Geology and Ground-Water Resources of Brown County, Kansas

By Charles K. Bayne
and Walter H. Schoewe

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ABSTRACT

Brown County is in the northern tier of counties in the State and is the second county west of the east border. It has an area of 576 square miles. It is in the Dissected Till Plains section of the Central Lowlands Province. The annual long-term mean precipitation is 34.20 inches, and the mean annual temperature is 53.3°F. Agriculture is the principal source of income in the County.

Rocks that underlie, but do not crop out in, the County range in age from Precambrian to Pennsylvanian (Virgilian). Rocks that crop out in the County range in age from Pennsylvanian to Permian. Cenozoic rocks consist of glacial till of Kansan age and loess of Wisconsinan and Illinoisan(?) ages. Fluvial deposits of Wisconsinan and Recent ages occur in the major valleys. The County lies in the Forest City Basin, which was a part of the North Kansas Basin prior to elevation of the Nemaha Anticline during Mississippian time.

Ground water is the principal source of water in the County; Horton is the only city that obtains its water supply from surface water. Glacial drift is the principal source of ground water in the area. Yields ranging up to 450 gpm (gallons per minute) are obtained from the glacial drift, but yields of less than 100 gpm are more common. Rocks of the Council Grove Group in northwestern Brown County yield as much as 250 gpm. Pennsylvanian sandstones in eastern Brown County yield small quantities of water. Generally less than 20 gpm of water are obtained from fluvial deposits in the major stream valleys.

Nearly all ground water in the area contains enough dissolved mineral matter to be considered hard. Chloride concentrations are not high at depths ordinarily reached by wells, but at greater depths they are present in high concentrations. Nitrate concentrations are higher in many wells than the recommended standards.

INTRODUCTION

PURPOSE OF INVESTIGATION

A program of investigation of the ground-water resources of Kansas was begun in 1937 by the U.S. Geological Survey and the State Geological Survey of Kansas in cooperation with the Environmental Health Services of the Kansas State Department of Health and the Division of Water Resources of the Kansas State Board of Agriculture. The investigation upon which this report is based was begun in the summer of 1960 and completed in the fall of 1962. The present status of other investigations in Kansas is shown in Figure 1.

Ground water is one of the principal natural resources of Brown County. Nearly all domestic and industrial supplies are obtained from ground water. It is the source of water supply for all cities in the County except Horton, which utilizes a surface-water supply.

At the present rate of withdrawal, much of the area has an adequate supply of ground water available, but local areas experience shortages during periods of prolonged drought. Therefore, knowledge of the quantity and quality of the available water supplies and the location of additional supplies is important.

LOCATION AND EXTENT OF AREA

Brown County is in the northern tier of counties and is the second county west of the east border of the State. It is bounded on the north by Richardson County, Nebraska, on the east by Doniphan County, Kansas, on the south by Atchison and Jackson counties, and on the west by Nemaha County. The county contains 576 square miles.

PREVIOUS INVESTIGATIONS

Although many reports have described rocks of the same age as those in Brown County and many have made specific reference to Brown County, only two reports, one by Schoewe

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(1938) and one by Fishburn and Davis (1962) describing the occurrence of celestite, are wholly concerned with Brown County.

Lee (1943) described the stratigraphy and structural development of the Forest City Basin. Moore (1936 and 1949) described the stratigraphy of the Pennsylvanian rocks in Kansas, including those in Brown County. Mudge and Yochelson (1962), in a report on the stratigraphy and paleontology of the uppermost Pennsylvanian and lowermost Permian rocks, referred to the rocks in Brown County; and Mudge, *et al.* (1959), in a report on the geology and construction-material resources in Nemaha County, described rocks which crop out in Brown County.

Frye and Walters (1950) studied glacial deposits in northeastern Kansas. A report by Frye and Leonard (1952) describing the Pleistocene geology of Kansas mentions localities in Brown County, and Schoewe (1946) described the coal resources of the Wabaunsee Group in the County. A report on the geology and ground-water resources of Jackson County, Kansas, by Walters

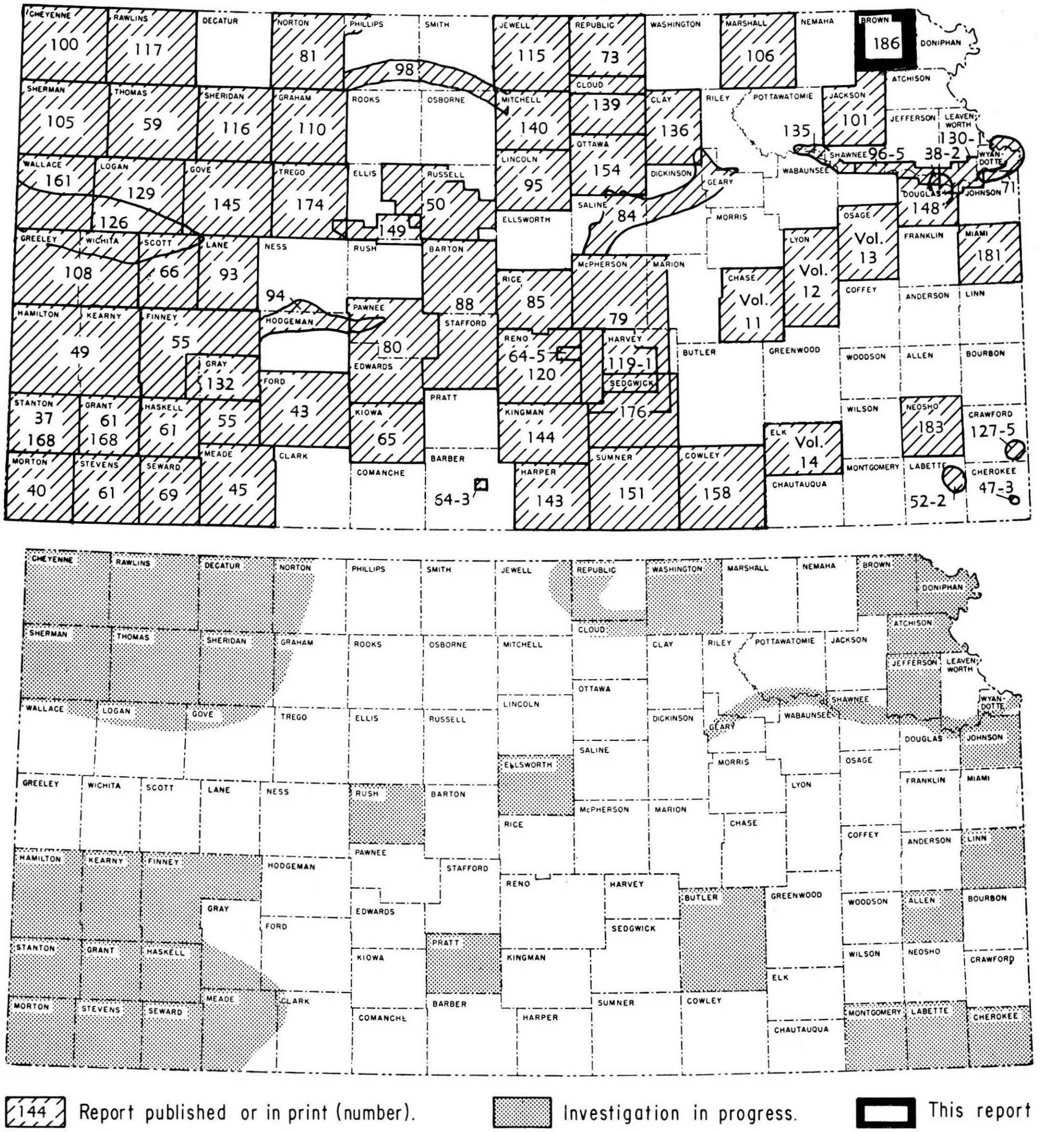

FIGURE 1.—Index map of Kansas showing area discussed in this report, and other areas for which ground-water reports have been published or are in preparation.

(1953) described rocks and ground-water conditions in Jackson County which are similar to those in Brown County, and Frye (1941) described ground-water conditions in Atchison County adjacent to Brown County.

METHODS OF INVESTIGATION

Field work in Brown County was begun by Schoewe in 1930. Further work by Schoewe was done on water supplies in 1934 in connection with the Kansas Emergency Relief Commission. Field work was begun by Bayne in Brown County in June 1960 and continued through October. Additional field work was done by Bayne in both 1961 and 1962. During the investigation, 130 wells were inventoried and other information was obtained. In 1960, 226 holes were augered for geologic and hydrologic information. Thirteen test holes were drilled by the State Geological Survey of Kansas with an hydraulic rotary drilling machine in areas where Paleozoic rocks were too deep to reach with the auger. In the preparation of this report, one driller's log of a public-supply well and logs of six holes drilled in 1948 and one drilled in 1957 were used.

The geology was mapped on areal photographs in the field and transferred to a base map modified from topographic quadrangle sheets.

During the investigation, 22 samples of water were collected and analyzed for the mineral content. Analyses of six samples previously collected and nine samples from municipal supplies are included in the report. All analyses were made by the Environmental Health Services Laboratory of the Kansas State Department of Health under the supervision of Howard Stoltenberg, chief chemist.

