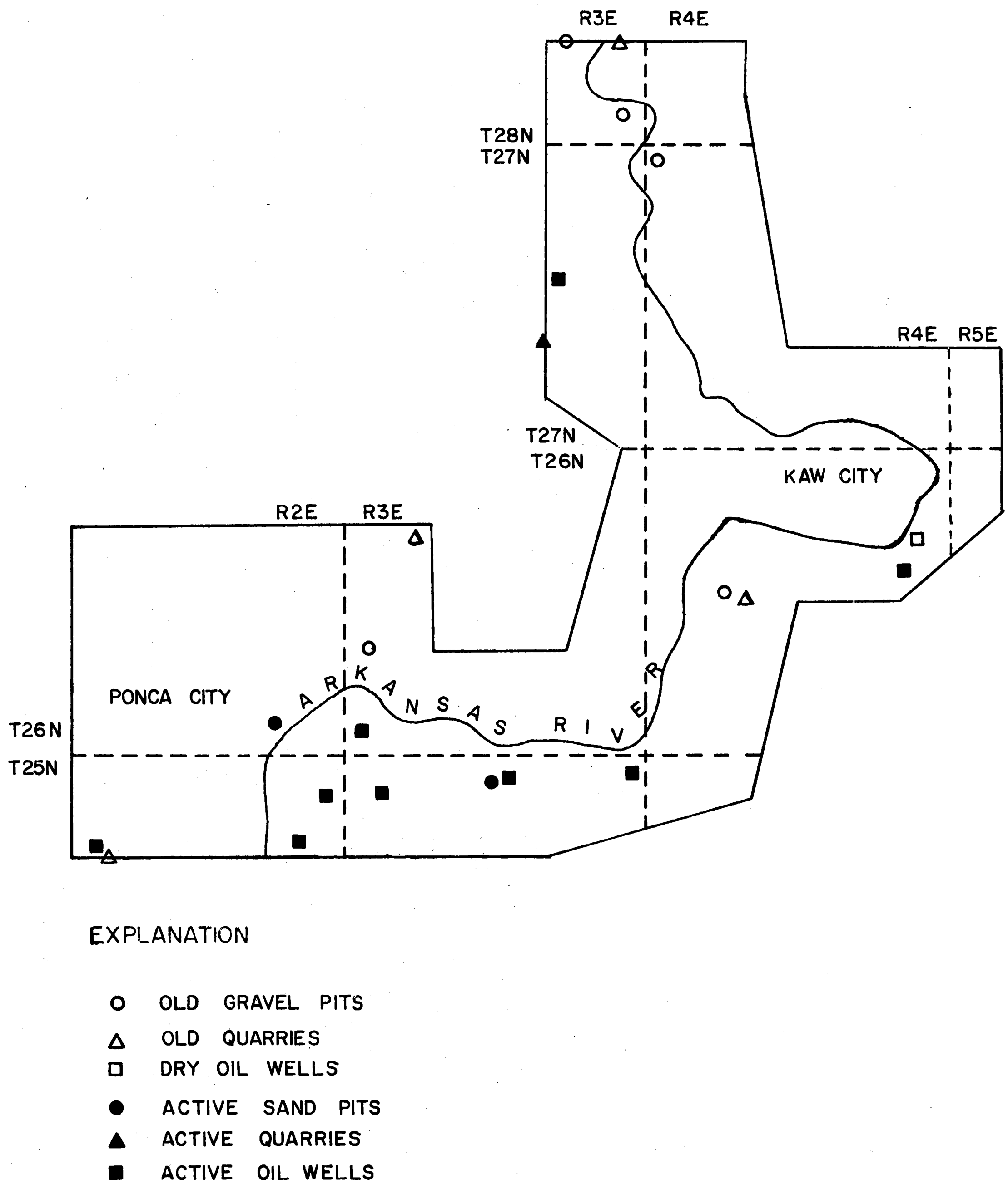


Fig. 8.--Past and present development of mineral resources in the study area

locations in the study area for use as stone and as aggregate. The rock also has been used as ballast for railroads in Kay County and surrounding areas, and as road metal for secondary county roads, highways and the streets of Ponca City. The Herington is one of the best limestones for concrete aggregate in north-central Oklahoma (Oklahoma Highway Department, 1967). It was used widely as building stone in Ponca City, and as riprap in the Ponca dam and lake area.

