ENGINEERING PROPERTIES OF KANSAS SOILS

by 1264

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INTRODUCTION

Soils, like water, are one of man's most vital natural resources. Soil covers most of the land surface, except for the steep and rugged mountain peaks and the lands of perpetual ice and snow. Soil is defined by engineers as the natural occurring rock debris, including the enclosed water and organic matter, which is found on or near the surface of the earth and can be moved by conventional earth moving machinery. The agriculturalist defines soil as the material on the surface of the earth capable of supporting vegetation. The geologist defines soil as all unconsolidated uncemented material produced by the weathering of the earth's mantle. In their natural state, soils are formed by the decomposition and disintegration of the earth's rocky crust, some remaining in place as residual soils while others are transported and deposited by the natural agencies - gravity, wind, water, and ice in their present position. Variations in the soil mantle occur due to the countless combinations of local conditions that have existed during millions of years and to the varying soil constituents and it is thus likely that there are no two locations where the soils are identical throughout their depths to bedrock. Because of the variations in composition and heterogeneous deposition, natural soils show extreme ranges of strength and compressibility. Still all soils have many characteristics in common. Every soil consists of mineral, organic matter, water, and air. The proportions vary, but these major components are usually present.

It is common to be told that soils vary to a degree that defies prediction. The purpose of this report is to show that the soils of Kansas fall naturally into eleven so-called physiographic provinces, Fenneman (1) and within each province the soils fall into three natural categories; upland, slope, and valley soils. Further it will be shown that the upland soils within a province will be similar over the entire province as will the slope and valley soils though the upland, slope, and valley soils will vary greatly from each other. The basic variation within each area usually lies in the thickness of the soil stratum rather than in the physical characteristics of the soil. Thus the classification, strength, and compressibility of an upland soil within a province will be found to be surprisingly constant.

Most soils have a profile, that is, a succession of layers above the weathered rock. These layers are the result of vegetation growth and are of prime importance to the agriculturist. They were first described by Dakuchaev (2) in 1873 and their importance to engineering construction has only recently been recognized. The soil profile consists usually of three or more layers (known as horizons) lying upon each other successively like the pages of a book. Most soil profiles include these three master horizons, identified by the letters from uppermost to lowermost as the A, B, and C horizons. The combined A and B horizons are called the solum, sometimes called "the true soil." The C horizon is the parent material from which the solum was derived and thus lies beneath the A and B horizons.

Soils have been classified in many ways, since the description of various soil types will vary according to the intended use of the soil. For the soil engineer, soil is either a foundation upon which he will rest his structure or a type of borrow material which he can use for fills and embankments. Casagrande (3) devised the most commonly used engineering classification scheme which was modified by the U. S. Army Corps of Engineers (4). Most Highway Departments use the A. A. S. H. O. scheme (5) while engineers constructing airfields use the F. A. A. classification (6). The engineer is also interested in the size of particles, Krumbein (7), Casagrande (8), ASTM (9), the effects of moisture on the soil as measured by the Atterberg limits test (10), the shearing strength, Coulomb (11), Rankine (12), Bishop and Henkel (13), the compressibility, Terzaghi (14) and in some cases the mineralogy. Engineers must also consider the competing economic uses that might be made of the soils by agriculturists and others.

Statement of the Problem

In Kansas, soils and rock formations have been described locally but no effort has been made to review the overall engineering picture of the soils. This study has been carried out to aid engineers in predicting in advance the type of soil to be expected in various parts of the state and the engineering problems that may be encountered so that the soil investigations for structures can be both adequate and economical.

Until recent times, soil engineers have relied almost exclusively upon detailed borings for the appraisal of soil conditions in connection with engineering projects. Each project was pursued without any idea of the soils that would be found and thus the soil investigations all started from "scratch." It was not possible to tentatively choose a reasonable foundation type until the first hole was drilled. Thus much time was lost either during the drilling or by the numerous return trips to the site to secure adequate information. Too often a spread footing is used on sites where drilling was extended to 100 feet while on other projects, piles were designed that penetrated deeper than the drill holes. This procedure is certainly uneconomical and time consuming, since it requires extra sampling and testing and/or unnecessary risk.