WELL-NUMBERING SYSTEM

The well and test-hole numbers in this report give the location of the wells and test holes according to the system of subdivision of the public lands by the U.S. Bureau of Land Management. The first numeral of the well number indicates the township, the second number indicates the range, and the third number indicates the section. The quarter sections (160 acres), quarter-quarter sections (40 acres), and the quarter-quarter-quarter sections (10 acres) are designated *a*, *b*, *c*, or *d* in a counterclockwise direction beginning in the northeast quadrant (Fig. 2). For example, well 1-15E-26dcd is in the SE SW SE sec. 26, T 1 S, R 15 E. If two or more wells are located in the same 10-acre tract, the location number is followed by serial numbers in the order in which they were inventoried.

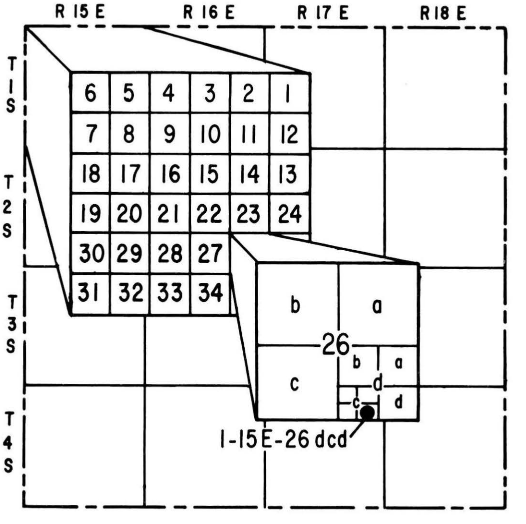

FIGURE 2.—Sketch of Brown County, Kansas, illustrating the well-numbering system used in this report. Location is section 26, T 1 S, R 15 E, showing the method of dividing sections into quarter sections, quarter-quarter sections, and quarter-quarter-quarter sections.

ACKNOWLEDGMENTS

Appreciation is expressed to the many residents of Brown County who supplied information on their wells and aided in the collection of field data. Special acknowledgment is due city officials who supplied information about municipal water supplies and to S. M. Ball, of the State Geological Survey of Kansas, for aid in stratigraphic work.

This report has been reviewed by members of the U.S. Geological Survey and the State Geological Survey of Kansas; R. V. Smrha, Chief Engineer, and H. L. Mackey, Engineer, Division of Water Resources, Kansas State Board of Agriculture; and J. L. Mayes, Chief Engineer, and B. F. Latta, Geologist, of the Environmental Health Services of the Kansas State Department of Health.

GEOGRAPHY

PHYSIOGRAPHY AND TOPOGRAPHY

Brown County is in the Dissected Till Plains section of the Central Lowlands Province (Schoewe, 1949). Northeastern Kansas was invaded by ice during two glaciations. The first may have entered Brown County, but it did not cover the entire County. During the second glaciation, ice covered all of Brown County, and the present landscape is the result of this glaciation and subsequent erosion. The glaciers left a mantle of glacial drift of variable thickness over the entire County, and the typical bedrock-controlled topography of the Osage Cuesta section south of this area is entirely lacking in Brown County.

Interstream areas are relatively smooth, broad, well-rounded remnants of the original ground-moraine topography left by the melting ice as the glacier retreated. Nearer to the major drainageways, the area is more dissected, the surface reduced to gentle slopes, and the valleys wide and open. Adjacent to the larger streams the surface is highly dissected into a rough, hilly topography. Most bluffs are very steep and ledges of limestone, sandstone, and shale crop out.

The highest point in the County, near the west border about 6 miles south of the Kansas-Nebraska line, is 1,330 feet above sea level. The lowest, about 850 feet above sea level, is in northeastern Brown County near the junction of the Nemaha River and Roys Creek. The names and locations of 7½-minute topographic quadrangles covering the County are shown in Figure 3.

DRAINAGE

The southeastern and east-central part of Brown County is drained by Wolf River, a tributary of the Missouri River. Southwestern and south-central Brown County are drained by the Delaware River, a tributary to the Kansas River. The northern part of Brown County is drained by Pony Creek, Walnut Creek, and Roys Creek, all of which are tributary to the Nemaha River.

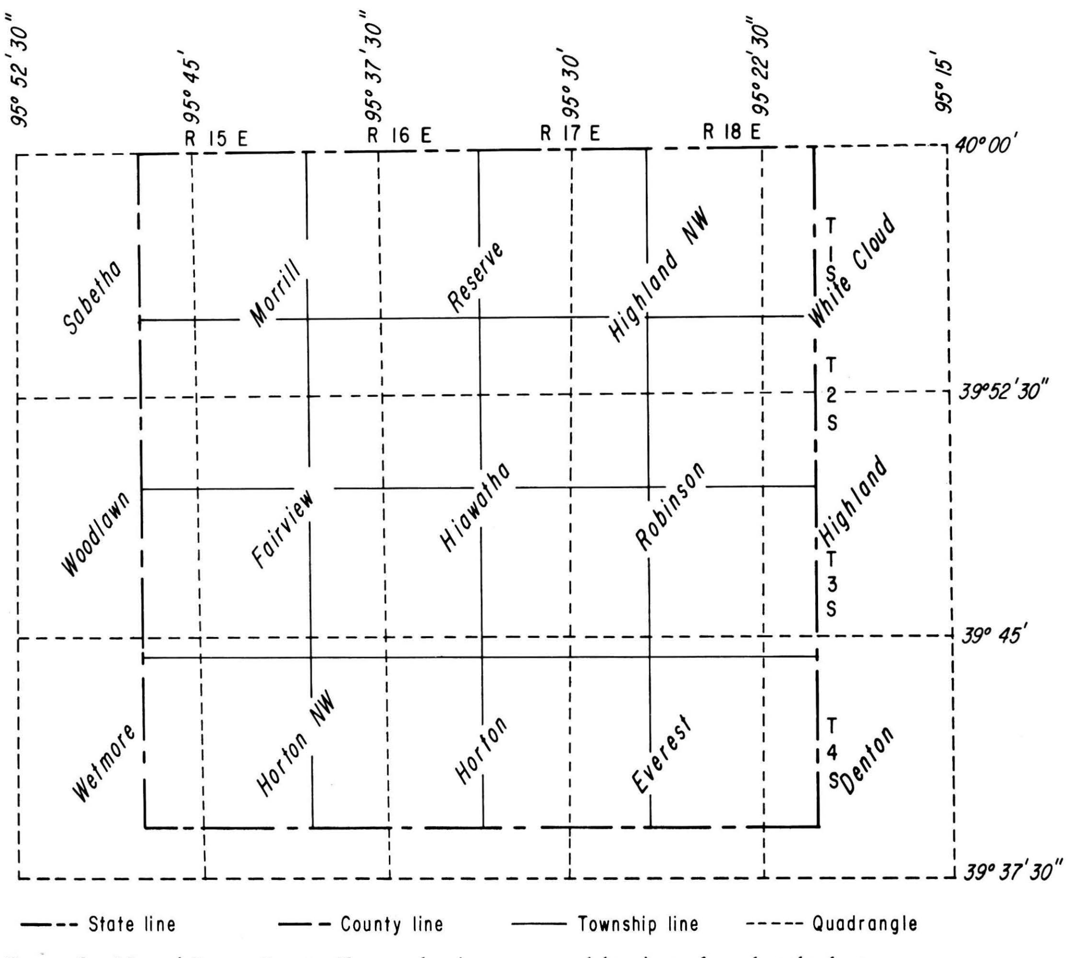

FIGURE 3.—Map of Brown County, Kansas, showing names and locations of quadrangle sheets.

CLIMATE

Brown County has a humid climate. A 75-year record of weather data covering the period 1889 to 1963 is available from the U.S. Weather Bureau station near Horton. The average annual precipitation for the period of record is 33.53 inches. In 44 of the years the precipitation was below average, and in 31 of the years the precipitation was above average. About 79 percent of the precipitation falls during the growing season of April through October. The monthly mean precipitation for the period 1931 to 1955 is given in Table 1, and the annual precipitation and the departure from the long-term mean precipitation are shown in Figure 4.

TABLE 1.—Monthly mean precipitation at Horton, Kansas.

Month	Precipitation, inches	Month	Precipitation, inches
January	0.99	July	3.13
February	.98	August	4.38
March	2.03	September	3.82
April	3.03	October	2.15
May	4.66	November	1.59
June	6.14	December	1.30
		Total	34.20

The summers are generally hot. The mean annual temperature is 53.3°F. The winters are characterized by brief severe cold periods. The lowest temperature of record was -25°F on February 12, 1899, and on December 5, 1924. The highest temperature of record, 112°F, occurred on August 13, 1936.

The average date of the latest killing frost is April 19, and the average date of the earliest killing frost is October 15. The average growing season is 179 days.

POPULATION

The population of Brown County, according to the 1960 census, was 13,229, a decrease of 9.7 percent from that in 1950. Urban areas increased 2.9 percent during this period, while rural areas decreased 13.4 percent. The population density is 22.9 persons per square mile compared to the State average of 26.6.

The 1960 population of the 10 incorporated cities was: Everest, 348; Fairview, 272; Hamlin, 99; Hiawatha, 3,391; Horton, 2,361; Morrill, 299; Powhattan, 128; Reserve, 138; Robinson, 317; and Willis, 109.

AGRICULTURE

Agriculture is the principal source of income in Brown County and the total income in 1959 from agricultural products was $17,000,000. The average gross income per farm was about $10,000, which is about the average of the State as a whole.

MINERAL RESOURCES

OIL AND GAS

Oil was produced from two wells in the Livengood field in northwestern Brown County during 1964. Production is from the Hunton group of Devonian and Silurian ages at a depth of about 2,580 feet. The field was discovered in 1944 and cumulative production is 104,060 barrels (Oros and Beene, 1965). Gas has not been found in commercial quantities in the County.

