Geology and Construction-Material Resources of Nemaha County, Kansas

GEOLOGICAL SURVEY BULLETIN 1060-D

Prepared in cooperation with the 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 MELVILLE R. MUDGE, CHARLES P. WALTERS, *and* RALPH E. SKOOG

GEOLOGY AND CONSTRUCTION MATERIALS OF PART OF NORTHEAST KANSAS

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GEOLOGY AND CONSTRUCTION-MATERIAL RESOURCES OF NEMAHA COUNTY, KANSAS

By Melville R. Mudge, Charles P. Walters, and Ralph E. Skoog

ABSTRACT

Nemaha County lies in the northernmost tier of Kansas counties and is in the third tier west of Missouri. This county is mantled almost entirely by Quaternary surficial deposits but sedimentary bedrock crops out in some of the major stream valleys.

The surficial deposits consist mostly of glacial deposits of Kansan age that are as much as 300 feet thick. These deposits are mainly glacial till with lenses of outwash gravel. Glaciolacustrine deposits (mostly silt) are found in small areas in southern Nemaha County. Overlying the glacial sediments are thin deposits of loess of Illinoian and Wisconsin age. Terrace material and colluvium are present in almost all of the valleys. Only the outwash gravel and glaciolacustrine deposits are presently (1956) of economic importance as engineering construction materials.

The bedrock crops out mainly in northern Nemaha County. These rocks range from the Topeka limestone of late Pennsylvanian age to and including the Wreford limestone of early Permian age. The limestones of Pennsylvanian age that are being used as construction material are the Church limestone member of the Howard limestone, the Reading and Elmont limestone members of the Emporia limestone, and the Tarkio limestone member of the Zeandale limestone. The limestones of Permian age that are being used as construction material are the Neva limestone member of the Grenola limestone and the Cottonwood limestone member of the Beattie limestone.

INTRODUCTION

PURPOSE OF THE INVESTIGATION

The State Highway Commission of Kansas and the United States Geological Survey are cooperating in the compilation of a Statewide construction-materials inventory. This report on Nemaha County, Kans., is a part of the general inventory, and a contribution to the geologic mapping and mineral-resources investigations being made in connection with the Department of Interior's program for the development of the Missouri River basin. A field party of the United States Geological Survey undertook an investigation of sources of engineering-construction materials in Nemaha County, Kans., in the spring of 1949; it was completed in the fall of the same year. A map was prepared to show the geologic occurrence of the construction materials and is included in this report. (See pl. 6.)

The primary objective of the investigation was to assemble all field and laboratory data pertaining to the geologic materials in Nemaha County that would be of use in the construction of dams, highways, railways, airports, and other engineering structures. Additional geologic data are included in this report, but only to the extent of providing information useful in the development of the prospects reported in the inventory or for the location of other materials required for future engineering needs.

GEOGRAPHY

AREA COVERED BY THE INVESTIGATION

Nemaha County is in the first tier of Kansas counties south of the Nebraska border and in the third tier west of Missouri. (See fig. 9.) The county is bounded on the east by Brown County, on the south by Jackson and Pottawatomie Counties, on the west by Marshall County, all in Kansas, and on the north by Pawnee and Richardson Counties, in Nebraska.

TOPOGRAPHY

The altitude of Nemaha County ranges from about 1,075 feet northeast of Wetmore to about 1,425 feet, in the south-central part of the county, a short distance northwest of Baileyville. The county is in the glaciated northeastern part of the State. Its topography is that of a dissected plain with relatively broad gentle slopes except in areas where streams have cut deep into glacial sediments. Drainage is well established in some parts of the county. Beds of limestone form conspicuous hillside benches where they crop out; locally these benches are at a considerable height above the streams that eroded them.

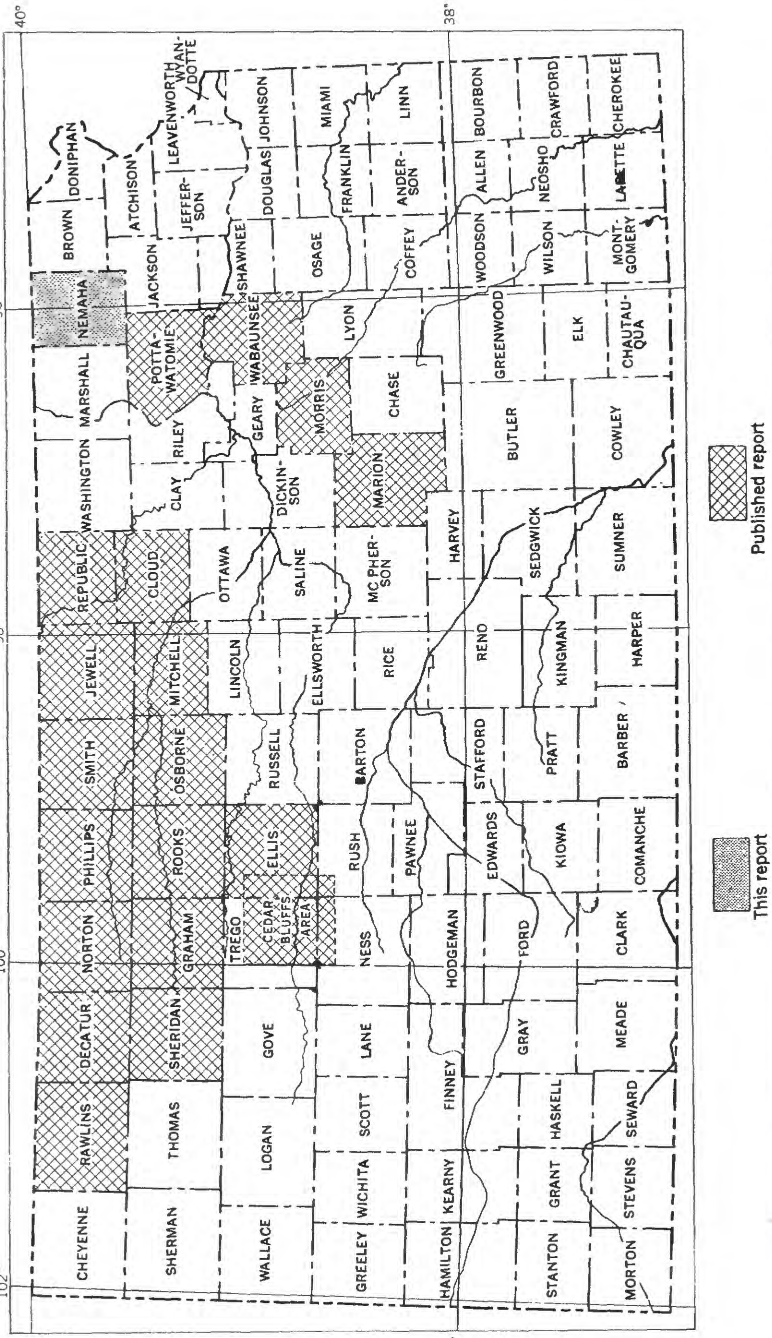

FIGURE 9.—Index map of Kansas showing area covered by this and other construction-materials reports.

Glacial sediments occur over most of the county but in some places erosion has exposed Permian and Pennsylvanian rocks. Material deposited directly by glacial ice (glacial till) is exceptionally thick in the central and southern parts of the county, and material deposited by melt water from the glacier (glacial outwash) covers much of the remainder of it. Terrace deposits are found along most of the major streams. Discontinuous outcrops of wind-deposited silt (loess) occur on the tops of the interstream areas in the northern half of the county; thinner and less extensive deposits are present in its southern half. The principal stream in Nemaha County is the Nemaha River, which flows northward through the central part of the county. Numerous smaller streams originate within the county. (See pl. 6.)

CLIMATE

Nemaha County is an area of continental-type climate in which the summers are relatively long and hot and the winters are short and fairly cold. The mean annual temparature is 53.5° F and ranges from a mean of 26.3° F in January to a mean of 79.1° F in July. On the average there are 100 cloudy days, 85 partly cloudy days, and 180 clear days a year. The average date of the first killing frost in the fall is October 11 and the average date of the last killing frost in the spring is April 27 (Flora, 1948).

The number of days each month in which the maximum daily temperature fell within ranges arbitrarily based on temperatures that are generally important in several phases of engineering construction is shown in figure 10 for the 10-year period 1937–46. Days in which the maximum temperature does not exceed 32° F occur only from November through March, and the maximum incidence is 9.3 days in January. July is the warmest month of the year, including an average of 17.8 days having a maximum temperature above 90° F. The chart also shows the average difference between the daily maximum and minimum temperatures for each month. The greatest difference in daily temperature, 27° F, is in October, and the least difference, 20° F, is in December.

Precipitation influences the number of working days in engineering construction; figure 10, also shows precipitation ranges at Centralia, Kans., for the 10-year period 1937–46.

During this period (Flora, 1948) there were an average of 19.5 days in June without measurable precipitation, 2.5 days in which precipitation ranged from a trace to 0.1 inch, 6.1 days in which 0.11 to 1 inch of rain fell, and 1.9 days in which the precipitation was more than 1 inch. Continuing rains for the most part fall in the late spring and early autumn. Other rainfall is generally in the form of showers. The normal annual precipitation is 30.33 inches.

TRANSPORTATION ROUTES

Nemaha County is served by three railroads: The Chicago, Rock Island and Pacific; Union Pacific; and Missouri Pacific.

Two transcontinental highways, U. S. 36 and U. S. 75, cross the county. These highways and Kansas Highway 9 are surfaced with bituminous materials. Kansas Highways 63 and 71, and many of the county roads, are surfaced with sand and gravel obtained from the Blue River in Marshall County. Other county roads and some of the township roads are surfaced with sand and gravel, and crushed rock from local sources. All roads and railroads are shown on plate 6.

INVESTIGATION PROCEDURE

Mapping was done on aerial photographs at the scale of 3 inches to 1 mile. Names of the units of the Shawnee group (Pennsylvanian), and Council Grove and Chase groups (Permian) are those used by the Kansas Geological Survey (Moore, Frye, and Jewett, 1944; Moore, Frye, Jewett, and others 1951). The classification of the Wabaunsee and Admire groups in the report follows Moore and Mudge (1956). The principal emphasis of this report is on construction materials while geologic problems not critically related to these materials are considered to be of secondary importance.

An effort was made to assemble all existing data pertaining to construction materials in the county; these data are presented in table 1, a summary of materials tests.

TABLE 1.—*Summary of tests on construction*

Location: All township designations are south and

Authority for test data: HC, State Highway Commission of Kansas. HC, sieve analysis and laboratory U.S. Geological Survey.

[Leaders indicate

No. on plate 6	Location	Estimated amount of material (cubic yards)	Average thickness (feet): Material	Average thickness (feet): Overburden	Accessibility	Lithologic unit	Description of materials
							Coarse aggregate
ca 1	NW¼SW¼ sec. 30, T. 1, R. 14.	5,100	12	1	Good	Glacial outwash	Mixture of limestone, flint and granite. Some clay and silt. Accepted for use as cover material under supp. specifications 37-301. Does not have sufficient material on No. 50 sieve. Loss by decantation is high for washed sand-gravel. Satisfactory for dry pit. Trace of mud balls.
ca 2	NW¼NW¼ sec. 28, T. 1, R. 13.	10,000	12	1	Good	Glacial outwash	Coarse fraction in percent: chert, trace; ironstone, 75; quartz, trace; granite, 25; diorite, trace; quartzite, trace. Fine fraction in percent: sandstone, 5; ironstone, 20; quartz, 60; shale, 10; granite, 5; schist, trace; quartzite, trace. Trace of mud balls. Color: straw.
ca 3	SE¼NE¼ sec. 35, T. 2, R. 12.	(1)	14	3	Good	Glacial outwash	Granitic, siliceous sand-gravel containing a yellow clay. Color: clear.
ca 4	NE¼NW¼ sec. 13, T. 3, R. 12.	80,000	25	1	Fair	Glacial outwash	Coarse fraction in percent: limestone, 30; granite, trace; diorite, 10; basalt, 5; quartzite, trace; conglomerate, 55. Fine fraction in percent: limestone, 60; chert, 10; sandstone, 20; granite, 5; diorite, 5; gabbro, trace; quartzite, trace. Color: clear.
ca 5	NW¼SE¼ sec. 12, T. 4, R. 14.	10,000	8	4	Fair	Glacial outwash	Coarse fraction in percent: chert, trace; sandstone, 55; ironstone, trace; granite, 25; quartzite, 20. Fine fraction in percent: sandstone, 15; quartz, 60; granite, 5; other basic igneous, 5; quartzite, 15; feldspar, trace. Color: clear.
ca 6	NE¼SE¼ sec. 28, T. 4, R. 14.	10,000	9	3	Good	Glacial outwash	Color: clear
							Mixed aggregate
ma 1	SE¼SE¼ sec. 26, T. 2, R. 12.	4,000	1	4	Good	Glacial outwash	PI=4
							Fine aggregate
fa 1	NW¼NW ¼ sec. 1, T. 4, R. 13.	20,000	12	1	Good	Glacial outwash	Coarse fraction in percent: sandstone, 55; ironstone, 10; quartz, trace; granite, 5; diorite, 5; quartzite, 5. Fine fraction in percent: ironstone, trace; quartz, 80; other basic igneous, 5; feldspar, 15. Trace of mud balls. Color: light straw.
fa 2	SW¼SE¼ sec. 18, T. 5, R. 11.	20,000	8	3	Good	Glacial outwash	Fine fraction in percent: quartz, 95; other basic igneous, 5; feldspar, trace. Color: clear.

materials of Nemaha County, Kansas

all range designations are east throughout table.

tests by State Highway Commission of Kansas; GS, sample collection and description of material by

data not available.]

Authority for test data	Date of test	Laboratory test data									Sieve analysis						Laboratory No.
		Weight per cubic foot (dry)	Specific gravity (dry)	Gradation factor	Compressive strength ratio		Los Angeles percent loss	Soundness (25 cycles)	Cementation	Absorption	Cumulative percent retained on—					Percent passed No. 200 (wash)	
					1 day	3 days					¾ in.	⅜ in.	No. 4	No. 16	No. 100		
HC	10–39	-----	-----	3.66	-----	-----	-----	-----	-----	-----	-----	10	22	52	97	3.8	38154
GS	2–50	93.0	2.56	3.01	0.55	0.65	27.0	0.90	-----	-----	1	9	16	34	89	6.97	66439
HC	10–33	-----	2.60	4.10	.80	.84	-----	-----	-----	-----	3	10	24	63	95	5.0	21951
GS	8–49	124.8	2.61	4.36	1.39	1.60	37.6	.92	-----	-----	9	26	39	64	89	8.98	63991
GS	7–49	98.2	2.58	3.55	1.02	.76	33.1	-----	-----	-----	11	18	26	41	86	13.04	63779
GS	7–49	106.4	2.58	3.13	1.39	1.34	27.00	-----	-----	-----	1	8	15	37	93	5.31	63780
HC	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	5	15	85	13.0	-----
GS	1–50	90.7	2.58	2.20	.55	.69	-----	-----	-----	-----	0	1	3	12	91	5.60	66437
GS	6–49	90.9	2.60	1.13	.66	.65	-----	-----	-----	-----	0	0	0	0	89	6.53	63546

TABLE 1.—*Summary of tests on construction*

No. on plate 6	Location	Estimated amount of material (cubic yards)	Average thickness (feet)		Accessibility	Lithologic unit	Description of materials
			Material	Overburden			
							Mineral filler
mf 1	SW¼SW¼ sec. 26, T. 2, R. 12.	50,000	16	0	Good	Terrace deposits	
mf 2	NW¼SW¼ sec. 18, T. 4, R. 11.	20,000	12	2	Good	Glaciolacustrine	LL=26; PI=4 (AA6088)
mf 3	SE¼SE¼ sec. 34, T. 5, R. 12.	35,000	30	1	Good	Glaciolacustrine	Fine fraction: quartz, 99 percent; other basic igneous, trace. LL=33; PI=8 (AA6087).
mf 4	NE¼SE¼ sec. 33, T. 5, R. 11.	20,000	12	2	Good	Glaciolacustrine	LL=33; PI=11 (AA6086)
							Chert gravel
cg 1	NW¼NW¼ sec. 14, T. 1, R. 13.	3,200	--	--	Fair	Sanborn formation.	Coarse fraction in percent: limestone, 60; chert, 25; sandstone, 5; quartz, trace; rhyolite, 5; quartzite 5. Fine fraction in percent: limestone, 30; chert, 20; sandstone, 10; ironstone, trace; quartz, 5; opal, 5; shale, trace; rhyolite, trace; andesite, trace; felsite, 5; schist, 5; quartzite, 20.
							Limestone
ls 1	NW¼NE¼ sec. 14, T. 1, R. 14.	8,000	--	--		Cottonwood limestone member.	Specify gravity saturated 2.36
ls 2	NW¼SE¼ sec. 25, T. 1, R. 14.	10,000	5	2	Good	Middleburg limestone member.	Specific gravity saturated 2.51
ls 3	SE¼SE¼ sec. 7, T. 1, R. 13.	8,000	--	--	Good	Wakarusa limestone member top 24 inches.	Specific gravity saturated 2.64
		8,000	--	--	Good	Wakarusa limestone member lower 12 inches.	
ls 4	NE¼SW¼ sec. 12, T. 1, R. 12.	40,000	5	5	Good	Howard limestone top limestone.	Specify gravity saturated, 26.5. Accepted for use under specifications (1945) secs. 107, 108, 109, 110, 111, 112 and 114.
						Howard limestone lower limestone.	Specific gravity saturated, 2.72. Accepted for use under specifications (1945) secs. 108, 109, 110, 111, 112 and 114.
ls 5	NE¼NW¼ sec. 12, T. 1, R. 12.	40,000	5	5	Good	Howard limestone.	Specific gravity saturated, 2.71. Accepted for use under specifications (1945) secs. 108, 109, 110, 111, 112 and 114. 2 feet silty shale overlying limestone has PI=8.
ls 6	SE¼NE¼ sec. 18, T. 1, R. 12.	15,000	3	2	Good	Tarkio limestone member top 33 inches.	Specific gravity saturated 2.41. Accepted under specifications (1945) sec. 112.
						Tarkio limestone member middle 12 inches.	Specific gravity saturated 2.50. Accepted under specifications (1945) secs. 110 and 112.
						Tarkio limestone member bottom 33 inches.	Specific gravity saturated 2.43. Accepted under specifications (1945) secs. 110 and 112.
ls 7	SE¼NW¼ sec. 24, T. 1, R. 12.	10,000	3	1	Good	Howard limestone.	Specific gravity saturated 2.76. Accepted under specifications (1945) secs. 107, 108, 109, 110, 111, 112 and 114.

materials of Nemaha County, Kansas—Continued

Authority for test data	Date of test	Laboratory test data									Sieve analysis						Laboratory No.
		Weight per cubic foot (dry)	Specific gravity (dry)	Gradation factor	Compressive strength ratio		Los Angeles percent loss	Soundness (25 cycles)	Cementation	Absorption	Cumulative percent retained on—					Percent passed No. 200 (wash)	
					1 day	3 days					¾ in.	⅜ in.	No. 4	No. 16	No. 100		
GS	9-49								100+								64769
GS	1-50	87.9	2.63						17						6	66.0	66440
GS	7-49	82.5	2.61						41						2	97.6	63990
GS	6-49	82.7	2.59						86						2	96.0	63545
GS	9-49		5.67				36.6	.89			39	52	60	74	93	6.33	
GS	1-50		2.20				51.0	.69		7.33							66441
GS	8-49		2.43				34.2	.84		3.58							64452
GS	1-50		2.60				23.4	.93		1.65							66442
GS	1-50		2.53				26.4	.93		1.76							66443
HC	12-45		2.62				26.6			1.21							49189
HC	12-45		2.67				25.3	.89		1.76							49190
HC	2-49		2.65				25.6	.90		3.75							62161
HC	10-49		2.32				44.0	.90		3.95							65427
HC	10-49		2.39				31.0	.70		4.75							65428
HC	10-49		2.32				35.0	.85		4.85							65429
HC	2-46		2.72				23.7	.93		1.24							49191

TABLE 1.—*Summary of tests on construction*

No. on plate 6	Location	Estimated amount of material (cubic yards)	Average thickness (feet): Material	Average thickness (feet): Overburden	Accessibility	Lithologic unit	Description of materials
							Limestone—Continued
ls 8	SE¼SW¼ sec. 29, T. 1, R. 12.	10,000	2	6	Poor	Reading limestone member.	Acceptable under sec. 131, art. 131.24 of specifications (1945).
ls 9	NE¼NW¼ sec. 32, T. 1, R. 12.	20,000	2	5	Poor	Reading limestone member.	Specific gravity saturated 2.45. Accepted under secs. 110 and 112 of specifications (1945).
ls 10	NE¼NW¼ sec, 23, T. 1, R. 11.	20,000	10	3	Good	Tarkio limestone member top ledge.	Specific gravity saturated 2.47. Accepted under secs. 110 and 112 of specifications (Ed. 1945).
						Tarkio limestone member middle part.	Specific gravity saturated 2.56. Accepted under secs. 110 and 112 of specifications (Ed. 1945).
						Tarkio limestone member bottom part.	Specific gravity saturated 2.60. Accepted under secs. 110 and 112 of specifications (Ed. 1945).
ls 11	SE¼SW¼ sec. 23, T. 1, R. 11.	3,000	6	4	Fair	Dover limestone member.	Specific gravity saturated 2.60.
ls 12	SE¼NE¼ sec. 24, T. 3, R. 14.	10,000	6	4	Good	Cottonwood limestone member top 3 feet.	Specific gravity saturated 2.39. Accepted under secs. 107, 108, 109, 110, 111, 112 and 114 of specifications (Ed. 1945) LL=19. P I=3 (AA-3581).
						Cottonwood limestone member lower part.	Specific gravity saturated 2.39. Accepted under secs. 108, 109, 110, 111, 112, and 114 of specifications (Ed. 1945).
ls 13	SE¼NW¼ sec. 36, T. 5, R. 12.	20,000	--	--	--------	Neva limestone member top bed.	Deval. 5.5 percent. Specific gravity saturated 2.52. Accepted under secs. 68, 71, 73 and 76 of specifications (Ed. 1937).
						Neva limestone member second bed from top.	Deval. 6.2 percent, unsound. Specific gravity saturated 2.45. Not accepted under secs. 68–71, 73 and 76 of specifications (Ed. 1937).
						Neva limestone member second bed from bottom.	Deval. 7.1 percent, sound at 25 cycles. Specific gravity saturated 2.36. Accepted for use under secs. 68, 69, 71 and 73 of specifications (Ed. 1937).
						Neva limestone member bottom limestone.	Deval. 4.2 percent, unsound. Specific gravity saturated 2.53. Not accepted under secs. 68–71, 73 and 76 of specifications (Ed. 1937).
ls 14	SW¼SE¼ sec. 36, T. 5, R. 12.	10,000	-	--	--------	Cottonwood limestone member.	Specific gravity saturated 2.47.