Another method for preparing soil investigations is proposed in this report, based on the principle that soils can be classified in place by means of the soil profile characteristics, easily obtained from the Department of Agriculture and the Geological Surveys. Long range planning and preliminary estimates can be made with the proper use of such information, thus saving time and money. All general soil information must be checked by some detailed borings and final recommendations made on the findings from the detailed soil report.

The following general guide for soil investigations is suggested:

1. Obtain information concerning the structure including size, shape, tolerance to deflections and expected permanence.

2. Check the expected soil conditions from the Department of Agriculture, county soil reports and bedrock condition with the State Geological Survey.

3. Design a tentative foundation based on the expected soil conditions and type of structure.

4. Lay out and conduct a soil investigation that will measure soil variability and exact thickness of the various soil layers. Plan for sampling to yield information on shear strength and compressibility to a depth, dependent upon the expected size and spacing of the footing, where stress is dissipated to a negligible amount.

5. Reevaluate the foundation concept if necessary.

6. Complete soil investigation and finalize foundation design.

Scope of the Study

The scope of this report is a thorough search of all the existing literature from the State Highway Commission of Kansas, the State Geological Survey of Kansas and the U. S. Department of Agriculture for data, much of which is unpublished, that will allow a generalization of the soil conditions in the various portions of Kansas.

GEOGRAPHY OF KANSAS

Kansas is at the heart of the Nation. Its central position among the states is evident in Fig. 1. Kansas has the distinction of having within its borders two significant landmarks. One of these is the geographical center of the adjoining 48 states, located approximately one mile north and one mile west of the town of Lebanon in Smith County, Kansas; the other is the Meades Ranch triangulation station or the geodetic datum known as the North American datum of 1927 in Osborne County, Kansas. This is the point of origin of all Federal mapping in the United States as well as in Canada and Mexico.

Kansas lies between 36° 59' 55.2" and 40° North latitude, and 94° 37' 03.4" and 102° 03' 02.3" West longitude. It is almost in the shape of a parallelogram with the exception of the northeast where the Missouri River cuts across the corner of the state. The greatest dimension, 411 miles, is east and west and the average width north and south is about 208 miles.

Kansas experiences much more extremes of temperature than would be expected for its midwest location. The three climatic factors responsible for the extremes in temperature are the following.

1. Altitude. Kansas lies between 686 feet in the east and 4,135 feet in the west, above sea level. Since temperature changes at the rate of about 3.3°F for each 1,000 feet in elevation, this makes a difference in the weather and climate in Kansas from east to west.

2. Land and Water Bodies. Kansas has a continental location, far from large oceanic bodies. Land cools and heats four to five times faster than water and this heating in summer and cooling in winter has much to do with the extremes of temperatures.