CONSTRUCTION MATERIALS

Concrete aggregate.—Material suitable for use as concrete aggregate is present in limited quantities in Brown County, but it is not produced commercially. The known reserves of sand and gravel generally contain too much silt to make good concrete aggregate. Most of the limestone is unsuitable for commercial use.

Structural stone.—Structural stone is present in limited quantities in Brown County but is not produced commercially. South of Brown County the Cottonwood Limestone Member of the Beattie Limestone is suitable as structural stone, but in Brown County this limestone is softer and is not as resistant to weathering as it is in the central part of the State and, therefore, is not used extensively.

Road metal.—Glacial outwash sand and gravel is produced from several pits in Brown County for use as road metal. In some of these pits glacial boulders are present, which limits the usefulness of this material. In northwestern Brown County chert gravel deposits are locally present in the highest uplands. These are more uniform in size than the glacial outwash gravel and generally do not contain boulders. They are used extensively for road metal in the northwestern part of the County.

Crushed stone from the Grenola Limestone and the Dover Limestone Member of the Stotler Limestone have been used for road metal, although good quarry sites are limited in the County.

Loess for use as a mineral filler in road metal is available in unlimited quantity in the northeast quarter of the County.

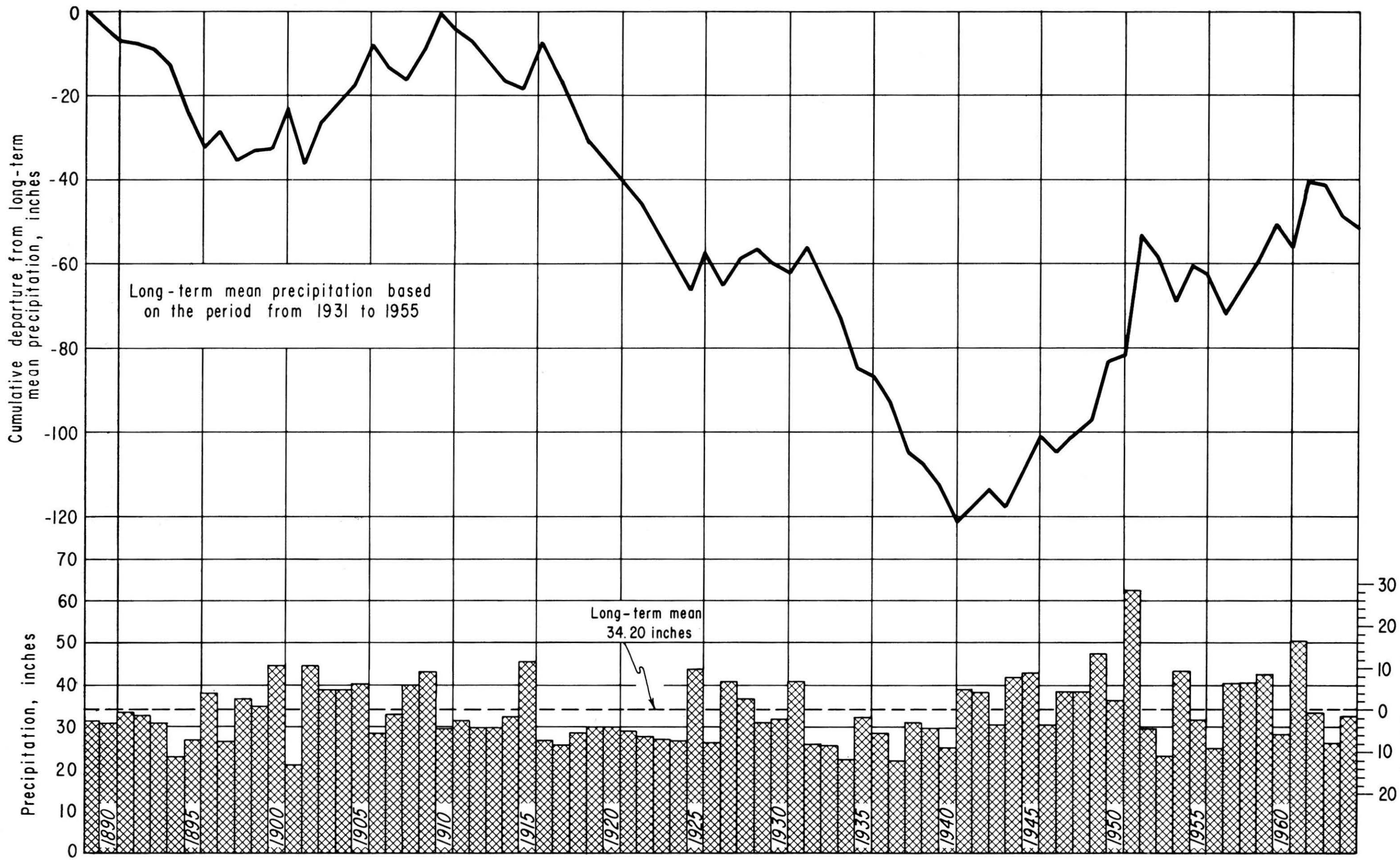

FIGURE 4.—Annual precipitation and departure from the long-term mean precipitation at Horton, Kansas.

Coal

An estimated 100,000 tons of Elmo coal have been mined in Brown County. The Elmo coal bed occurs near the top of the Cedar Vale Shale Member of the Scranton Shale. Although coal is no longer mined in the County, potential reserves estimated at 679,400,000 tons are present (Schoewe, 1946).

SUBSURFACE ROCKS[1]

Rocks which occur in the subsurface, but do not crop out in Brown County, range from Precambrian to Pennsylvanian (Virgilian) in age. Much of the following discussion of these buried rock units is from a report on the Forest City Basin by Lee (1943).

PRECAMBRIAN ROCKS

The Precambrian rocks which underlie Brown County are believed to be principally granite. The depth to the upper surface of the Precambrian ranges from 2,500 to 3,000 feet below sea level. The Precambrian rocks occupy an asymmetrical synclinal trough, the west flank of which rises sharply in the direction of the Nemaha Anticline. East of the synclinal axis the beds are less steeply dipping. Only one well in Brown County (sec. 8, T 1 S, R 15 E) has reached the Precambrian, at a depth of 4,016 feet.

PALEOZOIC ROCKS

The Precambrian rocks in Brown County are overlain by a succession of Paleozoic rocks. The Lamotte Sandstone of Late Cambrian age is the oldest of these rocks and is probably present in the part of the synclinal basin extending through the central part of the area. Rocks of the Arbuckle Group of Late Cambrian and Early Ordovician age overlie the Lamotte, where present, and the Precambrian in other areas. Few wells have penetrated these rocks and little is known of their thickness and lithology in the County; however, they probably underlie all of the area. The St. Peter Sandstone of Middle Ordovician age unconformably overlies Arbuckle rocks and in turn is unconformably overlain by the Middle Ordovician Viola (Kimmswick) Limestone and the Upper Ordovician Maquoketa (Sylvan) Shale. In a well in sec. 24, T 4 S, R 16 E, 265 feet of Viola and Maquoketa were penetrated.

Rocks of Silurian age rest unconformably on older rocks in the County. The Silurian rocks consist principally of dolomite in this area, but locally some limestone is interbedded with the dolomite. A thickness of 263 feet of Silurian rocks was present in the well in sec. 24, T 4 S, R 16 E, but these rocks thin toward the southeast as indicated by a log of a well in sec. 17, T 6 S, R 20 E, where the Silurian is absent. Rocks of Devonian age unconformably overlie Silurian rocks in Brown County. The Devonian rocks are predominantly dolomites. In some areas hundreds of feet of older rocks were removed by erosion prior to the deposition of Devonian beds. In the well in sec. 24, T 4 S, R 16 E, 163 feet of Devonian rocks were penetrated; however, in the well in sec. 17, T 6 S, R 20 E, where Silurian rocks were absent, more than 300 feet of Devonian rocks were present.

The Chattanooga Shale of Late Devonian and Early Mississippian age is about 231 feet thick in Brown County. This shale thins toward the southeast and is overlain by Mississippian rocks. The well in sec. 24, T 4 S, R 16 E, penetrated 282 feet of Mississippian; however, the Mississippian rocks do not exceed 100 feet in thickness in the northwestern part of the County and are locally absent over the Nemaha Anticline a few miles west of Brown County.

Rocks of the Cherokee Group of the Pennsylvanian System are about 650 feet thick in Brown County. In this area the Cherokee is composed principally of gray shale, although some black shale is present. The sandstone commonly present in the Cherokee in eastern and southeastern Kansas occurs sparsely in the County. The Cherokee Group thins toward the south and west and is absent in local areas in adjacent Nemaha County where it was never deposited over local highs on the Nemaha Anticline. In Brown County this unit is conformably overlain by rocks of the Marmaton and Pleasanton groups which have a combined thickness of about 200 to 250 feet. In this area the contact between the Marmaton and the Pleasanton is not distinct.

Rocks of the Kansas City Group overlie the Pleasanton rocks in the County. These, together with the overlying Lansing Group rocks, are composed of alternating beds of limestone and shale and some sandstone, and although the individual beds range considerably in thickness, the aggregate thickness of the rocks is 325 to 350 feet.

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[1] The nomenclature and classification of the geologic units described in this report follow the usage of the State Geological Survey of Kansas. They differ somewhat from usage adopted by the U.S. Geological Survey.