[1] Unlimited. [2] Unsound.

materials of Nemaha County, Kansas—Continued

Authority for test data	Date of test	Laboratory test data									Sieve analysis						Laboratory No.
		Weight per cubic foot (dry)	Specific gravity (dry)	Gradation factor	Compressive strength ratio		Los Angeles percent loss	Soundness (25 cycles)	Cementation	Absorption	Cumulative percent retained on—					Percent passed No. 200 (wash)	
					1 day	3 days					3/4 in.	3/8 in.	No. 4	No. 16	No. 100		
HC	8-47							.74									56184
HC	11-49		2.33				32.4	.87		5.20							65430
HC	3-49		2.39				35.4	.72		3.42							62156
HC	3-49		2.49				27.7	.83		2.93							62158
HC	3-49		2.54				26.4	.84		2.36							61157
GS	10-49		2.54				34.4	.87		2.44							64770
HC	6-48		2.28				48.5	.77		4.89							59334
HC	6-48		2.28				39.0	.87		4.69							59333
HC	2-42	159.9	2.45				33.7			3.0							44338
HC	2-42		2.36				34.6	(2)		4.0							44337
HC	2-42	139.8	2.24				33.1			5.4							44336
HC	2-42		2.46				34.0	(2)		3.1							44335
GS	7-49		2.36				46.5	.78		4.64							63652

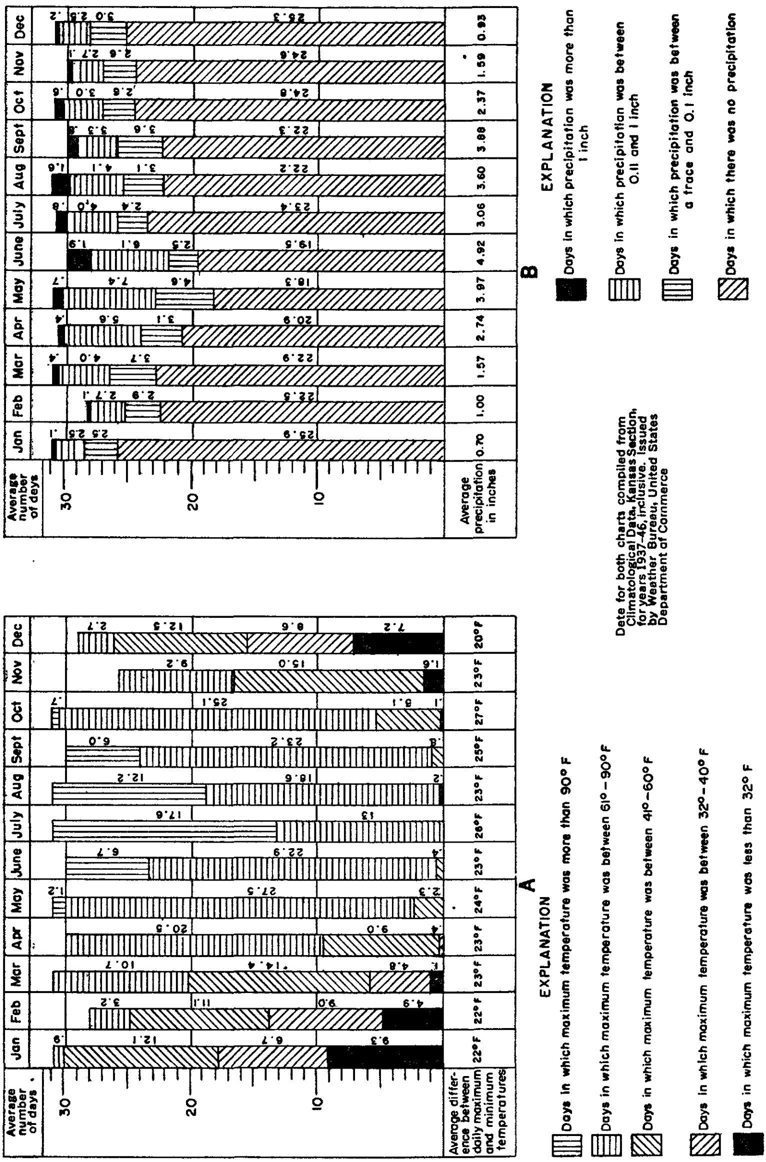

FIGURE 10.—Temperature and precipitation ranges at Centralia, Kansas.

ACKNOWLEDGMENTS

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CHARACTERISTICS OF THE OUTCROPPING STRATIGRAPHIC UNITS

INTRODUCTION

The discussion of the outcropping stratigraphic units of Nemaha County emphasizes the areal distribution, general characteristics, and thickness of each formation or group of formations. This part of the report presents the geologic information required for the location and effective development of the construction materials reported. Since many of the geologic units are poorly exposed in the county, some of these descriptions are based on only one exposure.

A summary of the geologic and construction-materials data for each stratigraphic unit is presented in plate 7. The areal distribution of the local stratigraphic units is shown on the geologic map of Nemaha County (pl. 6).

As an aid to the identification of the local geologic formations in the field, representative measured sections of each stratigraphic unit are included in the part of this report entitled "Stratigraphic sections" and are referred to in the discussion of each unit.

The locations of operated and prospect pits and quarries also are shown on plate 6. Symbols indicate whether the pit or quarry has been operated, or is a prospect; the type of construction material available at each site; and the estimated quantity of the material that can be removed under no more than moderate overburden (unconsolidated sediments less than 6 feet thick). Most of the sources of construction materials are listed in table 1, and are numbered within each classification of materials according to the following plan: the numbering starts in the northeasternmost township and continues westward along the same tier to the west boundary of the county; it is continued in the next tier to the south, starting again with the easternmost township 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 a township.

PENNSYLVANIAN SYSTEM

Of the many groups of formations that make up the Pennsylvanian system, only the two uppermost (Wabaunsee and Shawnee) crop out in Nemaha County. (See pls. 6 and 7.)

SHAWNEE GROUP—TOPEKA LIMESTONE

The Shawnee is the middle group of formations in the Pennsylvanian system. (See pl. 7.) In Nemaha County it is represented only by the upper part of the Topeka limestone, and it crops out in but two places along the Nemaha River. The two exposures of the Topeka limestone are in the SE¼NE¼ sec. 23 and NW¼NW¼ sec. 25, T. 15 S., R. 12 E. It is divided into 9 members of which only the uppermost 3 are exposed in this county. They are, in ascending order, the Du Bois limestone member, Holt shale member, and Coal Creek limestone member. The thickness of the Topeka limestone as exposed locally is 9.2 feet. (See pl. 7 and measured section 33.) The Du Bois limestone member consists of two beds of limestone separated by a thin bed of shale. The upper limestone is hard, dense, and gray and breaks with a conchoidal fracture. The lower limestone is medium hard, gray, and includes a thin bed of shale. The shale is somewhat silty, calcareous, and tan gray. Pelecypods are especially abundant in the two limestones, but other fossils are present. This member is 2.7 feet thick. The Holt shale member is clayey, noncalcareous, gray to dark gray, and limonite stained. It is 3.7 feet thick.

The Coal Creek limestone member consists of two beds of limestone separated by a bed of shale. The limestones are gray, mottled with gray green, and are medium hard and dense. The upper bed of limestone weathers to thin beds and contains abundant fusulinids. Other fossils are common in both limestone beds. The thin bed of shale is silty, calcareous, and tan to tan gray. This member is 2.8 feet thick.

The Topeka limestone can best be recognized by the fusulinids in the Coal Creek limestone member and by the dense pelecypod-bearing limestones of the Du Bois member.

WABAUNSEE GROUP

The Wabaunsee is the uppermost group of formations of the Pennsylvanian system in Nemaha County. (See pl. 7.) The formations and members of the Wabaunsee group are shown on plate 6.

The outcrop area of the Wabaunsee group extends through the central and western parts of the county, and its exposures are most numerous in the north-central part. (See pl. 6.) The aggregate thickness of the Wabaunsee group is 130 feet.

SEVERY SHALE

The Severy shale is very clayey and noncalcareous in the upper part but is silty and calcareous in the middle and lower parts. (See pl. 7.) This shale is somewhat sandy and micaceous and is gray to tan gray. It averages 22 feet in thickness. (See measured sections 31 and 32.)

HOWARD LIMESTONE

The Howard limestone is divided into five members which are, in ascending order, the Bachelor Creek limestone member, Aarde shale member, Church limestone member, Winzeler shale member, and Utopia limestone member. (See pl. 7.) Only the Utopia and Church limestone members and the Aarde shale member represent the Howard limestone in Nemaha County. In absence of the Bachelor Creek limestone member, the base of the Howard limestone is drawn at the base of the Nodaway coal bed—a persistent coal bed in the lower part of the Aarde shale member. The Howard limestone averages 7 feet in thickness.

The Aarde shale member is silty, slightly calcareous, dark gray to tan gray, and averages 4.5 feet thick. It contains some carbon stains, and minute gypsum crystals can be observed on the bedding planes. The base of the bituminous Nodaway coal bed is designated as the base of the Aarde in Nemaha County. Schoewe (1946, p. 103–109) lists several localities in northern Nemaha County where this coal was mined during World Wars I and II and as long ago as 1875. The coal ranges from 6 to 12 inches in thickness. Microfossils are present in the beds of shale overlying the Nodaway coal. (See measured sections 31 and 32.)

The Church limestone member is well exposed along both sides of the Nemaha River in the area west of Bern, and along Deer Creek south of Bern. It is hard, dense, dark blue gray, and fossiliferous and breaks with a conchoidal fracture. It commonly crops out as a massive bed of dense limestone, with some limonite stains and calcite crystals on the weathered surface. The weathered crust is tan brown and extends 2 or 3 inches into the rock before the dark blue gray of the unweathered stone is reached. This member forms a prominent hillside bench and averages 2.3 feet in thickness. (See measured sections 31 and 32.)

The Church limestone member is easily identified by its thickness, denseness, conchoidal fracture, and by the blue gray of the unweathered rock. The Winzeler shale member is not present in Nemaha County.

The Utopia limestone member is absent from most exposures of the Howard limestone and crops out only in secs. 12, 13, and in the NW¼ sec. 24, T. 1 S., R. 12 E. This member consists of thin beds of medium-hard gray to tan-gray fossiliferous limestone and ranges from a featheredge to 1.6 feet in thickness. (See measured section 32.)

The Utopia is readily identified by its gray fossiliferous thin-bedded limestone beds, and by its position above the massive Church limestone member of the same formation.

SCRANTON SHALE

The Scranton shale generally forms a long gentle slope between the Howard limestone below, and the Bern limestone above. The Scranton consists of five members which are, in ascending order, the White Cloud shale member, Happy Hollow limestone member, Cedar Vale shale member, Rulo limestone member, and the Silver Lake shale member. The Happy Hollow limestone member was not observed in Nemaha County; therefore, the White Cloud and Cedar Vale shale members are not differentiated. The average thickness of the Scranton shale is about 125 feet thick.

The White Cloud and Cedar Vale shale members undifferentiated (pl. 7) include all the units from the Rulo limestone members to the Howard limestone. The Rulo limestone member is generally absent, therefore, the upper contact of the White Cloud and Cedar Vale shale members undifferentiated is placed at the top of the Elmo coal bed, which is normally about 2 feet beneath the Rulo limestone member.

The White Cloud and Cedar Vale members undifferentiated consists of beds of silty, sandy, micaceous shale that locally include lime-cemented crossbedded ripple-marked sandstones. Limonite nodules, plates, and concretions are abundant in this unit, and thin beds of fossiliferous limestone are common. The shales are tan to blue gray, but local maroon zones are found in the upper part. Many exposures contain septarian concretions. Iron and carbon stains are present on some of the bedding and fracture planes. This unit averages 105 feet in thickness. (See measured sections 27, 30, 31, and 32.) The Rulo limestone member is medium hard, gray, highly fossiliferous, (pl. 7) and very lenticular. Only a single outcrop was observed in a streambank in the SE¼SE¼ sec. 31, T. 5 S., R. 12 E.; the Rulo limestone member pinches out toward the west side of the bank. This limestone is about 1.3 feet thick. (See measured section 30.)

The Silver Lake shale member is a gray-green to tan sandy to silty noncalcareous micaceous clay shale which contains thin sandstone beds. (See pl. 7.) This member ranges from 12 to 27 feet in thickness. (See measured sections 28, 29, and 30.)

BERN LIMESTONE

The Bern limestone was named by Moore and Mudge (1956, p. 2276–2277) after the city of Bern in the north-central part of the county. The type section is in a road cut in the SE¼SE¼ sec. 7, T. 1 S., R. 13 E., Nemaha County. Section 28 in stratigraphic sections is a measurement of the type section. The Bern limestone averages about 20 feet in thickness and it consists of three members, which are, in ascending order, the Burlingame limestone member, Soldier Creek shale member, and Wakarusa limestone member.

The Burlingame limestone member commonly consists of two beds of limestone separated by a thick bed of shale. However, the lower limestone pinches out in the southern part of the county.

In Nebraska, Condra and Reed (1943, p. 45–46) have divided the Burlingame limestone into three members, which are, in ascending order, the Taylor Branch limestone member, Winnebago shale member, and South Fork limestone member. These units in this report will be referred to as, the lower limestone, intervening shale, and upper limestone. The Burlingame limestone member averages 9 feet in thickness. (See measured sections 23, 26–30.)

The Burlingame limestone member is recognized by the small light-colored limestone inclusions, algae, thickness, and color.

The lower limestone consists of either 1 or 2 beds of limestone separated by a thin bed of shale. This limestone thins southward and is absent in the southernmost part of the county. It is gray to tan, has a variable hardness, and is 0.2 foot thick in the central part of the outcrop area. Limonite specks and calcite-filled cavities are common. The shale parting, where present, is silty, calcareous, gray to tan gray, and fossiliferous. This limestone ranges from a featheredge to 3.6 feet in thickness.

The intervening shale is gray to tan gray in most outcrops but contains maroon and green zones in the central part of the county. This shale is clayey and noncalcareous. Fossils are common in its lower part and it is about 5 feet thick.

The upper limestone is soft to medium hard, tan gray to tan brown, and porous. Small limestone fragments that weather to a lighter color than the matrix are visible in almost all outcrops of this bed. Fossils, including small algae, are present in most of the exposures in the southern part of the county. The limestone is unusually thin (0.5 feet) in the vicinity of Lake Seneca, but elsewhere its average thickness is 2 feet.

The Soldier Creek shale member ranges from a silty to a clayey calcareous shale. (See pl. 7.) In most outcrops, this shale is gray to gray brown, but maroon and green beds predominate in the central part of its outcrop area. Thin beds of clayey limestone are in the lower part of the member in some localities. This member thins toward the west but its thickness (8 feet) is constant elsewhere in the county. (See measured sections 23, 26, 27, and 28.)

The Wakarusa limestone member consists of 3 or more beds of limestone separated by thin beds of shale in the northern part of its outcrop area, of a single bed of limestone in the central outcrop area, and of 2 or more beds of limestone in the southern outcrop area. The limestone is soft to medium hard, tan brown, and fossiliferous. Fusulinids are abundant in the upper limestone beds. The lower limestone beds are commonly clayey with abundant limonite specks. The shale is silty, calcareous, and tan, gray, or gray green. The Wakarusa limestone member is 2.5 feet thick. (See pl. 7.) (See measured sections 23, 26, 27, and 28.)

The Wakarusa limestone member is easily identified by its thickness and color, by the presence of fusulinids, and by the many limonite specks in the lower limestone bed.

AUBURN SHALE

The Auburn shale consists of thick shale beds commonly interbedded with one or more thin limestone beds. (See pl. 7.) The beds of shale are silty and clayey, tan gray in the upper part of the formation, tan to yellow in the middle part, and gray green to tan gray in the lower part. The tan and yellow beds in the middle part of the formation are exposed in most of its outcrops. Fossils are abundant in the upper beds of limestone and shale. The thickness of the Auburn shale increases from the west, north, and south toward the central part of the county. The formation ranges in thickness from 15 feet in the northern part to 30 feet in the central part. (See measured sections 23, 25–27.)

The Auburn shale is best identified by the persistent tan to yellow shale beds in its upper part, and by its position beneath the easily recognized Reading limestone member.

EMPORIA LIMESTONE

The Emporia limestone is exposed in the north-central, central, and south-central parts of Nemaha County. This formation consists of three members, which are, in ascending order, the Reading limestone member, Harveyville shale member, and the Elmont limestone member. The Emporia limestone averages about 10.5 feet thick.

The Reading limestone member is hard, somewhat dense gray to gray-brown limestone which commonly weathers to 3 or 4 separate beds. There is a 2- or 3-inch thick brown weathered zone on the exposed surface of each of the limestone beds. In some outcrops, very thin shale partings appear near the top and base of the formation. This member contains many fragments of fossils, especially crinoid columnals. Its thickness is remarkably constant at 2.5 feet. (See pl. 7.) (See measured sections 23, 25, and 26.)

The Reading limestone member is readily identified by its uniform thickness, color, crinoid columnals, and the 3 or 4 beds of limestone seen on the weathered surfaces.

The Harveyville shale member is a clayey calcareous gray to gray-green shale. (See pl. 7.) In the southern part of its outcrop area, this shale averages 10 feet in thickness. Toward the north, however, some of the shale grades upward into limestone that is here defined as the lower part of the Elmont limestone member. The Harveyville shale member, therefore, averages but 3 feet in thickness in the northern part of its outcrop area. (See measured sections 23–25.)

The Elmont limestone member is 1 bed of limestone or 2 or more beds of limestone separated by thin beds of shale. Only the uppermost bed of limestone, considered to be typical of the member, is found elsewhere in the state. (See pl. 7.) It is a hard somewhat dense tan-gray to dark-blue-gray fossiliferous limestone, that has a rectangular fracture pattern. This bed of limestone is 1.3 feet thick. The shale beneath is clayey, calcareous and gray, and is 1.3 feet thick. The lower part of the member consists of one or more beds of hard slightly crystalline brown to tan-gray fossiliferous limestone. These lower beds of limestone are separated by tan-gray silty shale. The Elmont limestone member averages 5 feet in thickness. (See measured sections 23–25.)

The member is most easily identified by the presence of the uppermost bed of limestone, which is dark gray and fossiliferous, develops a characteristic rectangular fracture pattern, and is 1.3 feet thick at most points.

WILLARD SHALE

The Willard shale is silty, noncalcareous, slightly sandy, micaceous, and tan gray to blue gray. (See pl. 7.) The upper part generally contains one or more lenses of sandstone. Limonite plates and nodules form a veneer on the weathered surface of almost all of its outcrops. A bed of maroon shale is common in the upper part of this unit and is always present in the northern part of the outcrop area. In the southwest corner of the county the Willard shale includes many narrow channels filled with crossbedded micaceous sandstone and sandy ripple-marked shales. The most persistent bed of channel sandstone is in the upper part of the formation. It is massive and

3 to 4 feet thick in the southeastern part of the county, but becomes much thinner toward the north. The best exposures of such channels are exhibited in streambanks along the north side of secs. 31 and 32, T. 5 S., R. 11 E. They are also exposed in some roadcuts and streambanks in northern Pottawatomie County. The Willard shale averages 35 feet in thickness. (See measured sections 21–24.)