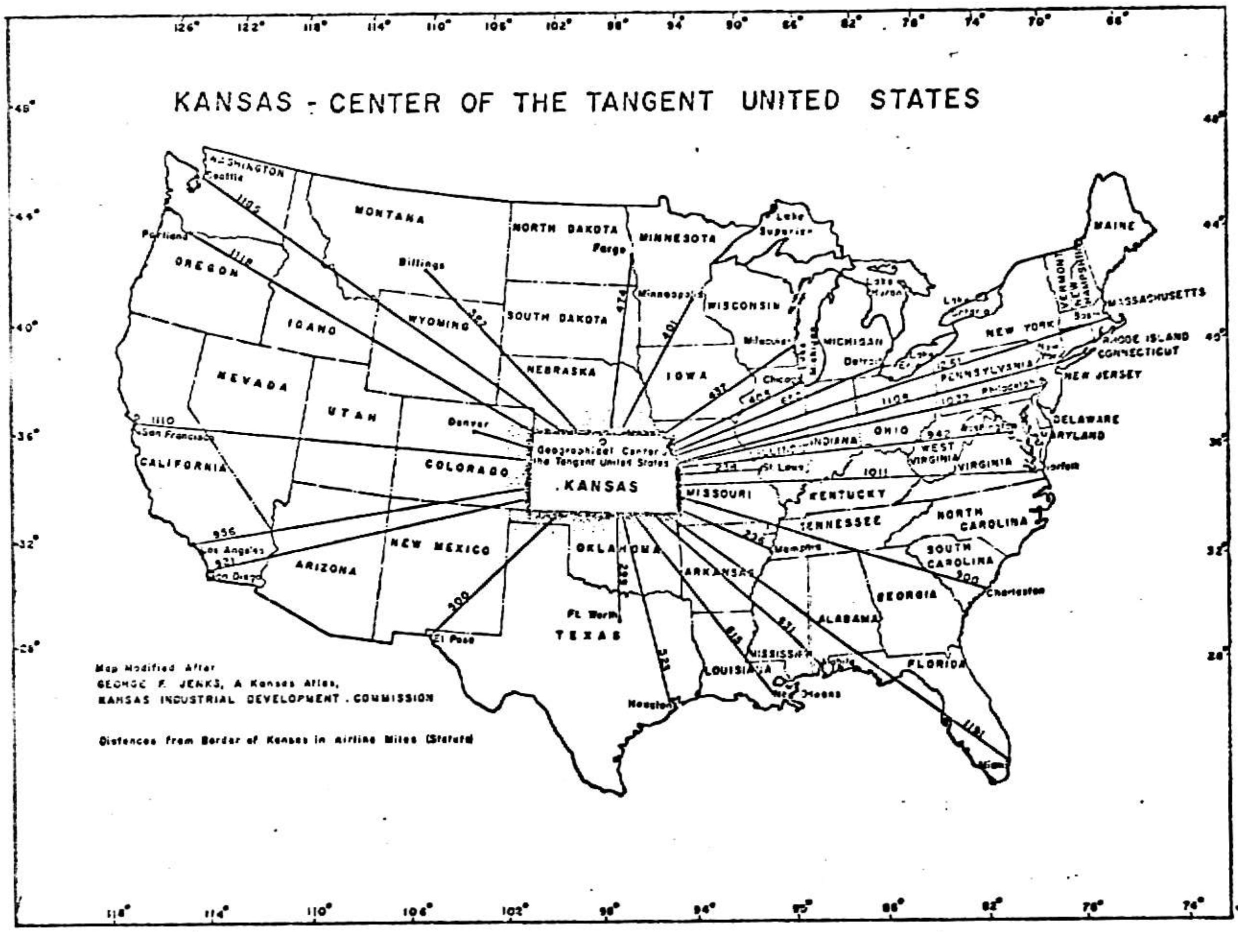


Fig. 1. The State of Kansas, from Self (15)

3. Cyclonic Storms. Kansas lies in the belt of cyclonic storms, an area that receives cold and warm air masses at irregular intervals, but especially during the winter months. These air masses cause such weather phenomena as high winds, tornadoes, hail, frost, blizzards, heat, floods and droughts.

As a result of these storms and the variation in altitude, Kansas has three rather distinct climatic zones (Fig. 2). Average winter and summer temperatures in these three zones are shown in Table 1.

The nearest ocean body to Kansas is the Gulf of Mexico and since there are no mountain barriers to onshore winds that blow over Kansas from this source area, the Gulf is by far the greatest source of precipitation in this area. Western Kansas is considerably farther from the Gulf of Mexico than is eastern Kansas and since there is a general trend for air to move from west to east, the onshore southerly winds tend to shift towards the east as they move towards Kansas. Thus western Kansas receives considerably less precipitation than eastern Kansas.

Normal annual precipitation ranges from slightly more than 40 inches in southeastern Kansas to near 30 inches in the northeastern counties and decreases rather uniformly to the west to a low of some 16 inches per year. The average for the state as a whole is about 27 inches (Fig. 3).