The Stanton Limestone of the Lansing Group is overlain by 130 to 195 feet of shale, sandstone, sandy shale, and minor amounts of limestone of the Douglas Group. In local areas in northeastern Kansas, the Weston Shale and the Iatan Limestone members of the Stranger Formation of the Douglas Group are present. These units, which formerly comprised the Pedee Group, have been entirely removed in parts of the area, and the Tonganoxie Sandstone Member of the Stranger Formation rests unconformably on the Stanton Limestone. West of the outcrop area along the Missouri River, the Weston Shale Member thins rapidly. In Brown County the Weston is probably no more than a few feet thick and may be absent locally. The Iatan Limestone is also absent locally. The thick sandstone beds commonly found in the Douglas Group in the area south of the Kansas River are not present in Brown County; however, sandy shale beds are common in the upper part.

The Lawrence Formation of the Douglas Group is overlain by a sequence of four limestone formations and three shale formations that comprise the Shawnee Group. In Brown County this group has a nearly constant thickness of about 300 feet. The individual beds of the Shawnee Group are comparatively uniform in thickness and lithology and are traceable over considerable distances. The upper and lower contacts of the Shawnee Group appear to be conformable with beds above and below.

GEOLOGY AND GROUND-WATER CHARACTERISTICS OF OUTCROPPING ROCK UNITS

The previously described Pennsylvanian rocks do not crop out in Brown County but crop out in eastern and southeastern Kansas. Rocks of Pennsylvanian, Permian, and Pleistocene ages crop out in Brown County (Table 2, Pl. 1). The Pennsylvanian and Permian rocks in Brown County are largely concealed by a mantle of Pleistocene glacial drift or loess. Bedrock outcrops are confined essentially to the major stream valleys with glacial drift and loess covering the interstream areas (Pl. 1). Alluvial deposits are widespread in the valleys of the larger streams.

PENNSYLVANIAN SYSTEM—UPPER PENNSYLVANIAN SERIES

Wabaunsee Group

The Wabaunsee Group in Brown County consists of about 400 feet of limestone, shale, sandy shale, sandstone, and coal. The limestones of the Wabaunsee Group are thinner than those of older Pennsylvanian strata or of the Council Grove Group of Permian age and characteristically weather to a tan or brown color. The shales of the Wabaunsee Group are generally tan, green, or gray, and contain channel sandstone and coal.

All but the lower two units of the Wabaunsee Group, the Severy Shale and the Howard Limestone, crop out in Brown County and are described on the following pages.

SCRANTON SHALE

The five members of the Scranton Shale (Pl. 1) are, in ascending order, the White Cloud Shale, Happy Hollow Limestone, Cedar Vale Shale, Rulo Limestone, and Silver Lake Shale. The Happy Hollow and Rulo limestone members are lenticular in this area and are locally absent. Where the Happy Hollow is absent, the White Cloud and Cedar Vale cannot be differentiated. Where the Rulo is absent the contact between the Cedar Vale and Silver Lake is placed at the top of the Elmo coal which occurs at or near the top of the Cedar Vale Shale Member. About 75 feet of the total thickness of the Scranton Shale is exposed in Brown County.

The White Cloud Shale Member consists of gray, bluish-gray, and some tan shale, sandy shale, and locally some sandstone. The only exposures of the Member in the County are in the Wolf Creek valley near Robinson. The base of the Member is not exposed, and the probable thickness of the unit is about 20 to 25 feet. No wells are known to produce water from the White Cloud, but small supplies[2] probably could be developed from the sandstone which occurs locally.

The Happy Hollow Limestone Member is generally a single tannish-brown bed of impure limestone, less than 1 foot thick, containing fusilinids and a brachiopod fauna. The Happy Hollow appears to be lenticular in Brown County and may be absent in local areas. The unit is best exposed in the Wolf Creek valley in the vicinity of Robinson. It does not yield water to wells in the area.

The Cedar Vale Shale Member, which overlies the Happy Hollow, is composed of beds of bluish-gray to tannish-gray shale, gray clay, sandy shale, and some sandstone. The Elmo coal occurs near the top of the Cedar Vale. This

[2] In this report, small supplies refers to yields generally less than 10 gpm, moderate supplies 10 to 100 gpm, and large supplies to more than 100 gpm.

TABLE 2.—Generalized section of outcropping rocks in Brown County, Kansas.

System	Series		Stage	Formation or rock unit		Thickness, feet	Character	Water supply*
Quaternary	Pleistocene		Wisconsinan and Recent	Alluvium and terrace deposits		0-55	Alluvial deposits of silt, clay, sand, and gravel within the valley walls of the major streams. Gravel composed of limestone, chert, and glacial material.	Yields small quantities of water to wells where saturated.
			Illinoisan(?) and Wisconsinan	Loess		0-86	Wind deposited silt generally in an upland position. Locally may contain silt older than Wisconsinan age.	Yields no water to wells in the County.
			Kansan and Yarmouthian	Glacial drift	Outwash deposits	0-100	Includes outwash deposits and glacial till. Outwash deposits consist of silt, clay, sand, gravel, and scattered boulders. Generally the sand and gravel is poorly graded but contains less silt and clay than the alluvial deposits of Recent and Wisconsinan age. Glacial till consists of a heterogeneous mixture of silt, clay, sand, gravel, and boulders. Clay is the most common grain size present. Lenses of relatively clean gravel may be locally present.	Yields moderate to large supplies of water from outwash deposits where they lie below the water table, and small to moderate supplies of water to wells from glacial till in most areas. Locally, the till yields no water to wells.
					Glacial till	0-115		
				Pro-Kansan lake deposits		0-50	Consists of fine to very fine sand and silt. Well graded and thinly laminated. Occurs only in buried valleys.	Yields no water to wells in the County although it lies below the water table.
			Nebraskan(?) and Aftonian	Pre-Kansan deposits		10-20	Chert gravel. Contains no glacial material.	Yields no water to wells in the County. Potential yields up to 100 gpm are available.
Permian	Lower Permian	Council Grove	Crouse Limestone			10-12	An upper limestone is tan, hard, and blocky to platy. The shale below is tannish-gray, calcareous and blocky. A lower limestone is a hard, gray, massive, fossiliferous limestone.	Yields no water to wells in the County.
			Easly Creek Shale			16-19	Silty, calcareous, grayish-green and maroon shale. Contains some thin calcareous beds and tan shale in the lower part.	Do
			Bader Limestone	Middleburg Limestone		4	The upper limestone is hard, massive, and light gray. The shale member is silty, calcareous, tannish-gray in the upper part and grayish-green in the lower part, and contains thin beds of limestone. The lower member consists of two limestone beds separated by a tannish-gray, silty, calcareous shale.	Do
				Hooser Shale		11		
				Eiss Limestone		10		

TABLE 2.—Generalized section of outcropping rocks in Brown County, Kansas (*Continued*).

System	Series	Group	Formation	Member	Thickness	Character	Water supply*
Permian	Lower Permian	Council Grove	Stearns Shale		15	Silty, calcareous, tannish-gray shale in the upper part and grayish-green shale in the lower part. Contains some limestone in middle part.	Do
			Beattie Limestone	Morrill Limestone	3	The upper limestone is porous and gray to tannish-gray. The shale member is silty, very calcareous, tannish-gray, thin-bedded, and very fossiliferous. The lower limestone is a massive, light-gray limestone containing chert nodules and numerous fusulinids, which locally forms hillside benches.	Yields small supplies of water to wells and springs in local areas from solution channels in the Cottonwood Limestone Member.
				Florena Shale	3-5		
				Cottonwood Limestone	5		
			Eskridge Shale		28-32	Clayey, calcareous shale, principally tannish-gray, but contains maroon zones in middle and lower parts and a persistent limestone bed in the upper part.	Yields no water to wells in the area.
			Grenola Limestone	Neva Limestone	11-14	The uppermost member is composed of alternating beds of limestone and shale, the top bed of which is a thick porous limestone which weathers brown. This bed is underlain by hard tannish-gray limestone beds and dark-gray shale beds. The shale below the top member is grayish-green and tannish-gray, silty and calcareous. The middle member is composed of two or more thin, hard, gray limestones separated by tan calcareous shale. The underlying shale member is thin-bedded, gray, and calcareous. The lower limestone member is a hard, gray, fossiliferous limestone.	Yields small to moderate supplies of water to wells and springs in the western part of the County.
				Salem Point Shale	6		
				Burr Limestone	4		
				Legion Shale	3		
				Sallyards Limestone	1		
			Roca Shale		30-35	Clayey, calcareous, gray and tannish-gray shale. Locally contains very dark-gray shale in lower part and a porous, cellular limestone in the middle part.	Yields moderate to large supplies of water from the porous limestone in northwestern Brown County.
			Red Eagle Limestone	Howe Limestone	1-1.5	The upper limestone is soft, clayey, porous, and weathers tan. The shale member is gray to dark-gray in the upper part and black in the lower part. The lower limestone is hard, gray to dark-gray, and very fossiliferous.	Yields small quantities of water to wells from the upper limestone.
				Bennett Shale	2.5-3		
				Glenrock Limestone	1.5		

