Geology and Construction-Material Resources of Pottawatomie County, Kansas

GEOLOGICAL SURVEY BULLETIN 1060-C

Prepared in cooperation with State Highway Commission of Kansas, as part of a program of the Department of the Interior for development of the Missouri River basin

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By GLENN R. SCOTT, FRANK W. FOSTER, *and* CARL F. CRUMPTON

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UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON : 1959

UNITED STATES DEPARTMENT OF THE INTERIOR

FRED A. SEATON, *Secretary*

GEOLOGICAL SURVEY

Thomas B. Nolan, *Director*

The U. S. Geological Survey Library catalog card for this publication appears after page 178.

For sale by the Superintendent of Documents, U. S. Government Printing Office
Washington 25, D. C

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GEOLOGY AND CONSTRUCTION-MATERIAL RESOURCES OF POTTAWATOMIE COUNTY, KANSAS

By Glenn R. Scott, Frank W. Foster, and Carl F. Crumpton

ABSTRACT

Pottawatomie County lies in northeast Kansas at the juncture of the Big Blue and Kansas Rivers. The Nemaha range, a long narrow anticline, trends southwestward across the eastern part of the county and exposes Pennsylvanian rocks at the surface 15 miles west of the normal outcrop area. Permian rocks crop out in the east and west. The chert-bearing limestone beds in the western part of the county underlie the Flint Hills Upland, a part of the Osage Plains. The Flint Hills escarpment, formed by the chert-bearing limestone beds, bifurcates; one branch follows the Big Blue River and the other follows the Nemaha range in the eastern part of the county.

The Kansan glacier covered all but the southwest corner of the county. The wind deposited a thin mantle of loess over the upland and in some valleys. The larger streams in the county are bordered by a series of persistent terraces.

The Pennsylvanian system is represented by the Wabaunsee group which consists of thin fossiliferous limestones alternating with thick unfossiliferous silty shale beds. Intraformational channel sandstone beds occupy part of the interval between some limestone beds. Less commonly the channels were cut downward through several limestone beds and were filled with many feet of sand and carbonaceous material. A shale bed 65 feet thick trends southeastward across the center of the county where the Grandhaven, Jim Creek, Nebraska City and Grayhorse limestone members were not deposited and shale deposition was continuous. Several coal beds are exposed; two are locally 18 inches thick.

The Permian rocks belong to the Admire, Council Grove, and Chase groups.

The rocks of the Admire group include several beds of coquinoidal limestone, a platy limestone with mudballs, an earthy limestone, an algal limestone, and intervening beds of variegated and tan-gray silty shale. An intraformational channel sandstone is extensive in the Stine shale bed of the Hamlin shale member.

Rocks of the Council Grove group are alternating massive gray limestone beds and unfossiliferous variegated silty and clayey shale beds. The limestone units are generally thicker than those in the underlying Admire and Wabaunsee groups, but are thinner than those in the overlying Chase group. Some shale beds in the Council Grove group are not variegated but are light gray and fossiliferous.

Cherty limestone beds separated by variegated silty shale comprise the lower part of the Chase group. The youngest rocks in the area are the silty chalky lime-

stone beds and silty calcareous shale beds of the middle part of the Chase group.

The pleistocene deposits are of pre-Kansan, Kansan, and post-Kansan ages. Deposits of pre-Kansan and Kansan chert gravel crop out on divides in the eastern and south-central parts of the county.

The Kansan glacier deposited clayey till, with erratics as much as 18 feet in length over all but the southwest corner of the county. The till was deeply weathered during post-Kansan time. The pre-Kansan channel of the Kansas River north of St. George was blocked with ice and subsequently filled with outwash which caused the river to flow southeastward through a series of spillways and diversion channels in Wabaunsee County. When the ice melted, the river cut its present channel south of St. George and Wamego. Fine sediments collected in ponds along the ice front and attained a thickness of almost 150 feet in the northeast corner of the county.

Broad terraces were formed as alluvium filled the stream valleys in post-Kansan time. Along the Kansas River Valley east of Wamego four terraces and the flood plain were mapped. Along the smaller streams in the county, successively younger layers of alluvium were superimposed to form a single terrace level. The alluvium along the Kansas River ranges from 50 to 80 feet in thickness.

Thin discontinuous deposits of loess crop out in the western part of the county and on the plateau near Fostoria. The loess appears to be correlative with the Loveland and Peorian loess sheets, which are thicker and more continuous north of Pottawatomie County.

Construction materials are available in sufficient quantity and of the necessary quality for use as concrete aggregate, road metal, mineral filler, riprap, and structural stone.

Aggregate for concrete is available from the alluvium of the Kansas and Big Blue Rivers (source of most concrete aggregate now used), from the coarser glacial outwash, and from crushed limestone. Road metal is obtainable also from limestone gravel dredged out of small streams and from chert gravel in the old gravel deposits. Mineral filler is obtainable from the finer outwash and from the large glacial lake deposit in the northeast corner of the county. Riprap of good quality is obtained from the Neva limestone member of the Grenola limestone, Tarkio limestone member of the Zeandale limestone, Americus limestone member of the Foraker limestone, and from the Brownville limestone member of the Wood Siding formation. Eight limestone beds that vary greatly in color, hardness, and texture are satisfactory for structural stone. Other limestone in the area might be usable for special building purposes or for agricultural lime.

INTRODUCTION

PURPOSE OF THE INVESTIGATION

The U. S. Geological Survey and the State Highway Commission of Kansas are cooperating in the compilation of a geologic map and inventory of construction materials in the Missouri River Basin of Kansas. The purpose of these investigations is to provide geologic maps and reports that will show the relations between the geology and the occurrence of construction materials. The Pottawatomie County report is a product of the geologic mapping and mineral resource investigation program of the natural resources studies of the basin (Missouri River Basin, 1944). A field party of the U. S. Geological Survey mapped this county during 7 summer months of 1948 and 1949.

GEOGRAPHY AND PHYSIOGRAPHY

Pottawatomie County is in the second tier of Kansas counties south of the Nebraska border and in the fourth tier west of Missouri. (See fig. 5.) The county is bounded on the north by Marshall and Nemaha Counties, on the west by Riley County, on the south by Wabaunsee County, and on the east by Jackson and Shawnee Counties. Pottawatomie County is near the western boundary of the Central Lowland physiographic province (Frye and Swineford, 1949). Two subdivisions of this province (fig. 6) are recognizable in the county—the Dissected Till Plains and Osage Plains (Schoewe, 1949, and Fenneman, 1917).

The Dissected Till Plains are further subdivided into the Kansas drift plains in the northeastern part of the county and the attenuated drift border which covers a belt extending northwestward across the center of the county. The Kansas drift plains include the thicker deposits of till (heterogeneous, unstratified, unsorted, mixture of clay, silt, sand, pebbles and boulders deposited directly by glacial ice) and loess (windblown silt) far from the ice margin. The attenuated drift border is the area along the margin of the glacier which is now covered by isolated patches of till, outwash sand or pebbles (deposited by melt water from the glacier in streams or ponds), or glaciolacustrine deposits (silt or clay deposited in ponds or lakes in front of the glacier) with associated pebbles, cobbles and boulders of glacial erratic material (transported by ice from distant source).

The Flint Hills upland, that part of the Osage Plains in the southwest corner of the county, is less conspicuous north of the Kansas River than south of the river. The Flint Hills escarpment bifurcates in Pottawatomie County, because of the distortion of the rocks by the Nemaha range (Eardley, 1951). One branch of the escarpment parallels the Big Blue River on the western border of the county and the other branch parallels the Nemaha range in the northeastern part. The thick flinty limestone beds are very resistant to erosion and form broad flat benches. The shale beds are less resistant and form the steep slopes between benches. Where glacial ice has moved across the Flint Hills, its scouring action and the deposition of till have reduced them to rolling hills. Throughout the glaciated part of the county the east-facing valley walls are gently sloping because of large accumulations of till at their bases, whereas the west-facing valley walls are steeper because there is less till at their bases.

Terraces have formed along the larger streams throughout the

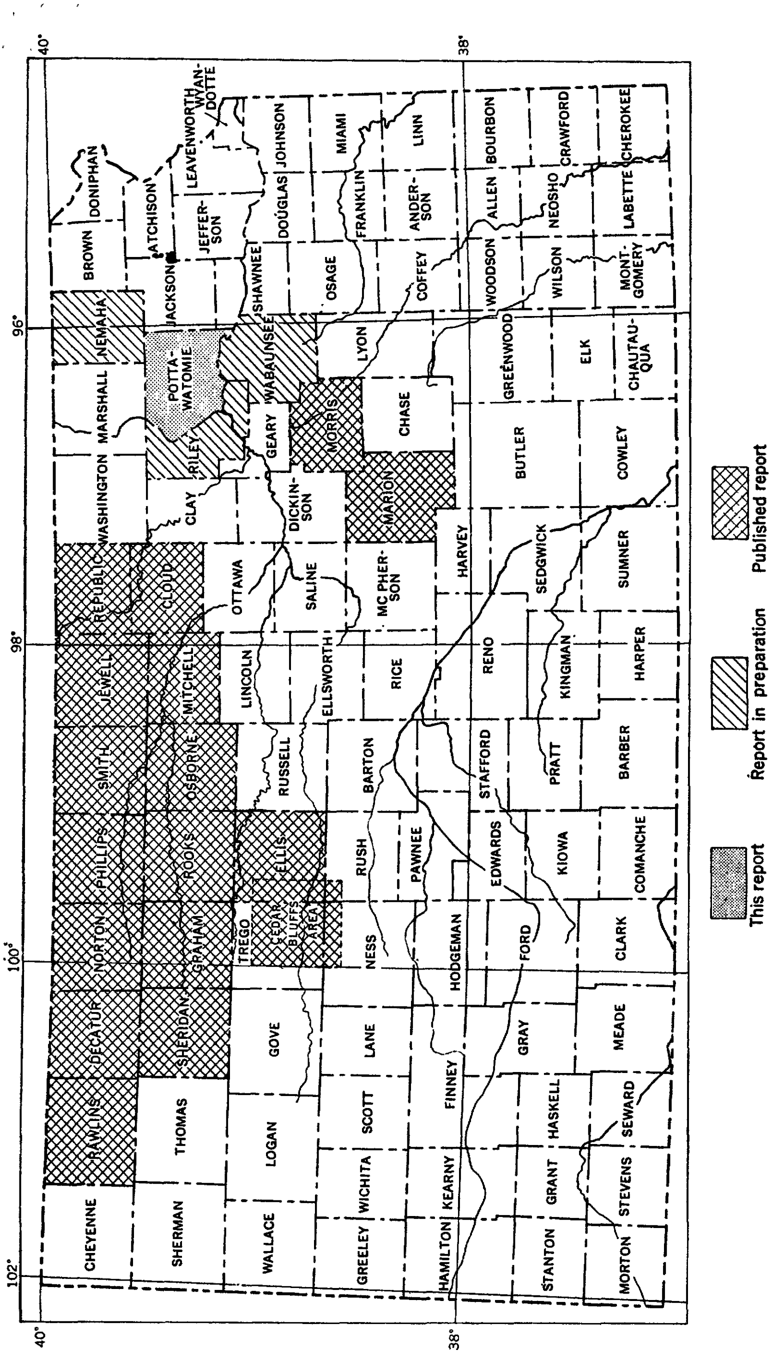

FIGURE 5.—Index map of Kansas showing area covered by this and other construction-materials reports.

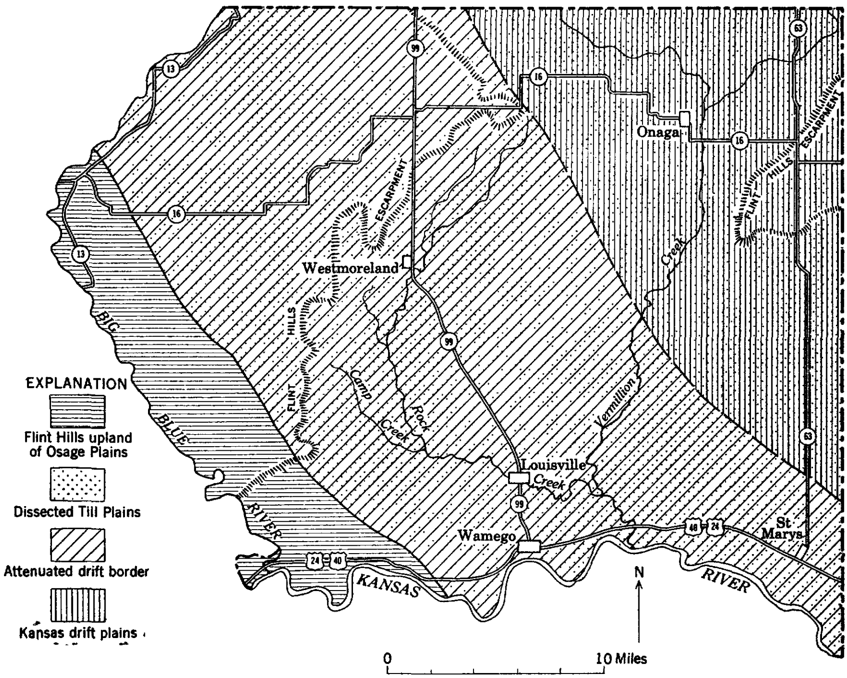

FIGURE 6.—Physiography of Pottawatomie County, Kans.

county but are broader in the area underlain by the softer Pennsylvanian rocks and along the Big Blue and Kansas Rivers. The terrace in the valley of the Kansas River at its confluence with Vermillion Creek is 5 miles wide; its narrowest point is a mile east of St. George where it is less than 1½ miles wide; its average width is 3 miles. The valley of the Big Blue River averages 1 mile wide but is 2 miles wide at Manhattan, in Riley County.

The lowest altitude in the county, about 930 feet above sea level, is at the southeast corner where the Kansas River leaves the county, and the highest altitude, about 1,520 feet, is on the dissected plateau near Blaine in the north-central part of the county.

DRAINAGE

The Kansas River is the principal stream in Pottawatomie County. An old channel of the river, prior to the flood of 1903, forms the southern boundary of the county. The present channel meanders across a broad flood plain that is flat except for terrace breaks and oxbow depressions. The former channel of the Big Blue River (preceding the 1903 flood) marks the western boundary of the county and the Big Blue River joins the Kansas River a mile east of Manhattan.

Spring, Carnahan, McIntire, and Cedar Creeks in the western part of the county are the larger tributaries of the Big Blue River. Vermillion Creek borders the axis of the Nemaha range for many miles, and with its major tributaries—Rock, French, and Red Vermillion Creeks—drains the central and northeastern parts of Pottawatomie County and empties into the Kansas River east of Wamego. Cross Creek drains the southeastern part of Pottawatomie County, and Clear Creek, a minor tributary of the Big Blue River, drains the north-central part.

CLIMATE

Pottawatomie County lies in an area where continental-type climate prevails; the summers are long and hot, and the winters are short and cold. The average annual precipitation is 32.1 inches (Flora, 1948, p. 26 and 81). The average date of the last killing frost in spring is April 18, and the average date of the first killing frost in the fall is October 18 (Flora, 1948, p. 223 and 224). The average number of cloudy days is 85 a year; of partly cloudy days, about 100 a year; and of clear days, about 180 a year (Flora, 1948, p. 239 and 240). Temperature and precipitation are important factors in various phases of engineering construction such as pouring concrete, laying bituminous mat, grading, and excavation. Figure 7, a chart showing temperature ranges at Wamego, Kans., was compiled from climatological data for the years 1942 to 1950 inclusive (U. S. Weather Bureau, 1942–1950). The chart indicates, for the 9-year period, the number of days each month on which the maximum daily temperature was within the temperature range important in certain construction activities.

Days on which the maximum temperature does not exceed 32° F. occur from November to March, inclusive, with a maximum monthly incidence of 7 days in January. August, the warmest month in the year, has an average of 15 days in which the daily maximum temperature exceeds 90° F. The chart also shows the average difference between the daily maximum and minimum temperatures. The greatest difference in daily temperatures, 27° F., is in October and the least difference, 21.2° F., is in December.

Figure 8 shows the average number of days in which precipitation fell within certain ranges at Wamego, Kans. The ranges are selected to show the effect of precipitation on the number of working days in engineering construction. As based on a 9-year average (U. S. Weather Bureau, 1942–1950) there may be, for example, 2.2 days in June in which the precipitation is more than 1 inch. Most of the precipitation in the range above 1 inch falls as heavy showers of short duration. Rain falling within the ranges of less precipitation is generally light and lasts longer.

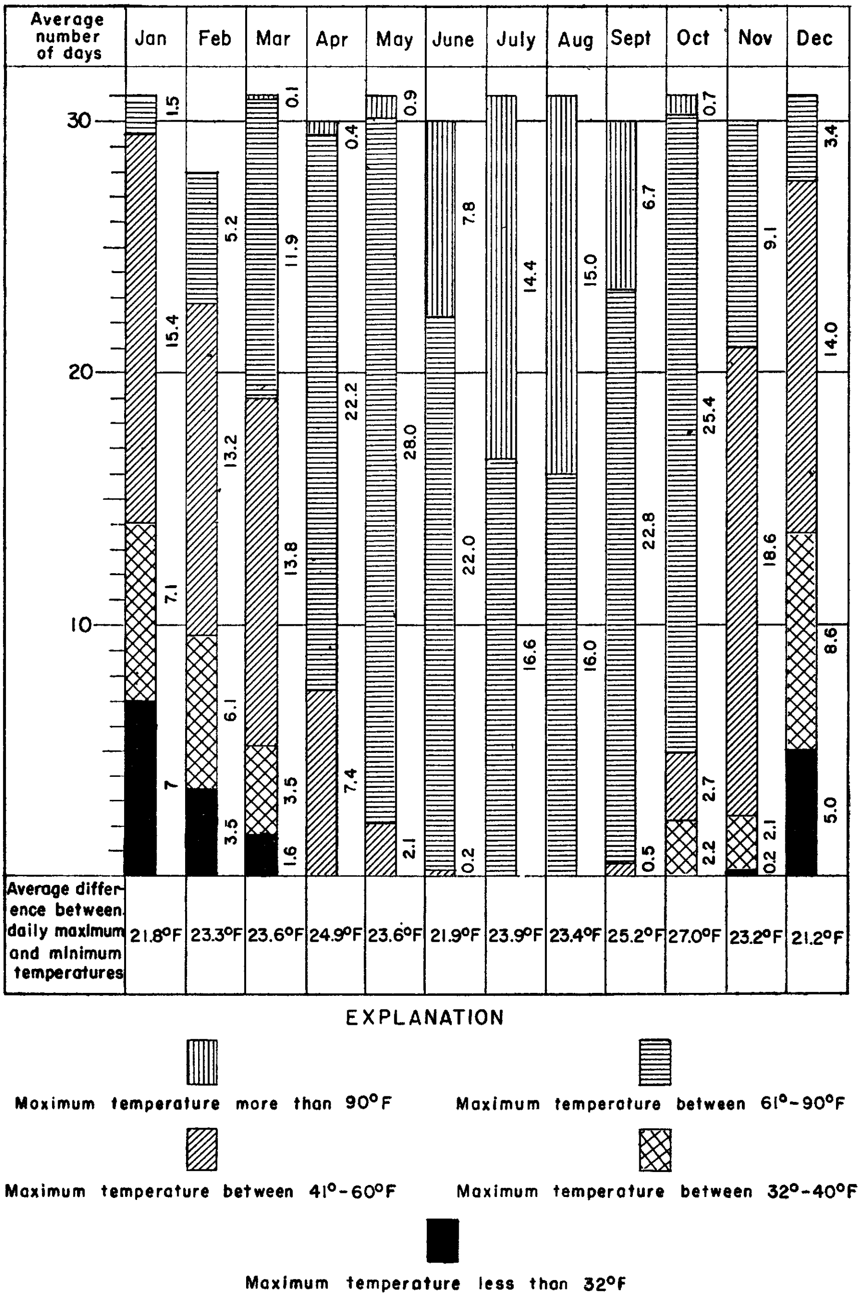

FIGURE 7.—Chart showing temperature ranges at Wamego, Kans.

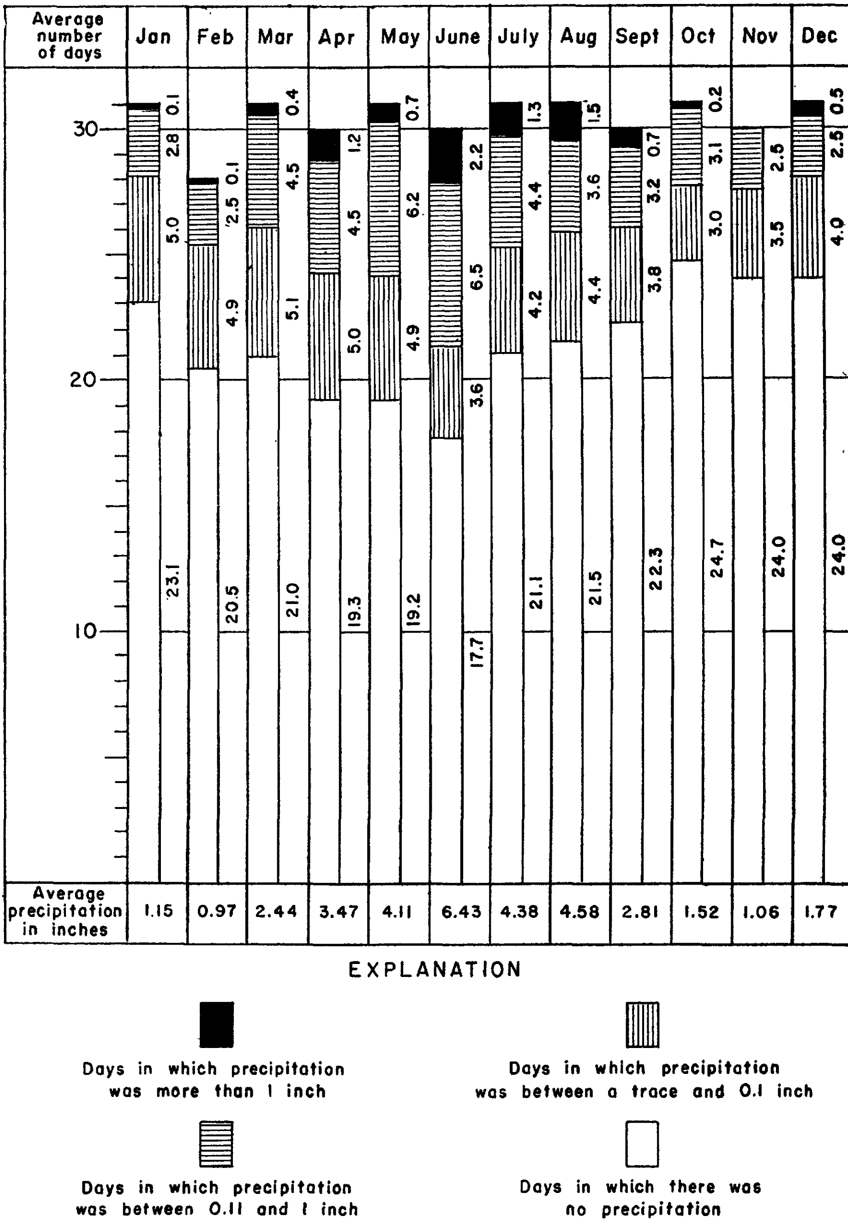

FIGURE 8.—Chart showing precipitation ranges at Wamego, Kans.