ZEANDALE LIMESTONE

The Zeandale limestone is exposed in the north-central and south-central parts of the county. This limestone contains three members, which are, in ascending order, the Tarkio limestone member, Wamego shale member, and Maple Hill limestone member. The average thickness of the Zeandale limestone is about 24 feet.

The Tarkio limestone member forms prominent hillside benches along both sides of Turkey Creek, especially in the eastern part of T. 1 S., R. 11 E. and the western part of T. 1 S., R. 12 E. The Tarkio is a hard gray-brown massive limestone, somewhat dense in the upper part and shaly near the base. (See pl. 7.) Large fusulinids are commonly abundant throughout, and small algal nodules are common in the uppermost part. Large rectangular blocks, weathered from its outcrop, slump down onto outcrops of the underlying Willard shale. The Tarkio limestone member is about 5 feet thick. (See measured sections 21–23.)

This member is easily identified by its prominent hillside bench, tan-brown to brown color, large fusulinids, and by its thickness.

The Wamego shale member is silty, noncalcareous, and gray brown in the upper and middle parts, and is mottled gray green and maroon, calcareous, and blocky in the lower part. (See pl. 7.) Fossils and thin lenses of limestone are common in the lower part. The Wamego shale member averages 18 feet in thickness. (See measured section 21.)

The Maple Hill limestone member is a medium-hard gray to tan-gray massive limestone. (See pl. 7.) The limestone fractures upon weathering to form elongate blocks which weather further to small blocks and chips. The exposed elongate blocks has the appearance of an I-beam. Small and large fusulinids, and other fossils are found in this member. It is about a foot thick. (See measured section 21.)

The Maple Hill limestone member is easily identified by its fossiliferous character, thickness, and I-beam-like appearance.

PILLSBURY SHALE

The Pillsbury consists of thick beds of gray-green shale separated by thin maroon zones. (See pl. 7.) The shale is clayey and noncalcareous, but may contain thin beds of sandy micaceous shale. It averages 25 feet in thickness. (See measured section 21.)

STOTLER LIMESTONE

The Stotler limestone is partly exposed in the northwestern and southwestern parts of the county. This formation consists of three members, which are, in ascending order, the Dover limestone member, Dry shale member, and Grandhaven limestone member. Exposures of the Dry shale member and Grandhaven limestone member were not seen in Nemaha County. In nearby areas where all of the Stotler limestone is exposed, its average thickness is about 20 feet.

The Dover limestone member is a medium-hard massive tan-gray to gray limestone which commonly weathers blocky to nodular and contains small algal nodules and a few large fusulinids. (See pl. 7.) Clay balls and limonite stains are common in this member in the southern part of its outcrop area, and in some places, is very fossiliferous. The Dover is about 5 feet thick. (See measured sections 20 and 21.)

The Dover limestone member is a good marker bed and can best be identified by its color, algal nodules, and large fusulinids.

The Dry shale member does not crop out in Nemaha County. (See pl. 7.) In Pottawatomie and Wabaunsee Counties it is composed of beds of clayey calcareous gray shale but locally includes some maroon sandy fossiliferous beds. The Dry shale member averages 14 feet thick.

The Grandhaven limestone member does not crop out in Nemaha County. (See pl. 7.) Exposures in Pottawatomie County show that this member consists of a bed of tan-brown to brown massive limestone which weathers blocky to shaly. It is sandy, conglomeratic, and fossiliferous. The Grandhaven limestone member is about 2 feet thick.

ROOT SHALE

The Root shale generally forms the long gentle slopes between the Wood Siding formation, above, and the Stotler limestone, below. The Root shale consists of three members, which are, in ascending order, the Friedrich shale member, Jim Creek limestone member, and French Creek shale member. The Root shale averages about 46 feet in thickness.

The Friedrich shale member consists of tan-gray to bluish-gray clayey calcareous shale. (See pl. 7.) Locally there are many maroon and gray-green lenses. A bed of very fossiliferous shale and a thin lens of coal are present in its upper part, and sandstone and sandy shale are locally in the lower part. A bed of fossiliferous gray limestone appears in many places near the middle of the member. Fossils are present in some of the upper beds of shale. The member is about 25 feet thick. (See measured sections 18 and 19.)

The Jim Creek limestone member is a medium-hard gray to gray-green limestone which develops a shaly appearance upon weathering. (See pl. 7.) Fossils are abundant and include many brachiopods. The Jim Creek limestone member is about 0.6 foot thick and is best identified by its thickness, color, fossils, and weathered appearance. (See measured section 18.)

The French Creek shale member is a gray-green to gray-brown to tan-gray clayey noncalcareous shale. (See pl. 7.) The Lorton coal bed, which is 0.3 foot thick, is almost always present a few inches beneath the base of the Wood Siding formation, and a sandy, somewhat micaceous shale generally occurs beneath the lens of coal. A thin fossiliferous limestone bed underlain by a thin coal bed is in the upper part of the shale, but about 2 feet beneath the Lorton coal. The limestone appears crystalline, a result of an abundance of fossil fragments. The French Creek shale member is about 20 feet thick.

WOOD SIDING FORMATION

The Wood Siding formation is exposed in the northwestern and west-central parts of the county. The Wood Siding is composed of five members which are, in ascending order, the Nebraska City limestone member, Plumb shale member, Grayhorse limestone member, Pony Creek shale member, and Brownville limestone member. (See pl. 7.) It is about 25.3 feet thick.

The Nebraska City limestone member, as present in this county, is a very fossiliferous dark-gray limestone which weathers to a shaly appearance. It contains an abundance of fossils (brachiopods) which aid in its identification. Its average thickness is 2 feet. (See measured section 17.)

The Nebraska City is easily identified by its thickness, weathered appearance, the abundance of fossils, and by its position above the Lorton coal bed.

The Plumb shale member is mostly clayey to silty and calcareous, but is sandy and micaceous toward the base. It is gray green in the upper part, maroon in the middle, and gray in the lower part. The member is about 13 feet thick. (See measured sections 15 and 17.)

The Grayhorse limestone member is medium hard, crystalline, and gray to gray brown. Nodules of iron oxide (limonite) and small clay balls are abundant in this limestone. It is fossiliferous, and averages 0.6 foot in thickness. (See measured section 15.) The Grayhorse can best be identified by the abundance of limonite nodules and clay balls, its color, thickness, and fossils.

The Pony Creek shale member is a silty to sandy micaceous shale and is gray to tan gray in the upper part and maroon in the lower part. Locally, 4- to 6-inch beds of sandstone are present in either the upper or middle parts of this shale; in most exposures they show crossbedding and ripple marks. (See pl. 7.) The Pony Creek shale member averages about 7 feet in thickness. (See measured section 15.)

The Brownville limestone member is medium hard, clayey, and tan gray with a greenish tint. It is massive and weathers blocky to nodular. Maroon stains, derived from the overlying Towle shale member of the Onaga shale, commonly covers the exposed surfaces. This member is 2.3 feet thick. (See measured sections 15 and 16.)

The Brownville limestone member has two kinds of brachiopods (*Marginifera* and *Chonetes*) that are an aid in its identification.

The Brownville limestone member is a good marker bed and is easily identified by its nodular stained surface and its color, thickness, and fossils.

PERMIAN SYSTEM

In Nemaha County all of the rocks of the Permian system are divided into three groups which are, in ascending order, the Admire, Council Grove, and the Chase.

The rocks of the Permian system that crop out in Nemaha County are here discussed according to groups of formations, starting with the oldest (lowermost), the Admire group.

ADMIRE GROUP

The Admire is the basal group of formations in the Permian system in Nemaha County. (See pl. 7.) No erosional break was observed between the rocks of the Admire group and those of the underlying Pennsylvanian system. Many of the formations of the Admire group do not crop out in Nemaha County. Brief descriptions of units which are not exposed were obtained from Condra and Reed (1943) who cite sections measured a few miles north of Nemaha County, from Glenn R. Scott (written communication) for sections in Pottawatomie County, and from the senior author's observations in adjacent counties.

ONAGA SHALE

The Onaga shale is the oldest Permian rock cropping out in Nemaha County. The Onaga consists of three members, which are, in ascending order, the Towle shale member, Aspinwall limestone member, and Hawxby shale member. The average thickness of the Onaga shale is about 31 feet.

The Towle shale member is a clayey noncalcareous tan-gray to gray-green shale, but it also includes some maroon or purple beds in the lower part. (See pl. 7.) This member averages about 20 feet in thickness. (See measured sections 14–16.)

The Aspinwall limestone member is a medium-hard light-gray massive limestone that weathers tan to tan gray. It contains a mixed fauna of pelecypods and brachiopods. The limestone rarely exceeds

1 foot in thickness. (See pl. 7.) (See measured section 13.) The Hawxby shale member is predominantly silty, calcareous, and tan gray or gray-green, but maroon zones are present in its middle part. (See pl. 7.) The maroon shale beds are commonly mottled with green, whereas, the gray-green shale beds are mottled with maroon. Iron stains are common on bedding and fracture planes. A thin lens of soft argillaceous and fossiliferous limestone is in the lower part of the member. The Hawxby is about 10 feet thick. (See measured section 13.)

FALLS CITY LIMESTONE

The Falls City limestone consists of two limestone beds separated by a bed of shale about 5 feet thick. The upper limestone bed, about 2 feet thick, is a coquina of fossil fragments which gives it an oatmeal-like appearance. The limestone is medium hard, tan, and massive. The shale bed is generally clayey, noncalcareous, and tan gray to dark gray. The lower part is fissile, whereas the upper beds are thin bedded. The lower limestone (about 0.5 foot thick) varies from very calcareous shale to soft impure shaly limestone. It is gray, weathers tan and contains many fossil fragments including crinoids and brachiopods. The Falls City limestone is about 7 feet thick. (See measured section 14.)

JANESVILLE SHALE

The Janesville shale does not crop out in Nemaha County. It contains three members, which are, in ascending order, the West Branch shale member, Five Point limestone member, and Hamlin shale member. The descriptions of these members were obtained from exposures in southeastern Nebraska (Condra and Reed, 1943, p. 36) and in Brown and Pottawatomie Counties, Kans. The Janesville averages about 75 feet in thickness.

The West Branch shale member is generally silty calcareous tan-gray to olive-drab and averages 30 feet in thickness. (See pl. 7.) Thin lenses of clayey limestone may be present in any part of the member. Local beds of sandy micaceous shale are in the upper part; these commonly contain wood and leaf fragments.

The Five Point limestone member is a medium-hard tan-gray limestone. (See pl. 7.) In many localities it consists almost entirely of fossil fragments which give it an oatmeal-like appearance. In Nebraska the Five Point limestone member ranges from 1.0 to 5.0 feet in thickness. (Condra and Reed, 1943, p. 36.)

Exposures of the Hamlin shale member were not seen in Nemaha County. In adjacent areas it contains beds of variegated shale in the upper 25 feet. Beneath these beds is the Houchen Creek limestone bed composed entirely of algal deposits. The lower part of the Hamlin shale member contains beds of variegated shale, sandy shale, and sandstone. This member averages about 40 feet thick.

COUNCIL GROVE GROUP

The Council Grove is the middle group of formations in the Permian system in Nemaha County. (See pl. 7.) It is composed of seven shale formations each of which is underlain by a limestone formation.

Units of the Council Grove group crop out in the northeastern part of the county (pl. 6), where some of the limestone beds form conspicuous hillside terraces. The shale beds form the nearly vertical slopes between terraces.

FORAKER LIMESTONE

The Foraker limestone is composed of three members which are, in ascending order, the Americus limestone member, the Hughes Creek shale member, and the Long Creek limestone member. (See pl. 7.) It averages 40 feet in thickness.

The Americus limestone member consists of 2 limestone beds separated by 1 of shale. The upper limestone is hard, gray to blue gray, and averages a foot in thickness. The lower limestone is medium hard, gray, and has a shaly appearance; it grades into calcareous shale in the eastern part of Brown County. This bed does not exceed 0.8 foot in thickness. The intervening shale is silty, calcareous, thin bedded, gray, and averages about 0.8 foot in thickness. Fossils, especially crinoid columnals, occur in both beds of limestone and in the intervening shale. This member averages about 2.6 feet in thickness.

The Americus limestone member is easily recognized by its dark-gray color, its abundance of crinoid columnals, its thickness, and by the two thin beds of limestone separated by shale.

The Hughes Creek shale member is silty, calcareous, and gray to dark gray. Two or more persistent beds of limestone are present in the upper and middle parts of this member, and thin lenses of limestone are present in its lower part. A variety of fossils are abundant in most of the shales and limestones, and fusulinids are especially abundant in the thicker limestone beds. This member is about 32 feet thick. (See measured section 12.) The Hughes Creek is easily identified by the variety and abundance of its fossils, the fusulinid-bearing limestone beds, and by its color.

The Long Creek limestone member is a soft slightly dolomitic massive gray to tan-brown limestone with small pink crystals of strontium sulfate (celestite) common in the upper part. The member rarely forms a conspicuous hillside bench, although it is relatively thick and massive. Fossils are rare or absent. The Long Creek averages about 7 feet in thickness, 8 feet thick over most of its outcrop area and thins toward the north. (See measured section 12.)

The Long Creek limestone member is easily recognized by its soft gray-brown beds and the celestite in its upper part.

JOHNSON SHALE

The Johnson shale is a silty calcareous tan-gray to gray-orange shale. (See pl. 7.) Nodules and plates of calcium carbonate are common in the lower part. The beds of shale vary from thin bedded to blocky. Locally there are some gray-green zones. The Johnson shale averages 17 feet in thickness. (See measured section 12.)

RED EAGLE LIMESTONE

The Red Eagle limestone is about 10 feet thick and consists of three members which are, in ascending order, the Glenrock limestone member, Bennett shale member, and the Howe limestone member. (See pl. 7.)

The Glenrock limestone member is characteristically medium hard, massive, and gray with an abundance of fusulinids and a thickness that is almost invariably 1.2 feet. (See measured section 12.)

The Bennett shale member is a clayey calcareous shale about 7 feet thick that is blocky and gray in the upper part but very thin bedded and dark gray in the lower part. The lower part contains many chitinous brachiopods. (See measured section 12.) The member is easily identified by its color, fossils, and position above the Glenrock limestone member.

The Howe limestone member is a soft clayey tan-brown massive and porous limestone. Microfossils (mainly ostracodes) are very abundant in its upper part. This limestone is about 3 feet thick and does not commonly form hillside benches. (See measured section 12.) The member is easily recognized by its color, microfossils, and position above the Glenrock limestone member.

ROCA SHALE

The Roca shale, a clayey calcareous blocky shale about 15 feet thick, consists of gray, tan, and gray-green beds of shale, with lenticular maroon and purple beds in the lower part; (see pl. 7) and gray-green zones are the most abundant. (See measured section 11.)

GRENOLA LIMESTONE

The Grenola limestone consists of five members which are, in ascending order, the Sallyards limestone member, Legion shale member, Burr limestone member, Salem Point shale member, and the Neva limestone member. (See pl. 7). It is about 28 feet thick.

The Sallyards limestone member is hard gray to tan-gray fossiliferous limestone; that weathers to blocky and irregularly shaped fragments. It averages about 1.5 feet in thickness. (See measured section 11.)

The Legion shale member is a silty calcareous gray nonfossiliferous shale which has a constant thickness of about 2 feet.

The Burr limestone member consists of two or more beds of limestone separated by thin beds of shale. The limestone beds are medium hard, gray, massive, and sparsely fossiliferous. The shale beds are silty, calcareous, and tan. This member is about 4 feet thick. (See measured section 11.)

The Salem Point shale member is poorly exposed in this county. It is silty, calcareous, tan to gray, thin bedded and about 4 feet thick.

The Neva limestone member, about 11 feet thick, consists of alternating layers of limestone and shale. The uppermost limestone bed is 3 to 8 feet thick, soft, and gray brown whereas the other limestone beds are medium hard and gray. Most are massive and porous. The shale beds are silty, calcareous, thin bedded, and dark gray. The thickest shale bed is in the lower part of the member and fossils are common in both limestones and shales. (See measured sections 9 and 10.)

This member is a good marker bed as it is easily recognized by the numerous beds of limestone and the thick bed of dark shale in its lower part. Fusulinids in the lower limestones and shales further aid in its identification.

ESKRIDGE SHALE

The Eskridge shale is mainly clayey and calcareous. (See pl. 7.) Tan and gray-green zones are conspicuous in the upper part of the formation and maroon, purple, and gray-green zones are abundant in the middle and lower parts. In the upper part there is a persistent thin bed of hard massive fossiliferous limestone. The Eskridge shale is about 37 feet thick. (See measured sections 9 and 10.) The Eskridge is easily recognized by its varicolored zones, by the persistent bed of limestone in its upper part, and by its position beneath the Beattie limestone.

BEATTIE LIMESTONE

The Beattie limestone averages about 14 feet in thickness and consists of three members, which are, in ascending order, the Cottonwood limestone member, Florena shale member, and Morrill limestone member. (See pl. 7.) There is a good exposure of the Beattie limestone in a road cut in the NE¼NE¼ sec. 1, T. 6 S., R. 12 E.

The Cottonwood limestone member is a light-gray massive limestone. In most hillside exposures it weathers into 2 or 3 beds that in turn weather into irregularly shaped blocks and small chips. The limestone is not very hard in this county and therefore does not always form the conspicuous rock terrace that it does elsewhere in the state.

Nodules of chert are scattered throughout the limestone, solution channels are present in most of the outcrops, and small fusulinids are abundant. The Cottonwood averages about 5 feet in thickness. (See measured sections 6, 7, and 8.)

The Cottonwood is a key bed inasmuch as it can be easily and definitely identified. Its abundance of small fusilinids, its scattered chert nodules, and its thickness are its outstanding characteristics.

The Florena shale member is silty, calcareous, tan gray, and thin bedded. Fossils are very abundant in its lower part, especially *Chonetes*. This shale is about 5 feet thick. (See measured sections 6 and 7.)

The Morrill limestone member consists of one or more limestone beds that are variable in hardness, gray to tan brown, and porous. Fossils are found in the limestone in some exposures. This member is about 3 feet thick. (See measured sections 6 and 7.)

STEARNS SHALE

The Stearns shale is mainly silty and calcareous. (See pl. 7.) It is tan gray in the upper part and gray green and purple in the lower part. A thin lenticular bed of limestone is near the top. The Stearns shale is about 16 feet thick. (See measured sections 4 and 6.).

BADER LIMESTONE

The Bader limestone consists of three members which are, in ascending order, the Eiss limestone member, Hooser shale member, and Middleburg limestone member. (See pl. 7.) A good exposure of this formation is in a road cut in the NE¼SE¼ sec. 25, T. 25 S., R. 14 E. The formation is about 25 feet thick.

The Eiss limestone member consists of two or more beds of limestone separated by a thick bed of shale. One or more beds of dolomitic limestone, commonly soft, but hard and dense in some outcrops, comprise the upper part of the member. They are tan, contain many small iron specks, and are commonly fossiliferous. The bed of shale is silty and clayey, calcareous, tan gray, and contains calcite-lined geodes. The lower bed of limestone is gray, shaly, and very fossiliferous. This member is about 10 feet thick. The upper limestone is about 3 feet, the shale bed is 5.5 feet, and the lower limestone is 1.6 feet thick. (See measured sections 4–6.) The Eiss is identified by the soft dolomitic bed in the upper part and by the abundance of small high-spiraled gastropods in the lower bed.

The Hooser shale member consists of silty calcareous varicolored shale beds. The shale is gray to tan gray in the upper part, and maroon and gray green in the middle and lower parts. This member contains one or more beds of clayey hard-gray limestone. The Hooser is about 11 feet thick. (See measured sections 4 and 5.) This member is easily identified by its varicolored zone and by its position beneath the Middleburg limestone member.

The Middleburg limestone member consists of one or more beds of massive medium-hard light-gray limestone. In some places a very thin bed of shale is in the middle part of this member. The upper beds of limestone weather porous or cavernous. Small high-spiraled gastropods are abundant in the lower beds. This member is about 4 feet thick. (See measured sections 4 and 5.) The Middleburg is easily identified by its thickness and abundance of high-spiraled gastropods.

EASLY CREEK SHALE

The Easly Creek shale is silty and calcareous, and contains many alternating gray-green and maroon zones. (See pl. 7.) Thin calcareous beds are present in the middle and lower parts. Fossils were not observed in this formation, which is about 16 feet in thickness. (See measured section 4.)