			Johnson Shale		5-7	Shale, platy, gray, tannish-gray and very dark-gray, and thin-bedded.	Yields no water to wells in the County.
			Foraker Limestone	Long Creek Limestone	6-8	The upper member is a soft, massive, impure, gray to tannish-gray limestone. The shale member is composed of gray, silty, calcareous shale and contains several persistent limestone beds in the upper and middle parts. The lower member is composed of two limestone beds and a shale bed: the upper limestone is hard, gray and fossiliferous; the lower limestone is variable in lithology from hard and massive to shaly.	Yields small to moderate supplies of water from the upper limestone, generally high in sulfates.
				Hughes Creek Shale	30-33		
				Americus Limestone	3-5		
		Admire	Janesville Shale	Hamlin Shale	40	The upper shale member is clayey, gray to tannish-gray, and locally contains celestite in joints and cracks; the lower part of this shale is sandy and contains sandstone lenses. The limestone member is a hard, dark grayish-brown limestone containing numerous fossil fragments and below this is a hard, gray, dense limestone which weathers platy. The lower shale member is composed of gray to grayish-green, and tan, clay shale.	Yields small quantities of water locally to wells from sandstone in the Hamlin Shale Member.
				Five Point Limestone	2-3		
				West Branch Shale	27		
			Falls City Limestone		2-6	An upper limestone is a porous coquina of pelecypod shell fragments having a rough surface. The shale below is tannish-gray, clayey, and noncalcareous. A lower limestone is impure shaly and generally cannot be distinguished from the underlying Hawxby Shale.	Yields no water to wells in the County.
			Onaga Shale	Hawxby Shale	10	The upper shale member is silty, calcareous and tannish-gray. The limestone member is thin, light-gray to tannish-gray, and hard. The lower shale member is tannish-gray, and noncalcareous, containing a dark-gray zone near the middle.	Yields no water to wells in the County. Small quantities of water are available from sandstone in the Towle Shale Member.
				Aspinwall Limestone	1		
				Towle Shale	25		
Pennsylvanian	Upper Pennsylvanian	Wabaunsee	Wood Siding Formation	Brownville Limestone	17-20	The limestones are gray to dark grayish-brown, hard, and fossiliferous. Shales are gray to grayish-brown and silty to sandy, with some sandstone locally.	Yields small quantities of water from sandstone in the Pony Creek Shale Member.
				Pony Creek Shale			
				Grayhorse Limestone			
				Plumb Shale			
				Nebraska City Limestone			

TABLE 2.—Generalized section of outcropping rocks in Brown County, Kansas (*Concluded*).

System	Series	Group	Formation	Member	Thickness	Character	Water supply*
Penn-sylvanian	Upper Penn-sylvanian	Wabaunsee	Root Shale	French Creek Shale Jim Creek Limestone Friedrich Shale	45-50	Gray to bluish-gray noncalcareous, sandy shale at the top of the formation separated from gray, sandy, calcareous shale by a thin, hard, blue to bluish-gray limestone. Coal occurs in the upper part of both shales.	Yields small supplies in local areas from sandy shale.
			Stotler Limestone	Grandhaven Limestone Dry Shale Dover Limestone	8-12	Hard, massive, tannish-gray, fossiliferous limestone and calcareous, sandy, gray to dark-gray shale locally containing sandstone.	Yields small supplies in local areas from sandy shale and sandstone in the Dover Limestone.
			Pillsbury Shale		15-25	Noncalcareous, gray to grayish-green, sandy shale. Locally contains sandstone.	Yields small amounts of water from sandstone.
			Zeandale Limestone	Maple Hill Limestone Wamego Shale Tarkio Limestone	16-20	Upper limestone is hard, gray to tannish-gray, vertically jointed, and fossiliferous. The shale member is silty, noncalcareous, and contains a thin coal bed near the top. The lower limestone is hard, massive, grayish-brown, and fossiliferous.	Yields no water to wells in the County.
			Willard Shale		30	Noncalcareous, sandy, micaceous, gray to tannish-gray shale. Locally contains sandstone in the upper part.	Yields small quantities of water locally from sandstone beds.
			Emporia Limestone	Elmont Limestone Harveyville Shale Reading Limestone	35-40	The upper limestone is hard, bluish-gray to grayish-brown and fossiliferous; locally pelletal in lower part. The shale member is gray to grayish-green. The lower limestone member is hard, dense, grayish-brown, and locally weathers into several beds separated by shaly limestone.	Yields no water to wells in the County.
			Auburn Shale		34	Gray to light-gray shale, limy and platy in lower part, silty in middle part, and limy in upper part. Contains a persistent black platy shale in the middle part.	Do

			Bern Limestone	Wakarusa Limestone	30-32	The upper limestone is a hard, bluish-gray to brown, dense, fossiliferous limestone. The shale is gray to greenish-gray and locally contains a concretionary zone near the base. The lower limestone is composed of several limestone beds separated by shale.	Yields small supplies of water to wells and springs locally.
				Soldier Creek Shale			
				Burlingame Limestone			
			Scranton Shale	Silver Lake Shale	75	The limestones are fossiliferous, thin, and impure and may be locally absent. The shale members are silty, sandy, and locally contain sandstone. A persistent coal occurs near the top of the middle shale member.	Small supplies are available from the sandstone and sandy shale.
				Rulo Limestone			
				Cedar Vale Shale			
				Happy Hollow Limestone			
				White Cloud Shale			

* In this report small supplies refers to yields generally less than 10 gpm, moderate supplies to 10 to 100 gpm, and large supplies to more than 100 gpm.

coal, which commonly is 12 to 18 inches thick, but has been reported to be as much as 30 inches thick locally, has been extensively mined in the Roys Creek area in northeastern Brown County and in Wolf Creek valley near Robinson (Schoewe, 1946). Most of the mining occurred many years ago, and since about 1934 little mining has been done except by individuals for personal use. No wells are known to produce water from the Cedar Vale, but small supplies are probably available from the sandy shale and sandstone in the unit.

The Rulo Limestone Member is a single bed of hard, gray, fossiliferous limestone, which is lenticular and locally absent. In Brown County the Rulo ranges in thickness from 0 to about 3 feet. No water is obtained from this unit in Brown County.

The Silver Lake Shale Member comprises the strata between the top of the Rulo Member and the base of the Burlingame Limestone Member of the Bern Limestone. The Silver Lake consists of gray, grayish-green, and tan shale. The shale is silty to sandy and locally contains a channel sandstone. Commonly the Silver Lake ranges in thickness from 20 to 25 feet, but thicknesses of sandstone of 25 to 30 feet have been observed, making the total thickness considerably more than is normal for this unit. Small supplies of water are available from the sandstone in the Silver Lake, but no wells are known to utilize this aquifer.

BERN LIMESTONE

The Bern Limestone consists of three members which, in ascending order, are the Burlingame Limestone, the Soldier Creek Shale, and the Wakarusa Limestone. The thickness of the Bern Limestone in Brown County is about 30 to 32 feet.

Section through the Bern Limestone and Auburn Shale in SW NW NW sec. 16, T 3 S, R 18 E, exposed in road ditch on a north-facing hill.

	Thickness, feet
Glacial drift	8±
EMPORIA LIMESTONE	
READING LIMESTONE MEMBER	
Limestone, impure, earthy, light-gray, blocky, contains large *Allorisma*	0.5
AUBURN SHALE	
Shale, gray and buff, platy in part; contains many thin limy zones	12.8
Shale, light-gray; contains many very thin beds of limestone	6.9
Shale, black, fissile to platy, limy at base	0.4
Shale, light-gray, not bedded; has appearance of loess	3.0
Shale, light-gray to gray; contains a persistent 1-foot bed of limestone 2 feet above base and 0.2-foot-thick limestone 5.8 feet above base	11.0
	34.1
BERN LIMESTONE	
WAKARUSA LIMESTONE MEMBER	
Limestone, bluish-gray on fresh break, weathers grayish-brown, breaks down into chips and small blocks	1.0
Limestone, dark bluish-gray on fresh break, weathers brown; contains many crinoids, fusilinids, and algae	1.7
Shale, gray, platy	1.1
Limestone, brown, impure, breaks into chips and blocks; contains a few brachiopods and crinoids	0.5
Shale, gray, well-bedded; contains no fossils	2.2
Limestone, grayish-brown, blocky to earthy, no fossils	0.6
	7.1
SOLDIER CREEK SHALE MEMBER	
Shale, gray, well-bedded and jointed	5.5
Covered interval	4.8
	10.3
BURLINGAME LIMESTONE MEMBER	
Covered interval (in nearby exposures contains a 1.3-foot limestone encrusted with algae and underlain by 0.8 foot of gray shale)	2.1
Limestone, light-brown; contains brachiopods and crinoids	1.0
Shale, grayish-buff	1.2
Limestone, gray, impure, weathers into chips and small blocks, few fossils	0.5
Limestone, contains limonite concretions in upper part, grayish-brown on fresh break, weathers reddish-brown, upper surface irregular	2.0
Base covered	6.8

The Burlingame Limestone Member consists of several limestone beds separated by thin beds of shale. The lower limestone can be separated into two beds, the lowest of which has an irregular upper surface, contains limonite concretions, and weathers reddish-brown. This bed is overlain by a thin bed of limestone that is lighter in color and weathers into small chips and blocks. The limestone is in turn overlain by a grayish-buff shale, that ranges in thickness from about 1 foot to 8 feet. The shale is overlain by a light-brown, fossiliferous limestone about 1 foot thick. Overlying this limestone is a thin, gray, clayey shale that is overlain by a thin, tannish-gray limestone encrusted with algae. The aggregate thickness of the Burlingame ranges from about 8 to 11 feet in Brown County. Only small quantities of water are obtained from it.

The Soldier Creek Shale Member is a gray, thin-bedded shale. Joints in the shale are present in most outcrops, and the shale adjacent to the joints is stained with limonite. The thickness of the Soldier Creek in Brown County is about 10 feet. The unit does not yield water to wells in the area.