RAILWAYS AND ROADS

Pottawatomie County is traversed by two main lines of the Union Pacific Railroad; one crosses the southern part of the county and the other crosses the northeast quarter.

A primary transcontinental highway, U. S. 24, crosses the southern part of the county. Four State highways serve the county, three trending north and one trending east. The county and township roads generally parallel section lines and most sections are accessible by roads.

INVESTIGATION PROCEDURE

The base used in mapping the western one-fourth of the county was compiled from aerial photographs (scale: 4 inches equal 1 mile) provided by the Soil Conservation Service of the U. S. Department of Agriculture. The eastern three-fourths of the county was mapped directly on aerial photographs (scale: 3 inches equal 1 mile) purchased from the Production and Marketing Administration of the U. S. Department of Agriculture. The final base (scale: 2 inches equal 1 mile) onto which the geologic information was transferred, was compiled from aerial photographs (scale: 3 inches equal 1 mile) by the U. S. Geological Survey; the planimetric maps were drafted by the Planning Department of the State Highway Commission of Kansas. Photographs were used for plotting culture and drainage and for the placement of the contact lines between adjacent stratigraphic units. Some of the mapped units are a single member; most of them are composed of two formations with as many as six members each. A limestone is generally used as the lower part of a map unit. The emphasis of the investigation is on construction materials; therefore other aspects such as detailed structural and paleontologic studies are not considered.

An effort was made to accumulate all available data pertaining to the construction materials in the county. These data, together with their sources, are incorporated in this report. In addition, the field party collected samples of construction materials for which data were not available. The samples were subjected to routine laboratory tests in the Road Materials Laboratory of the State Highway Commission at Manhattan, Kans. Two samples of aggregate material were analyzed with the aid of a binocular microscope in the laboratory of the Geology Department at Kansas State College. The results of the laboratory tests, and mineralogical analysis, together with the information from other sources, are presented in table 1.

ACKNOWLEDGMENTS

Information of value to the compilation of the geologic map or the construction materials data included in this report was contributed by the State Highway Commission of Kansas, at Topeka, Kans., S. E. Horner, chief geologist (deceased 1954), and R. D. Finney, engineer of materials, and his associates; K. T. Sherrill, Soil

Conservation Service, U. S. Department of Agriculture, Westmoreland, Kans., and E. L. Walker, County Engineer, Pottawatomie County, Westmoreland, Kans.

CHARACTERISTICS OF THE OUTCROPPING STRATIGRAPHIC UNITS

This discussion of the geologic units cropping out in Pottawatomie County emphasizes the areal distribution, general characteristics, thickness and the construction materials of each formation or group of formations. One or more representative measured sections are given for each formation or member. The measured sections were selected to show typical outcrops, or rarely, unusual outcrops of a unit in the county.

The areal distribution of the local stratigraphic units is shown on plate 5. The locations of pits, quarries, and prospects are also shown on plate 5. The symbols indicate whether the pit or quarry is or has been operated or is a prospect, the type of construction material available at each site, and the quantity of the material (in units of 10,000 cubic yards) that can be removed under no more than moderate overburden (unconsolidated sediments less than 6 feet thick). Materials represented on the map by vertical letters have been tested and are listed in table 1; those represented by inclined letters have not been tested and are not listed. All materials sources listed in table 1 are numbered within each materials classification according to the following plan: the numbering starts in the northeasternmost township and continues along the same tier to the west boundary of the county; it is continued in the next tier south starting again with the township in the easternmost range and proceeding to the west boundary of the county, and so on. Within a township the sources are numbered in the same sequence as are the sections of the township. Stratigraphic units exposed in Pottawatomie County are as follows:

Stratigraphic units exposed in Pottawatomie County, Kansas

Era	System	Group	Formation	Member	Thickness
Cenozoic	Quaternary		Alluvium		0–50
			Terrace alluvium		0–80
			Sanborn		0–10
			Dune sand		0–20
			Glaciolacustrine deposits		0–146
			Glacial outwash		0–100+
			Till		0–65
			Old gravel		0–40
Paleozoic	Permian	Chase	Doyle shale	Towanda limestone	15
				Holmesville shale	27–32.5
			Barneston limestone	Fort Riley limestone	18
				Oketo shale	13
				Florence limestone	27–33
			Matfield shale	Blue Springs shale	35
				Kinney limestone	2–4
				Wymore shale	15–20
			Wreford limestone	Schroyer limestone	8–18
				Havensville shale	6–20
				Threemile limestone	7–8
		Council Grove	Speiser shale		14–20
			Funston limestone		2–4
			Blue Rapids shale		15–18
			Crouse limestone		16+
			Easly Creek shale		15
			Bader limestone	Middleburg limestone	2
				Hooser shale	5–6
				Eiss limestone	4.5–10
			Stearns shale		10–15
			Beattie limestone	Morrill limestone	3.5–10.5
				Florena shale	3–6
				Cottonwood limestone	5–7
			Eskridge shale		25–30
			Grenola limestone	Neva limestone	10–20
				Salem Point shale	7
				Burr limestone	8
				Legion shale	5
				Sallyards limestone	1
			Roca shale		14–17
			Red Eagle limestone	Howe limestone	4.5
				Bennett shale	2.4–8.7
				Glenrock limestone	0.5–1.6

Stratigraphic units exposed in Pottawatomie County, Kansas—Continued

Era	System		Group	Formation	Member	Thickness
Paleozoic	Permian		Council Grove	Johnson shale		16.6–25.6
Paleozoic	Permian		Council Grove	Foraker limestone	Long Creek limestone	6–7.3
Paleozoic	Permian		Council Grove	Foraker limestone	Hughes Creek shale	35
Paleozoic	Permian		Council Grove	Foraker limestone	Americus limestone	2–4.5
Paleozoic	Permian		Admire group	Janesville shale	Hamlin shale [1]	72.5
Paleozoic	Permian		Admire group	Janesville shale	Five Point limestone	2
Paleozoic	Permian		Admire group	Janesville shale	West Branch shale	30
Paleozoic	Permian		Admire group	Falls City limestone		1–3
Paleozoic	Permian		Admire group	Onaga shale	Hawxby shale	20–25
Paleozoic	Permian		Admire group	Onaga shale	Aspinwall limestone	0.6–4.2
Paleozoic	Permian		Admire group	Onaga shale	Towle shale	6.0–22
Paleozoic	Carboniferous	Pennsylvanian	Wabaunsee group	Wood Siding	Brownville limestone	2–3.5
Paleozoic	Carboniferous	Pennsylvanian	Wabaunsee group	Wood Siding	Pony Creek shale [2]	8
Paleozoic	Carboniferous	Pennsylvanian	Wabaunsee group	Wood Siding	Grayhorse limestone	0.4–2
Paleozoic	Carboniferous	Pennsylvanian	Wabaunsee group	Wood Siding	Plumb shale	7
Paleozoic	Carboniferous	Pennsylvanian	Wabaunsee group	Wood Siding	Nebraska City limestone	1–1.5
Paleozoic	Carboniferous	Pennsylvanian	Wabaunsee group	Root shale	French Creek shale	28
Paleozoic	Carboniferous	Pennsylvanian	Wabaunsee group	Root shale	Jim Creek limestone	1–2.5
Paleozoic	Carboniferous	Pennsylvanian	Wabaunsee group	Root shale	Friedrich shale	15
Paleozoic	Carboniferous	Pennsylvanian	Wabaunsee group	Stotler limestone	Dry shale [2]	15
Paleozoic	Carboniferous	Pennsylvanian	Wabaunsee group	Stotler limestone	Dover limestone	2.5–3
Paleozoic	Carboniferous	Pennsylvanian	Wabaunsee group	Pillsbury shale		17
Paleozoic	Carboniferous	Pennsylvanian	Wabaunsee group	Zeandale limestone	Maple Hill limestone	1.8–3
Paleozoic	Carboniferous	Pennsylvanian	Wabaunsee group	Zeandale limestone	Wamego shale	24
Paleozoic	Carboniferous	Pennsylvanian	Wabaunsee group	Zeandale limestone	Tarkio limestone	4–8.2
Paleozoic	Carboniferous	Pennsylvanian	Wabaunsee group	Willard shale		28–37
Paleozoic	Carboniferous	Pennsylvanian	Wabaunsee group	Emporia limestone	Elmont limestone	2–5
Paleozoic	Carboniferous	Pennsylvanian	Wabaunsee group	Emporia limestone	Harveyville shale	20
Paleozoic	Carboniferous	Pennsylvanian	Wabaunsee group	Emporia limestone	Reading limestone	2–2.8
Paleozoic	Carboniferous	Pennsylvanian	Wabaunsee group	Auburn shale		25
Paleozoic	Carboniferous	Pennsylvanian	Wabaunsee group	Bern limestone	Wakarusa limestone	3–5.7
Paleozoic	Carboniferous	Pennsylvanian	Wabaunsee group	Bern limestone	Soldier Creek shale	1.2–3.3
Paleozoic	Carboniferous	Pennsylvanian	Wabaunsee group	Bern limestone	Burlingame limestone	1–3
Paleozoic	Carboniferous	Pennsylvanian	Wabaunsee group	Scranton shale	Silver Lake shale	25–27
Paleozoic	Carboniferous	Pennsylvanian	Wabaunsee group	Scranton shale	Rulo limestone	0–1.5
Paleozoic	Carboniferous	Pennsylvanian	Wabaunsee group	Scranton shale	Cedar Vale shale	0.4–1.5

[1] Hamlin shale member is further subdivided into: Oaks shale bed (top), Houchen Creek limestone bed, and Stine shale bed (bottom). This subdivision appears only in text.
[2] Where intervening units are missing, the Dry shale member and Pony Creek shale member are mapped as undifferentiated.

PENNSYLVANIAN SYSTEM

WABAUNSEE GROUP

All local Pennsylvanian rocks (about 245 feet) are well exposed in the southeast corner of the county and along the west flank of the Nemaha range from Wamego to the northeast corner of the county. The rocks are mostly gray and brown marine limestone, gray silty and clayey shale, and brown channel sandstone.

The units of the Admire and Wabaunsee groups are those recognized by the U. S. Geological Survey and by the Kansas, Nebraska, Iowa, Missouri, and Oklahoma Geological Surveys (Moore and Mudge, 1956).

SCRANTON SHALE

The Scranton shale contains in ascending order; the White Cloud shale member, the Happy Hollow limestone member, the Cedar Vale shale member, the Rulo limestone member, and the Silver Lake shale member. Only the latter three crop out in the county.

Cedar Vale shale member.—The Cedar Vale shale member crops out along Vermillion Creek for 3 to 4 miles to the north and south of Onaga.

The member is made up of tan-gray thin-bedded sandy, silty, and clayey shale, and blocky siltstone and claystone beds. These beds are calcareous in some outcrops and contain massive beds of tan or maroon limestone that range from 0.2 foot to 2.6 feet in thickness. Almost 20 feet of this shale is exposed in the county.

At most places a limonitic, persistent coal bed lies a foot below the top of the shale. The coal, called the Elmo coal, is subbituminous or lignitic, locally fossiliferous, and contains marcasite nodules. The thickness of the coal ranges from 0.4 foot near Onaga to 1.5 feet on the county line in the NW¼NW¼ sec. 5, T. 6 S., R. 12 E.

Rulo limestone member.—The Rulo limestone member crops out along Vermillion Creek east of Onaga. At least five outcrops were observed, and in each the member was a massive dense hard dark-gray or tan limestone that is platy or shaly and brown where weathered. Because of its low topographic position it does not form distinctive hillside benches in this county.

The limestone is lenticular, but averages 1.5 feet in thickness.

At three outcrops of the Scranton shale the Rulo limestone member had not been deposited; the Silver Lake shale member was deposited directly on the Cedar Vale shale member. The Elmo coal is present at two of these outcrops but is absent at the third.

Silver Lake shale member.—The Silver Lake shale member has an outcrop pattern similar to that of the Rulo limestone member. It is

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predominantly black or gray, blocky or fissile, silty or clayey shale; however, the upper parts of two outcrops show thin-bedded silty or sandy variegated shale interbedded with thin layers of sandy tan or gray limestone. One limestone contains calcite and marcasite nodules and is very fossiliferous. The thickness of the member ranges between 25 and 27 feet.

BERN LIMESTONE

The Bern limestone contains in ascending order: the Burlingame limestone member, the Soldier Creek shale member and the Wakarusa limestone member.

Burlingame limestone member.—The Burlingame limestone member crops out along the walls of the valley of Vermillion Creek, along several of its tributaries near Onaga, and beneath a culvert across the old east-west highway about 2 miles west of Wamego. The Burlingame and the Wakarusa members form a prominent limestone bench.

In most outcrops it is a single persistent bed of massive conglomeratic tan or tan-gray limestone that contains flattened clay balls as much as an inch in length. Limonite imparts a pink stain to the weathered surfaces. In a few outcrops another massive tan limonite-stained limestone lies above the persistent bed. The two limestone beds are separated by a calcareous tan-gray silty shale and both beds contain many large and small fusulinids. The member is from 1 foot to 1.6 feet thick where only the lower limestone is present, but is almost 3 feet thick where both limestone beds are present.

Soldier Creek shale member.—The Soldier Creek shale member crops out in about the same area as the Burlingame limestone member. The member is a blocky, micaceous olive-drab and maroon clayey shale or claystone, and where washed downslope, it stains the Burlingame limestone member shades of maroon or green. The shale is unusually thin in Pottawatomie County where it ranges between 1.2 and 3.3 feet in thickness.

Wakarusa limestone member.—The Wakarusa limestone member crops out near Onaga and along the north side of the highway between St. George and Wamego. It forms a well-defined bench. This member consists of several massive or shaly limestone beds separated by thin layers of shale. The limestone is tan gray or gray and weathers tan gray, gray, light rose, or red brown; it is marked by brown dendritic growths of manganese oxide. Fossils are abundant in some parts of the limestone which is from 3 to 5.7 feet thick.

AUBURN SHALE

The Auburn shale forms a long steep slope between the Wakarusa and Reading benches. The shale is thin bedded to fissile, various shades of gray and olive drab, and is sandy or silty in the lower part and clayey in the upper part. Some zones are calcareous. A fossiliferous gray nodular limestone lies near the middle of the formation in most outcrops. Its average thickness is 25 feet.

EMPORIA LIMESTONE

The Emporia includes in ascending order; the Reading limestone member, the Harveyville shale member, and the Elmont limestone member.

Reading limestone member.—The Reading limestone member crops out on the northwestern flank of the Nemaha range near Havensville, Onaga, and Duluth and forms a conspicuous hillside bench. Three or, rarely, four massive hard dense fossiliferous limestone beds make up this member. The nonpersistent lowest bed is dark gray and crystalline; the second bed is gray and has fossil shells with cavities lined with calcite crystals; the third bed is gray and the uppermost bed is brown. Thin layers of silty limonitic shale separate the beds of limestone, which weather brown. The thickness is between 2 and 2.8 feet.

Harveyville shale member.—The Harveyville shale member forms a long steep slope between the Reading and Elmont limestone members. The member is composed of micaceous clayey shale with some sandy shale near the base. The shale is gray or dark gray with brown limonite stains. Zones of limonite concretions appear near the top of the member. A mile southwest of Onaga a channel sandstone in the Harveyville is in contact with the top of the Reading. The shale is about 20 feet thick.

Elmont limestone member.—The Elmont limestone member crops out along the highway between St. George and Wamego, and near Onaga, Duluth, and Havensville. Because of its resistance to weathering and erosion, it forms a strong hillside bench.

This member is massive hard gray or dark-gray limestone that weathers to tan-gray or brown shaly fragments. Brown limonite particles lie on the weathered limestone in most outcrops and in some exposures clay nodules give the limestone a conglomeratic appearance. Elliptical solution channels separate the weathered blocks and small fusulinids project from the weathered surfaces. The thickness ranges from 2 feet in the northeast part of the county to 5 feet near St. George. The stone was once quarried east of St. George and probably was used as riprap along the Kansas River.

WILLARD SHALE

The Willard shale crops out in the same areas as the Elmont limestone member. It is a gray clayey shale or tan-gray sandy limonitic shale with limonite nodules. Intercalated with the shale in some places is a friable micaceous tan-gray indistinctly crossbedded sandstone. In the western part of sec. 20, T. 7 S., R. 11 E., the full thickness of the formation is crossbedded channel sandstone. The formation ranges in thickness from 28 feet near St. George, where the Elmont and Tarkio members are exceptionally thick, to 37 feet in other places where these two limestone members are of normal thickness.

ZEANDALE LIMESTONE

The Zeandale limestone includes in ascending order: the Tarkio limestone member, the Wamego shale member, and the Maple Hill limestone member.

Tarkio limestone member.—The Tarkio limestone member crops out between Wamego and St. George and northward along the west side of Vermillion Creek to Havensville. Its bench is one of the most prominent of those formed by the limestone units in the Wabaunsee group. The Tarkio is a massive dense light-gray or tan-gray limestone that weathers brown slabby or blocky with large fusulinids projecting from the weathered blocks. In a quarry a mile southeast of St. George the member is divided into two layers and is 8.2 feet thick, but elsewhere in the county it is only about 4 feet thick. Three quarries have been opened in the Tarkio limestone member between Wamego and St. George to produce riprap for use along the Kansas River.

Wamego shale member.—The Wamego shale member forms a gentle slope between the Tarkio and Maple Hill limestone members. The member consists of blocky olive-drab siltstone and claystone or gray clayey shale. Layers and stains of limonite are common throughout. Three coal beds were noted in the field: one, 0.1 foot thick, lies 6 inches above the base of the member; another, 0.5 foot thick, is 2 feet above the base; and a third, 1 foot thick, lies about 2 feet below the top. The two lower beds are absent in most exposures of the member. A gray finely conglomeratic limestone underlies the middle coal bed. In the SW¼NW¼ sec. 15, T. 7 S., R. 11 E., a massive crossbedded channel sandstone occupies the interval of the Wamego shale. The member is about 24 feet thick.

Maple Hill limestone member.—The outcrop pattern of the Maple Hill limestone member is similar to that of the Tarkio limestone member; however, its bench is less well defined. The limestone is massive, dense, and dark gray, but weathers light brown and forms rectangular blocks. The member contains a great number of small fusulinids, which are even more abundant than usual in an outcrop in the SE¼NE¼ sec. 7, T. 8 S., R. 11 E. Its thickness is normally 1.8 feet but it is more than 3 feet thick at the outcrop cited above.

PILLSBURY SHALE

The Pillsbury shale is about 17 feet thick and forms a steep, rounded slope between the Maple Hill and Dover limestone members. The formation consists of gray silty shale or olive-drab blocky claystone. Sandy shale and sandstone are not uncommon in the upper part of the formation. Limonite stains and nodules are common in this shale, as they are in most of the shales in the upper part of the Wabaunsee group.

A massive crossbedded channel sandstone crops out in a streambank in the NE¼SW¼ sec. 18, T. 7 S., R. 11 E. A short distance south of that outcrop, in the NE¼NW¼ sec. 19, T. 7 S., R. 11 E., a group of limy sandstone concretions are perched on pedestals like the pedestal rocks at Rock City, Kans.

STOTLER LIMESTONE

The Stotler limestone contains in ascending order; the Dover limestone member, the Dry shale member, and the Grandhaven limestone member. The Grandhaven limestone member was not differentiated in Pottawatomie County.

Dover limestone member.—The Dover limestone member crops out between Wamego and St. George, north along the west side of the Nemaha range to the county line, and along the east flank of the range near Havensville. The bench formed by the Dover limestone member is flat topped and has sharply defined shoulders.

The member consists of massive dense hard gray limestone that weathers light brown and nodular. Because it closely resembles the Tarkio limestone member there is considerable difficulty in distinguishing between them in the field. Both have large fusulinids, but the Dover has more corals and nearly every outcrop has some *Osagia*, a gray algal nodule 1 or 2 inches in diameter, that stands out in relief on top of the limestone and weathers out into nodules on the slope. Another characteristic of the Dover limestone member is that the fusulinids separate from the limestone and lie like grains of wheat on the shale slope below the outcrop. The Dover limestone member is generally a foot thinner than the Tarkio.

A section of limestone 8 feet thick is exposed in the NW¼NW¼ sec. 6, T. 9 S., R. 10 E. Here a massive gray-orange molluscan limestone 1 foot thick overlies the typically fusulinid-bearing Dover limestone member and is overlain in turn by a 0.7-foot massive dark-gray nonfossiliferous limestone. These two thin limestone beds are considered by Mudge (Mudge, oral communication) to be the Grandhaven limestone member of the Stotler limestone as shown in measured section 10. The thickness of the member is generally 2.5 to 3 feet.

Dry and Friedrich shale members undifferentiated.—The Dry and

Friedrich shale members occupy the interval between the Dover limestone member and the Jim Creek limestone member. The Grandhaven limestone member, which normally lies between the Dry and the Friedrich shale members, was not differentiated in Pottawatomie County. The Dry and the Friedrich shale members undifferentiated are gray sandy shale or olive-drab and maroon silty or clayey shale. Locally a thin black shale lies in the lower part. The thickness of these members is about 15 feet.

The Grandhaven limestone member was not differentiated during field mapping in the county. (*See* Dover limestone member.)

ROOT SHALE

The Root shale includes in ascending order; the Friedrich shale member, the Jim Creek limestone member, and the French Creek shale member. The Friedrich shale member was included with the Dry shale member of the Stotler limestone in the field mapping.

Jim Creek limestone member.—The Jim Creek limestone member crops out 3 to 4 miles north of Louisville along Kansas State Route 99, and near Onaga, Havensville, and Duluth. The limestone is not exposed on Jim Creek in sec. 29, T. 7 S., R. 11 E., where it is located in the original description of the type locality, but it crops out at several places along the southern and western borders of the section. More characteristic outcrops are in the SE¼NW¼ sec. 28, T. 6 S., R. 12 E. (road cut), and the NE¼NE¼ sec. 7, T. 8 S., R. 11 E. (stream cut).

The limestone is massive and fossiliferous. Where fresh, it is gray or tan mottled with light green; where slightly weathered it is tan gray and blocky or nodular; and where more fully weathered it is brown and shaly. It ranges from 1 foot to 2.5 feet in thickness.

The Jim Creek limestone member resembles the Elmont and Maple Hill limestone members and the Nebraska City limestone member. On a fresh surface the Jim Creek is tan mottled with light green; the Elmont limestone member is dark bluish gray; the Maple Hill limestone member is dark gray; and the Nebraska City limestone member is a mottled light brown and gray metallic-appearing limestone.