The only presently productive rock quarries in the study area are in the Fort Riley limestone in the west-central part of area (see Fig. 9). The quality and quantity are proven by U.S. Army Corps of Engineers and the Oklahoma Highway Department for all types of road, bridge, dam, building construction, concrete aggregate, etc. For the properties of limestones in the study area see Table 5.

Sand from the study area is used extensively in the surrounding area. It is mined both from flood plain alluvium and from terrace alluvium. Sand from pits in the flood plain deposits near Ponca City generally are class A and masonry grade with very low oxide content and low impurities. Most other deposits are also the same quality. The new terrace sand pit recently opened in NW¼ sec. 3, T. 25 N., R. 3 E. Osage County (see Fig. 9), processes sand of the same quality as sand from flood plain alluvium. It has shallow top soil and supplies sand for the new U.S. Highway 60 and other highways in the vicinity. McCord Terrace Alluvium and flood plain alluvium are the best sources of sand in the study area and are widely used as construction material. For these and other uses of unconsolidated deposits in the study area, see Tables 6 and 7.

Table 5.--Useability and chemical properties of limestone units in the study area

Formation Properties	Herington Limestone	Winfield Limestone	Fort Riley Limestone		Wreford Limestone	Crouse Limestone	
Approximate Thickness (feet)	15 - 20	8 - 11	15 - 25		15 - 20	10 - 25	
Apparent material suitability	Possible concrete aggregate	None	Locally suitable for base admi. riprap, etc.		locally suitable for riprap, etc.	None	
Apparent seepage	Some seeps noted	None noted	Some seepage		None noted	None noted	
Apparent rippability	Apparent non-rippable	Apparent rippable	Apparent non-rippable		Apparent rippable	Not good	
Chemical Comp. (% by wt.)			Upper Bed	Lower Bed		Upper Bed	Lower Bed
Limestone	95.2	93.6	95	7.1	87.8	71.6	95.0
Dolomite	1.6	3.3	2.5	89.3	8.2	6.4	3.0
Impurities	3.2	3.1	2.5	3.6	4.0	2.0	2.0

Table 6.--Physical and chemical properties of engineering soils in the study area

Properties		Capillary in. per in. of Soil	Permeability	Shrink and Swell	pH
Map Units	AASHO				
SP, SM	A-2	.12	Rapid	None	5.1-6.0
SM	A-2, A-4	.07-.12	Mod. Rapid	Low	1.5-8.4
ML, SM	A-2, A-4	.12	Moderate	Low	5.6-6.5
ML	A-4	.14	Moderate	Low	6.0-8.4
ML, CL	A-4	.14	Moderate	Low	5.1-8.4
CL	A-6	.17	Very Slow - Mod. Slow	Mod.	6.1-8.4
CL (Shallow)	A-6	.17	Mod. Slow	Mod.	5.6-6.0
CL, CH	A-7	.17	Very Slow	High	6.5-8.4
CH	A-7	.17	Very Slow	High	5.6-8.4

Table 7. Engineering characteristics of units mapped on engineering soils map

Properties	Top Soil	Selected Grading Material	Road Fill	Highway Location	Reservoir	Embankment
SP, SM	Poor, erodable	Good	Good when entire profile is used	Unstable slopes	High rate of seepage	Poor
SM	Poor to fair	Good	Poor to fair	Unstable	Seepage	Easily eroded
ML, SM	Poor, easily eroded	Good	Good	Features favorable	Features favorable	Features favorable
ML	Fair, easily eroded on steep slope	Unsuitable when wet	Poor, difficult to compact	Weak foundation	High seepage	Possible seepage
ML, CL	Good to fair	Poor, elastic when wet	Fair to poor	Weak foundation when wet	Features favorable	Features favorable
CL	Poor to fair	Unsuitable	Poor, unstable when wet	Unstable when wet	Features favorable	Fair, highly plastic
CL (Shallow)	Poor	Unsuitable	Less quantity	Good	Fair to poor	Limited material
CL, CH	Poor	Unstable	Poor, high shrinkage swell	Soft when wet	Features favorable	Limited material
CH	Poor	Unstable	Poor	Occasional flooding	Features favorable	Low stability

Surface and Ground Water

The Arkansas River is a major source of water in northern Oklahoma, supplying many towns. No major problem exists in treating this water for residental and industrial use north of the Salt Fork of the Arkansas River except silting. Discharge of the Arkansas River is recorded by the Tulsa District of the U.S. Army Corps of Engineers as averaging 2,320, 563 acre feet per year (from records of 48 years).