CROUSE LIMESTONE

The Crouse limestone consists of two limestone beds separated by a thick bed of shale. (See pl. 7.) The upper limestone is medium hard, tan, and blocky to platy; pits and calcite-filled cavities (geodes) are abundant. The lower limestone is medium hard, gray, massive, and fossiliferous. The intervening bed of shale is clayey, calcareous, tan gray, and blocky. This formation averages about 11 feet in thickness. The upper limestone is about 3 feet thick, the intervening shale bed about 7 feet thick, and the lower limestone bed is slightly more than a foot thick. (See measured section 4.)

The Crouse limestone is a good marker bed as it is easily recognized by the many thin limestone plates that cover the surface of its outcrop. It forms a prominent hillside bench in the area north of Sabetha.

BLUE RAPIDS SHALE

The Blue Rapids shale, for the most part, is clayey, calcareous, and gray green. (See pl. 7.) A maroon zone is present in the middle part, and thin beds of soft tan-gray limestone are found in the lower part. This shale is about 20 feet thick. (See measured section 3.)

The Blue Rapids shale is identified by its varicolored shale, the thin limestone beds in the lower part, and its position above the easily recognized Crouse limestone.

FUNSTON LIMESTONE

The Funston limestone consists of three or more limestone beds separated by beds of shale. (See pl. 7.) The limestone is hard, dense, gray, and massive; fossils are not abundant. The intervening shale beds are silty, calcareous, and gray. This formation is about 6 feet thick. (See measured section 3.)

SPEISER SHALE

The Speiser shale is clayey, calcareous, and varicolored. (See pl. 7.) Gray-green zones predominate in the upper part, and green and maroon zones are conspicuous in the lower part. A thin but persistent bed of gray hard fossiliferous limestone is present in the upper part of the formation. The Speiser shale is about 17 feet thick. (See measured section 3.)

The Speiser shale can best be identified by its position beneath the chert-bearing Threemile limestone member of the Wreford limestone, by its varicolored zones, and by the persistent thin limestone in the upper part.

CHASE GROUP—WREFORD LIMESTONE

Only the lowermost formation of the Chase group, the Wreford limestone, crops out in this county. (See pls. 6 and 7.) The areal distribution of that part of the Chase group exposed in Nemaha County is discussed under each member of the Wreford limestone. The Wreford limestone is divided into three members which are, in ascending order, the Threemile limestone member, Havensville shale member, and the Schroyer limestone member.

The Threemile limestone member is exposed in an area extending northwest from Sabetha to the State line. It forms conspicuous benches along the State line from sec. 3, T. 1 S., R. 14 E. to the east side of sec. 3, T. 1 S., R. 13 E.

The Threemile limestone is poorly exposed, and its outcrops consist mostly of weathered fragments of chert mantling the shoulder of a hill. This member consists of layers of light-gray fossiliferous limestone alternating with bands of chert, with a gray silty calcareous shale bed in the lower part. The Threemile averages about 8 feet thick and is easily recognized by the abundant chert, and the thin shale zone near its base.

The Havensville does not crop out in Nemaha County as it is covered by slump and slope wash from the Schroyer limestone member and the Sanborn formation. The interval between the Schroyer and Threemile is about 17 feet and this is presumed to be equal to the thickness of the Havensville.

Exposures of the Schroyer limestone member are not abundant, and they consist only of chert fragments and weathered limestone. Exposures of this member can be seen in secs. 5, 8, 15, and 17, T. 1 S., R. 14 E.

The Schroyer is massive medium-hard limestone that contains many lenses and nodules of chert. The chert has a conchoidal fracture, tends to break into small blocks and is gray or light gray. The limestone decomposes more readily than the chert and is generally absent from the weathered exposure. The Schroyer limestone is sparsely fossiliferous and its total thickness is about 10 feet.

QUATERNARY SYSTEM

The most recently deposited sediments in Nemaha County are those of the Quaternary system (pl. 7), almost all of which are unconsolidated; exceptions are local cemented zones. These sediments were deposited by wind, streams, gravity, and glaciers. Stream-deposited material occurs in stream valleys as alluvium and terrace deposits. Wind-deposited materials are found on some of the interstream areas and on the sides of some valleys. Sediments moved by gravity or slope wash are present along the sides of many stream valleys.

GLACIAL DEPOSITS

Several deposits associated with the glacier or glaciers that advanced into northeastern Kansas during the Pleistocene epoch (the great ice age) of the Quaternary period are mapped on plate 6, and their characteristics are summarized in plate 7. Sediments laid down directly by melting ice are mapped as glacial till (*Qgt*); those deposited by melt water coming from the ice are subdivided on basis of grain size and are shown on plate 6 as the map symbol *Qgo*, a gravelly sand, and *Qgo 1* a fine sand. The sediments believed to have been deposited in glacial lakes are shown on plate 6 as *Qgl*. *Qgl* is a silt and is represented on table 1 by the symbol mf. The sediments composing these three units were probably deposited at nearly the same time as the glacial till; they will probably correlate with deposits that Condra, Reed, and Gordon (1947, p. 20–21) have named Grand Island sand and gravel. All of the glacial deposits are probably Kansan in age, although it is possible that glacial deposits of Nebraskan age may be present in the county.

GLACIAL TILL

Glacial till is the most widely distributed stratigraphic unit in Nemaha County. (See pl. 6.) Its outcrops are continuous and most streams in the county have not yet cut through it. In some places it is covered by other Quaternary formations. The best exposures of glacial till can be seen along Kansas Highway 63 and in adjacent areas in the south-central part of the county.

Glacial till is a nonstratified deposit consisting mainly of clay and intermixed particles of silt, sand, granule, pebble, and boulder size. Lenses of fine sand are present throughout the till. The upper part of a soil profile developed in till is chiefly noncalcareous clay loam. It is brown, sandy to pebbly, and friable to crumbly. This upper part grades downward into tan-brown clay which is intermixed with silt- and sand-size particles. Iron stains and stringers and nodules of calcium carbonate are concentrated in this part of the profile. Lenses of sand are common. The lower part of the soil horizon is clayey and calcareous and varies from tan gray to dark gray or blue gray. The dark-gray surface is irregular and may grade upward into tan gray or may show a marked change in color. Lenses of sand and of various sizes and kinds of erratics are common. Large diagonal fractures are generally in all horizons but are most pronounced in the lower horizon. These fractures dip 60° from the horizontal and extend to an unknown depth. Most are filled with limonite and calcium carbonate, and some of the stains penetrate an inch or more into each wall of a fracture. Gravel lenses, some large, are incorporated in the till.

Erratic boulders occur in almost all exposures of till but are not abundant. Only one concentration of boulders was observed in the county; it is located in the SW¼ sec. 5, T. 2 S., R. 13 E. Most of the boulders are quartzite, but granite and other igneous rocks and greenstone and other metamorphic rocks are also represented. Smaller fragments of sandstone, limestone, and chert are less numerous. (See measured section 2.)

The known thickness of the glacial till ranges from a featheredge to 300 feet (Frye and Walters, 1950, p. 151). Test drilling in this county by the Ground Water Division of the U. S. Geological Survey reveals thick sections of blue-gray till and some thick beds of gravel to a depth of about 300 feet beneath the surface.

GLACIAL OUTWASH

Glacial outwash is the material deposited by melt-water streams flowing away from or parallel to an ice front. In Nemaha County, the glacial outwash is largely covered by till. Deposits of glacial outwash were mapped on the basis of the size of their constituent particles as coarse material and fine material (pl. 6).

Gravelly sand deposits are most numerous 1½ miles east and also a few miles southeast of Seneca. Scattered deposits occur 2 miles west of Seneca, a few miles west and south of Sabetha, in the vicinity of Woodlawn and Granada, and about 3 miles northwest of Wetmore. Almost all of the deposits of gravelly sand either at or near the surface are restricted to the northeastern part of the county.

Fine-sand deposits are most numerous in the southwest township of the county, although scattered deposits are present west of Centralia, east of Seneca, south of Corning, west of Wetmore, and west of Granada. Nearly all the outcrops of fine sand are restricted to the south half of the county.

The coarse outwash consists of fine sand with interbedded lenses of medium to coarse gravel. The sieve analysis of the sand and gravel shows an average of 3 percent retained on a ¾-inch sieve, 12 percent on a ⅜-inch sieve, 22 percent on a No. 4 sieve, 29 percent on a No. 16 sieve, and 92 percent on a No. 100 sieve. This coarser outwash contains well-rounded particles of quartz, metamorphic rocks and some igneous rocks; quartz is the main constituent of the various sizes represented. Some cobbles and boulders are present in the gravel. Granitic rocks are weathered to such an extent that their presence in the sediment is indicated only by small fragments of feldspar. In the gravel are occasional "rotten" granite boulders and a few fragments of chert, limestone, and sandstone with about 8 percent of red-brown silt and clay. In some places thick calcium carbonate-cemented zones (conglomerate) are at various positions within the deposit. Cemented zones possibly reflect fluctuations in the position of the water table. Crossbedding is apparent on a freshly exposed surface of conglomerate or sand. Some of the deposits exposed in sandpits and streambanks show the cross section of the channel in which the material was laid down.

The outwash classified as fine sand consists mainly of well-rounded quartz grains but contains particles of basic igneous rocks. About 8 percent of the material is red-brown silt and clay, mostly in the form of thin lenses. Throughout the deposit are small interbedded lenses of gravel. The fine-sand outwash in the southwestern part of the county contains no material large enough to be retained on a No. 16 sieve. Crossbedding is apparent in deposits exposed in streambanks or newly opened pits. Local zones within a deposit are heavily stained with iron. The sand-gravel outwash ranges from a featheredge to about 30 feet in thickness, and it averages about 10 feet in thickness. The fine-sand outwash ranges from a featheredge to 20 feet in thickness and averages about 7 feet in thickness.

GLACIOLACUSTRINE DEPOSITS

Silt occurs in large deposits near the southwestern corner of the county. (See pl. 7.) The largest deposits are in the eastern part of sec. 33, T. 5 S., R. 11 E.; in the NW¼SW¼ sec. 18, T. 4 S., R. 11 E., extending into Marshall County; and in the SE¼SE¼ sec. 34, T. 5 S., R. 12 E., extending into Pottawatomie County.

The glaciolacustrine deposits are composed of fine to coarse silt consisting almost entirely of white to colorless, rounded to angular grains of quartz. It also contains minor quantity of feldspar. Clay particles act as a binder although the amount of clay is small. Clay lenses, 1 to 2 inches thick and 1 to 2 feet long, are locally in these deposits. Bedding is apparent in all deposits, and iron stains are on the bedding planes. The color of the sediment varies from light gray to tan. Glaciolacustrine deposits range from a featheredge to about 50 feet in thickness and average about 30 feet.

SANBORN FORMATION

The Sanborn formation of Quaternary age mantles the interstream areas (pls. 6 and 7) and is present in the headward portions of small tributary valleys and along the base of the valley walls of most streams. Frye and Fent (1947, p. 41–51) have subdivided the formation into members, but it was not feasible to attempt the mapping of such members in the field, inasmuch as to do so would have required a greatly expanded program, including test drilling. The treatment of the Sanborn formation as an undivided unit seems adequate to serve the purpose of a construction-materials inventory.

As defined in this report, the Sanborn formation consists of materials deposited by wind, slopewash, and soil or mantle creep, and also includes materials reworked by intermittent streams. Wind-deposited silt (loess) of both Loveland and Peorian age were identified in Nemaha County but were mapped as part of the Sanborn formation. Their characteristics, except color, are similar. Loess mantles some of the interstream areas and is most extensive in the area extending from Sabetha to Bern and from Baileyville south to Centralia. Other thin, scattered deposits are present in the southwest and south-central parts of the county. Wind-deposited sediment probably occurs along the margins of many of the valleys but is indistinguishable from similar material laid down by other depositional agents.

The loess of the Sanborn formation consists of clayey silt which is gray (Peorian) or gray brown (Loveland). The gray loess is clayey in the upper part and grades into silty clay in the lower part. The *A* horizon and part of the *B* horizon of the soil profile have been thoroughly leached of soluble constituents. The silty clay of the *C* horizon becomes coarser with depth and contains some stringers and nodules of calcium carbonate and nodules of limonite. The gray-brown loess is clayey and noncalcareous in the upper part. It is darker brown, calcareous, and more silty in the lower part. Large seepages of subsurface water are common at the contact of loess and the glacial till that underlies it.

The material of the Sanborn formation deposited by agents other than the wind is mostly a mixture of silt-, clay-, and sand-size particles. It is tan gray, gray, or gray brown. Only in areas where streams cut into a rock formation is there rock debris intermixed with the silt and clay. Chert and limestone fragments are found in the Sanborn formation on the north side of Deer Creek, along Rock and Silver Creeks, and other small streams northeast of Bern. The chert fragments are semirounded to angular, brown to light-gray granules, pebbles, and cobbles and are contained in a brown clay binder.

Along both sides of Turkey Creek there are large quantities of gravity-moved (colluvial) material. This sediment is a dark-gray mixture of clay and silt which contains angular pebbles, cobbles, and boulders of limestone. Many erratics in the Sanborn formation make it difficult to distinguish this formation from glacial till, especially where some or all of the material in the Sanborn formation was derived from glacial till.

Two small lenses of volcanic ash were found in the NW¼ sec. 7, T. 4 S., R. 11 E. The volcanic ash is yellowish white to light gray and contains a high percentage of foreign material. The analysis by Landes (1928, p. 35–36) shows 25 percent is retained on a No. 200 sieve and 24 percent is retained on a No. 300 sieve. Each lens ranges from 1 to 1.5 feet in thickness. The Sanborn formation averages about 8 feet in thickness; it ranges from a featheredge to an estimated maximum thickness of about 16 feet. Loess attains a maximum thickness of 10 feet in the vicinity of Berwick.

TERRACE DEPOSITS

Terrace deposits of Quaternary age are mapped in the valleys of most streams in Nemaha County. (See pls. 6 and 7.) The terrace deposits along the Nemaha River and Turkey Creek average about 0.75 mile in width; maximum width is slightly more than a mile. Terrace deposits along the other streams do not exceed 0.75 mile in width and are generally 0.5 mile or less. A terrace deposit is well exposed along Nemaha River in the NW¼SW¼ sec. 26, T. 2 S., R. 12 E.

The terrace deposits consist of materials laid down by present-day streams in earlier cycles of deposition. They consist mainly of clay-size particles but also contain a high percentage of silt-size particles and are gray or tan gray. Thin lenses of fine sand are abundant in the basal part of the deposits. The sand is composed of particles of quartz and feldspar, and lenses of it range from a few inches to more than 2 feet in thickness. Rounded particles derived locally from limestone are incorporated in some of the sand lenses, and erratics are scattered throughout some deposits. Large quantities of fine sand are disseminated throughout the terrace deposit of Spring Creek. (See measured section 1.)

Terrace height above present flood plains ranges from 3 feet along some of the smaller streams to about 25 feet along most of the length of the Nemaha River. At the Nebraska line the terrace deposit is estimated to be about 40 feet in thickness. Other terrace deposits are probably between 10 and 20 feet thick.

ALLUVIUM

Sediments deposited by streams on their present flood plains (pl. 7) are mapped as alluvium on plate 6. The flood plain is the area adjacent to the stream channel and is covered by water during normal flood stage. Alluvium is found in the valleys of the Nemaha and Black Vermillion Rivers, and Turkey, Deer, Harris, and Spring Creeks. (See plate 6.) Less extensive deposits of alluvium occupy the lower parts of the valleys of smaller tributaries but are not shown on the map because of its small scale. The alluvium deposited by the Nemaha River and Turkey Creek is, in some places, as wide as 0.75 mile although its average width is about 0.25 mile. The alluvium deposited by the Black Vermillion River extends only 1.5 miles into Nemaha County. The flood plains of Deer and Spring Creeks are very narrow.

The alluvium deposited by Spring Creek consists mainly of gray to gray brown fine sand and silt whereas the material deposited by the Nemaha and Black Vermillion Rivers and Turkey, Harris, and Deer Creeks is mostly gray-brown to tan-gray silt and clay interbedded with lenses of fine to coarse sand. In some places the alluvium contains thin lenses of water-rounded material derived locally from limestone. Chert fragments and glacial cobbles and boulders (erratics) are common in the alluvium of Deer Creek. Erratics are almost always incorporated in the alluvium of the other streams.

The thickness of alluvium could not be accurately determined in the absence of test-hole data. It is estimated, however, that its maximum thickness is about 25 feet in the valleys of the Nemaha River and Turkey Creek, and about 20 feet in the valleys of the Black Vermillion River and Spring and Deer Creeks.

INVENTORY OF CONSTRUCTION MATERIALS

This inventory of construction materials in Nemaha County defines the construction materials as they are classified in this report and relates the materials to the map units in which they occur.

Where available, laboratory test data have been included to aid the reader in his evaluation of the materials. The information given in table 1 is based on standard testing procedures of the State Highway Commission of Kansas (1945) and the American Association of State Highway Officials (1947). It is expected that prospects listed in this report will be verified by subsequent augering, drilling, or test pitting and that the materials themselves will be subjected to laboratory tests prior to use in any construction project.

Although many prospect pits and quarries were located, no attempt was made to complete a survey of all possible sources of materials. In relating the geologic formations mapped on plate 6 to the construction materials available in Nemaha County, the fieldman should be aided in his search for the materials needed in a construction project.

AGGREGATE FOR CONCRETE

ENGINEERING AND GEOLOGIC CHARACTERISTICS

Aggregate for concrete is classified as fine aggregate, mixed aggregate, coarse aggregate, and as limestone in table 1 and on plate 6. In this report the distinction is arbitrarily based on the percentage of material retained on a standard No. 4 sieve. The portion of a sample retained on that sieve is designated as the coarse fraction. The material is classified as a coarse aggregate if the coarse fraction is 15 percent or more by weight of the whole sample, as a mixed aggregate if the coarse fraction is between 5 and 14 percent, and as a fine aggregate if the coarse fraction is less than 5 percent. The three aggregates will be considered together because of the standard practice of bringing the grading into specification by "sweetening" or screening.

The materials reported in this and other classifications are exposed at the surface or are under soft or unconsolidated overburden sufficiently thin to permit economical exploitation. Deposits that are overlain by thick or consolidated beds, or are relatively inaccessible, are not included in this inventory because of the additional expense involved in their removal or transportation.

STRATIGRAPHIC SOURCES AND PERFORMANCE CHARACTERISTICS

The following stratigraphic units are active or potential sources of aggregate for concrete.

GLACIAL DEPOSITS

The material deposited as glacial outwash is the only actual or potential glacial source of coarse or mixed aggregate, but it does not meet specifications for use in concrete. Six samples of coarse aggreage were collected from the outwash. (See ca1, ca2, ca3, ca4, ca5, ca6 in table 1 and on pl. 6.) They were obtained from operating pits or prospective sites in the vicinity of Seneca, Woodlawn, and Granada; west of Sabetha; and north of Wetmore. (See pl. 6.) This material is composed of glacial erratics and particles of limestone ranging from boulder to sand size and contains intermixed silt- and clay- size particles. The coarser constituents are particles of limestone, sandstone, quartz, granite, diorite, and quartzite. The minor constituents are particles of basic and acid igneous rocks, metamorphic rocks, chert, and shale. Chert (or chalcedony) is present in all deposits and ranges from a trace to 10 percent of the volume. A firmly cemented conglomeratic zone occurs in most of the deposits and has prevented the removal of part of the material in many of the operated pits.

The material listed as mixed aggregate in table 1 differs from coarse aggregate only in the percentages retained on the various sieve sizes. This material has the same mineral composition as coarse aggregate.

Two samples of fine aggregate were obtained from glacial-outwash deposits (pl. 6). This material is composed of particles of sandstone, quartz, granite, and diorite and other igneous rocks. No opal or chalcedony was observed in it. Large quantities of fine aggregate can be obtained in sec. 18, T. 1 S., R. 11 E.

According to Plummer and Hladik (1948) the clay and silt of the Sanborn formation and of glacial till make high-grade aggregate for concrete when processed ceramically. Frye, Plummer, Runnels, and Hladik (1949) state that ceramic aggregate made of silt and clay is a dense, hard product suitable for use as aggregate for concrete, road-surfacing material, railroad ballast, riprap, and lightweight aggregate.

LIMESTONES OF THE PERMIAN AND PENNSYLVANIAN SYSTEMS

Four limestones of the Permian and Pennsylvanian systems were accepted by the State Highway Commission as crushed rock for the coarse fraction in aggregate for concrete. The limestones are included in table 1 and are: ls. 4, the Utopia limestone member of the Howard limestone; ls. 7, the Church limestone member of the Howard limestone; ls. 12, the uppermost 3 feet of the Cottonwood limestone member of the Beattie limestone; and ls. 13, the bed of limestone at the top and the third bed from the base of the Neva limestone member of the Grenola limestone. The second bed and the basal bed of the Neva limestone member were rejected by the State Highway Commission for use as aggregate for concrete.