There is no prolonged dry season, but because of the fact that warm air can hold more moisture than cold air, most of the precipitation comes during the warm season. This rainfall is due to air being lifted and cooled by convection causing the well-known local thunderstorms of Kansas.

The month of least precipitation is January, when only 3 percent of the year's fall of moisture occurs. There is a steady increase in normal

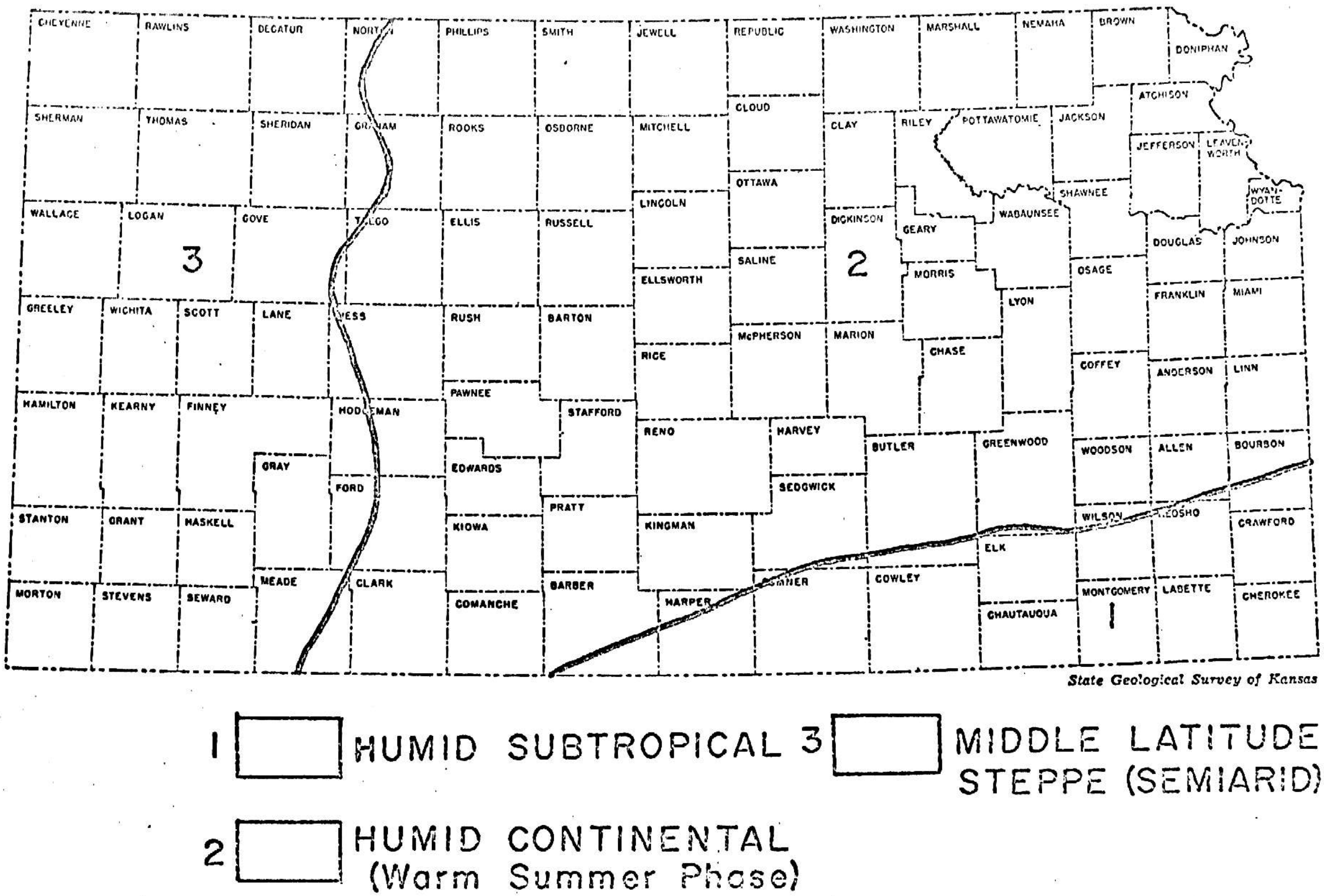


Fig. 2. Climates of Kansas

Table 1.