Ponca City, the biggest city in the area, uses water from Ponca Lake, 3 miles east of Ponca City, which is a man-made reservoir, and water from wells in the flood plain alluvium along the Arkansas River.

Ground water of good quality occurs at shallow depth in the terrace and flood plain alluvium of the Arkansas River and its main tributaries. Ground-water throughout much of the study area will be affected by the completion of Kaw Dam and Lake Project.

Because limestone with solution-widened joints and bedding planes overlies shale in much of the area, seepage is a major problem in road maintenance.

ENGINEERING GEOLOGY

Engineering geology is the application of all branches of geologic knowledge to interpret factors that affect the safety, efficiency, and economy of engineering works. It is an important and varied field pertaining to the construction of large structures that are built on, with, or through earth materials. Engineering works may succeed or fail according to how well they fit their geologic environment, and how well geologic processes that might affect them have been understood.

Engineering Soils Map

Soil is material that can be separated by gentle means (Means, 1963). The engineering soils map of the study area (Plate 2) is based upon published and unpublished maps of the Soil Conservation Service for Kay and Osage Counties, Oklahoma, supplemented by data obtained from the U.S. Army Corps of Engineers, the Oklahoma Highway Department, and field and laboratory investigations. These data were used to characterize the engineering properties of pedologic units as far as possible in the Unified Soils System (Appendix 1).

The Unified Soil Classification probably is the most widely used engineering soil classification system in the world. It incorporates grain-size classification and Atterberg limits of the materials being classified (see Appendices 1 and 2). All soils are classified into 15 groups, each group being designated by two letters from the following:

G - gravel

S - sand

M - non-plastic or low plasticity fine or silt.

C - Plasticity fine or clay.

Pt - Peat, humus, swamp soils.

O - organic

W - well graded

P - poorly graded

L - Low liquid limit, (i.e., below 50 and indicating low to medium compressibility).

H - High liquid limit (i.e., above 50 indicating high compressibility)

The first letter indicates the type of material as well as the major amount of the soil. The second letter indicates grading or plasticity. The procedure of grouping of soil in Unified Soils System is shown in Appendix 1. The weakness of this system is only that it is dealing with remolded soils but not of the structure of soil in place.

In the thesis area the more than 50 pedologic soils can be grouped into 9 groups by this Unified Soils System. It should be stressed that this engineering soils map (Plate 2) deals only with the A and B horizons of the surface soils. The 9 groups of the engineering classification used for Plate 2 are:

1. SP-SM, Dougherty Series.
2. SM , Carr Series, Carwile Series, Lincoln Series, Darnell-Stephenville Complex, Eufaula Series, Niotage-Darnell Complex, Sand Dune of Lincoln Material.
3. ML-SM, Shellabarger Series.

4. ML , Broken Alluvium Land, Dale silt loam of Dale Series, Loamy Broken Land, Newtonia Series, Caspiana Series, Dennis Series, Dennis-Verdigris Complex.

5. ML-CL, Humbarer Series, Norge Series, Vanoss Series, Waurika Series, Bates Series, Minco Series, Norge-Homing Complex, Pond Creek Series, Teller Series, Norge-Albion Complex.

6. CL , Breaks-Alluvial Land Complex, Brewer Series, Dale clay loam of Dale series, Eroded Loamy Land, Labette Series, Iabetter-Slickspots complex, Summit Series, Vernon Series, Kaw silty clay loam of Kaw Series, Foraker-Shidler complex, Grainola-Shidler complex, Whizbang Series.

7. CL (Shallow = 9" depth) - Sogn Series, Sogn-Summit complex.

8. CL-CH, Eroded clayey land.

9. CH , Lela Series.

The properties and engineering characteristics of the units used on the engineering soils map (Plate 2) are shown in Tables 6 and 7.

Surficial Geologic Map

For many engineering geologists the genetic classificaiton used on the surficial geologic map of the area (Plate 1) provides more complete and more easily interpreted engineering information than does the map showing the Unified Classification of surface pedologic soils (Plate 2). In any case, Plate 2 does not give significant information about surificial units below approximately 60 in.