CHERT GRAVEL

ENGINEERING AND GEOLOGIC CHARACTERISTICS

Chert gravel is used extensively in eastern Kansas as surface material on light-traffic roads. As defined in this report, it is an unconsolidated sediment composed of angular to subangular gravel-size fragments of chert derived from the weathering and erosion of beds of cherty limestone, incorporated in a matrix of silt-size particles. This material may also contain subrounded to rounded gravel-size fragments of local limestone beds and occasional pebbles, cobbles, or boulders of erratic rocks. The matrix may contain a minor percentage of fine sand or clay or both.

STRATIGRAPHIC SOURCES AND PERFORMANCE CHARACTERISTICS

Only one chert deposit was sampled (cg 1, table 1). The deposit is a part of the Sanborn formation and is composed predominantly of fragments of limestone, although it does contain some particles of chert. The other minor constituents are fragments of sandstone, quartz, opal, rhyolite, felsite, quartzite, and feldspar. This material is unusually coarse, but it includes a small amount of red-brown clay. There is another small deposit of chert gravel in the SE¼NW¼ sec. 29, T. 1 S., R. 13 E. Similar deposits occur in the northwestern part of Brown County just 2 miles across the county line.

MINERAL FILLER

ENGINEERING AND GEOLOGIC CHARACTERISTICS

Material composed predominantly of silt-size mineral particles (50 percent or more of the material passing the No. 200 sieve) is classified in this report as mineral filler. It may have no more than a trace of organic debris, but may contain minor amounts of fine sand or clay. W. E. Gibson of the Road Materials Laboratory, State Highway Commission of Kansas, states (oral communication) that material will qualify for mineral filler only if laboratory tests indicate a low coefficient of cementation.

STRATIGRAPHIC SOURCES AND PERFORMANCE CHARACTERISTICS

Four samples were tested for use as mineral filler and three of them were found to be acceptable. They were collected from terrace and glacial deposits.

TERRACE DEPOSITS

Only one sample was collected from a terrace deposit; that was obtained 0.5 mile east of Seneca. (See mf 1 in table 1 and on plate 6.) This material does not meet the requirements for mineral filler because of its high coefficient of cementation. Other possible sources in terraces and the Sanborn formation were investigated, but the quantity of clay intermixed with silt, the main constituent, is sufficiently high that the coefficient of cementation is excessive. It is doubtful that the terrace deposits or Sanborn formation in Nemaha County contain material acceptable as mineral filler.

GLACIAL DEPOSITS

Many large glaciolacustrine deposits of silt exist in the southwestern part of the county (pl. 6), and three samples (see mf 2, mf 3, and mf 4, in table 1) were obtained from these deposits. The coefficient of cementation of sample mf 2 is 17, and that of mf 3 is 41, both are within acceptable limits. The coefficient of cementation of sample mf 4 is 86 and, in the opinion of W. E. Gibson (oral communication), it is very likely that this material might also be accepted. The specific gravity of all three samples is 2.59 or higher. The liquid limit of mf 2 is 26 whereas that of both mf 3 and mf 4 is 33. The plasticity index of mf 2 is 4, that of mf 3 is 8, and that of mf 4 is 11. The sources of samples mf 3 and mf 4 are readily accessible to two state highways, and other large quantities of comparable material can be obtained in this general area.

RIPRAP

ENGINEERING AND GEOLOGIC CHARACTERISTICS

Riprap, as defined in this report, is any material suitable for protecting earthen fills from erosion. To be acceptable for this use the material must be relatively sound and free from cracks and other structural defects or impurities that would cause it to disintegrate by erosion, slaking, or freezing and thawing. It is desirable that the material be produced in blocks having approximately rectangular faces 7 inches or more in width, and that the specific gravity be 2.0 or higher.

STRATIGRAPHIC SOURCES AND PERFORMANCE CHARACTERISTICS

GLACIAL DEPOSITS

Some erratics in a boulder dump of glacial origin are suitable for use as riprap. Quartzite, the most abundant erratic, is the best suited of these rocks. Quartzite boulders, some as much as 3 feet or more in diameter, occur as field stones in areas mapped as glacial till (pl. 6); their average specific gravity is 2.6. The only large concentration of boulders in Nemaha County is in the SW¼ sec. 5, T. 2 S., R. 13 E. Boulders of all kinds have been used in wash checks and retaining walls but most, other than quartzite, disintegrate rapidly.

LIMESTONES OF THE PERMIAN SYSTEM

Only three limestone units of the Permian system have been accepted for use as riprap. (See ls. 2, ls. 12, and ls. 13 in table 1 and on pl. 6.) Ledges of stone judged to be acceptable are the top bed of the Middleburg limestone member of the Bader limestone (ls. 2); the Cottonwood limestone member of the Beattie limestone (ls. 12); and the top bed and the third bed from the bottom of the Neva limestone member of the Grenola limestone (ls. 13). Other limestone units of the Permian system that crop out in Nemaha County might be acceptable for use as riprap but they are under such thick overburden that it is doubtful if rock could be produced from them economically.

Limestone of the Cottonwood and Neva was used as riprap on the dam at Lake Sabetha. Limestone blocks of the Cottonwood, at the waterline, show some deterioration and some of those at the west end of the dam were replaced in 1939.

LIMESTONES OF THE PENNSYLVANIAN SYSTEM

Five limestones of the Pennsylvanian system were sampled as potential sources of riprap and other construction materials. All proved to be acceptable and are, the Dover limestone member of the Stotler limestone (ls. 11), some of the beds in the Tarkio limestone member of the Zeandale limestone (ls. 16), Reading limestone member of the

Emporia limestone (ls. 8 and ls. 9), Wakarusa limestone member of the Bern limestone (ls. 3), and the Utopia and Church limestone members of the Howard limestone (ls. 4, ls. 5, and ls. 7). The Reading limestone member of the Emporia limestone has been installed as riprap on the dam at Lake Nemaha and appears to be satisfactory.

STRUCTURAL STONE

ENGINEERING AND GEOLOGIC CHARACTERISTICS

Structural stone, as defined in this report, is any hard, dense rock material of adequate bearing strength to be quarried and cut to desired size and shape. Material classified as structural stone is acceptable for use in the construction of buildings, bridge piers and abutments, and retaining walls. Pleasing appearance is required for building stone but is not important to other uses of the same rock.

STRATIGRAPHIC SOURCES AND PERFORMANCE CHARACTERISTICS

GLACIAL DEPOSITS

Glacial erratics in sizes ranging from pebbles to boulders have been used in the construction of fences, porch supports, fireplaces, retaining walls, and foundations. The variation in their color makes erratics an ornamental building stone.

LIMESTONES OF THE PERMIAN AND PENNSYLVANIAN SYSTEMS

Only a few structures in Nemaha County are constructed of limestone, largely because the rock is relatively inaccessible. However, use of the following limestones as structural stone was observed. Stone of the Middleburg limestone member of the Bader limestone was used in the construction of a 2-story school house, now about 100 years old, in the SE¼NW¼ sec. 25, T. 1 S., R. 14 E.; it shows very little effect of weathering and no reaction with the mortar used. Blocks of the limestone at ground level show some pitting but very little slaking. This limestone has a pleasing appearance.

The Cottonwood limestone member of the Beattie limestone was used in the building of a 2-story house located in sec. 12, T. 3 S., R. 14 E. and constructed more than 50 years ago. There is some evidence of reaction with mortar, and of slaking and pitting. This limestone has a pleasing appearance and is the foundation stone in some of the houses in Sabetha.

Rock from the Reading limestone member of the Emporia limestone was used in the construction of a large church in the city of St. Benedict. Although the church was built in 1893, the limestone shows only a slight weathering effect: originally the limestone was brown, but some of the blocks have weathered to a lighter color. The trim stone in this church is the Cottonwood.

Stone from the Aspinwall limestone member of the Onaga limestone was used in building a house and barn located in the SE¼NW¼ sec. 28, T. 1 S., R. 11 E. The only evidence of deterioration is a slight amount of slaking at the ground line.

Stone from the Church limestone member of the Howard limestone has been used as wash-check material and in the construction of the abutments of small bridges. It has not been used in the construction of buildings.

ROAD METAL

ENGINEERING AND GEOLOGIC CHARACTERISTICS

Road metal, known also as surfacing material, base-course material, crushed stone, and aggregate, is defined in this report as any material that may be applied to a road to improve the performance characteristics of that road. Many geologic materials fulfill this requirement, and the list of such materials will vary from one area to another.

STRATIGRAPHIC SOURCES AND PERFORMANCE CHARACTERISTICS

SOURCES OF AGGREGATE FOR CONCRETE

Coarse and mixed aggregate from deposits of glacial outwash have been used extensively on many of the county and township roads. On some roads, this material was mixed with local crushed limestone or sand and gravel obtained from deposits along the Blue River in Marshall County (the source of most of the road metal used in Nemaha County). This glacial material, mixed or used separately, appears to be a good road metal for secondary roads. Mixed aggregate has been used as a filler sand on U. S. Highway 36.

SANBORN FORMATION

Chert gravel from the Sanborn formation, used as road metal in this county, was obtained from the northwestern part of Brown County. It was placed on some county and township roads in the northeastern part of Nemaha County. Field observation shows that chert gravels are well adapted for use as metal on secondary roads as they contain a clay binder and the chert particles are slightly rounded.

CRUSHED ROCK

Most of the limestones of the Permian and Pennsylvanian systems listed in table 1 have been or are being used as road metal. Limestones of the Cottonwood and Neva have been used extensively in the southern half of the county, and were quarried in northern Pottawatomie County, southern and eastern Nemaha County, and western Brown County. Most of the crushed limestone has been placed on county roads. Field observation shows that the Cottonwood is soft and pulverizes more easily than do the limestones of the Neva.

The Church limestone member of the Howard limestone, the Elmont and Reading limestone members of the Emporia limestone, and the Tarkio limestone member of the Zeandale limestone are used extensively as sources of road metal in the northern half of the county. Crushed rock from them is placed on county and township roads in this area, and its performance is satisfactory. Inasmuch as the Harveyville shale member of the Emporia limestone is very thin in the northern part of the county, the Elmont and Reading limestone members are generally quarried as a unit.

SUBGRADE AND EMBANKMENT MATERIAL

ENGINEERING AND GEOLOGIC CHARACTERISTICS

The following definition of subgrade and embankment material is adapted from the specifications compiled for the American Association of State Highway Officials (1937, p. 37–38). Suitable geologic materials for this kind of construction are fine granular unconsolidated sediments, including soil, of which 50 percent or more pass through a No. 200 sieve, coarse granular unconsolidated sediments and broken or crushed consolidated rocks, of which at least 65 percent by weight is retained on a No. 200 sieve, and broken or crushed rock.

STRATIGRAPHIC SOURCES AND PERFORMANCE CHARACTERISTICS

All materials listed in the preceding section are available in small quantities in Nemaha County for the construction of subgrades and embankments. They may be excavated along the alinement of the structure or may be obtained from adjacent areas. The occurrence of these materials is as follows.

FINE GRANULAR SEDIMENTS

Terrace deposits of the Sanborn formation contain almost unlimited quantities of silty clay, but even more extensive are the deposits of glacial till. Glacial till has a high percentage of clay and contains minor amounts of silt and sand. This material crops out in all parts of the county except the area adjacent to Turkey Creek north of St. Benedict.

COARSE GRANULAR SEDIMENTS

Almost all the sand and gravel produced in the county is obtained from deposits of glacial outwash. (See pl. 6.) The alluvium and terrace deposits contain only very small quantities of gravel. In the lower part of the Sanborn formation there are minor quantities of chert gravel.

BROKEN OR CRUSHED ROCK

Most limestones of the Pennsylvanian and Permian systems are durable and generally resist crumbling and solution.

The shales of the Pennsylvanian and Permian systems vary in their physical characteristics. The following silty shales might prove acceptable for use in subgrades or embankments.

- Permian system
  - Chase group
    - Havensville shale member of the Wreford limestone.
  - Council Grove group
    - Easly Creek shale.—(Clayey in basal part.)
    - Hooser shale member of the Bader limestone.—(Silty in northern part of the county but a clayey silt in southern part.)
    - Florena shale member of the Beattie limestone.—(Silty in northern part of county but clayey silt in southern part.)
    - Johnson shale.
    - Hughes Creek shale member of the Foraker limestone.—(Acceptable except for a thin bed of clay near middle.)
  - Admire group
    - Hawxby shale member of the Onaga shale.—(Silty shales predominate.)
- Pennsylvanian system.
  - Wabaunsee group
    - Pony Creek shale member of the Wood Siding formation.
    - Wamego shale.—(A clayey silty shale.)
    - Willard shale.—(Very sandy in southwestern part of county.)
    - White Cloud shale member of the Scranton shale.
    - Aarde shale member of the Howard limestone.
    - Severy shale.—(Clayey in uppermost part.)

The following shales are composed predominantly of clay and are possibly not usable in the construction of subgrades and embankments for that reason.

- Permian system.
  - Council Grove group
    - Speiser shale
    - Blue Rapids shale.—(Silty in part.)
    - Stearns shale.—(Composed of interbedded silty and clayey zones.)
    - Eskridge shale.—(Composed largely of clay shales.)
    - Roca shale.—(Silty only in upper part.)
    - Bennett shale member of the Red Eagle limestone.
  - Admire group
    - Towle shale member of the Onaga shale.—(Varies from a clay shale to a silty or sandy clay shale.)

Pennsylvanian system
  Wabaunsee group
    Plumb shale member of the Wood Siding formation.—(A silty clay.)
    Friedrich shale member of the Root shale.
    Pillsbury shale.—(Silty only in lower part.)
    Harveyville shale member of the Emporia limestone.—(Varies from clayey to silty shale.)
    Auburn shale.—(Predominantly clayey.)
    Soldier Creek shale member of the Bern limestone.—(Clayey in northern part of county, silty farther south.)
    Silver Lake shale member of the Scranton shale.—(A silty clay shale.)
    Cedar Vale shale member of the Scranton shale.

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STRATIGRAPHIC SECTIONS

The following measured sections include at least one of each geologic formation or member that crops out in Nemaha County. The sections were measured by Melville R. Mudge and Ralph E. Skoog.

1. *Section of a terrace deposit in the SW¼SW¼ sec. 26, T. 2 S., R. 12 E.*

Terrace deposit:

	Feet
4. Silty, noncalcareous, dark-gray, blocky; occasional erratics and limestone fragments	3.2
3. Silty, noncalcareous, gray, blocky; columnar structure; occasional erratics	1.2
2. Silty, noncalcareous, tan-gray; columnar structure; occasional erratics	1.4
1. Silty, noncalcareous, tan-gray, blocky	14.8
Total thickness exposed	20.6

Base covered.

2. *Section of glacial till in a streambank in the NE¼NW¼ sec. 29, T. 4 S., R. 11 E.*

Glacial till:

	Feet
4. Clay, sandy, somewhat silty, noncalcareous, dark-gray; many quartz and quartzite pebbles and granules	0.9
3. Silt and clay, sandy, noncalcareous, gray-brown; more clay than above; many small erratics	1.3
2. Silt and clay, sandy, predominantly clay, noncalcareous, tan- to tan-brown, blocky; many small erratics	2.1
1. Silt and clay, calcareous, tan-brown; some sand lenses, numerous calcareous veinlets and pipettes; many sizes and kinds of erratics including some limestone fragments. Lower 40 feet is clay with some silt and sand, calcareous; dark gray; many erratics and unweathered limestone fragments; limonite-filled fractures	14.0
Total thickness exposed	18.3

Base covered.

3. *Section from the Threemile limestone member of the Wreford limestone to the Blue Rapids shale, inclusive, in a road cut in the NW¼SW¼ sec. 3, T. 1 S., R. 14 E.*

	Feet
Soil: Silty and clayey, gray-brown; many chert nodules (1.0± feet).	
Wreford limestone:	
Threemile limestone member:	
18. Weathered limestone and chert covering top of Speiser shale	10.0±
Speiser shale:	
17. Shale, clayey, calcareous, gray and gray-green, thinbedded to blocky; weathers light gray green; some calcium carbonate nodules	3.6
16. Shale, clayey with some silt, calcareous, maroon, blocky	1.7
15. Shale, clayey, calcareous, gray-green mottled with purple in the upper part, violet in middle part, blocky; iron stains on fracture planes	3.5
14. Shale, clayey, calcareous, maroon, blocky; some calcium carbonate nodules on the surface	2.2
13. Shale, silty, noncalcareous, gray-green mottled with purple and maroon near the top, blocky; iron stains on fracture planes	2.1
	13.1
Funston limestone:	
12. Limestone, hard, dense, gray; weathers light gray and gray and blocky; some iron stains	.6
11. Colluvium (covered interval)	1.8
10. Shale, clayey, slightly calcareous, gray, blocky; some silt; weathers light gray to gray green; thin calcareous lens in the upper part	1.7
9. Limestone, hard, dense, gray; weathers light gray and blocky; some fossil fragments	.3
8. Shale, silty, calcareous, gray to light-gray-green, thin-bedded; some iron stains	.8
7. Limestone, hard, somewhat crystalline, gray; weathers tan gray and blocky; curved and shell-like fracture; limonite stains; some microfossils	.2
6. Limestone, soft, tan, heavily limonite stained; weathers tan brown and to irregular blocks; some iron specks	.9
	6.3
Blue Rapids shale:	
5. Shale, clayey, noncalcareous, gray to gray-green; weathers light gray green	11.9
4. Shale, silty, calcareous, light-gray-green, thin-bedded, iron-stained; mottled with maroon in the middle part, calcareous lenses in upper part and calcareous nodules on surface	3.4
3. Limestone, soft, tan-gray; weathers tan and blocky; many iron specks	.9
2. Shale, silty, calcareous, tan-gray, thin-bedded; some iron stains	.6
1. Limestone, soft, tan-gray, tinted light gray-green, blocky to thin-bedded; weathers tan; iron stains on fracture planes	.4
	17.2

Base covered.

4. *Section from the Crouse limestone to the Stearns shale, inclusive, in a road cut in the SE¼NE¼SW¼ sec. 25, T. 1 S., R. 14 E.*

	Feet
Glacial till:	
38. clayey, noncalcareous, brown; numerous small erratics. (5± feet).	
Crouse limestone:	
37. Limestone, medium-hard, massive, tan to tan-brown; weathers tan and blocky; some calcite-filled cavities	1. 7
36. Limestone, medium-hard, tan, thin-bedded; weathers shaly in upper and middle parts; iron specks; some fossils	1. 1
35. Shale, clayey, calcareous, tan-gray; weathers tan and blocky; some iron stains on fracture planes; some calcareous nodules scattered throughout	7. 1
34. Limestone, medium-hard, gray; weathers tan and blocky; some calcite-filled cavities, contains numerous fossils	1. 3
Total thickness exposed	11. 2
Easly Creek shale:	
33. Shale, silty, calcareous, thin-bedded to blocky, light-gray to gray-green; mottled with maroon in middle part; 4 thin wavy calcareous lenses in middle; iron stains on bedding planes; calcareous nodules in upper part	2. 8
32. Shale, silty, blocky; calcareous to very calcareous in lower part; maroon mottled with gray-green	. 4
31. Shale, silty, calcareous, tan-gray, blocky, weathers tan; some iron stains on fracture planes	. 2
30. Shale, silty, very calcareous, blocky; maroon mottled with gray green to tan in upper part	. 4
29. Shale, clayey, calcareous, gray-green, thin-bedded; weathers light gray green	. 3
28. Shale, silty, very calcareous, massive; maroon mottled with some gray green in upper part; weathers blocky	. 4
27. Shale, silty, calcareous, gray-green, thin-bedded; weathers light gray green	. 5
26. Shale, silty, very calcareous, maroon, massive; weathers blocky	. 3
25. Shale, clayey with some silt, calcareous, gray-green, thin-bedded; weathers light gray green	. 4
24. Shale, silty, calcareous, maroon, thin-bedded to blocky	1. 1
23. Shale, silty, calcareous, gray-green, thin-bedded; weathers light gray green	. 8
22. Shale, silty, calcareous, maroon, blocky	1. 1
21. Shale, silty, calcareous, gray-green, thin-bedded to blocky; weathers light gray; two calcareous lenses in middle part	. 9
20. Shale, silty, calcareous, maroon, thin-bedded	1. 7
19. Shale, silty, calcareous, light gray-green, thin-bedded	. 7
18. Shale, silty, calcareous, thin-bedded, maroon; mottled with gray green	. 9
17. Shale, clayey, calcareous, gray-green; weathers tan to gray green; thin-bedded numerous calcareous lenses which weather porous to cavernous	2. 9
Thickness	15. 8

4. *Section from the Crouse limestone to the Stearns shale, inclusive, in a road cut in the SE¼NE¼SW¼ sec. 25, T. 1 S., R. 14 E.*—Continued

	Feet
Bader limestone:	
Middleburg limestone member:	
16. Limestone, hard, tan-gray; weathers tan and blocky; cavernous and porous in upper part; few iron stains. Many fossil fragments in upper part which weather out and leave the surface of the rock with a porous appearance	1.1
15. Limestone, soft, tan-gray; weathers tan; weathers blocky to shaly in lower part; iron specks and stains common	.7
14. Limestone, hard, gray, massive; weathers tan gray; weathers blocky near top and shaly in lower part. Small high-spiralled gastropods abundant in lower part and fossil fragments are common throughout	2.0
Thickness exposed	3.8
Hooser shale member:	
13. Shale, silty, calcareous, tan-gray, thin-bedded; weathers tan; some iron stains	1.6
12. Limestone, hard, dense, gray; weathers light gray and blocky	.1
11. Shale, silty, calcareous, thin-bedded to blocky; gray green in upper part grading to tan gray in lower and middle parts; thin calcareous lenses in lower part; some iron stains on fracture planes	3.1
10. Shale, silty, calcareous, thin-bedded and blocky; maroon with gray-green lenses; mottled with gray green and has thin purple lens near base; calcareous nodules at base; some iron stains	3.1
9. Shale, silty, slightly calcareous, thin-bedded; maroon mottled with gray-green	.6
8. Shale, silty, calcareous, gray-green, weathers gray; thin bedded; some iron stains	.6
7. Limestone, hard, clayey, gray; weathers irregularly and porous; some calcite-lined cavities; speckled with iron stains	.2
6. Shale, silty, calcareous, tan-gray, blocky; weathers light gray	.3
5. Shale, clayey, noncalcareous, gray-green, blocky; weathers gray; some silt	.2
Thickness	9.8
Eiss limestone member:	
4. Limestone, soft, dolomitic, massive, tan; weathers tan brown, irregularly and porous; iron specks abundant	2.9
3. Shale, silty with some clay, calcareous, tan-gray to olive-drab, weathers tan; blocky; iron stains on fracture planes; some calcareous nodules and plates on weathered surface	5.6
2. Limestone, medium-hard, gray to light-gray, massive; weathers light gray and shaly. Small high-spiralled gastropods abundant in the lower part; other fossils abundant	1.6
Thickness	10.1
Total thickness of Bader limestone	23.7

4. *Section from the Crouse limestone to the Stearns shale, inclusive, in a road cut in the SE¼NE¼SW¼ sec. 25, T. 1 S., R. 14 E.*—Continued

	Feet
Stearns shale:	
1. Shale, silty, calcareous, thin-bedded to blocky; gray to gray-green with a purple lens in middle part; lower part weathers somewhat cavernous; some iron stains	5.3

Base covered.