French Creek shale member.—The French Creek shale member crops out in an area similar to that of the Jim Creek limestone member. In most places it forms a gentle slope between the Nebraska City and the Jim Creek limestone members. The French Creek shale member does not crop out along French Creek where it is located in the original description of the type locality. The nearest outcrop of French Creek shale is about 2 miles from French Creek where an excellent section is exposed in the SE¼NW¼ sec. 28, T. 6 S., R. 12 E.

The member consists of gray limonitic sandy shale or tan-gray silty shale with a persistent coal bed near the top. The Lorton coal, although no more than a foot thick anywhere in the country, was mined in the SE¼ sec. 4, T. 9 S., R. 9 E. (Schoewe, 1946, p. 125). Because of its thinness and position in a stream bottom at the base of a steep bluff very little production has resulted. The French Creek shale member is about 28 feet thick.

WOOD SIDING FORMATION

The Wood Siding formation contains in ascending order, the Nebraska City limestone member, the Plumb shale member, the Grayhorse limestone member, the Pony Creek shale member, and the Brownville limestone member.

Nebraska City limestone member.—The Nebraska City limestone member is limited to two outcrop areas in the county. One is a broad outcrop generally following Vermillion Creek and the other is confined to the southeastern part of the county. The Nebraska City limestone member is a massive single bed of metallic-gray or mottled blue and gray fossiliferous limestone in a fresh exposure. It weathers to a mottled brown and gray shaly limestone, and in a deeply weathered outcrop cannot be distinguished from the shale above and below it. The member ranges in thickness from 1 to 1.5 feet.

Plumb shale member.—The Plumb shale member that lies between the Nebraska City limestone member and Grayhorse limestone member was not differentiated in the county because the two limestones were not observed in a single outcrop. The shale that underlies the channel outcrop of the Grayhorse limestone member is gray sandy shale and gray and black clayey shale more than 7 feet thick.

Grayhorse limestone member.—The Grayhorse limestone member crops out in the NW¼NW¼ sec. 16, T. 9 S., R. 9 E., in a bed 2 feet thick on the edge of a channel in the Pony Creek sandstone, and in a 0.35-foot bed in the NE¼NW¼NW¼ sec. 4, T. 9 S., R. 10 E. The channel outcrop exposes a gray massive sandy limestone that contains abundant pyrite nodules and large pelecypods. In the other outcrop the limestone is hard, slightly porous, tan to tan brown, and contains limonite and clay balls. It weathers blocky and has a conglomeratic appearance.

Dry and Pony Creek shale members undifferentiated.—These beds which are chiefly shale, rest on the Dover limestone member and are overlain by the Brownville limestone member. They crop out in a belt less than 3 miles wide that extends from Louisville northward to a point about 3 miles south of Duluth. The units that normally lie between the Dover and the Brownville limestone members were not deposited, but instead, shale was deposited continuously.

The outstanding characteristic of the shale is the presence of septarian nodules as much as 2 feet in diameter which contain crystals of calcite, barite, and celestite. The shale is clayey or silty, thin bedded, and olive-drab to gray with limonite stains and nodules. The shale is about 55 feet thick.

Fine-grained micaceous sandstone crops out on the edges of the outcrop belt described above. It is crossbedded and lies in deep channels cut down through many feet of underlying beds. Large elliptical concretions of limestone with carbonized plant fragments are plentiful in the sandstone layers, and in some places are parallel to the crossbedded layers of the sandstone. The sandstone contains well-preserved fossil fern leaves which are exposed in the NW¼NW¼ sec. 15, T. 8 S., R. 10 E. The crossbedded layers are thin and the angle between bedding and crossbedding is small, suggestive of a deltaic depositional environment. The thickness of the sandstone probably exceeds 25 feet.

In the SW¼ sec. 5, T. 10 S., R. 10 E., in Cat Creek, another sandstone bed is exposed that fills a channel cut in the Tarkio limestone member. The sandstone is similar to that in the channel in the Pony Creek mentioned in the last paragraph, but because the top of the channel has been eroded, correlation was not attempted.

Pony Creek shale member.—The Pony Creek shale member forms a slope that extends from the Nebraska City limestone member up to the Brownville limestone member. The member is about 8 feet thick and mostly a gray, olive-drab, or maroon clayey shale. Fossils are abundant in the upper part of the shale.

Brownville limestone member.—The Brownville limestone member forms a persistent but minor bench in its outcrop area near Maryville and along Vermillion Creek. The member is made up of two brown massive dense fossiliferous limestone beds that weather tan and blocky or nodular. They are separated by a fossiliferous tan-gray silty shale. The bed ranges in thickness from 2 to 3.5 feet.

PERMIAN SYSTEM

The Permian rocks consist of thin limestone beds separated by thick shale beds (some of which are variegated). The rocks of the Admire, Council Grove, and Chase groups are about 570 feet thick.

ADMIRE GROUP

Rocks of the Admire group crop out along Vermillion Creek and in the southern part of the county, and are about 120 feet thick.

ONAGA SHALE

The Onaga shale contains in ascending order; the Towle shale member, the Aspinwall limestone member, and the Hawxby shale member.

Towle shale member.—The Towle shale member forms a short slope between the Aspinwall and the Brownville limestone members. The shale is a lumpy or blocky clayey shale or a varicolored silty shale. A blocky gray or light-gray molluscan limestone that weathers nodular crops out near the top of the member. A thin sandstone bed was observed slightly below the middle of the member at one outcrop. The sandstone is not crossbedded and is consistent in its thickness. A channel sandstone, which cuts downward from the Towle shale member in Riley and Wabaunsee Counties, is not present in Pottawatomie County. The member ranges from 6 to 22 feet in thickness.

Aspinwall limestone member.—The Aspinwall limestone member forms a low bench marked by 2- to 3-foot rectangular blocks. The limestone is massive, laminated, and contains clay balls flattened parallel to the bedding. The clay-ball layers are hard and dense whereas the rest of the limestone is coarse and somewhat softer. The member presents a mottled appearance with brown, gray-brown, and tan-gray streaks. It ranges in thickness from 0.6 foot to 4.2 feet. Because of the regularity of its rectangular jointing, the limestone has had considerable use as structural stone in small bridges.

Hawxby shale member.—The Hawxby shale member forms a gentle slope broken by a small limestone bench near its middle. Thin-bedded or blocky calcareous olive-drab clayey shale constitutes most of the member. The lower part of the shale is variegated in places. Thin massive blocky or nodular dense gray limestone beds are interbedded with the shale. The thicker middle molluscan limestone bed contains gastropods. The bed is between 20 and 25 feet thick.

FALLS CITY LIMESTONE

The Falls City limestone forms a small rounded bench. The formation consists of massive dense brown resinous limestone that weathers to small brown blocks with brown dendritic manganese oxide on the block faces. The limestone is soft where fresh, but hard where weathered. Fossils are extremely rare in the limestone which is from 1 to 3 feet thick.

JANESVILLE SHALE

The Janesville shale contains in ascending order; the West Branch shale member, the Five Point limestone member, and the Hamlin shale member.

West Branch shale member.—The West Branch shale member forms a long slope between the Five Point limestone member and the Falls City limestone. The member, which is about 30 feet thick, is composed of alternating shale and limestone beds. The shale is mostly

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black, gray, olive drab, or tan fissile or blocky clayey or silty. The limestone beds are tan gray or gray, massive, platy, cellular, or blocky. Some of the limestone beds are sandy. Fossils are locally abundant.

Five Point limestone member.—The Five Point limestone member forms a prominent bench only where it is thick. This member is a massive hard coarse-grained tan or tan-gray coquinoidal limestone. The thickness is quite variable, but rarely exceeds 2 feet. Two outcrops were observed whose thickness changed from 0.2 foot to 2 feet within the distance of a mile. The limestone was a molluscan coquina at both outcrops.

The limestone is an attractive and resistant building stone especially near Duluth, where it is pink. A house in the NW¼NE¼ sec. 8, T. 6 S., R. 11 E. is built of limestone from the Reading member with corner blocks of limestone from the Five Point member. The house was built in 1870 and both types of limestone are in perfect condition.

Hamlin shale member.—The Hamlin shale member is subdivided into three beds which are, in ascending order, the Stine shale bed, Houchen Creek limestone bed, and Oaks shale bed.

The Stine shale bed forms a long steep slope between the Americus limestone member of the Foraker limestone and the Five Point limestone member of the Janesville shale. This bed consists of calcareous nodular clayey shale or silty shale, variegated in the middle and upper parts. The two most characteristic zones in the bed are a fine micaceous stratified light-green 6- to 8-foot sandstone that is 22 to 26 feet below the top, and a 3-foot cellular tan-gray limestone that is about 6 feet below the top. Other thin beds of tan-gray or brown limestone are interbedded with the shale. A micaceous sandy shale underlies the sandstone and in turn, is underlain by a limonitic limestone in some places. Leaf fossils and petrified wood are not uncommon in these two beds. The Stine shale bed is unfossiliferous. Its thickness exceeds 48 feet in one place; however, a complete section was not measured.

The Houchen Creek limestone bed crops out in the eastern part of the county and extends southward almost to Belvue. The limestone is resistant to weathering and is so hard and brittle that it rings when hit with a hammer. The upper surface has a mammillary appearance with small knobs comprised of algae. The limestone is tan to gray brown and dense and fine grained except where it contains an abundance of fossil fragments and nowhere was the bed observed to exceed 0.5 foot in thickness.

The Oaks shale bed where it crops out in the northeast part of the county, is a maroon, tan-gray or gray-green, thin-bedded, calcareous, silty or clayey shale. A cavernous silt bed and lentils of noncalcareous, micaceous, fine-grained sandstone lie near the bottom. Thin granular limestone beds underlie the Americus limestone member of the Foraker limestone. The bed is about 24 feet thick.

COUNCIL GROVE GROUP

Rocks of the Council Grove group crop out in all but the south-central part of the county. They comprise about 270 feet of thin limestone and thick silty shales.

FORAKER LIMESTONE

The Foraker limestone contains, in ascending order; the Americus limestone member, Hughes Creek shale member, and Long Creek limestone member.

Americus limestone member.—The Americus limestone member forms a prominent bench throughout its outcrop area. It consists of two persistent massive dense light-gray limestone beds separated by thin-bedded tan-gray or olive-drab silty shale beds. Another dense light-gray limestone rarely underlies the two persistent beds. Both layers weather into large rectangular blocks that are about 1 to 1.6 feet thick, 4 feet wide, and 6 feet long. The whole member is fossiliferous; the side of nearly every block shows fossil fragments especially crinoid columnals that have weathered in relief.

Two outcrops were observed in Pottawatomie County where algae-bearing rocks similar to those in the Houchen Creek bed of the Hamlin shale member are part of the Americus limestone member. In the NW¼SE¼ sec. 2, T. 10 S., R. 12 E., and in the SW¼SE¼ sec. 16, T. 7 S., R. 11 E., partly silicified algal nodules are attached to the upper surface of the lower limestone. In places, another limestone bed underlies the two persistent beds in the Americus limestone member and this bed is more dense than the two overlying beds but was not observed to contain algae. The Americus limestone member ranges in thickness from 2 to 4.5 feet.

Hughes Creek shale member.—The Hughes Creek shale member forms a long, and in most places, steep slope between the Long Creek limestone member and the Americus limestone member.

As many as seven limestone beds are interbedded with the shale in places. The shale is fissile to blocky. Fresh exposures of the fissile to blocky clayey or silty shale are tan, tan gray, or olive drab in the upper part and gray in the lower part. Thin beds of massive or platy, dense, gray, tan-gray, tan or dark-gray limestone lie between the shale beds. The sequence is very fossiliferous and is about 35 feet thick.

Long Creek limestone member.—Although the Long Creek limestone member lies between two thick shale beds, it does not form a very prominent bench because the shale contains many limestone beds that equal it in resistance to erosion. The member consists of massive clayey dolomitic tan or gray-brown limestone containing jasper and pockets of crystalline quartz, calcite, and celestite. Iron stains are extensive near the base. The limestone weathers nodular and porous except in the upper part where it weathers blocky or platy. Shale beds that separate the limestone beds are thin-bedded, silty and calcareous, and tan gray or dark gray. The whole member is fossiliferous; the lower limestone beds are composed mostly of fusulinids. The member ranges in thickness from 6 to 7.3 feet.

JOHNSON SHALE

The Johnson shale forms a long gentle slope between the Glenrock limestone member of the Red Eagle limestone and the Long Creek limestone member. It consists mostly of fissile or blocky silty or clayey shale. Most of the shale is olive drab or gray, but the lower part is variegated, olive drab, gray, and maroon. Iron stains are common; flattened clay balls are present in one shale bed; and most of the shale is quite calcareous. Four limestone beds measured in one section of the formation range from a massive dense gray limestone that weathers blocky, to a massive soft dolomitic light-gray or tan-gray limestone that weathers blocky or shaly. Neither the limestone nor the shale beds are fossiliferous. The member is from 16.6 feet to 25.6 feet thick.

RED EAGLE LIMESTONE

The Red Eagle limestone is divided into the Glenrock limestone member, Bennett shale member, and Howe limestone member, in ascending order. It crops out along the Nemaha range and in the southwestern part of the county.

Glenrock limestone member.—The Glenrock limestone member forms a poor bench in parts of the county because of its thinness. This member is a massive dense petroliferous gray or tan-gray limestone between 0.5 foot and 1.6 feet thick, it is fossiliferous, and has a brecciated appearance in the southwest part of the county.

Bennett shale member.—The Bennett shale member forms a slope between the Howe limestone member and the Glenrock limestone member. The member is mostly a thin-bedded silty calcareous dark-gray shale, and contains a massive hard clayey light-gray limestone about 3 feet from the top. The limestone bed weathers blocky or fissile and contains some fossils; the shale weathers to small light-gray flakes. Limonite stains are extensive in the lower part and the member ranges in thickness between 2.4 and 8.7 feet.

Howe limestone member.—The Howe limestone member, which forms a poorly defined bench, consists of two or more massive tan or tan-gray limestone beds. The upper is harder and more resistant to weathering than the lower iron-stained part; however the whole member weathers cavernous or cellular. A blocky calcareous light-gray or tan-gray silty shale separates the limestone beds. In the northeast corner of the county the limestone is composed mostly of ostracodes, but elsewhere it is generally not fossiliferous. The thickness is about 4.5 feet.

ROCA SHALE

The Roca shale forms a long and gentle slope between the Burr limestone member and the Howe limestone member. This formation consists of blocky, hard, silty shale, and is variegated light green, dark green, olive drab, and maroon. The shale is calcareous throughout and contains one to three limestone beds. The limestone is impure and clayey, hard and dense, light gray, tan gray, or gray green, and is stained by limonite. The formation ranges between 14 and 17 feet in thickness.

GRENOLA LIMESTONE

The Grenola limestone includes, in ascending order; the Sallyards limestone member, Legion shale member, Burr limestone member, Salem Point shale member, and Neva limestone member.

Sallyards limestone member.—The Sallyards limestone member, although extensive, is too thin to form a bench. It is a massive hard dense light-gray limestone that weathers blocky. The upper part is fossiliferous in some outcrops and the member averages slightly less than a foot in thickness.

Legion shale member.—The Legion shale member forms an upper extension of the Roca slope and is a blocky olive-drab silty shale slightly calcareous and stained with iron. It weathers to small tan-gray chips and is about 5 feet thick.

Burr limestone member.—The Burr limestone member forms the lower part of a compound bench consisting of the thick Neva limestone member, thin Salem Point shale member, and thick Burr limestone member. The member consists of two limestone beds separated by shale. The limestone is massive, fine-grained, tan-gray and fossiliferous. The upper part is soft and porous with small cavities and weathers blocky; the lower part is hard and clayey and weathers blocky or shaly. The shale is a black or olive-drab clay and is fissile. The member is about 8 feet thick.

Salem Point shale member.—The Salem Point shale member forms a steep but short slope between the Neva limestone member and the Burr limestone member. This member consists of about 7 feet of blocky or fissile silty or clayey shale with 1 or 2 thin shaly dark-gray fossiliferous limestone beds in the middle. The shale is dark gray or olive drab. Pyrite nodules and iron stains are common in the limestone beds.

Neva limestone member.—The Neva limestone member forms a more prominent bench than the underlying Burr limestone member but less prominent than the overlying Cottonwood limestone member of the Beattie limestone. This member consists of a massive light gray fine-grained limestone with small tan-gray porous spots. In a fresh exposure or on a quarry face the member appears to be a single bed; however, when weathered it breaks down to 4 or 5 limestone beds with intervening beds of silty shale. Upon weathering, the upper part becomes cellular and the lower part slightly platy. The member which is fossiliferous throughout, is between 10 and 20 feet thick.

ESKRIDGE SHALE

The Eskridge shale forms a steep slope between the Cottonwood limestone member of the Beattie limestone and the Neva limestone member of the Grenola limestone. Its area of outcrop is about the same as that of the Cottonwood. This formation is a variegated shale that consists of light-gray and light-green platy or nodular silty shale in the upper part, and maroon, light-green and pink blocky silty shale near the base. Most sections contain one or more thin hard gray limestone beds; the shale is somewhat calcareous throughout. The thickness range is between 25 and 30 feet.

BEATTIE LIMESTONE

The three members of the Beattie limestone are, in ascending order; the Cottonwood limestone member, Florena shale member, and Morrill limestone member.

Cottonwood limestone member.—The Cottonwood limestone member crops out from the northeastern corner of the county southward almost to Belvue; from the north-central part of the county southward through Wheaton, Westmoreland, and nearly to the southwest corner of the county; and along the Big Blue River in the southwest and northwest parts of the county. This limestone forms a characteristic shrub-lined bench that is unlike the bench of any other limestone in this county. The shoulder is sharp and the limestone is resistant to weathering and erosion even after the overlying beds have been removed. The Cottonwood member is a massive light-gray porous limestone, which weathers platy in its lower part. It contains chert nodules that stand out conspicuously upon weathering. Although the limestone is soft on a fresh surface it casehardens when exposed to the atmosphere. Fusulinids are abundant in the middle and upper parts and the limestone ranges in thickness from 5 to 7 feet.

This limestone has been used more than all others in the county for construction purposes and is particularly useful as structural stone, crushed stone for concrete aggregate, and as road metal.

Florena shale member.—The Florena shale member has about the same outcrop area as the Cottonwood limestone member. It forms the lower part of the slope between the Eiss limestone member of the Bader limestone and the Cottonwood limestone member. The Florena is a thin-bedded gray calcareous silty shale with small blocky limestone beds in some places. The extremely fossiliferous shale is readily identified by its characteristic faunal suite. Nodules of chalcedony immediately underlie the Morrill member in some outcrops. The Florena ranges from 3 to 6 feet in thickness.

Morrill limestone member.—The Morrill limestone member crops out in about the same area as the Cottonwood limestone member. Because it is thin and only a short distance above the Cottonwood limestone member it rarely makes a bench, but generally is part of the slope between the Eiss limestone member and the Cottonwood limestone member. The Morrill member generally consists of two or more gray or light-gray limestone beds separated by thin shale beds. The limestone is dense, hard, is fossiliferous, and contains some beds that are petroliferous. The partings are mostly light-gray clayey shale. Cellular or spongy limestone is commonly present, as on the east side of sec. 6, T. 8 S., R. 12 E., and NW¼ sec. 11, T. 8 S., R. 9 E., and in some places contains calcite geodes. The member averages 3.5 feet in thickness. One unusually thick section of the Morrill was discovered in the SW¼NW¼ sec. 10, T. 6 S., R. 8 E. Here the limestone is 10.5 feet thick and consists of six limestone beds with no shale. This area might have great promise as a source of crushed limestone because the Florena is only 3.8 feet thick and the underlying Cottonwood is 7 feet thick making a total of 17.5 feet of limestone with only a thin shale intervening between the two thick limestones.

STEARNS SHALE

The Stearns shale forms the upper part of the slope between the Eiss limestone member and the Cottonwood limestone member. This formation is a varicolored blocky clayey shale. Thin limestone beds are common and the shale is slightly calcareous throughout. The limestone beds weather shaly or fissile and the shale weathers to small chips. The thickness ranges from 10 to 15 feet.

BADER LIMESTONE

The Bader limestone includes, in ascending order: the Eiss limestone member, Hooser shale member, and Middleburg limestone member.

Eiss limestone member.—The Eiss limestone member forms a well-developed low bench between Havensville and Emmett in the eastern part of the county. This bench also crops out north of Westmoreland in the central part of the county, along the Big Blue River in the southwestern part of the county, and near the northwest corner of the county. The upper limestone in this member is massive and slightly pitted when fresh, but weathers cavernous. The shale that separates this from the lower limestone is a fossiliferous calcareous light-gray clayey shale. The lower light-gray limonitic limestone is also fossiliferous and is conglomeratic in the lower 0.1 foot. The member is between 4.5 and 10 feet thick.

Hooser shale member.—The Hooser shale member forms a short gentle slope between the Eiss limestone member and the Middleburg limestone member and has an area of outcrop similar to that of the Eiss limestone member. The member varies in texture between silty shale at the top and clayey shale at the bottom. Calcium carbonate nodules are scattered throughout the lower part of the shale and the upper part is slightly calcareous. The shale is light-gray, gray, olive-drab, and maroon. It is about 5 or 6 feet thick.

Middleburg limestone member.—The Middleburg limestone member crops out in the north-central, southwestern, and east-central parts of the county and because of its thinness does not form a prominent bench. The Middleburg member is a massive, dense, gray or tan-gray fossiliferous limestone, is stained with limonite spots, and in places, has a mottled gray, tan-gray granular appearance. A thin dark-gray shale divides the limestone into two parts. The member rarely exceeds 2 feet in thickness and is generally about 1.5 feet thick.

EASLY CREEK SHALE

The Easly Creek shale crops out over most of the western part of the county, as well as south of Havensville and west of Emmett. It forms a steep slope between the thick Crouse limestone and the Middleburg limestone member of the Bader limestone. The formation is about 15 feet thick and consists of blocky calcareous clayey or silty shale that is variegated light gray, olive drab, and maroon. The colored layers are thinner than those in other variegated shales in the county.

CROUSE LIMESTONE

The Crouse limestone forms a triple bench that is not sharp but is easily recognizable on aerial photographs. It crops out south of Havensville, west of Emmett, and in the western part of the county. The Crouse limestone is platy, dense, and light gray in the upper part. The middle massive bed and the lower massive bed are separated from each other and from the upper limestone by 1 to 6 feet of tan-gray clayey shale. The lower limestone weathers cavernous.

The limestone beds and the shale beds are somewhat fossiliferous. The middle and lower limestones are softer than the upper limestone and have a chalky, granular appearance. Where the formation forms a double bench, a 2-foot shale divides the two 4-foot limestone beds. The member is more than 16 feet thick.