Average Temperatures from Mohler (16).

A. Humid Subtropical Climate

Month	Average temperature
January (winter)	above freezing
July (summer)	80° F

B. Humid Continental

Month	Average temperature
January (winter)	below freezing
July (summer)	75° F - 80° F

C. Middle Latitude Steppe

Month	Average temperature	
	Southern part	Northern part
January (winter)	above freezing	below freezing
July (summer)	75° F - 80° F	75° F - 80° F

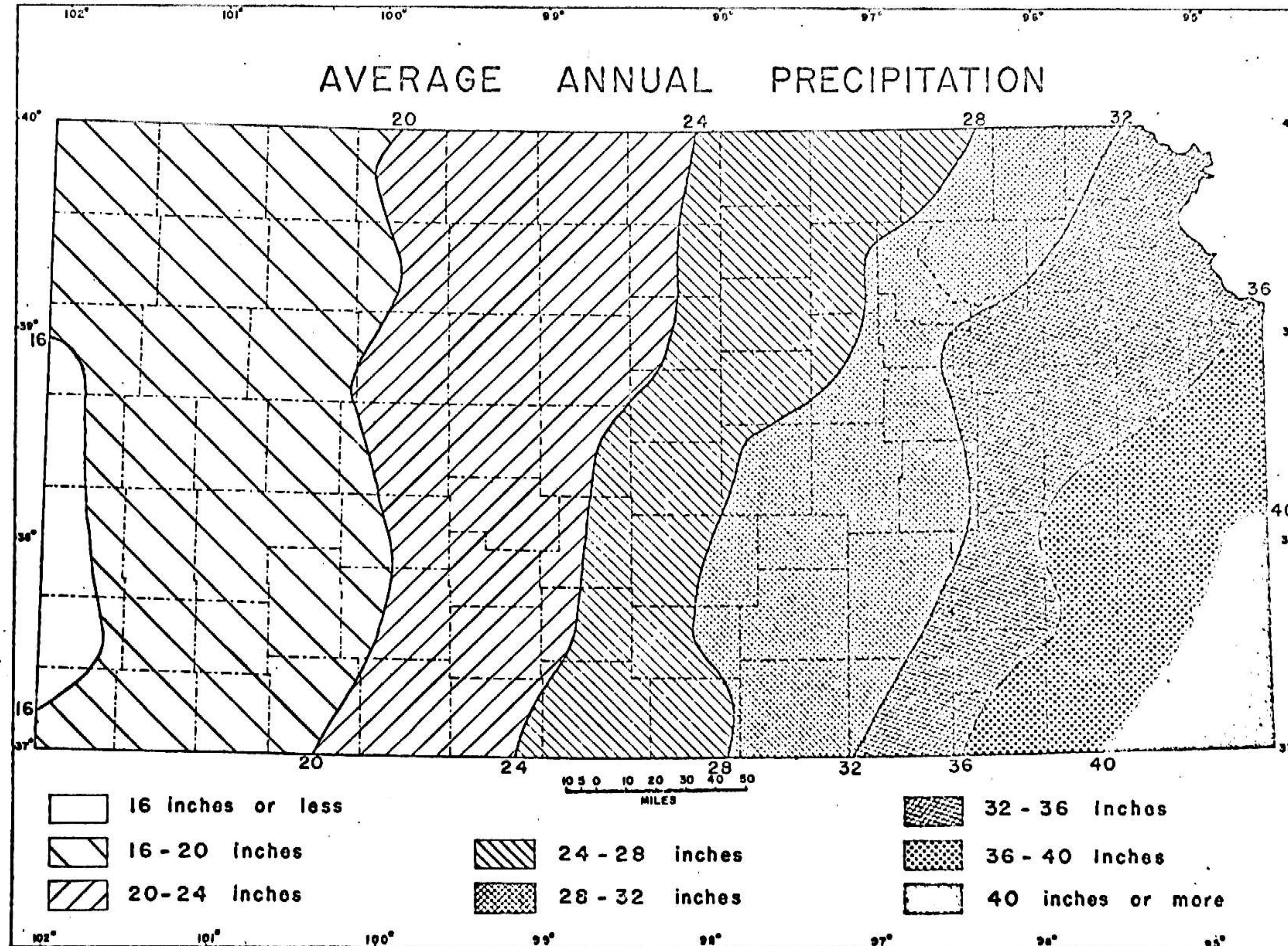


Fig. 3. Average Annual Precipitation, from Flora (17)

precipitation until June, which on the average receives more rain than any other month. After that, rainfall decreases until near the end of July, except in the extreme western counties. After September, there is a steady decline in precipitation until the end of the year.

GEOLOGY OF KANSAS

Geology is the science that treats the study of the earth, its material and structure, and the agencies and processes that affect the earth as a whole. Geological knowledge is especially useful in soil engineering in predicting structure, stratigraphy, and variations, both horizontal and vertical, in the soil and rock strata. A wealth of information is available from the State Geological Surveys such as:

1. The thickness and character of the rock strata in detail to the underlying Precambrian crystalline rock.

2. The depth and character of reliable water supplies.

3. The discontinuities such as faults, folds, and jointing in the bedrock including strike, dip, and extent.

4. The presence of economic minerals and the extent of commercial extraction in active areas.

5. The fluctuations of water level in streams and the change in the stream channel that are expected.

The bedrock in Kansas ranges in age from Precambrian to Quarternary (Table 2). Little is known about the lower Paleozoic rocks, because of the depth of burial beneath the state (Fig. 4).

At the close of the Precambrian period, the irregular surface of Kansas was composed of igneous and metamorphic rocks. Since then shallow seas have covered much or all of Kansas intermittently for millions of years during the Paleozoic and Mesozoic eras. Streams from surrounding highlands and the wave action against the shores deposited successive layers and mixtures of clay, silt, sand, and lime in these seas. These sediments were lithified into sedimentary rock units as the result of cementing action and compaction following deposition.

Table 2.

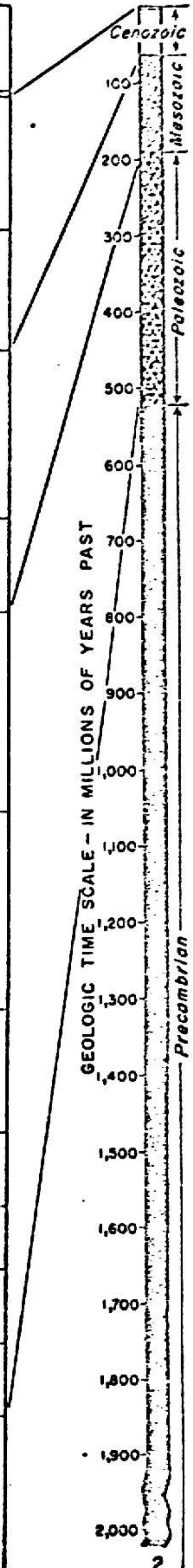
GEOLOGIC TIMETABLE AND KANSAS ROCK CHART