5. *Section of the Bader limestone in a road cut in the NE¼SE¼ sec. 25, T. 2 S., R. 14 E.*

	Feet
Easly Creek shale (1.5 feet).	
Bader limestone:	
Middleburg limestone member:	
16. Limestone, medium-hard, light-gray to blue-gray, massive; weathers tan to light gray; weathers blocky and to irregular plates; a few iron stains. Uppermost part is crystalline and contains fossil fragments which weather out and leave small cavities on surface. Minute high-spiralled gastropods abundant in upper part; other fossils common	3.5
Hooser shale member:	
15. Shale, clayey, calcareous, blocky, gray to olive-drab; weathers gray; some iron stains	0.8
14. Shale, clayey, silty, very calcareous, gray to light-gray, lenticular, blocky; weathers cream to white; some limonite stains	.4
13. Shale, silty, calcareous, tan-gray to olive-drab; weathers gray in upper part, tan to tan gray in middle and lower part; iron stains on fracture planes	2.7
12. Shale, silty, calcareous, tan-gray to olive-drab, blocky; weathers light gray; iron stains on fracture planes	1.2
11. Shale, clayey, calcareous, light-gray, limonite-stained, blocky; weathers nearly white and irregularly; this bed of shale is more resistant to weathering than those above and below it; some silt	1.0
10. Shale, silty, calcareous, gray to olive-drab mottled with maroon in the lower part; weathers light gray to tan gray; some iron stains	2.1
9. Shale, silty, calcareous, maroon, blocky to thin-bedded	1.4
8. Shale, silty, calcareous, gray to gray green mottled with maroon and purple in upper part, thin-bedded to blocky; some iron stains	1.0
7. Shale, silty, noncalcareous, maroon mottled with some gray and gray green, blocky; some limonite stains	.5
6. Shale, clayey, calcareous, gray to olive-drab, blocky to thin-bedded; weathers tan gray; some limonite stains	.7
Thickness	11.8
Eiss limestone member:	
5. Limestone, hard, dense, slightly clayey, light-gray, massive; weathers tan gray, and platy to irregular; some limonite stains; brown fossil fragments abundant; some small sharks' teeth	1.9

5. *Section of the Bader limestone in a road cut in the NE¼SE¼ sec. 25, T. 2 S., R. 14 E.*—Continued

	Feet
Bader limestone—Continued	
Eiss limestone member—Continued	
4. Limestone, medium-hard, light-gray, slightly porous; weathers tan to light gray and blocky to irregular; many minute calcite crystals; and calcite-lined cavities; limonite stains; crystalline zone at top. Small fossils abundant in lower part	1. 4
3. Limestone, soft, somewhat dolomitic, tan-gray, massive; weathers tan and blocky to cavernous; calcite-lined cavities and limonite stains abundant	1. 5
2. Shale, clayey, calcareous, tan-gray, blocky; weathers tan; iron stains on fracture planes; some calcite-filled fractures in upper part	5. 1
1. Shale, silty, calcareous, gray, thin-bedded; weathers light gray; fossils abundant	1. 6
Thickness	11. 5
Base covered.	
Total exposed thickness of Bader limestone	26. 8

6. *Section from the Eiss limestone member of the Bader limestone to the Cottonwood limestone member of the Beattie limestone, inclusive, in a road cut in the NE¼NW¼SE¼ sec. 1, T. 2 S., R. 13 E.*

	Feet
Glacial till:	
16. Clayey, tan to tan-brown; numerous chert nodules and small erratics (5± feet).	
Bader limestone:	
Eiss limestone member:	
15. Limestone, medium-hard, tan, thin-bedded; weathers tan gray; limonite stains on surface	1. 2
14. Shale, clayey, calcareous, tan, thin-bedded; weathers tan to light gray; some iron stains; numerous calcium carbonate nodules on the surface	4. 6
13. Shale, silty, very calcareous, gray; weathers tan gray; some iron stains; very fossiliferous	2. 2
Thickness	8. 0
Stearns shale:	
12. Shale, silty, calcareous, tan-gray, blocky; weathers tan, and cavernous, some calcareous lenses	1. 0
11. Limestone, clayey, tan-gray; weathers blocky; some iron stains	. 3
10. Shale, silty, noncalcareous, gray to olive-drab, blocky; weathers tan gray; calcareous lens in lower part; some iron stains	1. 8
9. Shale, clayey with some silt, calcareous, gray to gray-green with thin maroon lens in middle part, blocky; weathers light gray	3. 6
8. Shale, silty, calcareous, purple, thin-bedded	. 6
7. Shale, silty, calcareous, gray-green, thin-bedded; weathers light gray-green	1. 4
6. Shale, silty, calcareous, purple, blocky	1. 1

6. *Section from the Eiss limestone member of the Bader limestone to the Cottonwood limestone member of the Beattie limestone, inclusive, in a road cut in the NE¼ NW¼SE¼ sec. 1, T. 2 S., R. 13 E.*—Continued

	Feet
Stearns shale—Continued	
5. Shale, clayey, calcareous, gray to light-gray, thin-bedded; weathers light gray; many secondary calcareous lenses which tend to weather cavernous; numerous calcium carbonate nodules and stains in upper and lower parts; some silt	5. 5
Thickness	15. 3
Beattie limestone:	
Morrill limestone member:	
4. Limestone, soft, gray; weathers blocky and porous; numerous iron stains	. 9
3. Limestone, soft, clayey, tan-gray, massive; weathers to irregular blocks which have a shaly appearance; some iron stains	2. 4
Thickness	3. 3
Florena shale member:	
2. Shale, silty, calcareous; tan-gray, thin-bedded, very fossiliferous	3. 9
Cottonwood limestone member:	
1. Limestone, soft, gray to tan-gray, massive; weathers blocky and has a shaly appearance; fusulinids abundant	2. 7
Total exposed thickness of Beattie limestone	9. 9

Base covered.

7. *Section of the Beattie limestone in a road cut in the NE¼NE¼ sec. 1, T. 6 S., R. 12 E., Pottawatomie County, Kans.*

Soil: silty, clayey, gray-brown to gray (1.0± feet).

	Feet
Beattie limestone:	
Morrill limestone member:	
3. Limestone, hard, brown to tan-brown; weathers tan and blocky; limonite nodules; some fossils	. 3
Florena shale member:	
2. Shale, silty with some clay, calcareous, gray to olive-drab, thin-bedded; weathers tan; abundant calcareous plates that are very fossiliferous; fossils abundant	5. 5
Cottonwood limestone member:	
1. Limestone, hard, gray to tan-gray; massive; weathers tan; blocky, and to small irregular chips; some chert nodules near base, fusulinids abundant, other fossils common	4. 8

Underlain by the Eskridge shale.

Total exposed Beattie limestone	10. 6

8. *Section of the Cottonwood limestone member of the Beattie limestone and the Eskridge shale in a streambank in the NW¼SE¼ sec. 1, T. 2 S., R. 13 E.*

	Feet
Beattie limestone:	
Cottonwood limestone member:	
22. Weather limestone	3.0±
21. Limestone, moderately hard, tan-gray, massive; weathers tan, blocky, and irregular. Small fusulinids abundant	1.6
Total exposed thickness of Beattie limestone	4.6±
Eskridge shale:	
20. Shale, silty, very calcareous, tan, massive, weathers light gray and to small irregular blocks; some limonite stains and fossils	1.8
19. Shale, clayey, noncalcareous, gray-green, blocky; weathers light gray green; iron and limonite stains on fracture planes; secondary calcite as fracture fillings; some calcium carbonate stains in upper part; some silt	6.2
18. Shale, clayey, noncalcareous, maroon; mottled with gray green in the upper part; some iron stains	1.3
17. Shale, clayey, slightly calcareous, gray-green, thin-bedded to blocky; weathers light gray green; some iron stains	.4
16. Limestone, medium-hard, clayey; gray with a greenish tint; weathers light gray and blocky to small irregular chips; some iron stains; green stains on surface derived from overlying shale	1.2
15. Shale, clayey, calcareous, gray-green thin-bedded; weathers light gray green; some limonite stains	.2
14. Shale, clayey, calcareous, gray, thin-bedded; weathers light gray; some limonite stains	2.6
13. Shale, silty and clayey, calcareous, massive to blocky; light-green with purple tint near the top; iron stains on fracture planes	3.6
12. Shale, clayey, noncalcareous, lenticular, blocky; purple mottled with gray green in upper part, iron stains on fracture planes	1.1
11. Shale, silty, slightly calcareous, dark-maroon in upper part to light maroon in basal part, mottled with gray green in middle part; blocky; some iron stains on fracture planes; gray green lentil 0.3 foot thick near base	1.5
10. Shale, clayey, calcareous, maroon, blocky; some iron stains	1.8
9. Shale, clayey with some silt, calcareous, gray to gray-green, thin-bedded; weathers light gray green; some iron stains	.6
8. Shale, clayey, noncalcareous, dark-gray, thin-bedded to blocky	.8
7. Shale, clayey, calcareous, maroon, blocky; some silt	1.2
6. Shale, silty, calcareous; purple grading to maroon in lower part, mottled with some gray green in middle part; blocky	2.9
5. Shale, clayey, calcareous, light-green; massive to blocky; limonite stains on fracture planes	1.4
4. Shale, clayey, noncalcareous, purple with maroon tint in upper part, blocky	1.6
3. Shale, clayey with some silt, calcareous, violet mottled and tinted with light gray green in upper part, gray-green lentil in the middle part grading to maroon in lower part, massive to blocky; iron stains on fracture planes	5.4

8. *Section of the Cottonwood limestone member of the Beattie limestone and the Eskridge shale in a streambank in the NW¼SE¼ sec. 1, T. 2 S., R. 13 E.*—Continued

	Feet
Eskridge shale—Continued	
2. Shale, clayey, calcareous, light gray-green; massive, lenticular; some iron stains	1. 0
1. Shale, silty, calcareous, massive to blocky; maroon mottled with some gray-green	4. 1
	40. 7

Base covered.

9. *Section from the Cottonwood limestone member of the Beattie limestone to the Neva limestone member of the Grenola limestone, inclusive, in a road cut in the SE¼ SW¼ sec. 36, T. 5 S., R. 12 E.*

	Feet
Beattie limestone:	
Cottonwood limestone member:	
18. Weathered limestone	1. 0±
Eskridge shale:	
17. Shale, silty and clayey, calcareous, gray-green, blocky to thin-bedded; some iron stains	4. 4
16. Shale, clayey, calcareous, violet to light-gray, thin-bedded; iron stains on fracture planes; some fossils in lower part	3. 3
15. Shale, clayey, calcareous, light-gray, thin-bedded; calcareous plates abundant on weathered surface	3. 5
14. Shale, clayey, slightly calcareous, gray-green, thin-bedded; iron stains on fracture and bedding planes	2. 2
13. Shale, clayey, calcareous, light-gray to violet, thin-bedded to massive; thin limonite-stained zone near middle	3. 1
12. Shale, silty, calcareous, thin-bedded to blocky; violet mottled with gray-green, some iron stains	1. 1
11. Shale, clayey, slightly calcareous, tan-gray, thin-bedded; weathers light gray; some iron stains on bedding planes	1. 2
10. Limestone, hard, dense, brittle, tan-gray; weathers tan and blocky; conchoidal fracture; some iron stains; some microfossils in uppermost part	. 4
9. Shale, clayey, slightly calcareous, gray-green, blocky; thin lens of clayey limestone in upper part; iron stains on fracture planes	1. 7
8. Shale, silty, calcareous, thin-bedded to blocky; purple in lower part and violet in upper part	2. 1
7. Shale, silty; calcareous, gray-green, thin-bedded; some iron stains	. 9
6. Shale, silty noncalcareous, purple, blocky; some clay; some iron stains on fracture planes	3. 1
5. Shale, silty, calcareous, maroon speckled with light-gray, thin-bedded; some calcareous nodules	2. 1
4. Shale, silty, calcareous, gray-green to violet, thin-bedded; some calcareous nodules in upper part	. 6

9. *Section from the Cottonwood limestone member of the Beattie limestone to the Neva limestone member of the Grenola limestone, inclusive, in a road cut in the SE¼SW¼ sec. 36, T. 5 S., R. 12 E.*—Continued

	Feet
Eskridge shale—Continued	
3. Shale, silty, calcareous, thin-bedded; maroon with light-gray-green lens in upper part, contains thin calcareous lenses	2.5
2. Shale, silty, calcareous, gray-green, thin-bedded; weathers light gray green; maroon stains on surface; some limonite stains	1.6
Thickness	33.8
Grenola limestone:	
Neva limestone member:	
1. Limestone, hard, massive; contains thin shale partings; weathers blocky and to irregular chips; some iron stains; badly weathered	8.2
Base covered.	

10. *Section of the Eskridge shale and the Neva limestone member of the Grenola formation in a stream cut in the NE¼SW¼ sec. 1, T. 2 S., R. 13 E.*

	Feet
Eskridge shale:	
10. Shale, gray-green and maroon	2.0±
Grenola limestone:	
Neva limestone member:	
9. Limestone, soft, gray to gray-brown; weathers tan brown and irregularly; some secondary calcite in pore spaces, some microfossils	0.5
8. Limestone, medium-hard, tan-gray, massive, porous; weathers light gray; some maroon stains on the surface; weathers blocky; some fossil fragments	3.1
7. Shale, silty, calcareous, tan-gray, thin-bedded, lenticular; some iron stains and fossils	.1
6. Limestone, medium-hard, gray, massive, porous; weathers tan gray, blocky, and shaly near base; fossil fragments abundant	1.8
5. Shale, silty, calcareous, dark-gray, thin-bedded; weathers gray; fossils common throughout	.8
4. Limestone, medium-hard, gray; weathers light gray and shaly; iron stains on weathered surface; some fusulinids and other fossils	1.4
3. Shale, silty, calcareous, very dark gray, thin-bedded; fossils abundant	1.0
2. Limestone, medium-hard, gray; weathers blocky, some fossils	.3
1 Shale, silty, calcareous, dark-gray, massive to thin-bedded; weathers gray	1.4
Thickness exposed	10.4
Base covered.	

11. *Section of the Grenola limestone and the Roca shale in a streambank in the NW¼SE¼ sec. 1, T. 2 S., R. 13 E.*

(Top covered with slump and debris from a quarry a few feet above.)

	Feet
Grenola limestone:	
Burr limestone member:	
9. Limestone, hard, gray to dark-gray massive, fossiliferous; weathers tan gray and blocky	2.0
8. Limestone, soft, clayey, dark-gray; weathers tan gray, blocky and irregular	.7
Thickness exposed	2.7
Legion shale member:	
7. Shale, silty, calcareous, dark-gray to black, thin-bedded	.3
6. Shale, silty, slightly calcareous, gray; weathers tan to gray	1.9
Thickness	2.2
Sallyards limestone member:	
5. Limestone, hard, light-gray to tan-brown, massive; weathers blocky to irregular	1.5
Total exposed thickness of Grenola limestone	6.4
Roca shale:	
4. Shale, clayey, very calcareous, tan, thin-bedded; some silt and secondary calcium carbonate nodules	0.4
3. Shale, silty, calcareous, light-gray to tan; weathers blocky; iron stains on fracture planes	1.2
2. Shale, clayey, calcareous, gray-green, blocky; weathers gray to tan; iron stains on fracture planes	1.2
1. Shale, clayey, calcareous, light green to olive drab, blocky; weathers gray green to tan; iron stains on fracture planes	2.5
Thickness exposed	5.3

Base covered.

12. *Section from the Howe limestone member of the Red Eagle limestone to the Hughes Creek shale member of the Foraker limestone, inclusive, in a streambank in the NE¼SW¼ sec. 1, T. 2 S., R. 13 E.*

Slump: fragments of green and maroon shale and platy limestone. (8± feet).

	Feet
Red Eagle limestone:	
Howe limestone member:	
16. Limestone, soft, clayey, yellow-brown to tan, massive; weathers porous to irregular	2.2
Bennett shale member:	
15. Shale, clayey, calcareous, gray, blocky	.2
14. Shale, clayey, calcareous; some silt, dark-brown to black, blocky to thin bedded; weathers gray; fossiliferous	6.8
	7.0

12. *Section from the Howe limestone member of the Red Eagle limestone to the Hughes Creek shale member of the Foraker limestone, inclusive, in a streambank in the NE¼SW¼ sec. 1, T. 2 S., R. 13 E.*—Continued

	Feet
Red Eagle limestone—Continued	
Glenrock limestone member:	
13. Limestone, medium-hard, gray to tan; weathers light gray to tan brown and blocky; fossiliferous	1. 2
Total exposed thickness of Red Eagle limestone	10. 4
Johnson shale:	
12. Shale, silty, calcareous, tan-gray to olive-drab, thin-bedded to blocky; weathers tan to light gray; heavily limonite stained in lower part; limonite and iron stains on fracture planes	11. 1
11. Shale, silty, calcareous, gray to gray-orange, massive to thin-bedded; weathers light gray; calcium carbonate nodules near base	4. 1
10. Shale, silty, calcareous, olive-drab, massive to thin-bedded; calcium carbonate plates common	2. 6
Thickness	17. 8
Foraker limestone:	
Long Creek limestone member:	
9. Limestone, soft, slightly dolomitic, tan to tan-brown, massive; weathers to very irregular blocks	3. 1
8. Limestone, soft, clayey in upper part, slightly dolomitic, tan-gray, massive; weathers tan and blocky; heavily limonite stained in upper part; middle part contains some secondary calcite crystals	3. 6
7. Limestone, soft, gray to tan-brown; weathers blocky; some iron and limonite stains	1. 9
Thickness	8. 6
Hughes Creek shale member:	
6. Shale, silty, slightly calcareous, dark-gray, massive to blocky; weathers gray	3.9
5. Shale, silty, slightly clacareous, dark-gray; weathers gray	2. 9
4. Shale, silty, with some clay, calcareous, gray, thin-bedded to blocky; weathers light gray; very fossiliferous with fusulinids exceedingly abundant	2. 2
3. Limestone, medium-hard, clayey, gray, massive; weathers light gray and blocky to shaly; fossiliferous	1. 1
2. Shale, clayey with some silt, slightly calcareous very dark gray, thin-bedded to blocky; weathers gray; fossils abundant	2. 4
1. Limestone, medium-hard; light gray mottled with dark gray; weathers blocky; fusulinids and other fossils abundant	1. 5
Thickness exposed	14. 0
Total exposed thickness of Foraker limestone	22. 6

Base covered.