BLUE RAPIDS SHALE

The Blue Rapids shale crops out in both the eastern and western parts of the county, but is seldom seen in its entirety because it underlies the covered slope between the Crouse limestone and the Funston limestone. This formation is a platy to blocky calcareous silty clayey shale. The shale is variegated maroon, light green and gray in softer shades than the Blue Springs shale member of the Matfield shale and the Speiser shale. Calcareous nodules are abundant and amethyst crystal pockets are characteristic of the shale near Lake Pottawatomie. This section of the Permian strata, from the Blue Rapids shale through the Havensville shale member of the Wreford limestone, near Blaine and Lake Pottawatomie contains siliceous material in great abundance—especially quartz crystals, chert, and chalcedony. The Blue Rapids shale is from 15 to 18 feet thick.

FUNSTON LIMESTONE

The Funston limestone crops out in both the eastern and western parts of the county, but forms a much more prominent bench in the east because of its increased thickness and more massive character. The limestone is massive, porous, soft in the upper part, hard in the lower part, tan gray with a mottled salt and pepper appearance on a fresh surface, and weathers dark gray and cavernous. Near Blaine, the limestone contains a layer of chert nodules that have a casehardened calcareous layer on the outside with a core of blue-gray chert. Chalcedony nodules are common in the lower part of the limestone at outcrops containing chert. In these outcrops the member is divided into three layers whereas elsewhere it is one massive bed. The limestone ranges from 2 to 4 feet in thickness but is generally about 2.5 feet thick.

SPEISER SHALE

The Speiser shale crops out most extensively in the western part of the county, but it also crops out on the plateau east of the Nemaha range. This formation is a variegated blocky clayey shale, with stripes of maroon, light green, and gray shale about one foot thick. A persistent gray 5-foot thick limestone crops out 1 to 2 feet from the top of the member and is separated from the Threemile limestone member of the Wreford limestone by a gray fossiliferous clayey shale. The Speiser shale ranges from 14 to 20 feet in thickness.

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CHASE GROUP

The Chase group crops out mostly in the western half of the county. The Wreford limestone is also exposed between Havensville and St. Clere. About 180 feet of this group, consisting mostly of thick cherty limestones and variegated shales, is exposed in the county.

WREFORD LIMESTONE

The Wreford limestone is subdivided into the following members, in ascending order; the Threemile limestone member, Havensville shale member, and Schroyer limestone member.

Threemile limestone member.—The Threemile limestone member crops out over the western part of the county and southeast of Havensville and west of Emmett in the eastern part. Its bench is more conspicuous than the bench on the Schroyer and is easy to follow because of the large light-gray blocks that mark its edge. This member is the most persistent in thickness and lithology of all the cherty limestone beds in the county. It generally has a foot-thick massive light-gray finely crystalline limestone bed at the top and alternating 5-inch bluish-gray chert layers and 18-inch gray limestone layers below. In some sections this excellent sequence is interrupted by thin gray silty shale partings that evidently take the place of the chert beds in a slightly different depositional environment. Fossils are abundant and are especially well preserved on the outside of the chert nodules. The member ranges in thickness between 7 and 7.8 feet throughout the county.

The Threemile limestone member has been quarried for road metal, however the sharpness of crushed chert fragments makes it less suitable for this purpose than other available limestone. It has also been used for structural stone, but because the layer used contained chert nodules, every block that was observed had split beddingwise around the chert nodules. The top noncherty layer might be suitable for structural stone; however, excessive slaking of material from this layer was observed in the riprapped dam of Lake Pottawatomie.

Havensville shale member.—This member crops out in the western part of the county, east as far as Wheaton, and at the type locality southeast of Havensville. It forms the slope between benches of the Schroyer limestone member and the Threemile limestone member. The Havensville shale member varies widely in lithology, but generally it is a fissile calcareous silty or clayey shale with cellular limy beds and limestone layers as much as 3 feet thick. Locally the shale contains chalcedony nodules and quartz crystals. In most places the member is very fossiliferous and one limestone bed is pelecypod bearing. The shale is tan gray or gray with an olive cast and locally has a black fissile layer at the base. The thickness ranges from 6 to

20 feet but is generally about 18 feet. The extreme thinness at places is attributed to removal of the upper part by submarine currents before deposition of the thick crossbedded Schroyer limestone member.

Schroyer limestone member.—The Schroyer limestone member crops out in the northern and western part of the county as far east as Wheaton and along the eastern flank of the Nemaha range southeast of Havensville. The bench of the Schroyer limestone member is well developed except where it is obscured by the steep slope of the Matfield shale. The Schroyer limestone member consists of an upper massive light-gray coarse limestone and calcareous silty shale. Slightly above the middle is a cherty tan-gray fossiliferous limestone bed that is 2 to 6 feet thick in the western part of the county and slightly thicker in the eastern part. Below this are tan-gray calcareous silty shale beds, platy tan-gray limestone beds, and in some places a crossbedded massive gray crystalline limestone that contains flattened mud balls and which weathers platy. In the eastern part of the county the principal unit is the 6- to 8-foot thick cherty limestone; however it is interbedded with subordinate noncherty limestone beds and thin shale beds. The member ranges between 8 and 18 feet in thickness and is generally about 12 feet thick except in the western part of the county where the limestone is 18 feet thick.

MATFIELD SHALE

The Matfield shale is subdivided, in ascending order, into the Wymore shale member, Kinney limestone member, and Blue Springs shale member.

Wymore shale member.—The Wymore shale member is generally covered by colluvium from the overlying deposits and thus was seen in only a few stream cuts where it crops out in the western half of the county. The member is a thin-bedded silty shale. At one exposure it is tan gray in the upper part and maroon in the lower part. Most other exposures show it to be tan-gray or light-gray shale. A small deposit of gypsum was discovered at a spring issuing from the base of the Wymore in the NW¼SW¼ sec. 7, T. 7 S., R. 8 E. The Wymore shale member is 15 to 20 feet thick.

Kinney limestone member.—The Kinney limestone member crops out in the western half of the county. Because it does not form a strong bench, it generally forms part of the long slope below the Florence limestone member. One of the few good exposures shows it to be a massive soft fine-grained light-gray limestone that weathers gray and shows yellow cavities. In some places it consists of two limestones separated by a shale parting. This member is from 2 to 4 feet thick.

Blue Springs shale member.—The Blue Springs shale member is exposed best in artificial excavations and stream cuts because of its position under the resistant Florence limestone member of the Barneston limestone. It crops out in the western half of the county and is a blocky light-gray silty shale in the upper part but grades downward into a vivid variegated shale composed of light-green, maroon and brown layers, each about 2 to 3 feet thick. The Blue Springs shale member is about 35 feet thick.

BARNESTON LIMESTONE

The Barneston limestone is divided into the Florence limestone member, Oketo shale member, and Fort Riley limestone member, in ascending order.

Florence limestone member.—The Florence limestone member caps most of the buttes in the western half of the county. Erosion has produced sharp shoulders and steep slopes that fall away from the tablelike bench of this member. The Florence limestone member forms the most conspicuous bench of any limestone in the county. This bench and slope are confined to the section between the Florence limestone member and the Schroyer limestone member of the Wreford limestone in most places, but along Bluff Creek a much steeper slope exposes a section from the Florence limestone member to the Neva limestone member of the Grenola limestone. The top 24 feet of the Florence limestone member is a massive 8-foot bed of bluish-gray chert nodules alternating with beds, 6 feet thick, of dense light-gray limestone. Almost all the chert nodules are shattered and split away from their matrix. This phenomena is probably caused by water and frost action and certainly facilitates erosion. The lower part of the member is made up of alternating beds of cherty gray limestone and gray calcareous silty shale. The chert nodules in the lower part are separated and are flattened parallel to the bedding. The chert in the upper part, which is in distinct beds 8 to 10 inches thick, appears to weather out as nodules. The Florence limestone member averages about 30 feet thick with a maximum thickness of 33 feet and a minimum thickness of 27 feet.

Oketo shale member.—The Oketo shale member forms a gentle slope between the Fort Riley limestone member and the Florence limestone member in the northwestern part of the county. This member is a calcareous gray or tan-gray silty shale with thin massive gray limestone beds. Both the shale and the limestone are extremely fossiliferous. In many places the Oketo shale member erodes to form a light-gray barren slope between the Fort Riley and Florence limestone members. The member is about 13 feet thick.

Fort Riley limestone member.—At most places the Fort Riley limestone member forms a low, sharply defined bench above the bench formed by the Florence limestone member. Immediately north of Garrison, however, it forms the cap on a steep unbroken hill with sediments exposed from the Crouse limestone through the Fort Riley limestone member. The Fort Riley limestone member crops out only in the northwestern part of the county. Because of its commercial importance as a source of building stone it is mapped separately from the rest of the Barneston limestone.

The Fort Riley member is composed of layers of massive tan-gray coarse limestone in its upper part and thin-bedded calcareous silty shale and shaly fine-grained limestone in the lower part. The latter limestone becomes harder toward the southwest and is the near-basal rimrock at Fort Riley Military Reservation. Small limonite-stained cavities and pockets of calcite crystals are characteristic of the upper rimrock bed. Both the massive upper limestone and the shaly basal limestone are fossiliferous. The maximum thickness of the Fort Riley limestone member is probably 18 feet, however only partial sections could be found that were well enough exposed for measurement.

DOYLE SHALE

The Doyle shale consists of, in ascending order: the Holmesville shale member, Towanda limestone member, and the Gage shale member, which does not crop out in Pottawatomie County.

Holmesville shale member.—The Holmesville shale member crops out in the northwest corner of the county where it forms a gentle slope between the benches of the Towanda limestone member and the Fort Riley limestone member of the Barneston limestone. The member consists of alternating layers of shale and limestone. The shale beds are tan gray or tan, and vary from lumpy to nodular or thin bedded and clayey, to blocky and silty or limonitic and sandy. All of the shale is calcareous and some layers contain open calcite pockets. The limestone beds range from 0.4 foot to 6 feet in thickness. Tan-gray silty limestone that weathers slightly spongy, hard, brown, and crystalline, or soft, tan-gray, and nodular with calcite crystal pockets, is common in most outcrops. The member ranges from 27 to 32.5 feet in thickness. Complete, well-exposed sections of the Holmesville shale member are difficult to find because it is so near to the top of the beds that are preserved in the county, and most of these younger beds are stripped away.

Towanda limestone member.—The Towanda bed was named by R. C. Moore (Wilmarth, 1938, p. 2172) for outcrops in the western part of the El Dorado field near Towanda, Kansas. The limestone is now considered to be a member of the Doyle shale (Moore and others, 1951, p. 44).

The Towanda limestone member is stratigraphically the highest bedrock unit to crop out in Pottawatomie County. It crops out northwest of Olsburg in the northwestern corner of the county. This member is a tan-gray platy to massive fine- to coarse-grained crystalline limestone that forms a gently rounded bench above the Fort Riley limestone member of the Barneston limestone. It contains pockets of calcite crystals and weathers to porous crumbly yellowish nodules. Thin layers of calcareous tan shale separate some of the platy limestone beds. The finer grained layers of limestone contain a large quantity of silt. Although only 14.2 feet of the Towanda limestone member is exposed, it probably never was much thicker anywhere in Pottawatomie County.

PLEISTOCENE AND RECENT SEDIMENTS

The surficial deposits in Pottawatomie County belong to the Pleistocene and Recent series of the Quaternary system. They were deposited and reworked by streams, lakes, glaciers, and wind.

Pre-Kansan streams deposited gravel on areas that are now the higher divides in the area. The Kansan glacier overrode all except the southwestern corner of the county and plastered till on the divides, filled the valleys with glacial outwash, and filled local depressions in the till with pond deposits of silt and clay. Illinoian and Wisconsin winds blew silt and clay-size particles from the glacial drift and deposited them as a thin layer, rarely of mappable thickness. Streams alternately scoured their valleys and filled them with large accumulations of alluvium.

OLD GRAVEL

Overlying the bedrock on the high bluffs along the north wall of the Kansas River Valley between St. George and Wamego are thin but extensive deposits of gravel composed of chert pebbles. The rounded chert pebbles which were derived almost entirely from the cherty Wreford and Barneston limestone beds, are bound together with reddish-brown plastic clay that contains a small amount of coarse sand. The clay binds the deposit so firmly that, when dry, the gravel fractures through the chert pebbles rather than around them. Most of the pebbles have a black coating of manganese oxide or a reddish-brown coating of ferric oxide. Thin layers of clay or sand are occasionally interbedded with the gravel, as may be seen in a pit in the NW¼NE¼ sec. 12, T. 10 S., R. 9 E. Glacial erratics (ice-transported rock fragments from a distant source) are absent in these deposits, but are found in the glacial outwash of this area.

Other deposits of old gravel occur near Myers Valley on Wilson Branch of Rock Creek, and on Pleasant Run Creek. These deposits are overlain by till and occupy high points in a valley that was widened and deepened by streams flowing along the front of the melting Kansan glacier. The glacial erratics intermingled with the upper part of some of these chert gravel deposits indicate overriding by ice or reworking by outwash streams.

Cherty gravel of Kansan age crops out from Westmoreland to Moodyville along Rock Creek and the East Fork of Rock Creek. Small erratics are common in the gravel. These deposits, possibly till, contain more than 18 percent of clay and are firmly compacted.

One of the largest deposits of old gravel is 1 mile east of Emmett, where the deposit is about 40 feet thick and consists of sand and pebbles, and boulders as large as 2 feet in maximum dimension. The upper 4 feet of the deposit is firmly cemented by calcium carbonate. Most layers are loose or friable but some are compacted with clay. Limestone fragments are almost as abundant as chert in this deposit. This gravel also is overlain by till, and glacial erratics observed in the upper part of the gravel indicate some reworking by the Kansan glacier or by its outwash streams.

Another large deposit of old gravel lies a mile northeast of Havensville. Limestone fragments are more abundant than chert, and some slabs exceed 2 feet in maximum dimension. The deposit is more than 20 feet thick and is overlain by till.

The old gravel probably is the deposit of pre-Kansan streams that eroded the material from weathered benches of limestone and shale.

TILL

The unstratified deposits of the Kansan glacier are called till. Because the glacier entered the county from the northeast it left the thickest accumulations of till on the northeast-facing valley walls. All of the major boulder fields are on northeast-facing hillsides where they were dropped as the glacier overrode the hill. Till mantles all of the highland areas in the glaciated part of the county.

Although the till resists erosion by rills flowing on it, headward cutting of streams erodes it easily. Vertical fractures in the clayey till allow large blocks to cave as the streams undercut.

The till in the county is either clayey or silty. Clayey till is the predominant type and is similar to the till that crops out over most of northeastern Kansas and eastern Nebraska. The oxidized clayey till is orange red or red brown; the unoxidized till is dark gray. Generally, entire vertical sections of till are leached.

Seventeen samples of till show a range in grain size from 44 to 94 percent minus 200 mesh (U. S. Standard sieve series), and average 75 percent minus 200 mesh; one-half or more of the material may be clay, and the rest silt. Of the 25 percent of the material that is retained on the 200 screen, the larger part is sand, the next largest fraction is composed of pebbles.

Glacial erratics more than 18 feet long were observed in the till. The clay makes the till very compact, but causes it to shrink when dry, and polygonal cracks characterize almost every outcrop. When eroded, the pebbles and boulders that remain after the fine material has been removed form a lag pavement on the outcrop.

The silty till crops out near Duluth and northwest of Aikins. In both places it is friable; a sample collected near Duluth contains 93 percent minus 200 mesh material—most of which is silt. Striated pebbles and cobbles were found in the deposits at Duluth. The till near Aikins includes a skeletal block of limy silt containing angular chert fragments that before weathering was a mass of cherty limestone about 4 feet long. The upper part of the silty till is leached, but the lower part is strongly calcareous.

The rock fragments in the till are mostly quartzite, although some are chert, quartz, granite, greenstone, limestone, and feldspar. Of these, the granite, greenstone, and limestone are generally decomposed and much of the chert is divitrified. Petrified wood, agate and clay ironstone are found in places.

The clayey till was derived from the reworking of weathered limestone and shale. This clay and silt was added to the mass of detritus which was being pushed forward and overridden by the glacier. Although a small amount of the till is composed of erratic fragments that were moved hundreds of miles, most of it is composed of material which was moved less than 10 miles from its source.

The silty till was probably deposited by a glacier overriding its own glaciolacustrine deposits (glacial materials deposited in a pond or lake) during a readvance that followed a period of stagnation.

GLACIAL OUTWASH

The stratified deposits of the glacier melt water streams are called glacial outwash. In the area north of St. George the outwash is fine sand and silt, and in the area 2 miles east of Louisville it is coarse sand with some small pebbles.

The deposit north of St. George occupies an area of about 40 square miles and is more than 100 feet thick over almost one-half of this area. This thick and extensive deposit is due to the existence in the area of the pre-Kansan channel of the Kansas River which was filled with outwash by melt water from the Kansan glacier. Eleven samples of the outwash from this area contain an average of 45 percent minus 200 mesh material—most of which is silt—and 55 percent sand (most of which is fine sand). The upper part of the outwash is cemented by calcium carbonate in some places. Ferric oxide causes the red-brown stain below the humic layer. In the NW¼NE¼ sec. 25, T. 9 S., R. 9 E., limonite has been leached from the upper light-gray part of a soil profile characterized by distinct horizons and concentrated in a one-half inch layer that is itself being leached and reconcentrated in a lower reddish-brown sandy outwash. The outwash is less clayey and less stained toward the bottom. Fine deltaic crossbedding is common; an example of white well-rounded fine sand is well displayed in a road cut in the SW¼NW¼ sec. 7, T. 10 S., R. 9 E. Thin bands of coarse sand and clay flakes are interbedded with the fine sand. Despite an apparent lack of cement, the sand at this outcrop stands in a vertical bank. Another outcrop of crossbedded sand interbedded with glaciolacustrine clay is in the SW¼NW¼SE¼ sec. 22, T. 9 S., R. 9 E. Here alternating beds of lacustrine clay and both crossbedded and nonstratified sand are overlain by till. (*See* section on glaciolacustrine deposits for more detail on the lacustrine clay.) Other deposits that show reworking or disturbance of the outwash by ice are in the NW¼NE¼ sec. 21, T. 9 S., R. 9 E., and in the SE¼NW¼NW¼ sec. 16, T. 9 S., R. 9 E.

The area 2 miles east of Louisville is underlain by outwash (ma 1 in table 1) composed mostly of sand with some pebbles. Almost no local material is incorporated in this deposit. The outwash was probably deposited by Vermillion Creek or by the coalescing Vermillion Creek and Rock Creek late in the Kansan glacial age.

Another deposit of outwash northwest of St. Marys contains a considerable proportion of chert admixed with erratics. Here layers of varved glaciolacustrine clay are interbedded with layers of sand. In one pit the gravel is cemented by calcium carbonate to form a mortar bed.

Outwash sand is exposed on the highland northwest of Onaga, and outwash gravel crops out 2 miles northwest of Havensville and on the county line 3 miles north of Duluth.

KANSAN DRAINAGE CHANGES

When the centerline for U. S. Highway 24 was drilled north of St. George, the State Highway Commission of Kansas (Burton and Bearman, 1949) discovered that the southeast valley wall of the pre-Kansan Kansas River descended from station 316 (NE¼SE¼ sec. 3, T. 10 S., R. 9 E.) to station 291 (NE¼SW¼ sec. 3, T. 10 S., R. 9 E.), and determined the altitude of the valley floor at station 291 to be 998 feet above sea level. Several holes drilled near station 215, 1½ miles southwest of station 291, show the Elmont limestone to be 995 feet above sea level or about the same altitude as the present Kansas River at St. George.

No outcrops of bedrock were observed for 3 miles northwest of this valley wall. A belt 3 miles wide, without bedrock outcrops (pl. 5) trends northeast to Rock Creek where it turns southeast through Louisville to the junction of Vermillion Creek and the Kansas River. Rock Creek now flows in a valley whose great width is out of proportion to the small volume of water flowing in it.

The Kansan glacier moved southwestward across the county until its northwest-trending front stagnated a mile north of St. George. The Kansas River was dammed and Kaw Lake (Hay, 1893, p. 5; Smyth, 1898, p. 95–104; Todd, 1917, p. 187–199) filled the valley west of St. George. After a slight withdrawal of the glacier from its line of greatest advance, the lake waters found an outlet around the ice front, across a divide 1 mile southeast of St. George, and through a series of glacially dammed lakes and topped divides until it finally flowed back into the Kansas River through Wakarusa Creek in Shawnee County (Todd, 1908, p. 107–112; Mudge and Burton, 1959; Mudge, 1955).

Further withdrawal of the glacier was accompanied by accelerated deposition of outwash which kept the pre-Kansan channel of the Kansas River filled, and prevented release of Kaw Lake waters through this channel. Withdrawal of the ice undammed all of the lakes except Kaw Lake and caused the abandonment of the complicated diversion channel system. The water from Kaw Lake continued to flow through the newly cut narrow gap southeast of St. George, but it now flowed into a stream rather than into a lower lake, and followed the course of a small tributary valley northeast to its junction with the pre-Kansan Kansas River Valley east of Wamego. Formation of the new channel left an 8-square-mile highland area of bedrock between St. George and Wamego completely surrounded by deep channels and surficial deposits.

The glacier front apparently withdrew to a position near and parallel to the present Rock Creek where its movement almost ceased for a time. The pre-Kansan channels of Camp Creek and Rock Creek were freed of ice and became ice-marginal streams carrying water southeast around the ice front to a point 3 miles southeast of Flush where they joined and followed the pre-Kansan Kansas River Valley to its confluence with the present Kansas River Valley. Melt water from the glacier cut the wide valley through Flush and Myers Valley. Glaciolacustrine deposits on the south flank of Rock Creek Valley indicate that many small ponds stood along the ice margin. The outwash and glaciolacustrine deposits were later overridden by a minor readvance of the glacier, and till and a small terminal moraine were deposited on them. Melt water continued to flow into Wilson Branch of Rock Creek even after the glacier had withdrawn some distance, and two southwest-trending valleys east of Fostoria were lengthened and enlarged considerably by melt water flowing from the melting ice. Similar lengthening and enlargement of other southwest-trending valleys may be seen at other places in the glaciated part of the county.

A buried valley filled with more than 65 feet of silty till trends northwest from Emmett. The valley was probably formed before the Kansan glaciation by Vermillion Creek flowing southeastward from sec. 7, T. 7 S., R. 11 E. This buried valley is being re-cut by Meyano Creek which now joins Cross Creek at Emmett. After the Vermillion Creek Valley was filled by till, melt water from the glacier topped a divide near the present junction of Jim Creek and Vermillion Creek and flowed southward to join the Kansas River east of Wamego. From the northwest terminus of the valley in sec. 7, T. 7 S., R. 11 E., to its junction with the Kansas River, the Vermillion Creek now flows through a narrower channel than it does in its course north of the valley.

GLACIOLACUSTRINE DEPOSITS

The largest glaciolacustrine deposit covers an area of about 8 square miles in the northern part of R. 11 E. and R. 12 E., T. 6 S., near the northeast corner of the county. The deposit is chiefly light-gray unstratified loose silt but contains thin layers of clay and of dark carbonaceous boggy material. Three samples contained 96, 77, and 33 percent minus 200 mesh, indicating great disparity 4 to 67 percent in the amount of fine sand in the deposit. Although the silt is only slightly cemented with calcium carbonate and is easily eroded, it forms the vertical banks of deep flat-bottomed ravines.