ERAS	PERIODS	ESTIMATED LENGTH IN YEARS*	TYPE OF ROCK IN KANSAS	PRINCIPAL MINERAL RESOURCES
CENOZOIC	QUATERNARY (PLEISTOCENE)	1,000,000	*Glacial drift; river silt, sand, and gravel; dune sand; wind-blown silt (loess); volcanic ash.*	Water, agricultural soils, sand and gravel, volcanic ash.
CENOZOIC	TERTIARY	59,000,000	*River silt, sand, and gravel; fresh-water limestone; volcanic ash; bentonite; diatomaceous marl; opaline sandstone.*	Water, sand and gravel, volcanic ash, diatomaceous marl.
MESOZOIC	CRETACEOUS	70,000,000	*Chalk, chalky shale, dark shale, vari-colored clay, sandstone, conglomerate. Outcropping igneous rock.*	Ceramic materials; building stone, concrete aggregate, and other construction rock; water.
MESOZOIC	JURASSIC	25,000,000	*Sandstones and shales, chiefly subsurface.*	
MESOZOIC	TRIASSIC	30,000,000		
PALEOZOIC	PERMIAN	25,000,000	*Limestone; shale; evaporites (salt, gypsum, anhydrite); red sandstone and siltstone; chert; some dolomite.*	Natural gas; salt; gypsum; building stone, concrete aggregate, and other construction materials; water.
PALEOZOIC	PENNSYLVANIAN	25,000,000	*Alternating marine and non-marine shale, limestone, and sandstone; coal; chert.*	Oil, coal, limestone and shale for cement manufacture, ceramic materials, construction rock, agricultural lime, gas, water.
PALEOZOIC	MISSISSIPPIAN	30,000,000	*Mostly limestone, predominantly cherty.*	Oil, zinc, lead, gas, chat and other construction materials.
PALEOZOIC	DEVONIAN	55,000,000	*Subsurface only. Limestone, black shale.*	Oil
PALEOZOIC	SILURIAN	40,000,000	*Subsurface only. Limestone.*	Oil
PALEOZOIC	ORDOVICIAN	80,000,000	*Subsurface only. Limestone, dolomite, sandstone, shale.*	Oil, gas, water.
PALEOZOIC	CAMBRIAN	80,000,000	*Subsurface only. Dolomite, sandstone.*	Oil
PRE-CAMBRIAN	(Including PROTEROZOIC and ARCHEOZOIC ERAS)	1,600,000,000 +	*Subsurface only. Granite, other igneous rocks, and metamorphic rocks.*	Oil and gas.

(Not scaled for geologic time or thickness of deposits)