The Wakarusa Limestone Member consists of several limestone beds separated by thin beds of shale. The lower limestone is a thin-bedded, gray, blocky to earthy, nonfossiliferous limestone about 0.6 foot in thickness. This limestone is overlain by a thin-bedded gray shale about 2 feet in thickness. The shale is overlain by a brown, impure limestone about 0.5 foot thick which contains a sparse brachiopod fauna. Next above is a gray, platy shale about 1 foot thick. This shale is overlain by a 2.7-foot limestone which is bluish-gray at the top and dark bluish-gray in the lower part. The lower bed contains crinoids, large fusilinids, and algae. The aggregate thickness of the Wakarusa is about 7 feet. No water is obtained from this unit.

AUBURN SHALE

The Auburn Shale is about 34 feet thick in Brown County. In this area the Auburn may be divided into three lithologic units or zones. The lower zone is a gray to light-gray, platy shale containing a persistent limestone bed near the middle and another limestone near the base. The middle zone is a massive, silty, light-gray shale which on some outcrops resembles loess and on other outcrops a well-cemented mudstone. The upper zone is a gray, platy shale containing numerous thin limestone beds that are commonly quite fossiliferous. Between the upper platy zone and the middle (loess-like) shale, a black fissile or platy shale 0.2-foot to 0.4-foot thick occurs. This fissile shale, although thin, is very persistent and makes an excellent marker bed for identification of the Auburn Shale. The Auburn yields no water to wells in the area.

EMPORIA LIMESTONE

The Emporia Limestone (Pl. 1) consists of three members, which in ascending order are: the Reading Limestone, the Harveyville Shale, and the Elmont Limestone. The thickness of the Emporia in Brown County is 35 to 40 feet.

The Reading Limestone Member is composed of three or, locally, four limestone beds separated by thin beds of shale having an aggregate thickness in the County of 4.5 feet to 6.5 feet. The lower limestone bed is a soft, bluish-gray limestone ranging in thickness from 0.5 foot to 1 foot. This bed contains a brachiopod fauna and very large *Allorisma*. The lower limestone bed is overlain by a gray, thin-bedded shale which rarely exceeds 1 foot in thickness. This is generally overlain by a dark-gray thin-bedded shale which locally contains a very dark-brown fossiliferous limestone at the top. The upper limestone bed of the Reading is a dense, hard, bluish-gray limestone which weathers grayish-brown to brown. This bed contains fusulinids, crinoids, and brachiopods. The Reading yields no water to wells in Brown County.

Section through the upper part of the Auburn Shale, and the Reading Limestone Member and the lower part of the Harveyville Shale Member of the Emporia Limestone in NW SW SW sec. 4, T 4 S, R 18 E. Exposed in road cut about 1,000 feet north of corner.

	Thickness, feet
Glacial drift	
Interstratified till and outwash gravel	10+
EMPORIA LIMESTONE	
HARVEYVILLE SHALE MEMBER	
Shale, gray, clayey; contains thin limestone beds and some siltstone	12.0
Limestone, grayish-brown, blocky, few fossil fragments	0.8
Shale, dark-gray to grayish-green	0.8
Shale, light-gray to buff; contains a thin micaceous sandstone in upper part	14.8
	28.4
READING LIMESTONE MEMBER	
Limestone, dark-brown, upper surface very even, lower surface uneven; contains fusulinids, crinoids, and brachiopods	2.5
Shale, red and gray	1.0
Limestone, dull gray, weathers brown; contains many fossil fragments	0.3
Shale, gray	0.1
Limestone, soft, impure; contains large *Allorisma* and some brachiopods	0.5
	4.4
AUBURN SHALE	
Shale, gray, limy and platy in lower part	15.0
Shale, black, fissile to platy	0.5
Base covered	15.5

The Harveyville Shale Member includes the strata between the top of the Reading Limestone Member and the base of the Elmont Limestone Member. The Harveyville is composed of bluish-gray and tannish-gray clayey shale and has a thickness of 32 feet in Brown County. It contains a bed of limestone as much as 2 feet thick near the middle of the unit and, locally, a thin-bedded sandstone a few feet below this limestone. The Harveyville does not yield water to wells.

The Elmont Limestone Member in Brown County is composed of two limestone beds separated by a thin shale bed. The Elmont ranges in thickness from 3 to 5 feet. The lower limestone bed is grayish-brown and contains fossil fragments. Locally, this lower bed is pelletal or conglomeratic. The shale separating the upper bed from the lower bed is clayey, calcareous, and gray. The upper limestone is bluish-gray and fossiliferous and weathers to a grayish-brown color. Small fusulinids and brachiopods are the most common fossils. The Elmont yields no water to wells in the County.

WILLARD SHALE

The Willard Shale overlies the Elmont Limestone Member of the Emporia Limestone in Brown County (Pl. 1) and has a thickness of about 30 feet. The Willard is composed of noncalcareous, sandy, micaceous, gray to tannish-gray shale and commonly has one or more sandstone beds near the top. The lower part of the Willard is poorly exposed in Brown County; it forms the covered slope between the Emporia and Zeandale limestones. The upper part of the Willard is generally composed of sandstone exhibiting various degrees of cementation. In some outcrops the sandstone is almost a loose sand, while in other exposures it is well cemented and appears massive. Small quantities of water are available to wells from the sandstone in the Willard in south-central Brown County.

Section through the lower part of the Tarkio Limestone Member of the Zeandale Limestone and the upper part of the Willard Shale exposed in the bank of a creek in NW SW sec. 21, T 4 S, R 17 E.

	Thickness, feet
ZEANDALE LIMESTONE	
TARKIO LIMESTONE MEMBER	
Limestone, light-yellow or tannish-brown, hard, dense; fossil fragments	3.3
	3.3
WILLARD SHALE	
Shale, tannish-brown to grayish-brown	0.3
Sandstone, fine, tannish-brown, soft	5.1
Shale, tannish-brown, very sandy and micaceous	15.6
Base covered	21.0

ZEANDALE LIMESTONE

The Zeandale Limestone consists of three members which, in ascending order, are the Tarkio Limestone, Wamego Shale, and the Maple Hill Limestone members (Pl. 1). The thickness of the Zeandale ranges from 16 to 20 feet, and is best exposed in south-central Brown County.

Section of Zeandale Limestone measured by R. C. Moore in the spillway of Mission Lake near the C sec. 28, T 4 S, R 16 E.

	Thickness, feet
PILLSBURY SHALE	
Shale, yellowish-brown and bluish-gray; contains carbonaceous streaks, very sandy, micaceous upper part locally grades into yellowish-brown massive sandstone	14.0
Sandstone, yellowish-brown, medium- to fine-grained, soft, massive, cross-bedded and lenticular	3.0
Shale, light bluish-gray with brown streaks, calcareous, micaceous and sandy	5.5
	22.5
ZEANDALE LIMESTONE	
MAPLE HILL LIMESTONE MEMBER	
Limestone, light bluish-gray, weathers light greenish-brown, earthy, massive, breaks into small chips, lower part dark-blue, very hard, dense, fossiliferous	1.2
WAMEGO SHALE MEMBER	
Shale, light-blue, weathers brown, thinly laminated; lower part contains ironstone concretions 1 inch thick, 8 inches in diameter	10.0
TARKIO LIMESTONE MEMBER	
Limestone, light greenish-gray to brown, soft, shaly, grades to calcareous shale, forms slight projection	1.1
Shale, light-blue to purple, clayey, hard, blocky	0.3
Limestone, light creamy-buff to brown, weathers to rich dark brown on faces, very massive, hard; contains crinoids, abundant robust fusilinids, breaks into large angular blocks	4.0
	16.6
WILLARD SHALE	
Shale, light-blue, calcareous, blocky, upper 0.5 foot contains numerous *Chonetes, Enteletes, Derbyia, Productus,* and *Echinoconchus*	2.0
Sandstone, blue to bluish-gray, lower part thin-bedded to shaly, cross-bedded; contains dark carbonaceous streaks, grades locally into massive sandstone both laterally and vertically, upper part thin-bedded, ripple marked, and micaceous, weathers brown	4.5
	6.5

The Tarkio Limestone Member is a hard, grayish-brown to tannish-brown limestone containing crinoids, large fusilinids, and a few brachiopods. It is massive and breaks down into large, angular blocks. Locally, an upper bed of yellowish-brown earthy limestone about 1 foot thick is present. The Tarkio weathers to a rich brown color. The thickness of the Tarkio is about 5 feet. The Member yields no water to wells in the County.

The Wamego Shale Member is a light bluish-gray shale which weathers tannish-brown. Locally a zone of ironstone concretions occurs near the base of the Wamego, and locally a thin coal or carbonaceous zone is present just below the Maple Hill Limestone Member. The Wamego ranges in thickness from 10 to 14 feet. It yields no water to wells in the area.

The Maple Hill Limestone Member is a hard, gray to tannish-gray, earthy limestone which weathers to a tannish-brown color. The Maple Hill breaks along joints into large slabs which, upon further weathering, break into small chips and plates. Locally, the lower part of the Maple Hill is a very hard, dense, dark-blue limestone. The unit is very fossiliferous and ranges from 1 foot to 1.5 feet in thickness. The Maple Hill yields no water to wells in the area.

PILLSBURY SHALE

The Pillsbury Shale consists of beds of gray to grayish-green, sandy, micaceous shale interbedded with sandstone. The sandstone is massive to thin bedded locally and is generally soft, often breaking down into almost loose sand. The sandstone is locally cross-bedded and is ripple marked in the upper part. Shale is more prominent in the lower part of the Pillsbury, and a thin coal occurs locally near the top. Its thickness ranges from about 15 to 25 feet in Brown County. Wells yield small quantities of water from the sandstone beds.