SUGGESTIONS FOR FURTHER STUDY

Several things that probably should have been done in a study of this scope are as follows:

1. The geologic and geomorphic names used herein for the first time should have been formally established according to the procedures summarized by Stone (1966).

2. There should be a page-sized geomorphic map of the study area.

3. The orientations of drainage segments and of bedrock joints should be studied quantitatively and compared.

4. A more thorough search for paleosols and for eolion deposits should be made.

5. The deposits of Lake Blackwell I and Lake Blackwell II should be studied in more detail.

6. The engineering characteristics of the surficial geologic map units should be analyzed and presented in table form.

Topics of study which are logical extensions of this study are as follows:

1. A careful search for all evidence pertaining to climate in north-central Oklahoma during the Pleistocene should be made.

2. The surficial geology of the Arkansas Valley in north-central Oklahoma should be compared in detail with the surficial geology of the Cimarron Valley in north-central Oklahoma because the Arkansas Valley was affected repeatedly by metlwater from ice caps in the Rocky Mountains while the Cimarron Valley was not. Both areas evidently were affected

by repeated changes from a humid climate to an arid climate and back again.

3. The deposits of Lake Blackwell I and Lake Blackwell II should be traced westward.

REFERENCES CITED

Atwood, Wallace W., 1940, The physiographic provinces of North America: Ginn and Company. 535 p.

Barnes, C. P., 1948, Environment of natural grassland, U.S.D.A. Yearbook Agric., XIV-892 p.

Barnes, L. S., 1939, The last run, Kay County, Oklahoma 1893: The Courier Printing Co., Ponca City, Oklahoma.

Bateman, John H., 1950, Materials of construction: Pitman Publishing Co., 568 p.

Beckwith, H. T., 1930, Osage County, Oklahoma: Oklahoma Geological Survey, Bull. No. 40, Vol. III, p. 211-267.

Blair, John A., 1975, Surficial geology of the Cimarron River Valley from Interstate 35 to Perkins, north-central Oklahoma: Unpublished M.S. thesis, Oklahoma State University.

Branson, Carl C., 1962, Pennsylvanian System of the mid-continent, Pennsylvanian System in the United States: A.A.P.G., p. 431-460.

Bryan, R. C., 1950, The subsurface geology of the Deer Creek, Webb, and North Webb Oil Pools, Grant and Kay Counties, Oklahoma: Unpublished M. S. thesis, University of Oklahoma.

Clark, G. C. and Cooper, C. L., 1930, Kay, Grant, and Garfield Counties, Oklahoma: Oklahoma Geological Survey, Bull. No. 40, Vol. II, p. 67-104.

Clark, Thomas H. and Stearn, Colin W., 1960, The geological evolution of North America: The Ronald Press Co., New York, 434 p.

Colemane, A. P., 1926, Ice ages, recent and ancient: The Macmillan Co., 296 p.

Cook, Gregory Lee, 1973, Land-resource capability units of the Wagoner County area, northeastern Oklahoma: Unpublished M.S. thesis, Oklahoma State University, 55 p.

Culver, James R., 1967, Soil survey of Kay County, Oklahoma: U.S. Dept. Agr. Soil Cons. Serv., 86 p.

Dart, Wakefield, 1970, Recurrent climate stress on Pleistocene and recent environments of the Central Great Plains: Univ. of Kansas Press.

Eardley, A. J., 1962, Structural geology of North America: Second Edition: Harper and Row Publishers, 743 p.

Garner, A. F., 1974, The origin of landscapes: Oxford University Press, New York, 734 p.

Hartronft, B. C., 1967, Engineering classification of geologic materials, Div. 4: Oklahoma Dept. of Highways Research and Development Div., 284 p.

Heuby, Alexander Joseph, 1955, Surface geology of northeastern Kay County, Oklahoma: Unpublished M.S. thesis, Oklahoma University.

Holbrook, 1967, Climate of Kay County, Oklahoma in Culver, James R. Soil Survey of Kay County, Oklahoma: U.S. Dept. Agr. Soil Cons. Serv., p. 82-89.

Hunt, Charles B., 1966, Physiography of the United States: W. H. Freeman and Co., 480 p.

Hussey, Russell C., 1947, Historical geology, the geologic history of North America: McGraw-Hill Book Co., 465 p.