*Committee on Measurement of Geologic Time, National Research Council

State Geological Survey of Kansas



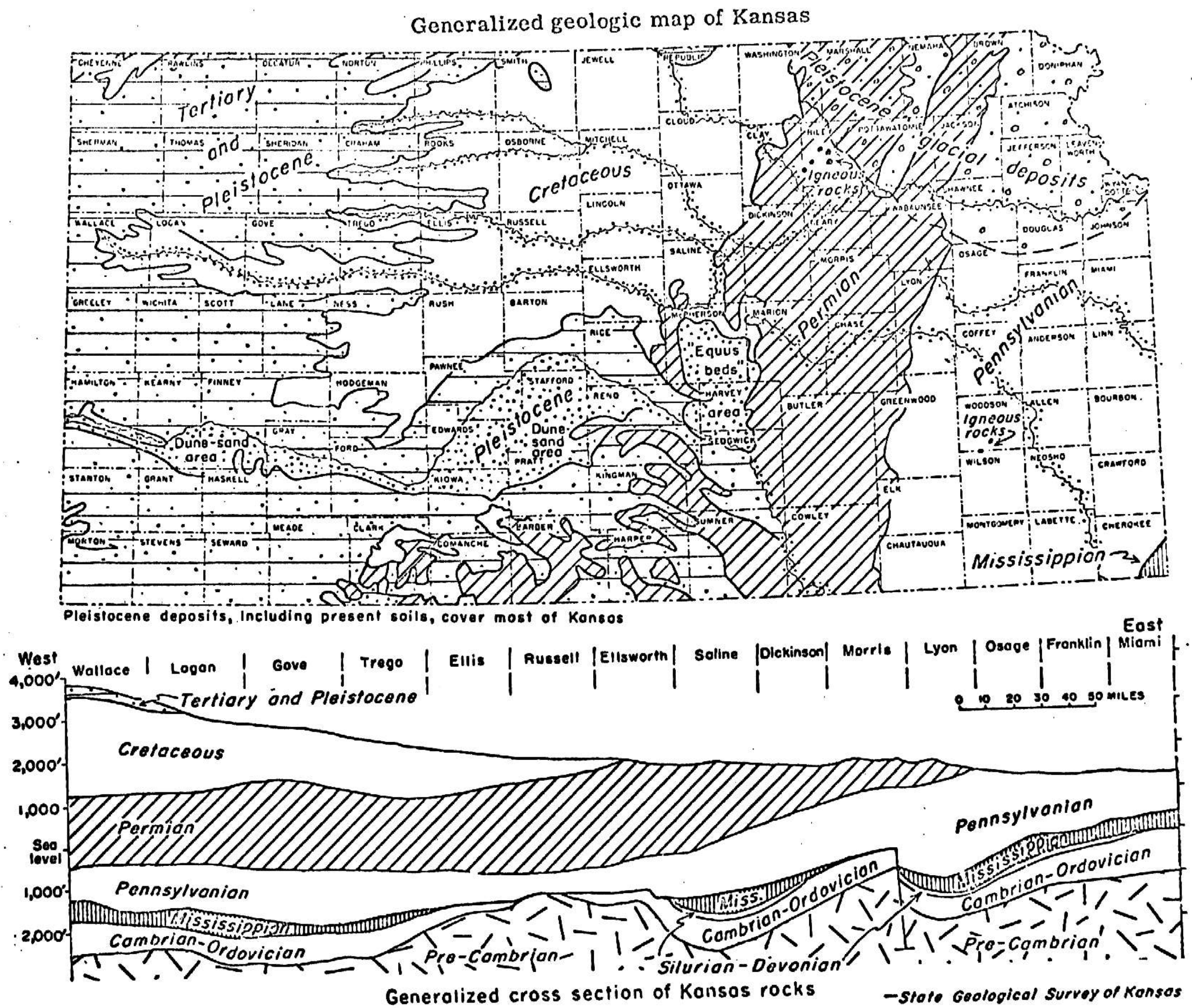


Fig. 4. Generalized Geologic Map of Kansas

After the retreat of the Cretaceous seas, Kansas underwent a long period of erosion. Late in Tertiary time, extensive deposits of gravel, sand and silt were spread all over the state by streams coming from the Rocky Mountains to the west, forming a huge deltaic like layer of coarse debris which is thickest near the mountains and thins to negligible thickness at the break of the plains.

During Pleistocene time, two huge continental ice sheets, the Nebraskan and the Kansan, invaded northeastern Kansas leaving behind the overcut and refilled river valleys and the till plains. Since Pleistocene time, the surface of Kansas has had essentially its present configuration subject day by day to erosion by wind and water.

Essentially all the surface rocks of Kansas ranging in age from Mississippian to the present are of sedimentary origin. These consist mainly of shale, sandstone and limestone. The maximum thickness of sedimentary rocks in the deepest part of the Hugoton Embayment is only about 9,500 feet. The section of sedimentary beds in other parts of Kansas is relatively thin as compared with this and the geosynclinal troughs and deeper basinal areas such as the Denver basin.

Igneous rock masses occur in Kansas in only two counties, Riley and Woodson. The Riley County igneous rocks, probably of Cretaceous age, are greenish, fine-grained basic volcanic rocks. In Woodson County, boulders of granite and granite porphyry are found scattered over an area of about 120 acres. The origin and age of these granite bounders is still in doubt, Schoewe (18).

The rock strata in Kansas constitutes a very shallow synclinal structure as shown in the Generalized cross-section of Kansas rocks (Fig. 4).

In the eastern one-half, the rocks dip mainly towards the west, while in the western, the main inclination is in an easterly direction. Seldom does the dip of surface rocks exceed 35 feet to the mile, Moore, Frye and Jewett (19).

Two definite structures are noted in the east-west cross-section (Fig. 5), at wells No. 24 and 13, which cause the Precambrian to occur at a shallower depth. These structures fade out to the south and are not evident in Fig. 6. Faulting and folding are quite common in the bedrock on a local scale and these have been carefully delineated by the Kansas Geological Survey in most areas.