STOTLER LIMESTONE

The Stotler Limestone is composed of three members which, in ascending order, are: the Dover Limestone, Dry Shale, and Grandhaven Limestone. In Brown County the Grandhaven Member was not observed and may not be present; however, it does occur in nearby areas.

The Dover Limestone Member is a hard, gray to tannish-gray limestone that weathers brown. It contains large fusulinids, algae, and a brachiopod fauna. The fossils and color of the Dover closely resemble those of the Tarkio Limestone Member of the Zeandale Limestone, but the two differ in weathering characteristics. The Tarkio breaks into large angular blocks upon weathering, whereas the Dover breaks into nodules or chips. The thickness of the Dover is about 5 feet. It yields no water to wells in the area.

The Dry Shale Member is composed of clayey, calcareous gray shale that locally contains beds of sandy shale and possibly some sandstone. The Dry Shale Member thins toward the northern part of the State, and it may be absent in local areas in Brown County. Where the Grandhaven Limestone Member is absent, the Dry Shale Member and the overlying Friedrich Shale Member of the Root Shale cannot be differentiated. The Dry Shale Member attains a maximum thickness of about 8 feet in the County. Some water is produced from sandstone at about the position of the Dry Shale Member; however, the sandstone may be in the lower part of the Friedrich instead of the Dry Shale Member.

The Grandhaven Limestone Member does not crop out in Brown County. Exposures in adjoining areas show that the Member consists of a bed of tannish-brown to brown limestone that weathers blocky to shaly. It is sandy, conglomeratic, and fossiliferous. It is about 2 feet thick.

ROOT SHALE

The Root Shale consists of three members which, in ascending order, are: the Friedrich Shale, Jim Creek Limestone, and French Creek Shale members. The Root Shale occupies a part of the slope between the bench-forming Brownville Limestone Member of the Wood Siding Formation and the Dover Limestone Member of the Stotler Limestone. The intervening limestones do not form a bench, and separation of the strata is difficult. The Root Shale is poorly exposed in Brown County, the best exposures occurring in vertical stream banks and a few roadside ditches. It ranges in thickness from about 45 to 50 feet.

The Friedrich Shale Member is a tannish-gray to bluish-gray calcareous clay shale in places containing a thin coal near the top. Locally, dark-gray lenses of shale occur throughout the Member, sandstone is present in the lower and middle parts, and a bed of fossiliferous shale occurs near the top. The Friedrich Shale Member is about 25 feet thick in Brown County. In the northern part of the State where the Grandhaven Limestone Member of the Stotler Limestone is missing, the Friedrich is difficult to separate from the underlying Dry Shale Member. Small quantities of water are available to wells from the sandstone in the Friedrich.

The Jim Creek Limestone Member is a hard, gray to bluish-gray limestone that breaks into small shaly-appearing chips upon weathering. The Jim Creek is very fossiliferous, and the fauna includes brachiopods and small fusulinids. The Jim Creek ranges in thickness from 0.5 to 1 foot in Brown County and yields no water to wells.

The French Creek Shale Member is a gray to grayish-green clayey, noncalcareous shale, locally sandy in the middle part. The Lorton coal (Schoewe, 1946) is generally present in the uppermost part of the French Creek, and another thin coal or, locally, a carbonaceous zone, occurs a few feet below the Lorton coal. A bed of fossiliferous shale occurs at the top of the French Creek. In places this bed is composed chiefly of *Derbyia*. The French Creek is about 20 feet thick. Small yields of water are available to wells from the sandy zones in the French Creek.

Section from upper part of Friedrich Shale Member of the Root Shale through the Brownville Limestone Member of the Wood Siding Formation measured by W. H. Schoewe in NE sec. 34, T 4 S, R 16 E.

	Thickness, feet
WOOD SIDING FORMATION	
BROWNVILLE LIMESTONE MEMBER	
Limestone, yellowish-brown, granular; contains crystalline calcite, weathers brown, platy base grades irregularly into shale below; contains abundant fossils	2.0
PONY CREEK SHALE MEMBER	
Shale, limy, micaceous and sandy; contains brachiopods; contains a thin, hard, blue limestone in the lower part (Grayhorse? Limestone Member)	9.0
PLUMB SHALE MEMBER	
Shale, sandy, red and gray	5.0
NEBRASKA CITY LIMESTONE MEMBER	
Limestone, massive, very fossiliferous; contains large *Productus*, crinoid, bryozoans, *Chonetes*, weathers light gray	1.6
	17.6
ROOT SHALE	
FRENCH CREEK SHALE MEMBER	
Limy shale, made up largely of *Derbyia*	1.0
Coal	0.1
Shale, gray	3.85
Coal	0.25
Shale, gray, sandy, laminated, pyritic concretions at base, thin beds of black shale	15.65
JIM CREEK LIMESTONE MEMBER	
Limestone, bluish-gray, fossiliferous, grades into unit below	0.35
Shale, dark-gray; contains thin plates of very fossiliferous limestone	1.0
FRIEDRICH SHALE MEMBER	
Shale, clayey, gray	6.0
Sandstone	1+
Base covered	28.2

WOOD SIDING FORMATION

The Wood Siding Formation is composed of five members which, in ascending order, are: the Nebraska City Limestone, the Plumb Shale, the Grayhorse Limestone, the Pony Creek Shale, and the Brownville Limestone. The Formation is best exposed in the southern part of Brown County in the valleys of Delaware River and its tributaries. The thickness of the Wood Siding ranges from about 17 to 20 feet. A measured section through the Wood Siding and the upper part of the Root Shale is given above.

The Nebraska City Limestone Member is a thin, but persistent, dark-gray limestone that weathers light gray. This Member is commonly about 1.5 feet thick and contains an abundant brachiopod fauna. No water is obtained from the Nebraska City in Brown County.

The Plumb Shale Member is a clayey, calcareous, gray shale which locally contains some red shale. In some places the lower part of the Plumb is sandy and micaceous. In Brown County the Member is about 4 feet thick. It yields no water to wells in the area.

The Grayhorse Limestone Member is a hard, gray to bluish-gray limestone which is locally very fossiliferous. It is commonly less than 1 foot thick. The Member is locally absent or consists of a very thin limestone or limy zone. It yields no water to wells in Brown County.

The Pony Creek Shale Member is a silty, gray shale that contains sandstone in the lower part. The uppermost bed of the Pony Creek is a very fossiliferous gray shale which contains *Chonetes* and *Marginifera*. This fauna is similar to that of the overlying Brownville Limestone Member. The Pony Creek ranges in thickness in the County from about 8 to 10 feet. Small supplies of water are available to wells from the sandstone beds in the Pony Creek.

The Brownville Limestone Member is a tannish-gray limestone which weathers brown. The limestone is commonly massive but weathers blocky to platy. The Brownville is abundantly fossiliferous, containing *Chonetes, Marginifera*, crinoids, and bryozoans. The Member is about 2 feet thick in Brown County and yields no water to wells in the area.

PERMIAN SYSTEM— LOWER PERMIAN SERIES

Rocks of the Lower Permian Series are divided into three groups in Kansas. These are, in ascending order: the Admire Group, Council Grove Group, and the Chase Group. Only rocks of the Admire and Council Grove groups crop out in Brown County.

ADMIRE GROUP

The Admire Group consists chiefly of clastic deposits but contains thin limestone beds. Shale predominates in this sequence of rocks, and, because there are few scarp-forming or resistant rocks present, the unit is poorly exposed throughout most of the County. Admire rocks occupy the long slope between the resistant rocks of the overlying Council Grove Group and resistant beds which occur well down into the Wabaunsee Group of Pennsylvanian age. The Admire Group consists of three formations with a thickness of about 110 feet in the County.

ONAGA SHALE

The Onaga Shale is the lowermost formation of the Admire Group and consists of three members which are, in ascending order: the Towle Shale, the Aspinwall Limestone, and the Hawxby Shale members. The thickness of the Onaga in Brown County is about 36 feet.

Measured section of strata from Five Point Limestone Member of the Janesville Shale through Brownville Limestone Member of the Wood Siding Formation exposed in road ditch along west side of sections 15 and 22, T 2 S, R 16 E.

	Thickness, feet
PERMIAN SYSTEM	
JANESVILLE SHALE	
FIVE POINT LIMESTONE MEMBER	
Limestone, dark-gray, weathers light gray and slabby; contains fossil fragments	1.8
WEST BRANCH SHALE MEMBER	
Shale, light-gray to bluish-gray, well-bedded to blocky and clayey; contains a thin, flaggy to nodular impure limestone about 10 feet above base	27.0
	28.8
FALLS CITY LIMESTONE	
Limestone, dark-brown, tannish-brown with dark reddish-brown spots on fresh break; a porous coquina of pelecypod shells	3.0
	3.0
ONAGA SHALE	
HAWKSBY SHALE MEMBER	
Shale, bluish-gray, blocky to platy	10.4
ASPINWALL LIMESTONE MEMBER	
Limestone, impure, weathers white, discontinuous	0.6
TOWLE SHALE MEMBER	
Shale, bluish-gray and tannish-gray; contains very dark-gray shale in middle part	25.5
	36.5
PENNSYLVANIAN SYSTEM	
WOOD SIDING FORMATION	
BROWNSVILLE LIMESTONE MEMBER	
Limestone, dark grayish-brown, two beds separated by thin shale parting, lower bed contains many *Chonetes,* other brachiopods, and crinoids	1.5
Base covered	1.5

The Towle Shale Member is a clayey, noncalcareous tannish-gray to gray shale. Dark-gray shale and maroon shale occur locally in the lower and middle part, and locally, a channel sandstone is present. The Towle is about 25 feet thick in Brown County, and, although no wells are known to obtain water from the Member, small quantities of water should be available from the channel sandstone.