The less silty glaciolacustrine deposits south of Rock Creek in the SW¼NW¼SE¼ sec. 22, T. 9 S., R. 9 E., contain more laminated clay interbedded with outwash sand. The clay beds are intricately deformed in a manner that suggests the clay was soft and mushy when the deforming forces were applied. The small folds and faults in these beds are probably the result of the glacier overriding its own outwash (Twenhofel, 1939, p. 535). A 2-inch layer of clay that swells when wet lies within a lenticular layer of clay at the same locality. The layers in the laminated part of the clay may represent seasonal varves, but they are thinner (one-sixteenth to one-eighth inch) than seasonal varves in other glacial lake clays.

The laminated part of the outwash clay west of St. Mary's consists of 1-inch layers of clay separated by 1-inch layers of sand. Each varve is about 2 inches thick. The evidence of erosion in the sand layers and the small channels cut in some of the clay layers indicates either a seasonal advance and retreat of the shoreline of the pond or that the streams were burdened with more sediments between the clay-depositing periods, a regimen similar to the seasonal fluctuation of glacial streams.

DUNE SAND

Two small deposits of sand that possess the hummocky topographic form of dunes lie on a bench of the Florence limestone member of the Barneston limestone in secs. 24 and 25, T. 7 S., R. 6 E. The bench (which is considered to be pre-Kansan) is at an altitude of about 1,210 feet, or about 200 feet above the present Big Blue River. The deposits consist of well-graded loose fine sand that is composed predominantly of well-rounded frosted quartz grains.

In the past, these deposits were considered to be Kansan glacial outwash that was reworked by the wind. The glacier lay only a short distance east of the dune sand and melt water might have brought sand from the glacier and deposited it on this bench. However, no outwash was found between the till boundary and the bench. Another possibility concerns Kaw Lake, which occupied the valley of the present Big Blue River during the time the Kansas River was dammed. Melt water from the glacier may have filled the valley with outwash to a depth of 200 feet and because the dune sand lies on a high bench cut on bedrock, subsequent erosion only partly removed it while entirely removing the outwash in the valley. The most probable theory is that the sand is pre-Kansan and represents the deposit of the stream that cut the bench.

The outwash sand north of St. George has been blown about by the wind. Dunelike forms were not recognized, but the sand grains in the upper parts of many outcrops are frosted and rounded. East of St. George erratic boulders of quartzite are polished by wind action.

SANBORN FORMATION

The name "Sanborn formation" was proposed by Elias (1931, p. 163) "for the Pleistocene loess, with some gravel and sand at base, which is widely distributed on divides in western Kansas." Since this proposal was made, the formation has been subdivided to include, "in ascending order, the following members: (1) Crete sand and gravel member; (2) Loveland silt member, commonly containing within its top the Sangamon buried soil; (3) unnamed early Wisconsinan [sic] alluvial deposits; (4) Peoria [sic] silt member, commonly containing within its top the Brady buried soil; (5) unnamed late Wisconsinan [sic] alluvial deposits; and (6) Bignell silt member." (Frye and Leonard, 1952, p. 106.)

In Pottawatomie County more types of deposits were mapped as Sanborn formation than were included in the original definition quoted above. Loess, colluvium (material moved downslope primarily by gravity and rill wash), old dissected terraces along the principal streams, and deposits of alluvium that are too small to map as such at the selected mapping scale are all included in the Sanborn formation. Most of the material is tan-gray, gray-brown, or red-brown silt.

Loess crops out on top of the bluffs along the Big Blue River northeast of Manhattan, and on the highland northward to Olsburg and Fostoria. A zonal soil is developed on the loess with a grayish-brown *A* horizon about 6 inches thick and a reddish-brown B_2 horizon several feet thick (U. S. Dept. of Agric., 1951, p. 175). The B_2 horizon contains enough clay minerals to be plastic; the total silt- and clay-size material in the B_2 horizon is 85 percent at an outcrop in the middle of the NW¼ sec. 33, T. 9 S., R. 8 E. This loess resembles the Loveland loess and in some places overlies Kansan till.

A tan-gray less clayey loess crops out along the Big Blue River at the foot of the bluffs northeast of Manhattan. It contains calcium carbonate nodules and stands in vertical banks. A similar loess, but with more clay, overlies Kansan till in the SW¼SW¼ sec. 27, T. 8 S., R. 8 E. The loess in both places closely resembles Peorian loess. Other outcrops of this loess are northeast of Fostoria and overlie glacial outwash north of St. George.

Colluvium mantles most hillsides but is mapped only where it is thick enough to obscure bedrock. It consists of a heterogeneous deposit of silt and sand with pebbles of limestone and chert. The fill in the high small valleys is mostly dark gray-brown silt derived from the glacial till.

Old dissected terraces that adjoin all the larger streams in the county consist of silty alluvium with some sand lenses and thin veneers of colluvium. Because the remnants are small, are mostly covered by colluvium, and have lost the flat terrace form, they are mapped as part of the Sanborn formation.

TERRACE ALLUVIUM

The terrace alluvium is stream-deposited silt, sand, and pebbles in the principal stream valleys. Although the material is lithologically similar to the alluvium of the valley floor, it is mapped separately because of its form.

Terraces have developed along all the principal streams in the county. Four terrace levels are recognized and mapped along the Kansas River, and three or less are mapped along the other stream valleys. The terraces are numbered successively (pl. 5) from oldest and highest to youngest and lowest. The numbers do not refer to Pleistocene glacial stages, but merely show the sequence of cutting and alluviation, and may or may not correspond with numbers for terraces of the same level in adjoining counties. The symbol Qt is to be interpreted as the same level as Qt_1; the $_{(1)}$ is used only where more than one terrace level is present.

All the terraces are composed of alluvium that was deposited during alternating cycles of cutting and filling. The alluvium is coarser in the lower part of each valley fill. Most of the coarse material is chert and limestone fragments commonly set in a lenticular matrix of sand in the silty alluvium. The upper part of each deposit of terrace alluvium is gray-brown silt deposited at flood stage. More than a foot of silt and clay may be deposited during a single flood. The silt is thicker on the older terraces. The depth from the top of the oldest terrace to the bedrock floor of the Kansas River Valley is estimated to exceed 80 feet.

ALLUVIUM

The use of the symbol Qal is restricted to the alluvium covered by a normal flood in the larger stream valleys. In mapping this material, only the lowest, and topographically uneven deposits were thus designated. Other deposits of similar material at the same or higher elevations that may also be covered by normal flood, were mapped as terrace alluvium (Qt) because of their flat surfaces.

The alluvium is the most recent deposit and because it is now being reworked, it consists partly of reworked local material from the higher level valley alluvium, and partly of material from upstream areas. The latter constituent is most noticeable in the deposits along the Big Blue and Kansas Rivers where granitic material makes up the greater part of the gravel. The minor part of the gravel is local chert, limestone, shale, and ironstone fragments. The alluvium in the smaller stream valleys is mostly local material with a few erratics derived from the glacial drift. Sieve analysis shows that the alluvium in the smaller valleys has a greater proportion of coarse material than the alluvium in the valleys of the Big Blue and Kansas Rivers. In neither locale is the material uniformly sorted throughout its outcrop; however, grains of a particular size are commonly congregated in lenslike bodies.

Mammalian remains are occasionally found in the gravel dump of oversize material at the Wamego sand pump, where sand and gravel are pumped from the Kansas River. Because of the scouring action of the river, teeth (especially of bison) are generally the only parts that are preserved.

The alluvium above the water table along the Big Blue and Kansas Rivers ranges from 2 to 15 feet in thickness and averages about 5 feet.

These thicknesses should not be used to compute reserves of alluvial gravel in the stream bed because they were measured above the water table. The total thickness in the Kansas River Valley may be as much as 50 feet. The washing action that results from excavating gravel from a stream removes the unwanted fine material and makes the silty alluvial gravel below the water table as valuable as the clean nonsilty gravel above the water table.

Gravel and sand from the alluvium of the Kansas River are used principally for concrete aggregate, bituminous aggregate, mortar sand, and road metal. The alluvial gravel from the smaller streams is coarser than the gravel pumped from the Kansas River and contains a large amount of silt and clay that compacts to make it stay on the road better than the sand-pump gravel. Cobbles 6 inches long are not uncommon in the gravel recovered by dragline from the smaller streams.

STRUCTURE

The Nemaha range (Eardley, 1951) is the most prominent structural feature in the county. It trends southwest from the northeast corner of the county, passes just west of Havensville, and crosses a point beneath Vermillion Creek 3 miles south of Onaga where it appears to branch, one branch trends west for 2 miles and then southwest to sec. 1, T. 8 S., R. 10 E., where the trace is lost; the other branch probably follows the present course of Vermillion Creek, but the flexure is so gentle as not to be apparent in reconnaissance-type mapping. Although the range was mapped as a simple anticline, it is probably faulted in places.

A fault of small stratigraphic throw but of great areal extent is shown on the map as 5 miles north of Manhattan. To the west it dies out in the alluvium of the Big Blue River but to the east it lies beneath Cedar Creek and extends eastward for 5 miles before dying out in sec. 11, T. 9 S., R. 8 E. Four other small faults were observed, but none had a stratigraphic throw of more than 10 feet or a linear extent of more than a mile. Three of these were normal faults and one was a very small thrust fault.

These features are only a minor deviation from the overall structure of eastern Kansas. The regional dip in this county averages about 13 feet to the mile to the northwest. The Five Point limestone member crops out at 1,050 feet altitude 3 miles north of St. Marys and the Middleburg limestone member crops out at 1,050 feet altitude 5 miles north of Olsburg—a stratigraphic interval of 260 feet between two points 20 miles apart.

INVENTORY OF CONSTRUCTION MATERIALS

The objective of this inventory of construction materials in Pottawatomie County is to define the materials as they are classified in this report and relate them to the map units in which they occur. Whenever available, laboratory test data have been introduced into the report to aid in the evaluation of the materials. The information given in table 1 is based on the standard testing procedures of the State Highway Commission of Kansas (1945; gradation factor, p. 16; sieve analysis, p. 333–334; and soundness, p. 335–336) and the American Association of State Highway Officials (1947; absorption, p. 251–252; compressive strength, p. 257–258; Deval abrasion, p. 235–236; liquid limit, p. 198–201; Los Angeles abrasion, p. 237–239; plasticity index, p. 202–204; specific gravity, p. 249–250; toughness, p. 240–241; and weight per cubic foot, p. 253–254).

It is expected that prospects listed in this report will be proved by subsequent drilling, or test pitting, and that the materials will be subjected to laboratory testing before acceptance for specific uses. Although many prospect pits and quarries were plotted on the map, no attempt was made to locate all possible sources of materials.

AGGREGATE FOR CONCRETE

ENGINEERING AND GEOLOGIC CHARACTERISTICS

In table 1 and on plate 5, aggregate for concrete is classified as fine aggregate and mixed aggregate. The distinction is arbitrarily based on the percentage of material retained on a No. 4 sieve. The portion of a sample retained on that sieve is designated as the coarse fraction. The material is classified as an aggregate if the coarse fraction is 5 percent or more by weight of the sample, and as a fine aggregate if the coarse fraction is less than 5 percent. Fine and mixed aggregate will be considered together because the grading of almost any aggregate material may be changed by "sweetening" or screening until it conforms to the required specifications.

Aggregate for concrete consists of sand and gravel-size fragments of hard durable minerals or rocks. The constituent particles are free from adherent coatings that would interfere with the bonding of cement with the particles. The presence of the following substances, if in quantities thought to be excessive, is noted under remarks in table 1: material passing the No. 200 sieve (wash); shaly, soft, or flaky fragments; sticks or other organic debris; clay lumps; and minerals which, because of their chemical composition, may react with the cement to the detriment of the concrete.

The materials reported in this classification are accessible from all weather roads and are exposed at the surface or have an unconsolidated overburden sufficiently thin to permit economic development.

The test characteristics of the materials indicate that some are not suitable for use in concrete. However, the same materials might be acceptable for other aggregate uses, such as aggregate for bituminous construction or for cover material.

STRATIGRAPHIC SOURCES AND PERFORMANCE CHARACTERISTICS

The stratigraphic units that are actual or potential sources of aggregate for concrete in Pottawatomie County are alluvium, glacial outwash, and limestone. The alluvium of the Kansas and Big Blue Rivers provides a great supply of aggregate. It is composed of sand, and a small amount of pebbles not more than 2 inches in diameter. Screened aggregates from the alluvium are widely used in engineering construction. The alluvium of the Big Blue River, and that at the Kansas River east of Manhattan, contains a large amount of chert. The chert is not present in the Kansas River west of its confluence with the Big Blue River.

The service record of the Kansas River aggregate is bad; that of the Big Blue River aggregate is good. In the normal type of concrete mixture the Kansas River aggregate deteriorates and produces abnormal expansion, map cracking, and loss of flexural strength in the structure. This sand-gravel can be made into serviceable aggregate by "sweetening" it with rather soft, durable, and absorptive limestones (Scholer and Gibson, 1948).

Seven samples, included in ma 2 and 3, were taken from the Kansas River. The results of the standard tests (table 1) indicate that the material is suitable for aggregate. The specific gravity averages 2.60; the gradation factor is 3.42; the compressive strength ratio is well above 1 and the aggregate is sound.

The glacial outwash also contains large supplies of aggregate. The outwash is composed of sand and a small amount of fine gravel. Coarser gravel is available in the lower part of the outwash north and west of St. George. The glacial outwash has been very little used because of the alteration of pebbles in the gravel, the thickness of sand covering the gravel, and the tremendous quantity of aggregate available in the alluvium of the Kansas and Big Blue Rivers. Considerable chert is mixed with the outwash just west of St. Marys, but chert is rare in the other outwash deposits.

Three samples, included in fa 1 and ma 1, were taken from the outwash. The results of standard tests (table 1) indicate that the material is suitable for use as aggregate. The specific gravity averages 2.60 and the gradation factor, 3.05. The compressive strength ratio was above 1 in 2 of the 3 samples tested.

Large volumes of cherty and noncherty limestone are available in the county. The Cottonwood limestone member of the Beattie limestone, Neva limestone member of the Grenola limestone, Burr limestone member of the Grenola limestone, Eiss limestone member of the Bader limestone, the Funston limestone, and the Fort Riley limestone member of the Barneston limestone are the gray limestone units that are generally used for concrete aggregate. The results of tests on the Cottonwood limestone member show widely varying results that reflect the sampling of weathered and unweathered layers, the variable lithology of the limestone, the presence of absence of chert nodules, and the presence or absence of fusulinids. The other noncherty limestone units will vary in the same way; each layer should be tested for a particular use. Tests were not made on the Threemile limestone member of the Wreford limestone, the Schroyer limestone members of the Wreford limestone, and the Florence limestone member of the Barneston limestone, which are the cherty limestone units that might be usable for concrete aggregate.

ROAD METAL

ENGINEERING AND GEOLOGIC CHARACTERISTICS

Road metal, known also as surfacing material, crushed stone, and aggregate, is defined in this report as material that may be applied to a road to improve the performance characteristics of that road. The geologic materials classed as road metal vary from one area to another. The materials in Pottawatomie County that have been used or are available for use as road metal are aggregate for concrete, limestone gravel, chert gravel, and crushed rock.

STRATIGRAPHIC SOURCES AND PERFORMANCE CHARACTERISTICS

Materials listed in the section on Aggregate have been used, or are available for use, in various types of road construction in Pottawatomie County. The alluvium of the Kansas River was the source of material used in the base course of a bituminous-mat on State Route 99 between Wamego and Westmoreland; it was used as loose road metal on light-traffic roads, such as State Routes 13, 16, and 63; and in various ways in other types of road construction. No information is available on the performance of glacial outwash as road metal, but some from deposits just west of St. Marys was used for that purpose. At least two roads were surfaced with crushed limestone before 1949. One of these was the road from Stockdale in Riley County to Olsburg in Pottawatomie County; the other was the road trending due north from Belvue. The performance record is good; however, the crushed stone is said to be slightly more expensive than other types of surfacing material. The Brownville limestone member was quarried for road metal until it was learned that the rock was too hard for road metal.

Limestone gravel is defined by the State Highway Commission of Kansas as a sedimentary material composed of rounded fragments of local limestone, generally about three-fourths of an inch long, incorporated in a matrix of silt-size particles. Limestone gravel is used extensively as road metal on secondary roads throughout northeast Kansas.

Chert gravel, clay gravel, or flint gravel with binder is defined by the State Highway Commission of Kanas as a hard gravel or chert stone occurring naturally with sand and a binder material. Chert gravel is used extensively as road metal on township roads along the Flint Hills in northeast Kansas.

Crushed rocks available for use in road construction are (a) limestone, a compact massive calcareous rock of variable hardness; and (b) shale, a calcareous silty shale or siltstone that is somewhat soft but still an excellent surfacing material to impart firmness to the clayey glacial till.

The materials included here as sources of crushed rock are listed in table 1 under limestone and mapped on plate 5 under the specific designations of limestone and shale because they may be used also as structural stone and riprap.

Several sources of material classified as limestone gravel are mapped on plate 5, and the test characteristics of material from five of these sources (lg 1 to 5) are given in table 1. The gravels occur in small quantities in colluvium and alluvium of the Sanborn formation in the higher and smaller stream valleys. The gravels contain limestone and shale from the small catchment area upstream from the deposits. Probably the largest supply of limestone gravel comes from the terrace deposits and the alluvium on the valley floors of the medium-size streams. This material is locally called creek gravel and near the outcrops of cherty limestone is more chert gravel than limestone gravel. Although the parent limestone contains more limestone than chert the abrasive power of the stream destroys the limestone first and leaves a residuum of chert particles. However, the older gravel in one deposit (lg 1) is predominately limestone.

Although the chert gravel deposits in the county have been exploited for many years, considerable quantities are still available. Most chert gravel deposits are at high altitudes; they are shown on plate 5 as old gravel. The material is composed of rounded pebbles of chert in a silt matrix in the deposits near Wamego, Flush, Emmett, and Havensville.

MINERAL FILLER

ENGINEERING AND GEOLOGIC CHARACTERISTICS

Material composed predominantly of silt-size particles (50 percent or more of the sample passes the No. 200 sieve) is classified in this report as mineral filler. It has no more than a trace of sticks or other organic debris, but may contain minor amounts of fine sand or clay. To qualify as mineral filler, this material must have a low coefficient of cementation. Deficiencies in this characteristic among the samples tested are noted under remarks in table 1. Failure of the material to pulverize easily, a factor of cementation, makes it more difficult to obtain a uniform distribution of the material throughout the mixture.

STRATIGRAPHIC SOURCES AND PERFORMANCE CHARACTERISTICS

Test data on two samples of mineral filler taken from the glaciolacustrine deposits in the northeast corner of the county (mf 1) indicates that part of the material might be acceptable as mineral filler, even though only 33 percent of one sample passed the No. 200 sieve. The cementation factor of one sample, an average of 41, was rather high. The mineral filler for the only bituminous-mat road in the county, State Route 99, is said to have been imported into the county. It is recommended that the cementation factor of any material be determined in the laboratory as a prerequisite to its utilization.

One sample of the silty till from the SW¼SW¼ sec. 30, T. 9 S., R. 9 E., was tested in the laboratory of the U. S. Geological Survey. It was found that 61.2 percent of the material passed the No. 200 sieve and that only 1.05 percent was retained on the No. 30 sieve. Most of the till is clayey; it, therefore, would not be expected to pulverize easily.

Two samples of glacial outwash that contain more than 50 percent minus 200 fraction, indicate that glacial outwash is a possible source of mineral filler.

Silt from the terrace deposits was not tested in the laboratory, but this stratigraphic unit has been a source in other counties and is a potential source in Pottawatomie County. However, it is doubtful that very much mineral filler can be obtained from a single site because most terrace deposits are poorly sorted.

RIPRAP

ENGINEERING AND GEOLOGIC CHARACTERISTICS

As defined in this report, riprap is any material that will protect earthen fills from erosion. The material for this use must be relatively sound and free from impurities and cracks and other structural defects that would cause it to disintegrate through erosion, slaking, or freeze-and-thaw. Blocks of riprap should have approximately rectangular faces 7 inches or more in width.

STRATIGRAPHIC SOURCES AND PERFORMANCE CHARACTERISTICS

Four limestone units in Pottawatomie County are probably suitable for riprap. They are the Neva limestone member of the Grenola limestone, Tarkio limestone member of the Zeandale limestone, Americus limestone member of the Foraker limestone, and the Brownville limestone member of the Wood Siding formation. The Neva limestone member of the Grenola limestone is giving satisfactory performance as riprap on Lake Pottawatomie. Among the other stones that are used as riprap on this lake is the lower layer of the Threemile limestone member of the Wreford limestone which, however, is slaking badly. The Tarkio limestone member of the Zeandale limestone is taken from three large quarries along the Kansas River between Wamego and St. George for use as riprap along the Union Pacific Railroad tracks that adjoin the Kansas River. The four criteria used in evaluating these limestone units for use as riprap were a freeze-and-thaw loss ratio (soundness) of not lower than 0.90; Los Angeles abrasion loss of not more than 30.0; absorption factor of not more than 4.0; and a specific gravity of at least 2.0. The Neva limestone member of the Grenola limestone met this test in only 4 of 8 samples; therefore each ledge should be tested for soundness and absorption before quarrying is begun. The other three limestone units were satisfactory in all respects.

STRUCTURAL STONE

ENGINEERING AND GEOLOGIC CHARACTERISTICS

Structural stone, as defined in this report, is any hard dense rock that can be quarried and cut to the desired size and shape. Thick-bedded fine-grained light-colored or light-gray limestone is generally considered the best kind of limestone for this purpose. Eight limestone units in the county would be satisfactory for this use.

STRATIGRAPHIC SOURCES AND PERFORMANCE CHARACTERISTICS

The Cottonwood limestone member is widely used in the county. It is an attractive light-gray stone that weathers darker gray with many small fusulinids projecting from the surface and it can be sawed readily to the desired dimensions. Although the tests show that its absorption is high and the soundness poorer than might be desired, the stone has been observed in good condition although subjected to much moisture in foundation and retaining walls. It has also been used satisfactorily in stone bridges and drainage structures.

The Neva limestone member is used in many buildings in the county, both new and old. The American Legion building in Wamego was constructed in 1949 of limestone from the Neva and many older buildings were observed that were in excellent condition. The stone, which can be sawed readily, is a lighter gray than the Cottonwood and does not darken as quickly when weathered.

The Fort Riley limestone member was used in the construction of a few farm buildings in the northwestern part of the county. Because it is not as thick in Pottawatomie County as in Riley and Geary Counties and on the Fort Riley Military Reservation, it is used less as structural stone. The upper rimrock is the only part of the member suitable for this use and its thickness barely exceeds 2 feet.

The Funston limestone is the most extensively used of the Permian limestones in the northeastern part of the county. The stone is gray and somewhat more porous than the three limestone units already discussed.