Means, R. E. and Parcher, J. V., 1963, Physical properties of soils: Charles E. Merrill Publishing Co., 465 p.

Meyer, Gary D., 1975, The surficial geology of the Guthrie North Quadrangle, Logan County, Oklahoma: Unpublished M.S. thesis, Oklahoma State University.

Noll, Charles R. Jr., 1955, Geology of southeastern Kay County, Oklahoma: Unpublished M.S. thesis, University of Oklahoma.

Pettijohn, F. J., 1956, Sedimentary rocks, Second Edition: Harper & Row, Publishers, New York, 718 p.

Portland Cement Association, 1962, PCA Soil Primer: Chicago, 52 p.

Querry, J. L., 1957, Subsurface Geology of South Central Kay County, Oklahoma: Unpublished M.S. thesis, University of Oklahoma.

Ruhe, Robert V., 1970, Soil-Paleosols and environment in Pleistocene and recent environments of the central great plains: University Press of Kansas, p. 37-52.

Schuchert, Charles, 1941, Stratigraphy of the eastern and central United States: John Wiley and Sons, Inc., New York, 1013 p.

Smith, Earl W., 1954, Subsurface geology of eastern Kay County, Oklahoma and Southern Conley County, Kansas: Unpublished M.S. thesis, University of Oklahoma.

Southard, L. G. and others, 1971 and 1972, The mineral industry of Oklahoma: U.S. Bureau of Mines Minerals Yearbook, 15 p.

Spangler, Merlin G., 1960, Soil engineering, Second Edition: International Textbook Co., 483 p.

Stone, John E., 1966, Policy of the Minnesota Geological Survey on nomenclature and classification for the Quaternary geology of Minnesota: Minn. Geol. Survey Administrative Report, 20 p.

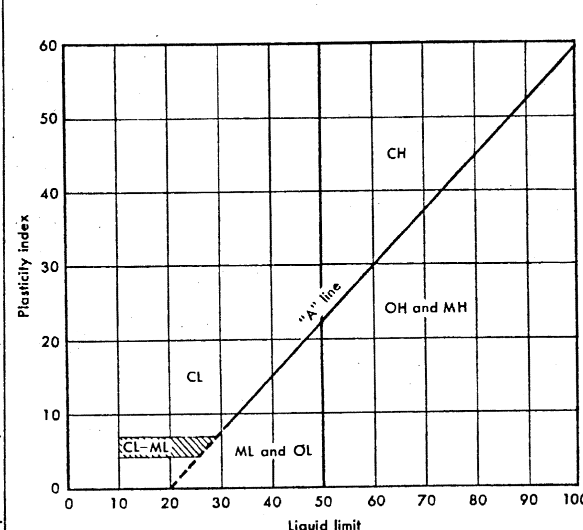
Thornbury, William D., 1969, Principles of geomorphology, Second Edition: John Wiley and Sons, New York, 594 p.

Thornthwaite, G. W., 1941, Atlas of climate types in the United States: U.S.D.A., Misc. Publ. 421, p. 1-7.

Weller, Mervin J. and Others, 1960, Dictionary of geological terms, Second Edition: Doubleday and Co. Inc., 545 p.

Appendix 1.--Unified soil classification system (from Portland Cement Association, 1962)