13. *Section of part of the Falls City limestone down into the Towle shale member of the Onaga shale in a streambank in the SE¼NW¼ sec. 1, T. 2 S., R. 13 E.*

	Feet
Slump and glacial till (5± feet).	
Falls City limestone:	
15. Shale, clayey with some silt, noncalcareous, black, thin-bedded; weathers gray; some iron stains on bedding planes	2.2
14. Limestone, soft, gray, blocky; weathers shaly in upper part; some fossils	.6
13. Shale, silty, very calcareous, gray to dark-gray, thin-bedded	1.0
12. Limestone, hard, dense, dark-gray; weathers gray to tan and irregularly; fossils very abundant	.2
Thickness exposed	4.0
Onaga shale:	
Hawxby shale member:	
11. Shale, silty, calcareous, dark-gray, weathers light gray; weathers thin-bedded in upper part and blocky in lower part	1.9
10. Shale, silty, very calcareous, gray to tan; weathers blocky and irregular; limonite and iron stains on fracture planes	1.3
9. Shale, silty, calcareous, maroon mottled with gray-green, massive; weathers blocky; calcium carbonate nodules abundant in lower part	2.2
8. Shale, silty, very calcareous, gray-green mottled with some maroon, massive; weathers blocky; limonite and iron stains on fracture planes; calcium carbonate nodules abundant throughout. Some fossils	2.6
7. Limestone, soft, clayey, light-green, weathers gray green and blocky; fossiliferous	.5
6. Shale, clayey, slightly calcareous, maroon mottled with green in upper part; blocky but becomes thin bedded in upper part; limonite stains on fracture planes	2.1
Thickness exposed	10.6
Aspinwall limestone member:	
5. Limestone, medium-hard, light-gray; weathers tan to tan brown; fossils abundant	0.8
Towle shale member:	
4. Shale, clayey with some silt, calcareous, tan to dark-gray, thin-bedded to blocky; weathers blocky to irregular	4.2
3. Shale, silty, noncalcareous, gray and light-green, blocky	1.9
2. Shale, silty, very calcareous, green, blocky; limonite stains on fracture planes	1.8
1. Shale, silty, calcareous, gray to light-green, blocky	4.0
Thickness exposed	11.9
Total exposed thickness of Onaga shale	22.5

Base covered.

14. *Section of the Falls City limestone and the Hawxby shale member of the Onaga shale in a bank in the SW¼NW¼ sec. 1, T. 2 S., R. 13 E.*

Glacial till: clay with some fine sand and erratics; tan brown (4± feet).

	Feet
Falls City limestone:	
4. Limestone, medium-hard, tan; weathers tan gray and blocky; some limonite stains; oatmeal texture because of very abundant fossil fragments	1.9
3. Shale, clayey, noncalcareous, thin-bedded to very thin bedded tan-gray in upper part to dark-gray in lower part	4.4
2. Shale, silty, very calcareous, tan-gray, thin-bedded; weathers tan; fossil fragments abundant	.4
Thickness exposed	6.7
Onaga shale:	
Hawxby shale member:	
1. Shale, clayey and silty, gray, blocky; weathers light gray; some iron stains	9.0

Base covered.

15. *Section from the Towle shale member of the Onaga shale into the Plumb shale member of the Wood Siding formation along a streambank in the NE¼SW¼ sec. 23, T. 1 S., R. 13 E.*

Glacial till and colluvium (4± feet).

	Feet
Onaga shale:	
Towle shale member:	
8. Shale, clayey, noncalcareous, maroon near base, gray-green in upper part, blocky	2.3
Wood Siding formation:	
Brownville limestone member:	
7. Limestone, soft, tan-gray, iron-stained; weathers tan and blocky to nodular; some solution channels, fossiliferous	1.9
Pony Creek shale member:	
6. Shale, sandy, micaceous, calcareous, gray to tan-gray, blocky to thin-bedded; weathers gray; calcareous lenses in upper part; iron stains on fracture planes	2.9
5. Shale, silty, micaceous, slightly sandy, noncalcareous, maroon mottled with gray green, thin-bedded to blocky, limonite stained	4.1
Thickness	7.0
Grayhorse limestone member:	
4. Limestone, crystalline, medium-hard, gray; weathers tan gray, and thin bedded to blocky; limonite nodules abundant; fossiliferous	.5
Plumb shale member:	
3. Shale, clayey, calcareous, gray-green to gray, blocky; calcium carbonate-filled fractures; some silt	2.1

15. *Section from the Towle shale member of the Onaga shale into the Plumb shale member of the Wood Siding formation along a streambank in the NE¼SW¼ sec. 23, T. 1 S., R. 13 E.*—Continued

	Feet
Wood Siding formation—Continued	
Plumb shale member—Continued	
2. Shale, clayey, very calcareous; blocky; maroon mottled with gray-green; many pits and pores	.9
1. Shale, silty, slightly sandy, micaceous, noncalcareous, maroon	3.8
Thickness exposed	6.8
Total exposed thickness of Wood Siding formation	16.2

Base covered.

16. *Section of the Towle shale member of the Onaga shale and Brownville limestone member of the Wood Siding formation in a road cut in the SW¼NW¼ sec. 1, T. 2 S., R. 13 E.*

Glacial till: clayey, noncalcareous, tan-brown; numerous erratics (5± feet).

	Feet
Onaga shale:	
Towle shale member:	
5. Shale, clayey, calcareous, tan, blocky	1.2
4. Shale, silty, calcareous, tan to light-gray, thin-bedded	5.5
3. Shale, clayey, slightly calcareous, dark-green in lower part to gray and light-gray-green in upper part, blocky; iron stains on fracture planes; purple tint near top	8.4
2. Shale, silty, calcareous, maroon mottled with green, thin-bedded to blocky; some mica; heavily limonite stained in upper part	6.8
Thickness exposed	21.9
Wood Siding formation:	
Brownville limestone member:	
1. Limestone, medium-hard, clayey, tan-gray to gray-green, massive; weathers tan gray to tan brown and blocky to irregular small fragments; fossils abundant. Thickness	2.8

Underlain by the Pony Creek shale member.

17. *Section of the Plumb shale and Nebraska City limestone members of the Wood Siding formation in a streambank in the SE¼SW¼ sec. 23, T. 1 S., R. 13 E.*

Glacial till and colluvium: clayey to sandy, gray to gray-brown; numerous erratics (11.5 feet).

	Feet
Wood Siding formation:	
Plumb shale member:	
3. Shale, slightly sandy and micaceous, noncalcareous; maroon mottled with gray; limonite nodules	6.2
2. Shale, micaceous, slightly sandy, noncalcareous, gray, thin-bedded; iron stains in upper part	4.3
	10.5
Nebraska City limestone member:	
1. Limestone, clayey, soft, tan-gray, blocky; weathers shaly; very fossiliferous	2.2
Total exposed thickness of Wood Siding formation	12.7

Base covered.

18. *Section of the Plumb shale member of the Wood Siding formation down into the Friedrich shale member of the Root shale in a streambank in the SE¼SW¼ sec. 23, T. 1 S., R. 13 E.*

	Feet
Wood Siding formation:	
Plumb shale member:	
13. Shale, slightly sandy and micaceous, noncalcareous, maroon mottled with gray; some limonite nodules	6. 2
12. Shale, micaceous, slightly sandy, noncalcareous, gray, thin-bedded; iron-stained in upper part	4. 3
Thickness exposed	10. 5
Nebraska City limestone member:	
11. Limestone, argillaceous, soft, tan-gray, massive; weathers shaly; *Derbyia*, *Composita*, *Meekella*, contains echinoid spines, crinoid columnals, and bryozoans	2. 2
Total exposed thickness of Wood Siding formation	12. 7
Root shale:	
French Creek shale member:	
10. Shale with coal bed	2. 0
9. Limestone, medium-hard, gray to gray-brown; weathers tan gray and shaly; has crystalline appearance because of abundance of fossils	1. 6
8. Shale, clayey, slightly calcareous, gray-brown, thin-bedded, limonite-stained; weathers tan	. 2
7. Coal, black, blocky; light gray clay beneath; limonite stains abundant	. 1
6. Shale, silty, noncalcareous, tan-gray, weathers tan, and thin bedded to blocky; slightly sandy and micaceous in upper part, limonite stains and plates abundant in upper part	8. 2
5. Shale, clayey, noncalcareous, gray to tan-gray, thin-bedded; some iron stains on fracture planes; thin white-shelled pelecypods near top	8. 1
Thickness	20. 2
Jim Creek limestone member:	
4. Limestone medium-hard, gray to gray-green; weathers light gray and blocky to shaly; fossiliferous	. 6
Friedrich shale member:	
3. Shale, silty with some clay, gray-orange, blocky; weathers tan gray; fossiliferous	. 9
2. Shale, clayey, calcareous, gray, blocky; iron stains on fracture planes; thin-bedded in upper part	6. 5
1. Shale, silty clayey, calcareous, gray, massive to blocky; weathers gray green; iron stains on fracture planes	3. 2
Thickness exposed	10. 6

Base covered.

19. *Section of a part of the Friedrich shale member of the Root shale in a streambank in the SE¼SW¼ sec. 23, T. 1 S., R. 13 E.*

Glacial till: sandy clay with numerous erratics (3± feet).
Root shale:
Friedrich shale member:

	Feet
5. Shale, clayey, calcareous, maroon mottled with some gray, blocky	2.0
4. Shale, silty, calcareous, tan-gray mottled with brown and gray-green, blocky, lenticular; calcium carbonate nodules abundant	.6
3. Shale, clayey, calcareous, gray mottled with maroon; blocky; calcium carbonate nodules abundant	6.3
2. Shale, silty, calcareous, gray to gray-green, thin-bedded; some iron stains. Very fossiliferous lens near top	1.4
1. Shale, very calcareous, gray, blocky; weathers light gray; some fossils	1.5
	11.8

Base covered.

20. *Section of part of the Dover limestone member of the Stotler limestone in a streambank in the SE¼SW¼SW¼ sec. 23, T. 1 S., R. 11 E.*

Soil and glacial till (5±feet).
Stotler limestone:
Dover limestone member:

	Feet
1. Limestone, medium-hard, gray, massive; weathers tan gray, blocky, and to small chips; limonite nodules abundant; fossils very abundant	5.7

Base covered.

21. *Section from the Dover limestone member of the Stotler limestone to the Willard shale, inclusive, in a road cut in the SE¼NE¼ sec. 23, T. 1 S., R. 11 E.*

Soil: silty, gray-brown; some limestone fragments (1± foot).
Stotler limestone:
Dover limestone member:

	Feet
15. Limestone, weathered, medium-hard, tan-gray, nodular to blocky; some iron stains and algae	2.2
14. Limestone, medium-hard, tan-brown with brown specks; weathers gray-brown and blocky; some iron stains	.6
Thickness exposed	2.8
Pillsbury shale:	
13. Covered interval; some maroon and gray green shales exposed in roadbed	10.1
12. Shale, clayey, noncalcareous, sandy and micaceous in upper part, thin-bedded to blocky, gray-green mottled with maroon; some thin maroon lenses; some iron stains	11.4
11. Shale, silty, noncalcareous, maroon, blocky	.7
10. Shale, silty, slightly calcareous, gray-green; weathers tan gray; some iron stains	3.6
Thickness	25.8

21. *Section from the Dover limestone member of the Stotler limestone to the Willard shale, inclusive, in a road cut in the SE¼NE¼ sec. 23, T. 1 S., R. 11 E.*—Continued

	Feet
Zeandale limestone:	
Maple Hill limestone member:	
9. Limestone, medium-hard, gray, weathers tan gray and blocky; some iron stains; Weathered limestone has I-beam appearance. Small fusulinids abundant, other fossils common	.7
Wamego shale member:	
8. Shale, silty with some clay, noncalcareous, gray-brown, thin-bedded; weathers tan gray; some limonite stains	12.5
7. Shale, silty, calcareous, gray to gray-green, thin-bedded; numerous limestone lenses which contain clay balls and limonite nodules; some fossils	2.1
6. Shale, silty, noncalcareous, gray-green mottled with maroon, blocky; some limonite stains	.9
5. Shale, silty, noncalcareous, maroon mottled with gray-green, blocky; some limonite stains	2.1
	17.6
Tarkio limestone member:	
4. Limestone, hard, somewhat dense, massive, gray-brown; weathers tan brown; weathers blocky to somewhat shaly near base; iron stained and some iron nodules on the surface. Large fusulinids very abundant, other fossils common, small algal nodules abundant in upper part	4.9
Total thickness of Zeandale limestone	23.2
Willard shale:	
3. Shale, silty, calcareous, gray-green, thin-bedded; weathers tan gray; some limonite stains	.8
2. Shale, silty, calcareous, maroon, thin-bedded; limonite stains and nodules in upper part	.8
1. Shale, silty, slightly calcareous, tan-gray to gray becoming gray-green in upper part, thin-bedded; weathers tan gray; some limonite stains on surface	28.3
Thickness exposed	29.9

Base covered.

22. *Section of the Tarkio limestone member of the Zeandale limestone and Willard shale in a streambank in the NE¼NW¼ sec. 31, T. 5 S., R. 11 E.*

Till: silty and clayey with some sand; red brown; small erratics (4± feet).

	Feet
Zeandale limestone:	
Tarkio limestone member:	
7. Limestone, hard, brown to tan-brown, limonite stained; weathers blocky to nodular; large fusulinids abundant	1.4

22. *Section of the Tarkio limestone member of the Zeandale limestone and Willard shale in a streambank in the NE¼NW¼ sec. 31, T. 5 S., R. 11 E.*—Continued

	Feet
Zeandale limestone—Continued	
Willard shale:	
6. Sandstone, medium fine-grained, very micaceous, gray-brown, massive; weathers tan; limonite nodules and flakes; some crossbedding	8.8
5. Shale, sandy, very micaceous, gray to dark-gray, thin-bedded; weathers light gray; some iron stains	.5
4. Sandstone, very fine grained, micaceous, soft, massive, gray, crossbedded; weathers tan gray; some calcium carbonate cement and iron nodules	1.8
3. Thick sandstones and thin shale partings; shales grade laterally into sandstones; sandstones are micaceous, noncalcareous; and crossbedded to massive; shales are sandy, micaceous, thin bedded, and have carbon stains on bedding planes	2.1
2. Sandstone, soft, calcareous, crossbedded; thin shale lentils; some carbon stains and limonite nodules	1.9
1. Sandstone, grading down into shale; shale is gray to dark gray, massive to bedded; sandstone is fine grained, micaceous, massive to thin bedded, and contains many ripple marks and clay balls	4.1
Thickness exposed	19.2

Base covered.

23. *Section from the Tarkio limestone member of the Zeandale limestone to the Burlingame limestone member of the Bern limestone, inclusive, in a road cut along the east side of sec. 30, T. 1 S., R. 12 E.*

Soil: silty, gray-brown (1± foot).

	Feet
Zeandale limestone:	
Tarkio limestone member:	
25. Limestone, medium-hard, dense, gray-brown, massive, weathers brown and blocky, conchoidal fracture. Large fusulinids very abundant	1.4
Willard shale:	
24. Shale, silty, slightly sandy and micaceous, noncalcareous, tan-gray to gray, thin-bedded; sandstone lenses in upper part; limonite plates and nodules very abundant on weathered surface	30.0
Emporia limestone:	
Elmont limestone member:	
23. Limestone, hard, somewhat dense, gray to dark-gray; weathers tan gray and blocky; some limonite stains and nodules; fractures to small elongated blocks. Small fusulinids and other fossils common	1.3
22. Shale, clayey, noncalcareous, tan-gray, blocky; weathers tan; some limonite stains	1.6
21. Limestone, hard, slightly crystalline, brown to gray-brown; weathers tan; heavily limonite stained; some fossil fragments	2.2
20. Limestone, medium-hard, tan-gray mottled with tan; weathers blocky to platy; some iron stains. Some fossil fragments	.5

23. *Section from the Tarkio limestone member of the Zeandale limestone to the Burlingame limestone member of the Bern limestone, inclusive, in a road cut along the east side of sec. 30, T. 1 S., R. 12 E.*—Continued

	Feet
Emporia limestone—Continued	
Elmont limestone member—Continued	
19. Shale, silty, calcareous, tan-gray, thin-bedded; weathers tan; some iron stains in upper part	.2
18. Limestone, medium-hard, semi-crystalline, tan-gray mottled with light-gray-green; weathers tan and blocky; some iron stains and fossil fragments	.2
Thickness exposed	6.0
Harveyville shale member:	
17. Shale, clayey, calcareous, gray, thin-bedded; weathers tan gray; some iron stains	2.6
Reading limestone member:	
16. Limestone, hard, somewhat dense, gray to dark-brown, massive; weathers tan brown, blocky and to irregular fragments; heavily limonite stained; 4 limestone beds separated by 3 shale partings; fossiliferous	2.6
Total thickness of Emporia limestone	11.2
Auburn shale:	
15. Shale, silty, very calcareous, gray to light-gray, blocky to nodular; weathers light gray; some iron stains; fossiliferous	1.1
14. Shale, clayey with some silt, calcareous, tan-gray, blocky; weathers tan; numerous thin calcareous lenses and heavily limonite stained in upper part; some iron stains on fracture planes	9.1
13. Shale, silty, very calcareous, tan to yellow; blocky to thin-bedded; iron stains on bedding planes; limonite plates and nodules abundant on weathered surface	3.6
12. Shale, clayey with some silt, calcareous, gray, thin-bedded; weathers gray green	1.7
	15.5
Bern limestone:	
Wakarusa limestone member:	
11. Limestone, clayey, tan-gray; weathers tan and blocky; some iron stains and fossils	.4
10. Shale, silty, calcareous, gray-green, thin-bedded; weathers tan gray; some fossils	.2
9. Limestone, soft, clayey, tan-gray tinted with green; weathers tan and to irregular blocks; iron specks and stains	.5
8. Shale, silty, calcareous, gray-brown to gray, thin-bedded; weathers light gray; some iron stains	.7
7. Limestone, soft, tan-brown; weathers tan and nodular; iron stains on fracture planes; some fossils	.4
6. Shale, silty, calcareous, gray, thin-bedded; fossiliferous; weathers light gray	.2
5. Limestone, soft, tan-brown; weathers tan and blocky; heavily limonite stained and some limonite specks; some fossils	.8
	3.2

23. *Section from the Tarkio limestone member of the Zeandale limestone to the Burlingame limestone member of the Bern limestone, inclusive, in a road cut along the east side of sec. 30, T. 1 S., R. 12 E.*—Continued

	Feet
Bern limestone—Continued	
Soldier Creek shale member:	
4. Shale, silty, noncalcareous, gray, blocky; weathers light gray green; iron stains and nodules abundant	5. 2
Burlingame limestone member:	
3. Limestone, soft, red-brown to tan-gray, earthy; porous; many limonite-filled tubes and specks	1. 4
2. Shale, largely covered	7. 5
1. Limestone, hard, gray to gray-brown, weathers tan gray and blocky; limonite specks and nodules; fossil fragments very abundant	. 9
Thickness exposed	9. 8
Total exposed thickness of Bern limestone	18. 2
Base covered.	

24. *Section from the Willard shale to the Harveyville shale member of the Emporia limestone, inclusive, in a streambank in the NE¼NW¼ sec. 1, T. 6 S., R. 11 E., Pottawatomie County, Kans.*

	Feet
Soil: silty and clayey, dark-gray (2± feet).	
Willard shale:	
6. Shale, clayey, noncalcareous, gray to light-gray, thin-bedded; limonite stained near base	2. 1
Emporia limestone:	
Elmont limestone member:	
5. Limestone, hard, somewhat dense, gray to dark-gray, massive; weathers tan gray and blocky; fractures to form elongated blocks; iron stains on fracture planes. Small fusulinids and other fossils	1. 3
4. Shale, clayey, calcareous, gray, blocky; weathers light gray; some iron stains	. 9
3. Limestone, hard, gray, weathers tan gray and blocky; thin shale lentil in middle part; some iron stains	1. 1
Thickness	3. 3
Harveyville shale member:	
2. Shale, silty to clayey, very calcareous, gray to gray-green, blocky; some iron stains	. 9
1. Shale, clayey, calcareous, gray, weathers light gray; thin-bedded in part, remainder blocky	4. 2
Thickness exposed	5. 1
Total exposed thickness of Emporia limestone	8. 4
Base covered.	

25. *Section from the Elmont limestone member of the Emporia limestone to the Auburn shale, inclusive, in a road cut in the SW¼SW¼ sec. 36, T. 5 S., R. 11 E.*

Glacial till: sandy clay, tan-brown to gray-brown; sand and erratics at base (4±feet).