The Reading limestone member of the Emporia limestone was used in constructing many of the stone buildings at Onaga. Two of the three layers in the member are brown and the third is gray. In most buildings only one layer was used for the entire building; however, in a few buildings all three layers were used indiscriminately. The attractive stone is quite durable and requires very little sizing because the normal thickness of each of the three layers is between 0.6 and 0.8 foot. In some quarries a rectangular joint system reduces even further the work of sizing the stone.

The Americus limestone member of the Foraker limestone has been used less for buildings than it has for stone bridges, culverts, and other small structures. Each of the two layers averages a foot in thickness and blocks as large as 4 by 6 feet are common; it is, therefore, well adapted for floors and for the aprons of bridges. Its performance is excellent and very little slaking was observed even where it was subjected to the most adverse conditions.

The only use that was observed of the Aspinwall limestone member of the Onaga shale was in small bridges. It splits readily along the bedding plane; therefore even though its thickness is variable it can be adapted to a variety of uses. Unfortunately, in many places its joints form inequiangular parallelograms rather than rectangles.

The Five Point limestone member of the Janesville shale has not been used much in the construction of buildings. Near Duluth, it is an attractive orange-pink stone and has been used more than in other parts of the county. Its specific gravity is above 2.0, which is lower than that of most other limestone units because it is a coquina. Because the rate of absorption is high it should probably be used above the ground level to keep it from disintegrating too rapidly.

Other limestone units have been used in small amounts for all purposes, but the eight limestone units discussed here are the most important in the county for use as structural stone.

LITERATURE CITED

American Association of State Highway Officials, 1947, Standard specifications for highway materials and methods of sampling and testing, pt. 2, 5th ed., 361 p.

Burton, R. H., and Bearman, C. H., 1949, Geological Report and Geo-Engineering Survey: Project 24–75 F 605 (1) Pottawatomie County: State Highway Commission of Kansas.

Eardley, A. J., 1951, Structural geology of North America: Harper, New York, p. 37–39.

Fenneman, N. M., 1917, Physiographic divisions of the United States: Assoc. American Geographers Annals, v. 6, p. 19–98.

——— 1938, Physiography of eastern United States: McGraw-Hill Book Co., N. Y., 714 p.

Flora, S. D., 1948, The climate of Kansas: Kansas State Board of Agriculture Rept., v. 67, no. 285, 320 p.

Frye, J. C., and Leonard, A. B., 1952, Pleistocene geology of Kansas: Kansas State Geol. Survey Bull. 99, 230 p.

Frye, J. C., and Swineford, Ada, 1949, The Plains Border physiographic section: Kansas Acad. Sci. Trans., v. 52, no. 1, p. 71–81.

Hay, Robert, 1893, Pres. address, The geology of the Great Plains: Kansas Acad. Sci. Trans., v. 13, p. 3–6.

Hoover, W. F., 1936, Petrography and distribution of a highly weathered drift in the Kansas River Valley: Jour. Sed. Petrology, v. 6, no. 3, p. 143–153.

Lohman, S. W., 1941, Ground water conditions in the vicinity of Lawrence, Kansas: Kansas Geol. Survey Bull. 38, pt. 2, p. 17–64.

Moore, R. C., 1949, Divisions of the Pennsylvanian system in Kansas: Kansas Geol. Survey Bull. 83, 203 p.

Moore, R. C., Frye, J. C., Jewett, J. M., Lee, Wallace, and O'Connor, H. G., 1951, The Kansas rock column: Kansas Geol. Survey Bull. 89, 132 p.

Moore, R. C., and Mudge, M. R., 1956, Reclassification of some lower Permian and Upper Pennsylvanian strata in northern mid-continent: Am. Assoc. Petroleum Geologists Bull., v. 40, no. 9, p. 2272–2278.

Mudge, M. R., 1956, Sandstones and channels in Upper Pennsylvanian and lower Permian in Kansas: Am. Assoc. Petroleum Geologists Bull., v. 40, no. 4, p. 654–678.

——— 1955, Early Pleistocene geomorphic history of Wabaunsee, southeastern Riley, and southern Pottawatomie Counties, Kansas: Kansas Acad. Sci. Trans., v. 58, no. 2, p. 271–281.

Mudge, M. R., and Burton, R. H., 1959, Geology of Wabaunsee County, Kansas: U. S. Geol. Survey Bull. 1068.

Schoewe, W. H., 1946, Coal resources of the Wabaunsee Group in eastern Kansas: Kansas Geol. Survey Bull. 63, 144 p.

——— 1949, The geography of Kansas: Kansas Acad. Sci. Trans., v. 52, no. 3, p. 261–333.

Scholer, C. H., and Gibson, W. E., 1948, Effect of various coarse aggregates upon the cement-aggregate reaction: Jour. American Concrete Inst., v. 19, no. 10, p. 1009–1032.

Smyth, B. B., 1898, The buried moraine of the Shunganunga: Kansas Acad. Sci. Trans., v. 15, p. 95–104.

State Highway Commission of Kansas, 1945, Standard specifications for state road and bridge construction: 512 p.

Todd, J. E., 1908, Drainage of the Kansas ice sheet: Kansas Acad. Sci. Trans., v. 22, p. 107–112.

——— 1917, History of Kaw Lake, Kansas: Kansas Acad. Sci. Trans., v. 28, p. 187–199.

Twenhofel, W. H., 1939, Principles of sedimentation: McGraw-Hill Book Co., N. Y., 610 p.

U. S. Congress Documents, 1944, Missouri River Basin, conservation, control, and use of water resources: 78th Cong., 2d sess., S. Doc. 191.

U. S. Department of Agriculture, 1951, Soil survey manual, Handbook no. 18, 503 p.

U. S. Weather Bureau, 1942–1950, Climatological data, Kansas section: U. S. Dept. of Commerce.

Wilmarth, M. G., 1938, Lexicon of geologic names of the United States: U. S. Geol. Survey Bull. 896, pts. 1 and 2, 2396 p.

STRATIGRAPHIC SECTIONS

1. *Section in a stream cut in the NE¼SW¼ sec. 18, T. 6 S., R. 12 E., where the Rulo limestone member of the Scranton shale crops out 0.2 foot above the Elmo coal.*

	Feet
Scranton shale (part):	
Rulo limestone member (part):	
4. Limestone, dark grayish-brown, massive; crystalline calcite commonly replaces crinoid columnals; weathers light gray, shaly; contains small fusulinids	1. 2
Cedar Vale shale member (part):	
3. Shale, gray, sandy	. 2
2. Coal, limonitic, impure; Elmo coal	. 4
1. Siltstone, light-gray to tan-gray, blocky	4. 0
Thickness of Cedar Vale shale member exposed	4. 6
Thickness of Scranton shale exposed	5. 8

2. *Section in a stream cut 200 yards south of section 1 in the SE¼SW¼ sec. 18, T. 6 S., R. 12 E.*

	Feet
Bern limestone (part):	
Burlingame limestone member (part):	
6. Limestone, brown, massive; conglomeratic with clay nodules; weathers tan; contains large and small fusulinids	1. 0
Scranton shale (part):	
Cedar Vale and Silver Lake shale members undifferentiated (part):	
5. Shale, gray, clayey; weathers light gray	25. 3
4. Coal, limonitic, impure; Elmo coal	. 7
3. Claystone, gray, blocky; weathers light gray	14. 4
2. Limestone, tan; massive in upper 0.4 foot; tan and maroon, shaly to nodular in lower 2.2 feet	2. 6
1. Shale, light-gray, clayey; weathers light gray	1. 4
Thickness exposed	44. 4

3. *Section in a road cut in the SW¼SE¼ sec. 2, T. 7 S., R 11 E.*

	Feet
Bern limestone (part):	
Wakarusa limestone member (part):	
5. Limestone, tan, massive; crystalline calcite commonly replaces crinoid columnals; weathers tan; fossiliferous	0.6
Soldier Creek shale member:	
4. Claystone, variegated, blocky	3.3
Burlingame limestone member (part):	
3. Limestone, tan, massive, limonite stained; weathers maroon (stained from variegated shale above), blocky; contains fusulinids	.5
2. Shale, tan-gray, silty, calcareous; weathers light-gray	.6
1. Limestone, tan, massive; conglomeratic with clay nodules; weathers maroon; contains fusulinids	1.6
Thickness exposed	2.7
Thickness of Bern limestone exposed	6.6

4. *Section in a stream cut in the SW¼SE¼ sec. 2, T. 7 S., R. 11 E.*

	Feet
Bern limestone:	
Burlingame limestone member:	
12. Limestone, gray mottled brown, massive; conglomeratic with flattened clay balls; contains fusulinids	1.3
Scranton shale (part):	
Cedar Vale and Silver Lake shale members undifferentiated (part):	
11. Shale, variegated light-green and maroon, silty	2.4
10. Limestone, tan, blocky; weathers brown	.4
9. Shale, olive drab, clayey; weathers light green	2.6
8. Limestone, light greenish-gray, massive, sandy	.6
7. Shale, olive-drab, sandy, calcareous; weathers light green	1.5
6. Shale, black, clayey; contains limestone nodules; weathers gray; fossiliferous	1.0
5. Limestone, gray, fine-grained; contains calcite and marcasite nodules; weathers gray; fossiliferous	.2
4. Claystone, black, blocky; weathers light gray	18.1
3. Coal, black, limonitic; contains marcasite nodules; fossiliferous near top; Elmo coal	.6
2. Shale, silty; has vertical fracture pattern with coal in fractures	6.7
1. Claystone, dark-gray, blocky, calcareous; weathers tan. A 0.2 foot silty limestone lies at top of claystone	1.3
Thickness of Cedar Vale and Silver Lake shale members undifferentiated exposed	35.4

5. *Section in a road cut in the SW¼NW¼ sec. 18, T. 10 S., R 10 E.*

	Feet
Emporia limestone:	
Reading limestone member:	
17. Limestone, gray and brown, massive, dense, hard; weathers gray and brown; splits into four separate layers; fossiliferous	2. 8
Auburn shale:	
16. Shale, tan-gray, clayey; weathers tan gray	. 7
15. Shale, dark-gray, clayey; weathers dark gray	1. 3
14. Shale, olive-drab, silty; weathers tan gray	6. 8
13. Limestone, gray, shaly, nodular; weathers gray; fossiliferous	1. 1
12. Shale, tan-gray, silty, calcareous	5. 7
11. Shale, light-gray, silty	. 1
10. Shale, olive-drab, silty; weathers to gray or light-gray muddy lumps	7. 5
Total thickness of Auburn shale	23. 2
Bern limestone (part):	
Wakarusa limestone member:	
9. Limestone, tan-gray, sandy appearing; weathers tan gray in small pebbles	. 5
8. Limestone, gray, shaly; weathers gray; fossiliferous	. 8
7. Limestone, tan-gray, massive; weathers tan gray	1. 2
6. Limestone, tan-gray; weathers tan gray and shaly	1. 2
5. Limestone, tan-gray mottled with tan, massive, sandy	. 5
4. Shale, gray, silty, calcareous; weathers gray	. 3
3. Limestone, tan-gray, massive; weathers reddish brown with brown dendritic figures	1. 2
Total thickness of Wakarusa limestone member	5. 7
Soldier Creek shale member:	
2. Shale, olive-drab; blocky, clayey, micaceous; weathers gray	1. 2
Burlingame limestone member (part):	
1. Limestone, tan-gray, massive; weathers pink due to limonite; conglomeratic with clay balls; contains small fusulinids	1. 6
Thickness of Bern limestone exposed	8. 5

6. *Section in a road cut in the SE¼NE¼ sec. 13, T. 10 S., R. 9 E.*

	Feet
Emporia limestone:	
Elmont limestone member:	
9. Limestone, gray, massive; vertical joints widened by solution; weathers tan gray; contains small fusulinids	2. 2
Harveyville shale member:	
8. Shale, dark-gray, clayey, micaceous; weathers dark gray	2. 3
7. Limonite, brown, concretionary	. 1
6. Shale, gray, clayey, limonitic; weathers gray	17. 0
Total thickness of Harveyville shale member	19. 4

6. *Section in a road cut in the SE¼NE¼ sec. 13, T. 10 S., R. 9 E*—Continued

	Feet
Emporia limestone—Continued	
Reading limestone member:	
5. Limestone, brown, massive, dense, hard; crystalline calcite commonly replaces crinoid columnals; weathers brown; fossiliferous	0.6
4. Limestone, gray, massive, dense, hard; crystalline calcite commonly replaces crinoid columnals; weathers gray; fossiliferous	.7
3. Limestone, gray, massive, dense, hard; crystalline calcite commonly replaces crinoid columnals, and calcite crystals radiate into shell cavities; weathers gray; folssiliferous	.8
2. Shale, brown, silty, limonitic; weathers tan gray	.5
1. Limestone, dark-gray, crystalline; weathers dark gray; fossiliferous	.2
Total thickness of Reading limestone member	2.8
Total thickness of Emporia limestone	24.4

7. *Section in quarries in the Tarkio and Elmont limestone members in the SW¼NE¼ sec. 15, T. 10 S., R. 9 E.*

	Feet
Zeandale limestone (part):	
Wamego shale member (part):	
7. Shale, gray, silty	?
6. Shale, tan-gray, silty, limonitic	1.0+
Thickness of Wamego shale member	1.0+
Tarkio limestone member:	
5. Limestone, light-gray, massive; weathers brown, slabby to nodular; large gray fusulinids project from sides of blocks. Divided into two layers—upper layer is 4.2 feet thick, lower layer is 4 feet thick	8.2
Thickness of Zeandale limestone exposed	9.2+
Willard shale:	
4. Shale, gray; covered except for 6 feet of clayey shale at bottom	28.7
Emporia limestone:	
Elmont limestone member:	
3. Limestone, dark-gray, massive; vertical joints; clay nodules give conglomeratic appearance; weathers brown limonitic at top; contains small fusulinids	5.0
Harveyville shale member:	
2. Shale, gray, sandy; weathers tan gray	21.3
Reading limestone member:	
1. Limestone, brown to gray, massive, dense, hard; weathers brown to gray, fossiliferous; divides into 3 or 4 beds in most places	2.0
Total thickness of Emporia limestone	28.3

8. *Section in a road cut to a quarry in the NE¼NW¼ sec. 18, T. 10 S., R. 10 E.*

	Feet
Zeandale limestone (part):	
Tarkio limestone member (part):	
7. Limestone, light-gray, massive; flinty appearing; weathers brown, chalky, and nodular with large gray fusulinids projecting	5.7
Willard shale:	
6. Shale, gray, sandy, limonitic; contains ironstone concretions; weathers tan gray	4.8
5. Sandstone, tan-gray, micaceous, soft, friable; somewhat cross-bedded; contains limonite nodules	2.9
4. Shale, tan-gray, sandy, limonitic	.7
3. Sandstone, tan-gray, soft, friable, limonite stained	.6
2. Shale, tan-gray, sandy, limonitic; slope appears tan gray, speckled with brown limonite nodules	28.0
Total thickness of Willard shale	37.0
Emporia limestone (part):	
Elmont limestone member (part):	
1. Limestone, gray, massive; weathers brown, shaly with limonite particles on top; contains small fusulinids	2.0

9. *Section in a stream cut in the NE¼NE¼ sec. 12, T. 9 S., R. 9 E.*

	Feet
Stotler limestone:	
Dover limestone member (part):	
11. Limestone, gray, massive, hard, dense; weathers light brown, nodular; algal nodules weather out on slope; contains large fusulinids	2.8
Pillsbury shale:	
10. Shale, gray, silty; contains limonite nodules; weathers tan gray	16.8
Zeandale limestone:	
Maple Hill limestone member:	
9. Limestone, dark-gray, massive, dense; crystalline calcite commonly replaces crinoid columnals; weathers brown, shaly in rectangular blocks	1.8
Wamego shale member:	
8. Shale, dark-gray, clayey; weathers tan gray mottled with gray; some limonite stains	20.8
7. Limonite, reddish-brown, blocky; weathers reddish brown	.1
6. Coal, black mottled with brown, limonitic, impure	.5
5. Limestone, gray; pebbly; contains brown 0.02 foot spots of limonite; weathers dark gray	.5
4. Siltstone, olive-drab, blocky; weathers gray	1.1
3. Coal, black; with brown limonite streak	.1
2. Claystone, olive-drab, blocky; contains brown spots of limonite	.5
Total thickness of Wamego shale member	23.6

9. *Section in a stream cut in the NE¼NE¼ sec. 12, T. 9 S., R. 9 E*—Continued

	Feet
Zeandale limestone—Continued	
Tarkio limestone member:	
1. Limestone, tan-gray, massive, dense; weathers grayish brown, blocky; contains large fusulinids	4. 0
Total thickness of Zeandale limestone	29. 4

10. *Section in a stream cut in the NW¼NW¼ sec. 6, T. 9 S., R. 10 E. (stratigraphic names and tops and bottoms according to M. R. Mudge—oral communication)*

	F
Root shale:	
Jim Creek limestone member:	
9. Limestone, tan, massive; mottled with light green; weathers tan gray and nodular; fossiliferous	2. 3
Dry and Friedrich shale members undifferentiated:	
8. Shale, variegated olive-drab and maroon clayey	14. 6
7. Shale, black, silty; weathers dark gray	. 8
Total Dry and Friedrich shale members undifferentiated	15. 4
Total thickness of Root shale	17. 7
Stotler limestone:	
Dover limestone member: (Units 4, 5, and 6 are probable correlatives of Grandhaven limestone member south of Kansas River)	
6. Limestone, dark-gray, massive; weathers tan	. 7
5. Shale, dark-gray, silty, calcareous; weathers tan gray; contains fusulinids	. 9
4. Limestone, grayish-orange, massive; shells colored orange; weathers tan gray and blocky; fossiliferous	1. 0
3. Shale, light-green, nodular, silty, calcareous; weathers light green mottled with tan gray. (Unit 3 is probable correlative of Dry shale member south of Kansas River)	1. 8
2. Limestone, light-gray, massive, dense; weathers tan gray and nodular; fossiliferous; contains large fusulinids. (Typical Dover limestone)	3. 5
Total thickness of Stotler limestone	7. 9
Pillsbury shale (part):	
1. Claystone, olive-drab; weathers light gray, blocky	2. 8

11. *Section in a road cut in the NE¼NW¼ sec. 27, T. 8 S., R. 10 E.*

	Feet
Falls City limestone:	
9. Limestone, brown, resinous, massive, dense; soft where fresh; weathers hard and blocky with brown manganese dendrites on joint planes; slightly fossiliferous	3. 0
Onaga shale:	
Hawxby shale member:	
8. Shale, variegated gray, maroon, and tan-gray, silty, calcareous; tan-gray limestone with molluscs 8 feet from the top	21. 0
Aspinwall limestone member:	
7. Limestone, grayish-brown, massive; silty at base; coarse and fine layers stratified at top; weathers grayish brown, cavernous, in rectangular joint blocks	4. 2
Towle shale member:	
6. Shale, variegated light-green, gray, olive-drab, and maroon, silty	12. 8
Total thickness of Onaga shale	38. 0
Wood Siding formation:	
Brownville limestone member:	
5. Limestone, brown, massive, dense; weathers tan; fossiliferous	1. 3
4. Shale, tan-gray, silty; extremely fossiliferous	. 5
3. Limestone, light-brown, massive, dense; weathers tan; fossiliferous	1. 7
Total thickness of Brownville limestone member	3. 5
Dry and Pony Creek shale members undifferentiated:	
2. Shale, olive-drab to gray, silty, limonitic; septarian nodules as much as 2 feet in diameter containing crystals of calcite, barite, and celestite	55. 0
Total of Wood Siding formation exposed	58. 5
Stotler limestone (part):	
Dover limestone member (part):	
1. Limestone, brown, massive, dense; weathers tan gray to cream, nodular; algal nodules weather out on surface of ground; fossiliferous	4. 0
Thickness of Stotler limestone exposed	4. 0

12. *Section in a stream cut in the SW¼SE¼ sec. 16, T. 8 S., R. 10 E.*

	Feet
Wood Siding formation (part):	
Nebraska City limestone member:	
4. Limestone; brownish tan in upper 0.2 foot; bluish gray mottled with tan in lower foot; massive; weathers shaly; fossiliferous	1.2
Root shale and Stotler limestone undifferentiated (part):	
French Creek shale member:	
3. Shale, gray, sandy, limonitic	28.5
Jim Creek limestone member:	
2. Limestone, gray, massive; weathers brown, shaly with limonite stains on upper surface; crinoid columnals and other fossils project from surface	1.3
Dry and Friedrich shale members undifferentiated (part):	
1. Shale, light-gray; sandy in upper part, silty in lower part. Thickness exposed	9.5
Thickness of Root shale and Stotler limestone undifferentiated exposed	39.3

13. *Section in a road cut on an east-trending road in the NW¼NW¼ sec. 5, T. 9 S., R. 10 E.*

	Feet
Onaga shale (part):	
Towle shale member:	
9. Limestone, light-gray, nodular; weathers light gray, shaly; contains molluscs	1.0
8. Claystone, olive-drab, blocky	5.7
Thickness of the Onaga shale exposed	6.7
Wood Siding formation:	
Brownville limestone member:	
7. Limestone, brown, massive; weathers tan, blocky to nodular; fossiliferous	3.0
Pony Creek shale member:	
6. Shale, variegated olive-drab, maroon, clayey; limonitic in lower part	8.7
Grayhorse limestone and Plumb shale members missing.	
Nebraska City limestone member:	
5. Limestone, massive; metallic gray when fresh; crystalline calcite commonly replaces crinoid columnals; weathers brown mottled with gray; shaly; fossiliferous	1.5
Total thickness of Wood Siding formation	13.2
Root shale (part):	
French Creek shale member:	
4. Shale, olive-drab, clayey; weathers tan gray	.3
3. Coal; black and brown layers; limonitic; impure; Lorton coal	.25
2. Underclay, light-gray, silty; weathers light gray	.25
1. Shale, tan-gray, silty, limonitic	10.4
Thickness of Root shale exposed	11.2

14. *Section in a road cut on an east-trending road in the NW¼NW¼ sec. 4, T. 9 S., R. 10 E.*

	Feet
Onaga shale (part):	
Hawxby shale member (part):	
9. Limestone, tan, blocky; weathers tan gray, nodular; contains molluscs	0.8
8. Claystone, olive-drab, blocky; weathers tan gray	1.4
7. Limestone, tan, massive; weathers tan mottled with gray, nodular	.6
6. Claystone, variegated tan, tan-gray and maroon, calcareous	9.2
Thickness of Hawxby shale member exposed	12.0
Aspinwall limestone member:	
5. Limestone, brown, massive, medium-grained, stratified; tan gray flattened clay balls; fossiliferous in lower part	2.1
Towle shale member:	
4. Shale, variegated, tan-gray and maroon, silty; weathers tan gray, light pink	1.4
3. Limestone, light-gray, blocky; weathers light gray, nodular; contains molluscs	.9
2. Shale, olive-drab, blocky; weathers light green	3.7
Total thickness of Towle shale member	6.0
Thickness of Onaga shale exposed	20.1
Wood Siding formation (part):	
Brownville limestone member:	
1. Limestone, brown, massive, dense; weathers tan; fossiliferous	2.0