Major divisions			Group symbols	Typical names	Laboratory classification criteria	
Coarse-grained soils (More than half of material is larger than No. 200 sieve size)	Gravels (More than half of coarse fraction is larger than No. 4 sieve size)	Clean gravels (Little or no fines)	GW	Well-graded gravels, gravel-sand mixtures, little or no fines	Determine percentages of sand and gravel from grain-size curve. Depending on percentage of fines (fraction smaller than No. 200 sieve size), coarse-grained soils are classified as follows: Less than 5 per cent .... GW, GP, SW, SP; More than 12 per cent .... GM, GC, SM, SC; 5 to 12 per cent .... *Borderline* cases requiring dual symbols**	$C_u = \frac{D_{60}}{D_{10}}$ greater than 4; $C_c = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ between 1 and 3
			GP	Poorly graded gravels, gravel-sand mixtures, little or no fines		Not meeting all gradation requirements for GW
		Gravels with fines (Appreciable amount of fines)	GM* d / u	Silty gravels, gravel-sand-silt mixtures		Atterburg limits below "A" line or P.I. less than 4 — Above "A" line with P.I. between 4 and 7 are *borderline* cases requiring use of dual symbols
			GC	Clayey gravels, gravel-sand-clay mixtures		Atterburg limits above "A" line with P.I. greater than 7 — Above "A" line with P.I. between 4 and 7 are *borderline* cases requiring use of dual symbols
	Sands (More than half of coarse fraction is smaller than No. 4 sieve size)	Clean sands (Little or no fines)	SW	Well-graded sands, gravelly sands, little or no fines		$C_u = \frac{D_{60}}{D_{10}}$ greater than 6; $C_c = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ between 1 and 3
			SP	Poorly graded sands, gravelly sands, little or no fines		Not meeting all gradation requirements for SW
		Sands with fines (Appreciable amount of fines)	SM* d / u	Silty sands, sand-silt mixtures		Atterburg limits below "A" line or P.I. less than 4 — Limits plotting in hatched zone with P.I. between 4 and 7 are *borderline* cases requiring use of dual symbols.
			SC	Clayey sands, sand-clay mixtures		Atterburg limits above "A" line with P.I. greater than 7 — Limits plotting in hatched zone with P.I. between 4 and 7 are *borderline* cases requiring use of dual symbols.
Fine-grained soils (More than half of material is smaller than No. 200 sieve)	Silts and clays (Liquid limit less than 50)		ML	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands, or clayey silts with slight plasticity		
			CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays		
			OL	Organic silts and organic silty clays of low plasticity		
	Silts and clays (Liquid limit greater than 50)		MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts		
			CH	Inorganic clays of high plasticity, fat clays		
			OH	Organic clays of medium to high plasticity, organic silts		
	Highly organic soils		Pt.	Peat and other highly organic soils		