Emporia limestone:

	Feet
Elmont limestone member:	
9. Limestone, medium-hard, somewhat dense; dark-gray; weathers tan and blocky; fractures to small elongated blocks; some iron stains; fossiliferous	1. 2
8. Shale, silty, calcareous, gray to tan-gray, thin-bedded; weathers tan gray; fossiliferous	. 7
7. Shale, clayey, calcareous, gray, blocky; weathers light gray; some iron stains	. 5
6. Conglomerate; well cemented in lower part; many limestone fragments, clay balls; some limonite stains nodules and fossils	. 7
Thickness	3. 1
Harveyville shale member:	
5. Shale, clayey with some silt, calcareous, gray to gray-green, thin-bedded to blocky; some mica; weathers gray; some iron stains on fracture planes	9. 7
Reading limestone member:	
4. Limestone, hard, dense, gray; weathers gray brown and blocky; thin shale partings near top and base; fossiliferous	2. 4
Total thickness of Emporia limestone	15. 2
Auburn shale:	
3. Shale, silty, calcareous, gray, thin-bedded; weathers tan gray; calcareous zone near middle; iron stains on fracture planes; some fossils	1. 1
2. Limestone, medium-hard, gray; weathers tan gray and blocky; thin-bedded zone in middle part; iron stained and many limonite nodules; very fossiliferous	. 6
1. Shale, silty, calcareous, gray to tan-gray, thin-bedded to blocky; many calcareous lenses; fossiliferous	6. 6
Thickness exposed	8. 3

Base covered.

26. *Section from the Reading limestone member of the Emporia limestone to the Burlingame limestone member of the Bern limestone in a road cut in the NW¼ NW¼ sec. 10, T. 1 S., R. 12 E.*

Glacial till: clayey, gray-brown; some erratics (6±feet).

Emporia limestone:

	Feet
Reading limestone member:	
26. Limestone, hard, dense, gray to brown, massive; weathers tan brown and blocky; 3 limestone beds separated by 2 shale partings; fossiliferous	2. 8

26. *Section from the Reading limestone member of the Emporia limestone to the Burlingame limestone member of the Bern limestone in a road cut in the NW¼ NW¼ sec. 10, T. 1 S., R. 12 E.*—Continued

	Feet
Auburn shale:	
25. Shale, silty, calcareous, tan-gray, thin-bedded, heavily limonite stained; weathers tan; fossiliferous	. 4
24. Limestone, clayey, medium-hard, dense, gray, weathers tan gray and blocky; some iron stains; some fossils	. 5
23. Shale, clayey with some silt, calcareous, gray-brown, thin-bedded; weathers tan; limonite stained. Thin very fossiliferous zone near base; some fossils in rest of shale	. 4
22. Limestone, clayey, medium-hard, gray; weathers light gray and nodular; some iron stains; fossiliferous	. 5
21. Shale, silty, calcareous, tan-gray, thin-bedded to blocky; weathers tan; some iron stains. Upper part fossiliferous	5. 7
20. Limestone, medium-hard, somewhat crystalline; gray mottled with gray-green; weathers thin-bedded to blocky; some limonite nodules; very fossiliferous	. 3
19. Shale, clayey, calcareous, gray, thin-bedded; weathers tan gray; some iron stains	. 1
18. Limestone, medium-hard, gray mottled with gray-green, weathers tan and blocky. Fossils abundant and white when weathered	. 3
17. Shale, silty, calcareous, tan to yellow, massive to blocky; many calcareous nodules on surface; some iron stains	2. 7
16. Shale, clayey, slightly micaceous, noncalcareous; gray-green to gray, thin-bedded to blocky; some iron stains on surface	9. 5
Thickness	20. 4
Bern limestone:	
Wakarusa limestone member:	
15. Limestone, soft; tan brown; weathers blocky; heavily iron stained. Fusulinids abundant, other fossils common	. 7
14. Shale, clayey, calcareous, tan-gray, thin-bedded; heavily limonite stained in lower part	. 4
13. Limestone, soft, tan-brown, limonite-stained; weathers blocky to nodular; calcite-filled fractures; fossiliferous	. 6
12. Shale, silty, calcareous, gray-brown, thin-bedded; weathers tan; some iron stains and fossil fragments	. 2
11. Limestone, medium-hard, tan-brown, weathers tan and blocky; fractures in elongated blocks; iron stained, some fossils	. 7
Thickness	2. 6
Soldier Creek shale member:	
10. Shale, clayey, calcareous, gray, blocky to thin-bedded, limonite-stained; weathers tan gray; many calcium carbonate-filled cracks and lenses	6. 1
9. Limestone, soft, brown, heavily limonite stained; weathers tan brown and nodular	. 7
8. Shale, silty, calcareous, gray, blocky; calcareous nodules abundant; limonite stained in upper part	1. 1
Thickness	7. 9

26. *Section from the Reading limestone member of the Emporia limestone to the Burlingame limestone member of the Bern limestone in a road cut in the NW¼ NW¼ sec. 10, T. 1 S., R. 12 E.*—Continued

Bern limestone—Continued

Burlingame limestone member:

	Feet
7. Limestone, dense, tan-gray to brown, varies from soft to hard; weathers tan and blocky with top surface very irregular; some limestone inclusions	2.1
6. Shale, clayey, noncalcareous, gray to gray-brown thin-bedded; weathers gray; some iron stains	3.8
5. Shale, silty, very calcareous, tan; weathers blocky; some fossils and iron stains	.6
4. Shale, silty, calcareous, tan-gray, thin-bedded; weathers gray; some limonite stains, fossiliferous	.8
3. Limestone, medium-hard, gray; weathers tan and blocky; some iron stains; fossiliferous	.5
2. Covered interval (colluvium)	2.1
1. Limestone, hard, dense, tan-brown; weathers tan gray and blocky; conchoidal fracture; some calcite-filled cavities	.5
Thickness	10.4

Base covered.

27. *Section from the Auburn shale to the Silver Lake and Cedar Vale shale members undifferentiated of the Scranton shale in a road cut in the NW¼SW¼SW¼ sec. 15, T. 3 S., R. 12 E.*

Reading limestone member of the Emporia limestone removed by quarrying.

Auburn shale:

	Feet
26. Limestone, medium-hard, gray; weathers tan gray and blocky; fossiliferous	0.3
25. Shale, silty, calcareous, tan-gray, thin-bedded; weathers tan; many limestone lenses; some limonite stains; fossiliferous	8.5
24. Shale, clayey, calcareous, gray, thin-bedded; weathers gray green; some iron stains on bedding planes	3.3
23. Shale, silty, calcareous, tan, blocky; weathers tan to yellow; iron stained	5.7
22. Shale, silty, calcareous, dark-gray-green, blocky; weathers gray; some iron stains on bedding planes	1.7
21. Shale, clayey, calcareous, tan-gray, blocky; weathers tan; some iron stains	4.1
20. Shale, clayey, calcareous, olive-drab, blocky; weathers tan gray; some iron stains	4.2
19. Shale, silty, calcareous, tan-gray, thin-bedded; weathers light tan; irregular calcium carbonate-fracture fillings	1.6
18. Shale, clayey, calcareous, gray-green, blocky; weathers light gray green	2.3
Thickness	31.7

27. *Section from the Auburn shale to the Silver Lake and Cedar Vale shale members undifferentiated of the Scranton shale in a road cut in the NW¼SW¼SW¼ sec. 15, T. 3 S., R. 12 E.*—Continued

	Feet
Bern limestone:	
Wakarusa limestone member:	
17. Limestone, soft, tan-brown speckled with brown, iron-stained; weathers gray brown and blocky to nodular; celestite-filled cracks; fossiliferous	1. 6
Soldier Creek shale member:	
16. Shale, silty, calcareous, gray-brown, thin-bedded, limonite-stained; weathers tan; some fossils	. 5
15. Shale, silty with some clay, calcareous, tan-gray to gray-green mottled with maroon in lower part, blocky; weathers tan gray; limonite specks; iron stains on fracture planes; some calcareous plates	1. 5
14. Shale, silty with some clay, slightly calcareous, maroon grading to gray-green in lower part; blocky; limonite-stained areas in lower part	4. 2
13. Shale, silty, very calcareous, thin-bedded to nodular, gray-brown, heavily limonite stained; weathers tan	1. 4
12. Shale, silty, calcareous, gray, thin-bedded; weathers light gray; some limonite specks; fossiliferous	. 4
Thickness	8. 0
Burlingame limestone member:	
Upper limestone:	
11. Limestone, soft, clayey, tan-gray mottled with gray-green; weathers gray brown and nodular; some limonite stains and specks; small limestone inclusions very abundant. Small algae and other fossils common	. 5
Intervening shale:	
10. Shale, slightly sandy, calcareous, gray-green, blocky; weathers light gray; some iron stains	2. 1
9. Shale, silty, calcareous, tan-gray; mottled with gray, blocky; weathers tan; clay balls and limonite nodules abundant; some iron stains	. 5
8. Shale, silty, calcareous, maroon, thin-bedded to blocky; limonite-stained areas in basal part	3. 2
7. Shale, silty with some clay, calcareous, gray, blocky; weathers light gray; some iron stains	. 4
6. Shale, silty and slighty sandy, calcareous, tan, blocky; weathers tan brown; some iron stains	1. 6
Lower limestone:	
5. Limestone, clayey, soft, tan; weathers platy to blocky; some iron stains and limonite nodules	. 2
Thickness	8. 5

27. *Section from the Auburn shale to the Silver Lake and Cedar Vale shale members undifferentiated of the Scranton shale in a road cut in the NW¼SW¼SW¼ sec. 15, T. 3 S., R. 12 E.*—Continued

Scranton shale:
Silver Lake and Cedar Vale shale members undifferentiated:

		Feet
4.	Shale, clayey, calcareous, gray, blocky; weathers light gray; some iron stains	5. 7
3.	Covered interval (colluvium)	5. 4
2.	Shale, clayey, gray-green	2. 1
1.	Coal bed	. 6
	Thickness exposed	13. 8

Base covered.

28. *Section from the Wakarusa limestone member of the Bern limestone to the Silver Lake shale member of the Scranton shale, inclusive, in a road cut and streambank in the SE¼SE¼ sec. 7, T. 1 S., R. 13 E.*

Soil and glacial till: clay, tan-brown to gray; some small erratics (8±feet).
Bern limestone:
Wakarusa limestone member:

		Feet
12.	Limestone, hard, dense, gray to brown; weathers tan brown and blocky; iron stains on surface; conchoidal fracture. Small and large fusulinids abundant; other fossils common	1. 4
11.	Shale, silty, calcareous, tan to gray, thin-bedded; limonite stains in lower part	. 3
10.	Limestone, medium-hard, tan-brown, massive, limonite-stained; weathers tan and irregular to nodular; some fossils	. 5
9.	Shale, silty, calcareous, gray, thin-bedded; weathers tan gray	. 2
8.	Limestone, hard, tan-gray, massive, limonite-stained; weathers tan and blocky; fossiliferous	. 5
		2. 9

Soldier Creek shale member:

7.	Shale, clayey, calcareous, tan-gray to gray, blocky; weathers tan; iron stains on fracture planes and limonite-stained zone in lower part	8. 0

Burlingame limestone member:

6.	Limestone, medium-hard, tan-brown, massive, iron-stained; weathers to blocks and irregular plates; numerous iron specks and calcite-filled cracks and cavities; limestone inclusions which weather lighter than the matrix; some fossils	2. 6
5.	Covered interval (colluvium)	1. 4
4.	Shale, clayey, noncalcareous, gray to gray-brown, thin-bedded; some iron stains	3. 2
3.	Limestone, soft, tan-brown, heavily limonite stained; weathers irregularly and blocky; contains fossil fragments	1. 4

28. *Section from the Wakarusa limestone member of the Bern limestone to the Silver Lake shale member of the Scranton shale, inclusive, in a road cut and streambank in the SE¼SE¼ sec. 7, T. 1 S., R. 13 E.*—Continued

	Feet
Bern limestone—Continued	
Burlingame limestone member—Continued	
2. Limestone, medium-hard, gray, weathers tan gray and blocky; some limonite stains, contains fossil fragments and microfossils	.7
Thickness	9.3
Total exposed thickness of Bern limestone	20.2
Scranton shale:	
Silver Lake shale member:	
1. Shale, clayey, calcareous, tan-gray, blocky; weathers tan; limonite stains in upper part	2.5
Base covered.	

29. *Section of the Burlingame limestone member of the Bern limestone and Silver Lake shale member of the Scranton shale in a road cut in the SW¼NW¼ NW¼ sec. 15, T. 1 S., R. 13 E.*

	Feet
Bern limestone:	
Burlingame limestone member:	
9. Limestone, hard, somewhat dense, tan-brown, weathers tan to brown and blocky to irregular; many calcite inclusions; limestone inclusions in upper part	2.1
8. Shale, clayey, noncalcareous, tan-gray mottled with dark-gray, thin-bedded; limonite stains on some fracture and bedding planes	5.8
7. Limestone, medium-hard, brown, weathers yellow brown and blocky to nodular; heavily limonite stained; some calcium carbonate on fracture planes; some fossils	.7
6. Shale, silty, calcareous, gray, thin-bedded; weathers tan gray; very fossiliferous	.7
5. Shale, clayey, calcareous, tan-gray mottled with gray, thin-bedded; limonite stained and many carbon stains; some plant fragments	.6
4. Limestone, hard, somewhat dense, brown; weathers tan brown and blocky to shaly in upper part; small white limestone inclusions in the upper part; heavily limonite stained; nodules of secondary calcium carbonate on weathered surface; some clay nodules and microfossils. Shaly part fossiliferous	1.6
Scranton shale:	
Silver Lake shale member:	
3. Shale, silty, calcareous, light-gray to tan-gray, thin-bedded; many calcium carbonate limonite and stained lenses; some mica and microfossils	3.4
2. Limestone, medium-hard, gray-brown, limonite-stained; weathers brown and platy; many limonite and clay nodules; some minute hematite nodules on the surface; fossiliferous	.6
1. Shale, sandy and micaceous, tan-gray, thin-bedded; weathers tan; many limonite stains	2.2
Thickness exposed	6.2
Base covered.	

30. *Section from the Burlingame limestone member of the Bern limestone to the Cedar Vale shale member of the Scranton shale, inclusive, in a road cut and streambank in the SE¼SE¼ sec. 31, T. 5 S., R. 12 E.*

	Feet
Bern limestone:	
Burlingame limestone member:	
11. Limestone, medium hard, tan; weathers blocky to nodular; some small limestone inclusions. Fossiliferous, including some small algal discs	2. 1
Scranton shale:	
Silver Lake shale member:	
10. Shale, clayey and silty, calcareous, gray-green, blocky; some limonite stains; many calcium carbonate nodules on the surface	3. 8
9. Shale, slightly sandy and micaceous, calcareous; yellow-tan, blocky, heavily limonite stained; thin sandstone and oolitic lenses	1. 7
8. Shale, slightly sandy, slightly calcareous, gray, thin-bedded; many sandstone lenses; heavily limonite stained; some mica	4. 4
7. Shale, clayey, noncalcareous, gray-green, thin-bedded to blocky; iron stains on some bedding and fracture planes; some silt	17. 1
Thickness	27. 0
Rulo limestone member:	
6. Limestone, medium-hard, gray, weathers tan gray and blocky; very fossiliferous. This limestone bed is present in eastern part of streambank but pinches out completely toward the west. Measurement of Silver Lake shale in western part of exposure began at top of the Elmo coal	1. 3
Cedar Vale shale member:	
5. Shale, silty, calcareous, gray-brown, thin-bedded; weathers tan gray; some iron stains, and microfossils	. 3
4. Coal (Elmo), bituminous, black, thin-bedded to blocky, fractured; iron stains abundant; many wood fragments	1. 3
3. Shale, clayey, noncalcareous, gray, thin-bedded to blocky; many limonite stains	3. 1
2. Shale, carbonaceous, slightly calcareous, black, thin-bedded to very thin-bedded; some gypsum crystals, iron stains and fossils	1. 1
1. Shale, clayey, slightly calcareous, gray-green, blocky; some iron stains	6. 4
Thickness exposed	12. 2
Total exposed thickness of Scranton shale	40. 5

Base covered.

31. *Section of the White Cloud shale member of the Scranton shale, Howard limestone, and Severy shale in a streambank in the NW¼SW¼SE¼ sec. 24, T. 1 S., R. 12 E.*

	Feet
Soil: silty to sandy, tan-brown (2± feet)	
Scranton shale:	
White Cloud shale member:	
8. Shale, silty, micaceous, slightly sandy, noncalcareous, gray to olive-drab, thin-bedded to blocky; weathers tan to tan gray; wood fragments and carbon stains; limonite and iron stains abundant; limonite plates and nodules abundant on weathered surface	12. 1
7. Shale, silty, very calcareous, gray-brown, thin-bedded; weathers tan; heavily iron stained; some fossils and fossil fragments	. 3
	12. 4
Howard limestone:	
Church limestone member:	
6. Limestone, hard, dense in lower part; iron-stained gray with 2 to 3 inches of a gray-brown weathered zone at surface; weathers blocky; conchoidal fracture. Fossils abundant in lower part but only common in upper part	2. 1
Aarde shale member:	
5. Shale, silty and clayey, calcareous, thin-bedded; dark-gray becoming tan gray in middle part	1. 9
4. Shale, silty, slightly calcareous, dark-gray, thin-bedded; weathers light gray; minute gypsum crystals in lower part, some fossils in upper part, including microfossils	. 8
3. Coal, black to dark-gray; weathers blocky to platy; iron stains abundant on fracture planes	1. 1
Thickness exposed	3. 8
Severy shale:	
2. Shale, silty, noncalcareous, gray, thin-bedded; many limonite stains	. 3
1. Shale, silty, calcareous, gray, thin-bedded; limonite stains in upper part	1. 4
Thickness exposed	1. 7
Base covered.	

32. *Section of the White Cloud shale member of the Scranton shale, Howard limestone, and Severy shale in a road cut in the SW¼SE¼SW¼ sec. 1, T. 1 S., R.12 E.*

	Feet
Soil: silty to sandy with some clay; gray brown (3± feet).	
Scranton shale:	
White Cloud shale member:	
6. Shale, silty, sandy; tan-gray to light-gray, thin-bedded; limonite plates and nodules on weathered surface, some mica	5. 1

32. *Section of the White Cloud shale member of the Scranton shale, Howard limestone, and Severy shale in a road cut in the SW¼SE¼SW¼ sec. 1, T. 1 S., R. 12 E.*—Continued

	Feet
Howard limestone:	
Utopia limestone member:	
5. Limestone, medium-hard, gray to tan-gray, massive; weathers gray brown and thin-bedded; limonite stains and nodules in middle part; fossiliferous	1. 6
Church limestone member:	
4. Limestone, hard, dense, gray, massive; weathers tan brown and blocky; conchoidal fracture; limonite stains and calcite crystals on weathered surface; some fossils	2. 1
Aarde shale member:	
3. Shale, silty, slightly calcareous, tan-gray with gray lenses, thin-bedded to blocky; weathers tan; some carbon stains in the gray lenses; some limonite stains	4. 1
2. Coal, bituminous, black, blocky limonite-stained; wood fragments and minute gypsum crystals abundant	1. 0
Thickness	5. 1
Total thickness of Howard limestone	8. 8
Severy shale:	
1. Shale, clayey, noncalcareous, gray to tan-gray, thin-bedded; slightly sandy and micaceous in lower part; limonite stains on some bedding planes and limonite-filled fractures	3. 1
Base covered.	

33. *Section of the Topeka limestone in a streambank in the SE¼NE¼ sec. 23, T. 1 S., R. 12 E.*

Soil: silty and clayey, gray to gray-brown (4.0± feet).

	Feet
Topeka limestone:	
Coal Creek limestone member:	
7. Limestone, medium hard; gray mottled with some gray-green; weathers gray and thin bedded; some limonite stains. Fusulinids abundant; other fossils common; all weather white	1. 0
6. Shale, silty, calcareous, tan to tan-gray, thin-bedded; weathers tan; some limonite stains	. 4
5. Limestone, hard, dense, gray; weathers brown and blocky; some limonite stains; fossiliferous	1. 4
	2. 8
Holt shale member:	
4. Shale, clayey, noncalcareous, thin-bedded, heavily limonite stained; gray in upper part and dark-gray in lower part; weathers tan gray	3. 7

33. *Section of the Topeka limestone in a streambank in the SE¼NE¼ sec. 23, T. 1 S., R. 12 E.*—Continued

	Feet
Topeka limestone—Continued	
Du Bois limestone member:	
3. Limestone, hard, dense, gray; weathers blocky; conchoidal fracture; pelecypods abundant	.9
2. Shale, clayey with some silt, calcareous, tan-gray, thin-bedded; weathers tan	.4
1. Limestone, medium-hard; gray; thin shale parting; pelecypods abundant	1.4
Thickness exposed	2.7
Total exposed thickness of Topeka limestone	9.2
Base covered.	

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FRED A. SEATON, *Secretary*

GEOLOGICAL SURVEY

Thomas B. Nolan, *Director*

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[All plates are in pocket]

ILLUSTRATIONS