15. *Section in a road cut on the south side of the SW¼ sec. 2, T. 8 S., R. 10 E.*

	Feet
Janesville shale (part):	
Five point limestone member:	
26. Limestone, tan-gray, massive, hard; weathers tan gray; coquinoidal limestone (weathered block measured)	0.8
West Branch shale member:	
25. Shale, black, clayey; weathers gray	3.8
24. Limestone, tan-gray, shaly; weathers light gray; fossiliferous	.8
23. Shale, olive-drab, silty (mostly covered)	5.6
22. Limestone, tan, blocky, silty; calcite veins present; weathers tan gray	.3
21. Shale, gray and olive-drab, silty (mostly covered)	1.6
20. Limestone, olive-drab, cellular	1.0
19. Shale, olive-drab, clayey; contains small white calcareous nodules; weathers light green (partly covered)	11.0
18. Limestone, gray, platy, sandy; weathers gray, shaly	1.3
17. Shale, olive-drab, clayey; weathers light gray	2.5
16. Limestone, gray, platy; weathers gray; fault and slickensides in ditch on north side of road	1.0

15. *Section in a road cut on the south side of the SW¼ sec. 2, T. 8 S., R. 10 E*—Continued

	Feet
Janesville shale (part)—Continued	
West Branch shale member—Continued	
15. Shale, tan, silty; weathers tan gray (mostly covered)	1.4
14. Limestone, tan, massive to thin-bedded, sandy; weathers tan gray, platy; fossiliferous	.7
13. Shale, olive-drab, silty; weathers light gray	1.2
Total thickness of West Branch shale member	32.2
Thickness of Janesville shale exposed	33.0
Falls City limestone:	
12. Limestone, tan, blocky, fine-grained; soft where fresh; hard where weathered; contains brown dendrites	1.0
Onaga shale:	
Hawxby shale member:	
11. Limestone, dark-gray, blocky, fine-grained; weathers gray	1.4
10. Shale, olive-drab, clayey; weathers light green (mostly covered)	7.7
9. Limestone, gray, nodular, weathers gray	1.6
8. Shale, olive-drab, platy, silty; extremely calcareous in lower part	2.8
7. Limestone, gray, massive; contains limonite spots; weathers gray, nodular	.7
6. Shale, olive-drab, clayey; weathers light green	10.5
Total thickness of Hawxby shale member	24.7
Aspinwall limestone member:	
5. Limestone, tan, massive; laminated, with flattened clay balls; weathers tan	.6
Towle shale member:	
4. Shale, maroon, lumpy, clayey	2.0
3. Limestone, gray, nodular; stained reddish gray from maroon shale above	2.5
2. Shale, variegated maroon, olive-drab, silty (partly covered)	17.5
Total thickness of Towle shale member	22.0
Total thickness of Onaga shale	47.3
Wood Siding formation (part):	
Brownville limestone member (part):	
1. Limestone, brown, massive, dense; weathers brown; fossiliferous	2.0

16. *Section in a stream cut in NW¼SW¼ sec. 15, T. 9 S., R. 11 E.*

	Feet
Foraker limestone (part):	
Americus limestone member:	
12. Limestone, gray, massive, dense; crystalline calcite commonly replaces crinoid columnals; weathers gray	1.0
11. Shale, gray, silty	.3
10. Limestone, gray, massive, dense; weathers gray; fossiliferous	1.3
Total exposed thickness of Foraker limestone	2.6
Janesville shale (part):	
Hamlin shale member (part):	
Stine shale bed (part) (Oaks shale bed and Houchen Creek limestone bed missing):	
9. Shale, tan-gray, silty, calcareous; weathers tan gray in cellular nodules	5.8
8. Limestone, tan-gray, cellular; weathers tan gray and nodular	3.0
7. Shale, variegated light-green and maroon, silty	14.6
6. Limestone, tan-gray, concretionary, mammillary	1.0
5. Shale, gray, silty	1.6
4. Sandstone, light-green, stratified, micaceous, friable; very little crossbedding	8.4
3. Shale, gray, sandy; micaceous; silty at bottom	9.8
2. Limestone, dark-gray, massive; limonitic at top	.8
1. Shale, gray, silty	3.0
Total thickness of Janesville shale exposed	48.0

17. *Section in a road cut in the SE¼SE¼ sec. 2, T. 10 S., R. 12 E.*

	Feet
Janesville shale (part):	
Fivepoint limestone member:	
8. Limestone, tan, massive, coarse-grained; weathers tan gray; contains molluscs	1.7
West Branch shale member (part):	
7. Shale (covered)	5.2
Thickness of Janesville shale exposed	6.9
Falls City limestone:	
6. Limestone, resinous-brown, massive, fine-grained, dense; weathers tan	.8
Onaga shale (part):	
Hawxby shale member:	
5. Shale (covered)	14.0
4. Limestone, gray, massive, hard, dense; becomes grayish blue mottled with gray toward bottom; limonite spots; contains some gray clay balls; weathers gray and blocky	4.5
3. Shale, variegated olive-drab and maroon, clayey, slightly calcareous	5.2
Total thickness of Hawxby shale member	23.7
Aspinwall limestone member:	
2. Limestone, tan-gray, tan banded, massive, laminated, fine-grained	1.0

17. *Section in a road cut in the SE¼SE¼ sec. 2, T. 10 S., R. 12 E*—Continued

	Feet
Onaga shale (part)—Continued	
Towle shale member (part):	
1. Shale, variegated olive-drab, maroon, clayey	6.0
Thickness of Onaga shale exposed	30.7

18. *Section in a road and stream cut in the NE¼NE¼ sec. 28, T. 7 S., R. 10 E.*

	Feet
Foraker limestone (part):	
Americus limestone member (part):	
4. Limestone, gray, massive, dense; crystalline calcite commonly replaces crinoid columnals	2.0
Janesville shale (part):	
Hamlin shale member (part):	
Stine shale bed (part) (Oaks shale bed and Houchen Creek limestone bed missing):	
3. Shale, light-green to gray, silty, calcareous; contains gray nodules	22.0
2. Sandstone, light-green, fine-grained, micaceous; weathers tan	6.0
1. Shale, light-green to gray, sandy, micaceous	1.0
Thickness of Janesville shale exposed	29.0

19. *Section in a road cut in the NE¼NE¼ sec. 7, T. 9 S., R. 9 E.*

	Feet
Foraker limestone (part):	
Americus limestone member:	
8. Limestone, light-gray, massive, dense, hard; crystalline calcite commonly replaces crinoid columnals which weather out on face of blocks; weathers tan gray	0.9
7. Shale, gray, silty	.3
6. Limestone, tan-gray, massive, dense, hard; crystalline calcite commonly replaces crinoid columnals; weathers tan gray	1.0
Thickness of Americus limestone member of Foraker limestone	2.2
Janesville shale (part):	
Hamlin shale member (part):	
Stine shale bed (part) (Oaks shale bed and Houchen Creek limestone bed missing):	
5. Shale, variegated tan-gray, light-gray, light-green, olive-drab and maroon, clayey; calcareous in upper part	20.6
4. Limestone, tan-gray, blocky, fine-grained; weathers tan gray	.3
3. Shale, variegated, clayey	3.0
2. Limestone, resinous-brown, platy, fine-grained; contains dark-brown dendrites of manganese oxide	.5
1. Shale, variegated maroon, tan-gray and olive-drab, clayey	2.5
Total thickness of Janesville shale exposed	26.9

20. *Section in a stream cut in the NW¼NE¼ sec. 26, T. 7 S., R. 9 E.*

	Feet
Roca shale (part):	
9. Limestone, light-gray, massive, dense, flinty appearing; weathers dark gray with light-green streaks from overlying green shale	1.0
8. Claystone, variegated maroon and light gray, blocky	7.7
Thickness of Roca shale exposed	8.7
Red Eagle limestone:	
Howe limestone member:	
7. Limestone, tan-gray, massive, cellular; weathers dark gray, contains ostracodes	4.0
Bennett shale member:	
6. Shale, black, clayey; calcareous layer 3 feet from top; weathers dark gray	8.7
Glenrock limestone member:	
5. Limestone, gray, massive; weathers gray and shaly; fossiliferous	.5
Total thickness of Red Eagle limestone	13.2
Johnson shale (part):	
4. Claystone, olive-drab, blocky	2.3
3. Limestone, gray, massive; weathers gray	.6
2. Shale, variegated light-gray, olive-drab and maroon, fissile to blocky, silty; calcareous at bottom	8.5
1. Limestone, gray, platy, dense; weathers light gray	3.0
Thickness of Johnson shale exposed	14.4

21. *Section in a road cut on the west side of the SW¼SW¼ sec. 16 and on the west side of the W½ sec. 21, T. 9 S., R. 11 E.*[1]

	Feet
Grenola limestone:	
Neva limestone member:	
42. Limestone, light-gray massive; contains tan-gray porous spots; weathers light gray and shaly	9.0
Salem Point shale member:	
41. Shale, tan, silty; weathers tan gray	6.8
Burr limestone member:	
40. Limestone, gray, massive, dense; weathers gray and blocky	2.5
Total thickness of Grenola limestone	18.3
Roca shale:	
39. Claystone, variegated olive-drab, light-gray and maroon, blocky. Interval partly covered	11.4
38. Limestone, light-gray, silty, shaly; weathers light gray	3.5
37. Claystone, olive-drab, blocky, calcareous; weathers light green	6.7
Total thickness of Roca shale	21.6

[1] Legion shale member and Sallyards limestone member of Grenola limestone not recognized in this section.

21. *Section in a road cut on the west side of the SW¼SW¼ sec. 16 and on the west side of the W½ sec. 21, T. 9 S., R. 11 E.*[1]—Continued

	Feet
Red Eagle limestone:	
Howe limestone member:	
36. Limestone, tan, massive; calcite crystal pockets; weathers tan and cavernous	1.2
35. Siltstone, gray to light-gray, blocky, calcareous; weathers gray	3.2
34. Limestone, light-gray, shaly; weathers light gray	.5
Total thickness of Howe limestone member	4.9
Bennett shale member:	
33. Siltstone, tan, blocky; weathers tan	2.4
Glenrock limestone member:	
32. Limestone, tan-gray, massive, dense, petroliferous; weathers tan gray; fossiliferous	1.6
Total thickness of Red Eagle limestone	8.9
Johnson shale:	
31. Shale, olive-drab to dark-gray, clayey; calcareous toward bottom; weathers gray	8.9
30. Limestone, gray, platy, dense; weathers light gray	2.0
29. Siltstone, olive-drab, blocky; weathers tan gray	3.0
28. Limestone, gray, nodular, silty, limonitic; weathers gray	.3
27. Siltstone, olive-drab, blocky; weathers gray. Partly covered	2.4
Total thickness of Johnson shale	16.6
Foraker limestone (part):	
Long Creek limestone member (part):	
26. Limestone, tan; crystalline with calcitcrystale pockets; weathers tan, nodular	6.0
Hughes Creek shale member:	
25. Shale, tan to tan-gray, blocky to thin-bedded, silty, calcareous; weathers tan gray	4.8
24. Limestone, gray mottled with tan gray, massive; weathers gray mottled with tan; fossiliferous	.9
23. Shale, olive-drab, silty; weathers tan gray	5.7
22. Limestone, tan, platy to nodular, silty; weathers tan gray	.2
21. Shale, olive-drab, clayey; weathers tan gray	2.9
20. Limestone, gray, mottled with tan gray, shaly; weathers gray mottled with tan gray; fossiliferous	1.0
19. Shale, gray to black, silty; weathers gray	2.0
18. Limestone, dark-gray, massive, dense; weathers dark gray; fossiliferous	.2
17. Limestone, gray, shaly, weathers gray; fossiliferous	.8
16. Limestone, gray, massive, dense; weathers gray and blocky; fossiliferous	.7
15. Claystone, gray, blocky; weathers gray; fossiliferous	3.0

21. *Section in a road cut on the west side of the SW¼SW¼ sec. 16 and on the west side of the W½ sec. 21, T. 9 S., R. 11 E.*[1]—Continued

	Feet
Foraker limestone (part)—Continued	
Hughes Creek shale member—Continued	
14. Limestone, gray mottled with tan gray, massive; weathers dark gray, shaly; fossiliferous fusulinid limestone	1.0
13. Shale, gray; clayey; weathers tan gray	11.4
Total Hughes Creek shale member	34.6
Americus limestone member:	
12. Limestone, light-gray, massive, dense; some calcite cleavages; weathers gray	1.0
11. Shale, tan-gray, silty; weathers tan gray	.6
10. Limestone, light-gray, massive, dense; weathers tan gray	1.6
Total Americus limestone member	3.2
Thickness of Foraker limestone exposed	43.8
Janesville shale (part)	
Hamlin shale member (part):	
Oaks shale bed:	
9. Sandstone (calcarenite—composed of fragments of limestone), gray, conglomeratic; some granules, lenticular	.4
8. Shale, gray, blocky, clayey, calcareous	.5
7. Limestone, gray, shaly, soft; weathers shaly and nodular	.6
6. Shale gray, to gray-green, thin-bedded, silty to clayey, calcareous; cavernous in lower part; calcareous nodules and plates abundant	14.1
5. Shale, tan-gray, fine-grained, sandy, micaceous, noncalcareous; some sandstone lentils	4.3
4. Siltstone, tan, stained with maroon, shaly, cavernous	.9
3. Shale, maroon, mottled with gray green, thin-bedded, clayey, calcareous	3.2
Total Oaks shale bed	24.0
Houchen Creek limestone bed:	
2. Limestone, tan, hard, brittle; mammillary on upper surface; massive algal bed	.5
Stine shale bed (part):	
1. Sandstone and sandy shale, tan-brown, thin to thick-bedded, micaceous, noncalcareous; gray in upper part	5.6
Thickness of Janesville shale exposed	30.1

[1] Legion shale member and Sallyards limestone member of Grenola limestone not recognized in this section.

22. *Section in a stream cut in the NE¼NW¼ sec. 3, T. 8 S., R. 9 E. measured by M. R. Mudge and R. E. Skoog.*

	Feet
Eskridge shale (part):	
65. Siltstone, grayish-green, blocky, calcareous; mottled with purple in the lower part, maroon in upper part	6. 6
Grenola limestone:	
Neva limestone member:	
64. Limestone, light-gray, massive, moderately hard; weathers blocky; fossiliferous	4. 95
63. Shale, grayish-green, silty, calcareous; weathers light gray	. 25
62. Limestone, gray, massive, hard, dense; weathers tan gray and blocky	. 8
61. Shale, tan-gray, silty, calcareous	. 05
60. Limestone, gray, massive, moderately hard; weathers tan gray, shaly	. 5
59. Shale, grayish-green, silty, very calcareous	. 3
58. Limestone, tan-gray, massive, soft; some grayish-green stains; weathers "rotten" and has a conglomeratic appearance	7. 1
57. Siltstone, tan-gray mottled with gray, blocky, calcareous; fossiliferous	. 9
56. Shale, very dark gray, clayey, calcareous; iron stains on fracture planes	1. 6
55. Limestone, tan-gray, massive, moderately hard; weathers blocky	1. 7
Total Neva limestone member	18. 15
Salem Point shale member:	
54. Shale, tan-gray mottled with some gray, silty, calcareous; some limonite stains	1. 9
53. Limestone, light-gray, massive, moderately hard; weathers tan gray and blocky to shaly; numerous limonite-stained areas; fossiliferous	1. 9
52. Shale, light gray-green, thin-bedded to blocky, silty, calcareous; some limonite stains	2. 9
Total thickness of Salem Point shale member	6. 7
Burr limestone member:	
51. Limestone, tan, massive, soft, blocky and porous; weathers tan gray; fossiliferous	3. 8
50. Shale, very dark gray, clayey, noncalcareous; mottled in some places with tan gray; some limonite-stained zones	1. 4
49. Limestone, tan-gray mottled with gray, massive, hard; weathers blocky; some fossil fragments	2. 3
Total thickness of Burr limestone member	7. 5

22. *Section in a stream cut in the NE¼NW¼ sec. 3, T. 8 S., R. 9 E. measured by M. R. Mudge and R. E. Skoog*—Continued

	Feet
Grenola limestone—Continued	
Legion shale member:	
48. Shale, tan-gray, blocky, silty, calcareous; some iron stains	0.7
47. Shale, light-gray to gray, blocky, silty, calcareous	4.1
Total thickness of Legion shale member	4.8
Sallyards limestone member:	
46. Limestone, tan-gray, massive, hard, dense; weathers blocky, fossiliferous in upper part	.9
Total thickness of Grenola limestone	38.05
Roca shale:	
45. Shale, dark grayish-green, silty, calcareous; small round-to-angular lime grains very abundant; weathers light grayish green and blocky	.7
44. Limestone, tan-gray, massive, hard, dense; has grayish-green tint; weathers light gray and blocky to nodular; some iron stains	1.4
43. Siltstone, grayish-green, blocky, calcareous; mottled in some places with grayish brown; numerous limonite stains	4.3
42. Siltstone, very light gray, blocky, calcareous; some limonite stains	.9
41. Claystone, dark grayish-green, calcareous; weathers gray to grayish green, blocky	2.4
40. Limestone, tan-gray, massive, hard, dense in part; has grayish-green tint; weathers light gray and blocky; some limonite stains	1.8
39. Siltstone, grayish-green, blocky, calcareous	.2
38. Limestone, light-gray, massive, hard, dense; weathers blocky to shaly	1.2
37. Siltstone, green, blocky, calcareous; mottled with maroon in the middle part	4.4
Total Roca shale	17.3
Red Eagle limestone:	
Howe limestone member:	
36. Limestone, tan-gray, massive, moderately hard; porous with some of the pore spaces filled with calcite; some limonite stains; weathers tan; blocky; fossiliferous in middle part	1.4
35. Shale, tan-gray, silty, calcareous; weathers gray; some limonite stains	.4
34. Limestone, tan-gray, massive, soft, dolomitic; numerous limonite stains; weathers tan, blocky and in thin chips	2.5
Total thickness of Howe limestone member	4.3

22. *Section in a stream cut in the NE¼NW¼ sec. 3, T. 8 S., R. 9 E. measured by M. R. Mudge and R. E. Skoog*—Continued

	Feet
Red Eagle limestone—Continued	
Bennett shale member:	
33. Shale, dark-gray, silty, calcareous; weathers gray; some iron stains; fossiliferous; some microfossils in the lower part	3.2
Glenrock limestone member:	
32. Limestone, gray, massive, hard, crystalline in part; weathers brown and blocky; fossiliferous at top	.5
Total thickness of Red Eagle limestone	8.0
Johnson shale:	
31. Shale, dark grayish-brown, silty, calcareous; weathers gray; dark gray specks numerous in lower part; limonite stains in upper part: microfossils abundant in upper part	.6
30. Claystone, gray, very calcareous: mottled with light gray; dark-gray clay balls abundant (flat, angular; some have maximum diameter of three-fourths of an inch); some iron stains on fracture planes; weathers light gray and blocky	1.5
29. Claystone, dark-gray, blocky, calcareous; some iron stains on fracture planes	4.7
28. Limestone, gray, massive, hard, dense; weathers tan gray, blocky to platy	1.0
27. Siltstone, tan-gray, blocky, calcareous; some lime nodules	.2
26. Limestone, dark grayish-brown, moderately hard; weathers tan gray and blocky; some iron stains	.1
25. Claystone, dark-gray, noncalcareous; mottled with grayish green; fractures 60° from the horizontal; iron stains on fracture planes; weathers light grayish green, blocky	.4
24. Limestone, light-gray to tan-gray, massive, soft, dolomitic in part; weathers light gray, blocky to shaly	1.3
23. Limestone, grayish-brown, massive, hard; weathers light gray and blocky to shaly; some iron stains	.4
22. Siltstone, grayish-green, calcareous; limestone lenses in middle; limonite and iron stains on fracture planes; weathers light grayish green; blocky	4.6
21. Claystone, gray, blocky to thin-bedded, very calcareous; fractures at 45° from the horizontal; weathers light gray; basal part weathers nodular	5.7
20. Claystone, grayish-green, noncalcareous; weathers light grayish green and blocky; limonite stains on fracture planes	1.0
19. Siltstone, maroon, blocky; calcareous, mottled with grayish green	.9
18. Siltstone, grayish-green, blocky, calcareous; fine-grained lime lenses near the top	3.8
Total thickness of Johnson shale	26.2

22. *Section in a stream cut in the NE¼NW¼ sec. 3, T. 8 S., R. 9 E. measured by M. R. Mudge and R. E. Skoog*—Continued

	Feet
Foraker limestone (part):[2]	
Long Creek limestone member:	
17. Limestone, tan, massive, soft, porous, dolomitic; calcite-lined cavities abundant; weathers to irregular blocks and plates	4. 1
16. Shale, tan-gray, silty, calcareous	. 3
15. Limestone, tan, massive, moderately hard; weathers blocky; fossiliferous	. 5
14. Shale, dark-gray, silty, calcareous; weathers light gray	. 3
13. Limestone, grayish-brown, massive, medium-hard; weathers tan gray and blocky to shaly; iron stains abundant near the base	2. 1
Total thickness of Long Creek limestone member	7. 3
Hughes Creek shale member (part):	
12. Shale, dark-gray, thin-bedded to blocky, clayey, noncalcareous; weathers gray; extremely fossiliferous	3. 8
11. Siltstone, dark-gray, blocky, calcareous, very calcareous in the top part; weathers gray; fossiliferous	1. 8
10. Limestone, dark-gray, massive, soft; weathers gray, shaly and in irregular fragments; fossiliferous	. 9
9. Shale, dark-gray, thin-bedded to blocky, silty, calcareous; weathers gray, some iron-stained areas; fossiliferous	2. 1
8. Limestone, tan-brown, massive, moderately hard; weathers blocky; some limonite stains on surface; fossiliferous	1. 2
7. Shale, dark-gray, silty, calcareous; more calcareous in the lower part; weathers gray; extremely fossiliferous	5. 8
6. Limestone, dark-gray, massive, moderately hard; weathers tan-gray and blocky to shaly	1. 1
5. Shale, dark-gray, clayey, slightly calcareous; weathers gray, fossiliferous	. 6
4. Limestone, tan-gray, massive, moderately hard; weathers blocky; some carbon specks	. 9
3. Siltstone, dark-gray, blocky, slightly calcareous; weathers gray	2. 8
2. Limestone, tan to tan-brown, massive, soft; numerous clay balls; weathers tan, blocky and to irregular nodules; limonite stains abundant; fossiliferous	1. 5
1. Shale, dark-gray, clayey, noncalcareous; some light-gray lenses; blocky in the upper part and thin bedded toward the base; weathers gray; some iron stains on fracture planes, numerous large fractures at an angle of 30° from the horizontal	8. 1
Thickness of Hughes Creek shale member exposed	30. 6
Thickness of Foraker limestone exposed	37. 9

[2] As part of a local structure, the Americus limestone member is exposed 75 yards to the east.