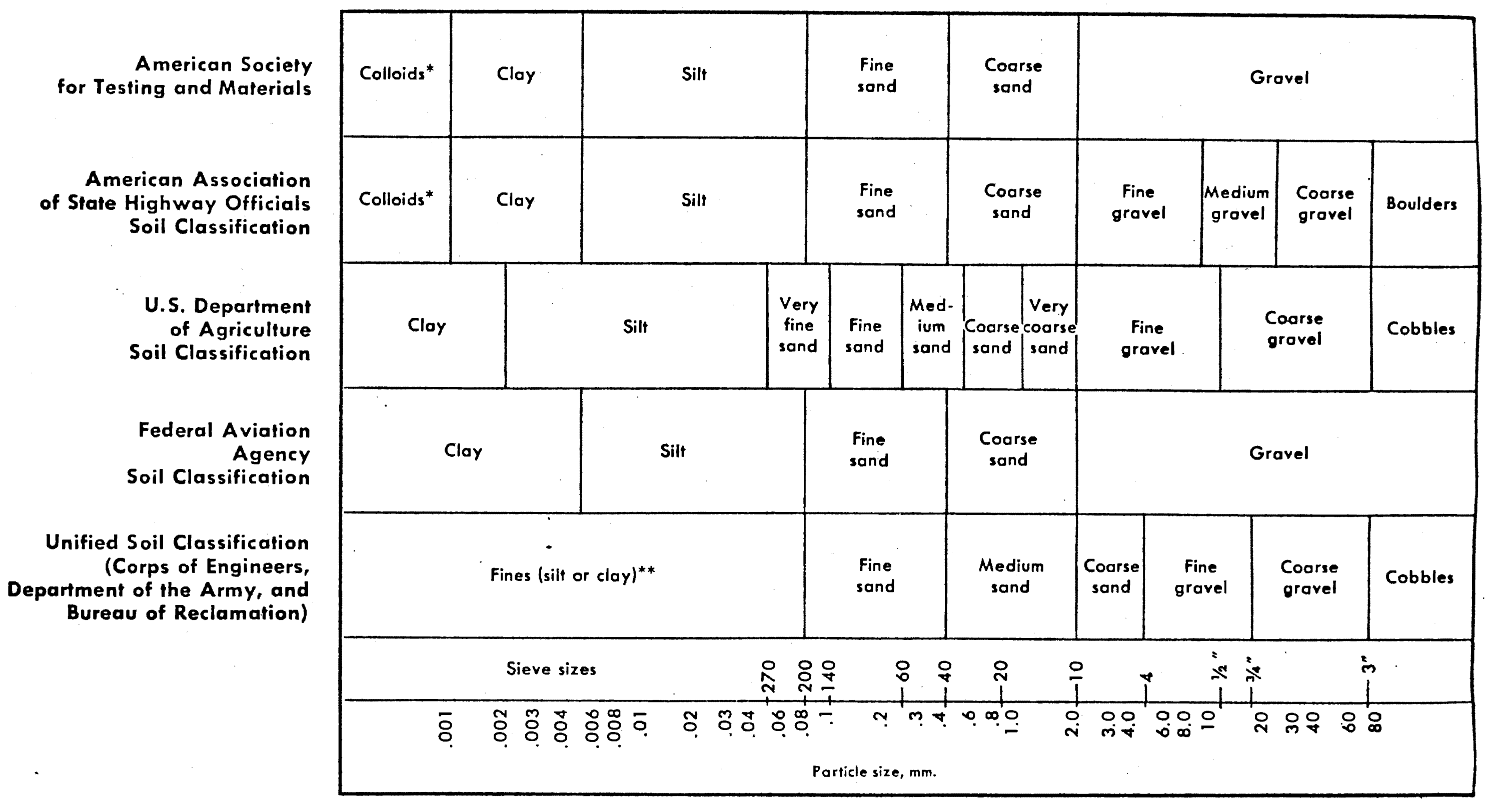


Plasticity Chart

*Division of GM and SM groups into subdivisions of d and u are for roads and airfields only. Subdivision is based on Atterburg limits; suffix d used when L.L. is 28 or less and the P.I. is 6 or less; the suffix u used when L.L. is greater than 28.

**Borderline classifications, used for soils possessing characteristics of two groups, are designated by combinations of group symbols. For example, GW-GC, well-graded gravel-sand mixture with clay binder.

Appendix 2.--Soil separate size limits (from Portland Cement Association, 1962)



*Colloids included in clay fraction in test reports.

**The L.L. and P.I. of "Silt" plot below the "A" line on the plasticity chart, Table 4, and the L.L. and P.I. for "Clay" plot above the "A" line.

Appendix 3.--AASHO classification of highway subgrade materials (from Portland Cement Association, 1962)

General classification	Granular materials (35 per cent or less of total sample passing No. 200)							Silt-clay materials (More than 35 per cent of total sample passing No. 200)			
Group classification	A-1		A-3	A-2				A-4	A-5	A-6	A-7
	A-1-a	A-1-b		A-2-4	A-2-5	A-2-6	A-2-7				A-7-5, A-7-6
Sieve analysis, per cent passing:											
No. 10	50 max.										
No. 40	30 max.	50 max.	51 min.								
No. 200	15 max.	25 max.	10 max.	35 max.	35 max.	35 max.	35 max.	36 min.	36 min.	36 min.	36 min.
Characteristics of fraction passing No. 40:											
Liquid limit				40 max.	41 min.	40 max.	41 min.	40 max.	41 min.	40 max.	41 min.
Plasticity index	6 max.		NP	10 max.	10 max.	11 min.	11 min.	10 max.	10 max.	11 min.	11 min.*
Group Index**	0		0	0		4 max.		8 max.	12 max.	16 max.	20 max.

Classification procedure: With required test data available, proceed from left to right on chart; correct group will be found by process of elimination. The first group from the left into which the test data will fit is the correct classification.

*P.I. of A-7-5 subgroup is equal to or less than L.L. minus 30. P.I. of A-7-6 subgroup is greater than L.L. minus 30

** Group index $= 0.2a + 0.005ac + 0.01bd$

where

a = that portion of percentage passing No. 200 sieve greater than 35 per cent and not exceeding 75 per cent, expressed as a positive whole number (1 to 40)

b = that portion of percentage passing No. 200 sieve greater than 15 per cent and not exceeding 55 per cent, expressed as a positive whole number (1 to 40)

c = that portion of the numerical L.L. greater than 40 and not exceeding 60, expressed as a positive whole number (1 to 20)

d = that portion of the numerical P.I. greater than 10 and not exceeding 30, expressed as a positive whole number (1 to 20)

The group index is given in parentheses after the soil group number. In this case the soil would be listed as an A-6(7).

VITA

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