23. *Section in a stream cut in the SW¼SE¼ sec. 24, T. 7 S., R. 9 E.*

	Feet
Eskridge shale (part):	
7. Shale, variegated, blocky to fissile, silty	10. 0
Grenola limestone (part):	
Neva limestone member:	
6. Limestone, light-gray, massive, soft; weathers gray, shaly with tan-gray porous spots; fossiliferous	8. 7
Salem Point shale member (part):	
5. Shale, silty; olive drab at top, black in middle, dark gray at bottom	. 9
4. Limestone, dark-gray, laminated; black and tan-gray layer 0.6 foot from top contains pyrite nodules; weathers gray, shaly near bottom	2. 0
3. Siltstone, olive-drab, blocky	2. 0
2. Limestone, dark-gray, platy; weathers gray; fossiliferous	1. 0
1. Shale, gray, silty	1. 0+
Thickness of Salem Point shale member exposed	6. 9
Thickness of Grenola limestone exposed	15. 6

24. *Section in a road cut on Kansas State Highway 63, SW¼NE¼ sec. 34, T. 9 S., R. 12 E.*

	Feet
Grenola limestone (part):	
Salem Point shale member (part):	
10. Shale, olive-drab, silty; weathers light gray	4. 0
Burr limestone member:	
9. Ostracode fragments, tan-gray; has sandy appearance; weathers tan gray	. 3
8. Limestone, light-gray, massive, fine-grained; small tan-gray pockets; weathers tan gray	4. 0
7. Shale, black to olive-drab, fissile to blocky, clayey; weathers gray	2. 0
6. Limestone, dark-gray, massive to shaly; weathers gray to tan gray; fossiliferous	2. 4
Total Burr limestone member	8. 7
Legion shale member:	
5. Siltstone, olive-drab, blocky; slightly calcareous in middle and lower parts; weathers tan gray	4. 9
Sallyards limestone member:	
4. Limestone, light gray, massive, dense; weathers gray	. 8
Thickness of Grenola limestone exposed	18. 4
Roca shale (part):	
3. Shale, olive-drab, silty; weathers light gray	2. 4
2. Limestone, light-gray, massive, dense; weathers tan gray to dark gray	. 7
1. Siltstone, variegated olive-drab, maroon, blocky, hard	11. 0
Thickness of Roca shale exposed	14. 1

25. *Section in a road cut in the NE¼NE¼ sec. 34, T. 8 S., R. 7 E.*

	Feet
Beattie limestone (part):	
Cottonwood limestone member:	
14. Limestone, gray, massive, cherty; weathers gray; fossiliferous	5.8
Eskridge shale:	
13. Shale, gray, silty, calcareous; weathers gray	5.9
12. Limestone, light-gray, blocky, dense flinty appearing; weathers light gray	.7
11. Shale, lavender and light-gray, silty, calcareous	3.0
10. Shale, gray, silty; weathers gray	.3
9. Limestone, gray, fine-grained, hard; weathers gray	.2
8. Shale, gray, silty; weathers gray	.4
7. Limestone, gray, fine-grained, hard; weathers gray	.4
6. Shale, gray, silty, calcareous; weathers gray	3.6
5. Siltstone, light-gray, nodular; weathers light gray	.5
4. Shale, variegated light-gray, dark-gray and maroon, silty	16.0
Total Eskridge shale	31.0
Grenola limestone (part):	
Neva limestone member (part):	
3. Limestone, gray, fine-grained; weathers gray	.6
2. Limestone, gray, shaly, fine-grained; weathers gray	.8
1. Limestone, gray, massive, medium-hard; fine-grained with tan-gray porous pockets; weathers dark gray	5.0
Thickness of Neva limestone member of the Grenola limestone exposed	6.4

26. *Section in a stream cut in the SW¼NW¼ sec. 10, T. 6 S., R. 8 E.*

	Feet
Beattie limestone:	
Morrill limestone member:	
8. Limestone, tan-gray, massive, sandy; calcite crystal cavities; weathers dark gray	4.0
7. Limestone, gray, massive, soft, fine-grained; calcite crystal cavities; weathers light gray	1.6
6. Limestone, gray, platy, fine-grained; weathers gray	1.7
5. Limestone, dark-gray, shaly; weathers dark gray; fossiliferous	.7
4. Limestone, dark-gray, massive; crystalline calcite commonly replaces crinoid columnals; weathers dark gray; fossiliferous	1.3
3. Limestone, dark-gray, shaly; weathers dark gray	1.2
Total Morrill limestone member	10.5
Florena shale member:	
2. Shale, dark-gray, silty; weathers dark gray; extremely fossiliferous	3.8
Cottonwood limestone member:	
1. Limestone, light-gray, massive; chert nodules scarce; weathers gray and shaly; fossiliferous	7.0
Total Beattie limestone	21.3

27. *Section in a road cut in the NW¼SW¼ sec. 30, T. 8 S., R. 8 E.*

	Feet
Stearns shale:	
14. Siltstone, gray, platy, calcareous (almost a limestone); weathers tan gray mottled with gray	1.7
13. Siltstone, gray; weathers into small gray flakes	.6
12. Claystone, black, platy; weathers dark gray	.6
11. Shale, gray, calcareous; weathers gray	.6
10. Siltstone, gray, blocky; weathers gray	1.1
9. Limestone, gray, silty; weathers white, nodular	.7
8. Siltstone, grayish-brown, blocky; weathers gray	4.0
Total Stearns shale	9.3
Beattie limestone (part):	
Morrill limestone member:	
7. Limestone, gray, dense, petroliferous, hard; weathers tan gray; fossiliferous	1.4
6. Shale, light-gray, clayey; weathers light gray	.7
5. Limestone, light-gray, fine-grained, hard; weathers light gray	.6
4. Limestone, gray, shaly; weathers gray	1.0
3. Limestone, gray, silty, dense; weathers gray	.6
Total Morrill limestone member	4.3
Florena shale member:	
2. Shale, gray, calcareous; chalcedony nodules in upper 0.3 foot; weathers gray; fossiliferous	1.7
1. Limestone, gray, blocky; weathers gray; fossiliferous	1.3
Thickness of Florena shale member exposed	3.0
Thickness of Beattie limestone exposed	7.3

28. *Section in a road cut in the SE¼NE¼ sec. 25, T. 7 S., R. 8 E.*

	Feet
Bader limestone:	
Middleburg limestone member:	
18. Limestone, gray, massive; weathers gray and blocky; fossiliferous	2.0
Hooser shale member:	
17. Shale, light-gray, calcareous; weathers light gray	.8
16. Shale, olive-drab, blocky, clayey	.4
15. Shale, silty; gray in upper part, tan in lower part	2.0
14. Shale, maroon, clayey; secondary calcium carbonate nodules in lower part	1.5
Total Hooser shale member	4.7

28. *Section in a road cut in the SE¼ NE¼ sec. 25, T. 7 S., R. 8 E*—Continued

	Feet
Bader limestone—Continued	
Eiss limestone member:	
13. Limestone, gray, massive; coarse and pitted in upper part; dense in lower part; weathers gray	1.8
12. Shale, light-gray, clayey, calcareous; weathers light gray	1.6
11. Limestone, light-gray, limonitic; conglomeratic in lower 0.1 foot; weathers light gray; extremely fossiliferous	1.0
Total Eiss limestone member	4.4
Total thickness of Bader limestone	11.1
Stearns shale:	
10. Siltstone, light-gray, nodular, calcareous; weathers light gray	3.3
9. Limestone, gray, shaly, platy; dense in upper part and fissile in lower part	2.6
8. Claystone, black, blocky; weathers to dark-gray flakes	.6
7. Claystone, olive-drab, blocky	1.0
6. Shale, light-brown, clayey; weathers tan	.6
5. Limestone, weathers gray, dense; mottled grayish brown	.3
4. Claystone, dark-green, blocky; weathers dark gray	1.3
3. Claystone, light-green, blocky; weathers light gray	.5
2. Claystone, maroon, blocky; weathers maroon	1.6
Total Stearns shale	11.8
Beattie limestone (part):	
Morrill limestone member:	
1. Limestone, gray, blocky; conglomeratic in upper part; weathers gray	1.4

29. *Section in a road cut in the SW¼NW¼ sec. 15, T. 7 S., R. 9 E.*

	Feet
Funston limestone:	
11. Limestone, tan-gray, massive, cherty; weathers dark gray	2.7
Blue Rapids shale:	
10. Shale, variegated olive-drab, maroon and light-gray, blocky, clayey, calcareous; contains amethyst crystals	14.7
Crouse limestone:	
9. Limestone, light-gray, platy, dense, flinty appearing; weathers light gray	3.5
8. Shale, tan-gray, clayey	1.0
7. Limestone, gray, massive, dense; weathers tan gray; abundant small tan gastropods	.7
6. Shale, tan-gray, clayey; weathers light gray; limestone 0.1 foot thick near top	5.7
5. Limestone, upper part is light gray; weathers gray shaly; lower part is gray with tan-gray porous spots; massive; weathers dark gray and cavernous; fossiliferous	5.3
Total Crouse limestone	16.2

29. *Section in a road cut in the SW¼ NW¼ sec. 15, T. 7 S., R. 9 E*—Continued

	Feet
Easly Creek shale:	
4. Shale, light-gray, blocky, clayey; weathers light gray	5. 4
3. Shale, maroon, shaly, calcareous; weathers maroon	. 5
2. Siltstone, variegated maroon, light-gray and olive-drab, blocky	9. 2
Total Easly Creek shale	15. 1
Bader limestone (part):	
Middleburg limestone member:	
1. Limestone; upper part gray with limonite spots, weathers gray; lower part tan gray, massive, dense, weathers tan gray	1. 5

30. *Section in a road cut in the NW¼NW¼ sec. 10, T. 7 S., R. 9 E.*

	Feet
Funston limestone (part):	
7. Limestone, tan, massive, cavernous; mottled salt-and-pepper appearance on fresh surface; soft at top, hard at bottom; weathers grayish brown	1. 9
Blue Rapids shale:	
6. Shale, olive-drab, clayey, contains amethyst crystals; weathers light green	1. 7
5. Limestone, tan-gray, nodular, shaly; weathers tan gray	. 8
4. Shale, grayish-brown, silty, calcareous; contains amethyst crystals; weathers gray	2. 3
3. Siltstone, olive-drab, platy; weathers light green	1. 1
2. Siltstone, variegated olive-drab, maroon, and dark-gray, blocky; lumpy calcareous zones and calcareous nodules throughout	12. 5
Total Blue Rapids shale	18. 4
Crouse limestone (part):	
1. Limestone, light-gray, platy; weathers light gray with light-green stains in upper part	5. 7

31. *Section in a road cut in the SE¼SE¼ sec. 9, T. 7 S., R. 9 E.*

	Feet
Funston limestone:	
5. Limestone, tan-gray, massive, cavernous; weathers dark gray	1. 2
4. Chert, case hardened calcareous layer on outer one-half inch of nodules and blue hard chert on inside. (Chert is rarely present in Funston limestone)	. 2
3. Limestone, tan-gray, massive, pitted; weathers tan gray with pits becoming rusty; when chert nodules are absent, this layer is part of upper 1.2 foot massive limestone, making total of 2 feet	. 6
2. Limestone, tan-gray, massive, dense; weathers tan gray with gray flecks of calcite throughout. Chalcedony nodules found in some places at top of this layer	. 7
Total Funston limestone	2. 7
Blue Rapids shale (part):	
1. Shale, olive-drab, clayey; with chalcedony nodules, quartz crystals, and calcite geodes; weathers tan gray	2. 0

32. *Section in a road and stream cut in the NW¼SE¼ sec. 4, T. 7 S., R. 7 E.*

	Feet
Wreford limestone (part):	
Schroyer limestone member (part):	
18. Limestone, gray to tan-gray, massive, crossbedded, sandy; weathers gray and pitted	2.0
17. Limestone, tan-gray, platy; weathers to thin plates	5.2
Thickness of Schroyer limestone member exposed	7.2
Havensville shale member:	
16. Shale, tan-gray, silty; weathers tan gray	5.0
15. Limestone, gray, massive, laminated; weathers tan gray; contains pelecypods	2.7
14. Shale, gray, silty; weathers gray	4.6
13. Shale, black, clayey; weathers dark gray	1.8
Total Havensville shale member	14.1
Threemile limestone member (part):	
12. Limestone, gray; platy; cherty; weathers tan gray	2.6
11. Limestone, gray; massive; dense; pock marked; weathers gray	1.6
10. Chert, bluish-gray; vertical fractures	.4
9. Limestone, gray, dense; weathers gray	.2
8. Shale, gray, silty	.2
7. Limestone, light-gray, massive, fine-grained; weathers gray	.8
6. Shale, gray, silty	.2
5. Chert, bluish-gray; vertical fractures present	.5
4. Limestone, light-gray, massive; weathers gray	.5
Total Threemile limestone member	7.0
Thickness of Wreford limestone exposed	28.3
Speiser shale:	
3. Shale, black, silty; weathers dark gray	1.8
2. Limestone, gray to gray mottled with tan, very extensive; weathers gray	.45
1. Shale, variegated, silty	17.4
Total Speiser shale	19.65

33. *Section in a road cut in the NW¼SE¼ sec. 5, T. 8 S., R. 7 E.*

	Feet
Barneston limestone (part):	
Florence limestone member:	
17. Limestone, gray, massive, cherty; contains bluish-gray chert	13.0
Matfield shale:	
Blue Springs shale member:	
16. Siltstone, variegated, blocky; mostly covered	35.0
Kinney limestone member:	
15. Limestone, light-gray, massive, soft fine-grained; yellow around cavities; weathers gray	2.0
Wymore shale member:	
14. Shale, silty; tan gray in upper part, maroon in lower part	17.5
Total thickness of Matfield shale	54.5

33. *Section in a road cut in the NW¼SE¼ sec. 5, T. 8 S., R. 7 E.*—Continued

	Feet
Wreford limestone:	
Schroyer limestone member:	
13. Limestone, light-gray, massive, coarsely crystalline; weathers gray	2.4
12. Shale, light-gray, silty, calcareous	1.2
11. Limestone, gray, massive, fossiliferous	1.0
10. Limestone, gray, massive, cherty; weathers gray; fossiliferous	2.0
9. Limestone, gray, massive; only slightly cherty; weathers gray	1.6
8. Shale, tan-gray, clayey	.8
7. Limestone, tan-gray, platy, petroliferous; contains lenses of shale; weathers tan gray	4.5
6. Limestone, gray, massive, finely crystalline; yellow porous pockets; weathers gray; fossiliferous	2.0
5. Limestone, gray, massive, crossbedded; flattened mud balls; crystalline; varies in thickness laterally; weathers gray	.8
4. Limestone, tan-gray, platy, crystalline; weathers tan gray	2.7
Total Schroyer limestone member	19.0
Havensville shale member:	
3. Siltstone, tan-gray, blocky; weathers tan gray	17.0
Threemile limestone member:	
2. Limestone, gray, massive, cherty; weathers gray	7.2
Total Wreford limestone	43.2
Speiser shale (part):	
1. Claystone, variegated, blocky; persistent thin limestone bed near top	11.6

34. *Section in a stream cut in the NE¼NW¼ sec. 23, T. 7 S., R. 8 E.*

	Feet
Wreford limestone (part):	
Schroyer limestone member:	
7. Limestone, tan-gray, massive, cherty; weathers gray; fossiliferous	4.0
6. Limestone, tan-gray, blocky; small cavities lined with calcite crystals; weathers tan gray	1.8
5. Shale, tan gray, calcareous	.7
4. Limestone, light-gray, massive; weathers gray	.8
3. Shale, tan-gray, silty, calcareous	.4
2. Limestone, tan-gray, platy, soft, medium coarse-grained	5.4
Total Schroyer limestone member	13.1
Havensville shale member (part):	
1. Shale, gray, thin-bedded, sandy	6.2
Thickness of Wreford limestone exposed	19.3

35. *Section in a road cut in the NW¼NW¼ sec. 20, T. 6 S., R. 8 E.*

	Feet
Wreford limestone (part):	
Threemile limestone member (part):	
3. Limestone, gray, massive, cherty; weathers gray	5.0
Speiser shale:	
2. Shale, variegated, clayey; calcareous zone at base	13.8
Funston limestone:	
1. Limestone, tan-gray, massive, cavernous; weathers tan gray	1.5

36. *Section in a road cut on Kansas State Highway 99, in the SW¼SW¼ sec. 3, T. 7 S., R. 9 E.*

	Feet
Wreford limestone (part):	
Schroyer limestone member (part):	
6. Chert fragments, residual, brown stains present	4.0
Havensville shale member:	
5. Shale, tan-gray, calcareous; limestone lenses and cellular beds throughout; chalcedony nodules and quartz crystals scattered through shale; weathers light gray; fossiliferous	20.1
Threemile limestone member:	
4. Limestone, gray, massive, cherty; weathers gray; fossiliferous	7.0
Thickness of Wreford limestone exposed	31.1
Speiser shale (part):	
3. Shale, gray, clayey; weathers gray; fossiliferous	2.3
2. Limestone, gray, massive; weathers gray; extensive	.4
1. Shale, variegated, clayey	4.0
Thickness of Speiser shale exposed	6.7

37. *Section in a road cut in the NW¼NW¼ sec. 36, T. 7 S., R. 7 E.*

	Feet
Barneston limestone:	
Fort Riley limestone member:	
15. Limestone, tan-gray, massive, porous; limonite stained where cavities occur; coarse crystalline; weathers tan gray; cavities lined with calcite crystals in lower foot; fossiliferous	2.6
14. Shale, tan-gray, silty, calcareous; weathers tan gray in small chips	.9
13. Limestone, tan-gray, massive, fine-grained; weathers tan gray	1.6
12. Limestone, tan-gray, shaly; weathers tan gray; fossiliferous	5.9
Total Fort Riley limestone member	11.0
Oketo shale member:	
11. Shale, tan-gray, calcareous, fossiliferous	5.9
10. Limestone, gray, massive, fossiliferous	.8
9. Shale, tan-gray, silty, calcareous	6.0
Total Oketo shale member	12.7

37. *Section in a road cut in the NW¼NW¼ sec. 36, T. 7 S., R. 7 E.*—Continued

	Feet
Barneston limestone—Continued	
Florence limestone member:	
8. Limestone, massive, cherty; beds of bluish-gray chert nodules alternate with 0.6 foot beds of light-gray dense limestone; fossiliferous	24. 0
7. Shale, gray, silty, calcareous	. 5
6. Limestone, gray; with flattened chert nodules	. 6
5. Shale, gray, silty, calcareous	. 5
4. Limestone, tan-gray; contains flattened chert nodules	. 4
3. Shale, gray, silty, calcareous	1. 3
2. Limestone, gray, nodular, limonite spots	. 3
Total Florence limestone member	27. 6
Total Barneston limestone	51. 3
Matfield shale (part);	
Blue Springs shale member (part):	
1. Shale, variegated light-green, light-gray, and maroon, silty, hard	14. 7

38. *Section in a road cut in the SE¼NE¼ sec. 10, T. 7 S., R. 7 E.*

	Feet
Doyle shale (part):	
Towanda limestone member (part):	
1. Limestone, tan gray, platy, medium hard, porous, contains calcite cavities; weathers tan	14. 2

39. *Section in a road cut on Kansas State Highway 16, SE¼NW¼ sec. 16, T. 7 S., R. 8 E.*

	Feet
Doyle shale (part):	
Holmesville shale member (part):	
10. Shale, tan, silty, calcareous; weathers tan	2. 0
9. Limestone, tan, blocky; weathers tan	1. 0
8. Shale, tan, silty, calcareous	4. 0
7. Shale, gray, clayey; weathers gray	3. 9
6. Shale, tan, sandy, limonitic; weathers tan	1. 0
5. Limestone, brown, hard, crystalline; weathers tan	. 4
4. Siltstone, tan, blocky, calcareous; weathers tan	2. 8
3. Limestone, tan-gray, slightly spongy appearing; cavities with calcite crystals; weathers tan gray	6. 0
2. Siltstone, tan-gray, blocky, calcareous; cavities lined with calcite crystals	5. 9
Thickness of Doyle shale exposed	27. 0
Barneston limestone (part):	
Fort Riley limestone member (part):	
1. Limestone, tan-gray, massive; calcite crystal pockets; weathers gray	6. 0

40. *Section in a road cut in the SE¼NE¼ sec. 9, T. 7 S., R. 7 E.*

	Feet
Doyle shale (part):	
Towanda limestone member (part):	
5. Limestone, tan-gray, platy; contains calcite geodes; weathers tan	2.0+
Holmesville shale member:	
4. Shale, tan-gray, silty, calcareous; weathers tan	15.4
3. Limestone, tan-gray, nodular; contains calcite geodes; weathers tan gray	.5
2. Shale, tan-gray, silty, calcareous; weathers tan	16.6
Total Holmesville shale member	32.5
Thickness of Doyle shale exposed	34.5
Barneston limestone (part):	
Fort Riley limestone member (part):	
1. Limestone, tan-gray, massive, pitted; weathers gray; fossiliferous	5.0

41. *Section in a road cut in the SE¼SE¼ sec. 10, T. 7 S., R. 7 E.*

	Feet
Doyle shale (part):	
Towanda limestone member:	
6. Limestone, tan-gray, massive, crystalline; with calcite crystal cavities; weathers tan gray; four separate beds	2.6
5. Shale, tan-gray, clayey, calcareous	.3
4. Limestone, tan-gray to light-gray, platy, fine-grained; weathers tan gray	4.3
3. Limestone, gray, massive, fine-grained; weathers tan gray	2.6
2. Limestone, tan-gray, platy to massive, coarse-grained; many cavities lined with calcite crystals; weathers tan gray	4.0
Total Towanda limestone member	13.8
Holmesville shale member (part):	
1. Shale, tan-gray, nodular, clayey; weathers lumpy	3.1
Thickness of Doyle shale exposed	16.9

INDEX

The U. S. Geological Survey has cataloged this publication as follows:

Scott, Glenn Robert, 1918–
Geology and construction-material resources of Pottawatomie County, Kansas, by Glenn R. Scott, Frank W. Foster, and Carl F. Crumpton. Washington, U. S. Govt. Print. Off., 1958.

iv, 97–178 p. maps (1 col.) diagrs., tables. 25 cm. (U. S. Geological Survey. Bulletin 1060–C. Geology and construction materials of part of northeast Kansas)

Part of illustrative matter fold. in pocket.
"Prepared in cooperation with State Highway Commission of Kansas, as part of a program of the Department of the Interior for development of the Missouri River basin."
"Literature cited": p. 147–148.

(Continued on next card)

Scott, Glenn Robert, 1918– Geology and construction-material resources of Pottawatomie County, Kansas ... 1958. (Card 2)

1. Geology—Kansas—Pottawatomie Co. 2. Building materials. 3. Petrology—Kansas—Pottawatomie Co. (Series: U. S. Geological Survey. Bulletin 1060–C. Series: U. S. Geological Survey. Geology and construction materials of part of northeast Kansas)

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