The Aspinwall Limestone Member is a medium-hard, gray to tannish-gray limestone that weathers white. This Member, although commonly about 1 foot thick, is variable in thickness and may be locally absent. The Aspinwall yields no water to wells in the County.

The Hawxby Shale Member is a silty, calcareous, tannish-gray to gray shale. Dark-gray shale occurs locally in the middle part of the unit, which is about 10 to 12 feet thick in Brown County. The Hawxby is poorly exposed in the County where it underlies the steep, grassy slope below the Falls City Limestone. The Hawxby Shale Member yields no water to wells.

FALLS CITY LIMESTONE

The Falls City Limestone is composed of two limestone beds separated by a shale bed. The upper limestone bed is a coquina of pelecypod shells which give the rock a porous or granular appearance (when struck with a hammer, the limestone has a hollow sound). This limestone is commonly about 2-feet thick; however, in the NE cor. sec. 7, T 4 S, R 16 E and NW cor. sec. 8, T 4 S, R 16 E, it thins to about 3 inches in thickness but retains its normal lithologic and textural appearance. This bed generally forms a bench on the slopes and is an excellent marker bed in this area. The upper limestone bed of the Falls City appears to be an excellent water reservoir, and seeps occur in local areas just below the Falls City, but no wells are known to obtain water from this bed. The lower limestone bed is composed of impure, shaly limestone and is probably discontinuous, as it cannot be distinguished in most outcrops of this section of rocks. The shale separating the two limestone beds is a clayey, tannish-gray, noncalcareous shale where it can be identified and is generally about 3 feet thick.

JANESVILLE SHALE

The Janesville Shale consists of two shale members and one limestone member, having a total thickness of about 70 feet in Brown County. The members of the Janesville are, in ascending order: the West Branch Shale, the Five Point Limestone, and the Hamlin Shale.

The West Branch Shale Member is composed of about 27 feet of gray, grayish-green, and tan shale. This shale is silty, calcareous, and locally contains thin zones of impure limestone. The West Branch does not yield water to wells in the County.

The Five Point Limestone Member is composed of two limestone beds and an intervening shale bed that varies in thickness within relatively short distances. The upper limestone bed is generally a hard, dense, gray limestone containing many fossils, but locally it may be an earthy, rubbly, fossiliferous limestone. The shale bed is a drab, grayish-brown, clay shale which varies in thickness from less than 1 foot to about 4 feet. The lower limestone is a gray, dense, hard limestone which weathers platy, the individual plates being about 0.5-inch thick. This lower limestone generally is unfossiliferous and uniform in appearance and weathering characteristics, but locally, it is a dense, gray limestone containing small gastropods in the lower part and a brachiopod fauna in the upper part. Here the limestone becomes nodular upon weathering. The Five Point is as much as 5 feet thick in local areas but is commonly 3 feet thick or less. No wells obtain water from it in Brown County.

The Hamlin Shale Member is about 40 feet thick in Brown County. The Hamlin is composed principally of gray and tannish-gray calcareous, clay shale, but locally, the upper few feet may contain black or dark-gray fissile shale. Sandstone and sandy shale are present in the middle and lower parts. Locally in Brown County, celestite ($SrSO_4$) occurs in veins or joint fillings in the shale just below the zone containing the dark shale. This zone is about 10 feet thick and, according to Fishburn and Davis (1962), the celestite was a product of chemical precipitation brought about by stagnation of a local area in the Permian sea and concentrated in the joint-controlled veins by circulating ground water. Below the celestite zone, sandstone, sandy shale, and gray and tan clay shale are present to the top of the Five Point Limestone Member. Some water is available to wells from the sandy shale and sandstone in the Hamlin, but yields are small.

Section of part of Foraker Limestone and Hamlin Shale Member of the Janesville Shale exposed in road cuts west from NE NW NE sec. 7, T 3 S, R 16 E.

	Thickness, feet
COUNCIL GROVE GROUP	
FORAKER LIMESTONE	
HUGHES CREEK SHALE MEMBER	
Shale, sandy, tannish-gray and light-gray; contains a brachiopod fauna	3.0
Limestone, dark-gray, weathers tannish-gray; contains fusulinids	1.0
Shale, gray, fossiliferous	2.2
Limestone, hard, dark-gray, weathers tannish-gray; contains fusulinids	1.0
Shale, gray and light-gray	5.6
Limestone, impure, buff, upper 4 inches hard, contains a mixed brachiopod fauna and fusulinids in lower part	1.2
Shale, gray and tannish-gray	6.8
Limestone, impure, nodular; contains *Productus* and spiriferid brachiopods	1.2
Shale, light-gray, sandy in part; contains thin sandy siltstone partings	5.8
Shale, dark-gray, platy	5.0
	32.8
AMERICUS LIMESTONE MEMBER	
Limestone, gray, crinoidal bed, hard	0.9
Shale, dark-gray	1.0
Shale, black	0.6
Shale, tannish-gray	2.0
Limestone, gray, impure, massive to nodular	1.0
	5.5
ADMIRE GROUP	
JANESVILLE SHALE	
HAMLIN SHALE MEMBER	
Shale, gray	1.0
Shale, light-gray, very limy	1.0
Shale, light tannish-gray	3.2
Shale, gray; contains celestite in joint fillings	10.4
Shale, gray, sandy	6.2
Shale, gray; contains calcareous pellets	4.5
Sandstone, massive, micaceous, well-cemented	2.0
Shale, tannish-gray, very sandy	6.0
Base covered	34.3

Council Grove Group

The Council Grove Group, according to the Kansas classification, is composed of seven limestone and seven shale formations. Six of the limestones and five of the shales crop out in Brown County, comprising a thickness of about 220 feet of strata.

Rocks of the Council Grove are considerably different from those of the Admire and Wabaunsee groups. The limestone units of the Council Grove are generally thicker than those of the other groups, and many contain appreciable amounts of chert which is scarce in the older rocks. The Council Grove limestones are generally lighter in color and lack the brown color upon weathering of the Admire and Wabaunsee limestones. The shale in the Council Grove is variegated in color and contains more lime and is more fossiliferous than the older rocks. Coal and sandstone are rare in occurrence in comparison with the older rocks.

FORAKER LIMESTONE

The Foraker Limestone consists of three members which are, in ascending order: the Americus Limestone, the Hughes Creek Shale, and the Long Creek Limestone. The total thickness of the Foraker Limestone is about 40 feet.

The Americus Limestone Member consists of two limestone beds separated by an intervening shale bed. The upper bed is a hard, gray to bluish-gray limestone containing crinoids, brachiopods, and bryozoans. It ranges in thickness from about 0.7 to 1.0 foot and maintains a rather uniform appearance and thickness in the County. The lower limestone, which is about 1 foot thick, is quite variable in lithology in the County. Locally this bed may be a pelletal limestone containing fossil fragments, or it may be a dense, hard limestone resembling the upper bed. In other exposures, the lower bed is shaly and grades into the underlying shale, which is the top of the Admire Group. The shale bed between the two limestone beds is tannish-gray to gray and in most exposures contains a thin, black zone near the middle. It is calcareous and unfossiliferous and ranges in thickness from about 1 foot to 3.5 feet but commonly is about 1.5 feet in thickness. The Americus yields no water to wells in the area.

The Hughes Creek Shale Member is a silty, calcareous, gray to tannish-gray shale and generally contains some dark-gray shale in the lower part. Several thin beds of limestone occur in this Member. The Hughes Creek is fossiliferous throughout; fusulinids are especially common in the thicker limestone bed. The Hughes Creek is about 32 feet thick in the County and does not yield water to wells in the area.

The Long Creek Limestone Member is a soft, massive, gray to tannish-gray, slightly dolomitic limestone. It is locally porous and cavernous. The Long Creek ranges in thickness from 6 to 8 feet in Brown County but is poorly exposed because it is less resistant to weathering than the underlying limestone. It weathers back from the bench formed by these limestones and is generally mantled by colluvial material. Water is available to wells from the porous limestone in the Long Creek, but it is generally high in sulfates. The sulfate concentration increases with depth.

JOHNSON SHALE

The Johnson Shale is a silty, calcareous and platy, dark-gray shale in the upper part and a gray, blocky, calcareous shale in the lower part. The lowermost part is fossiliferous containing a mixed fauna of brachiopods, crinoids, and bryozoans. The Johnson Shale averages about 20 feet in thickness in most of its outcrop area in Kansas, but in Brown County the Johnson ranges from 5 to 7 feet in thickness. The Johnson Shale yields no water to wells in the County.

RED EAGLE LIMESTONE

The Red Eagle Limestone is about 5.5 feet thick in Brown County and consists of three members which, in ascending order, are: the Glenrock Limestone, the Bennett Shale, and the Howe Limestone.

Section from lower part of Grenola Limestone down to the Johnson Shale. Exposure in a creek bank in NE SE SE sec. 3, T 1 S, R 15 E, measured by C. K. Bayne and S. M. Ball.

	Thickness, feet
GRENOLA LIMESTONE	
BURR LIMESTONE MEMBER	
Limestone, bluish-gray, weathers tannish-gray	0.5
LEGION SHALE MEMBER	
Shale, gray, calcareous, poorly exposed	3.0
SALLYARDS LIMESTONE MEMBER	
Limestone, tannish-gray	0.9
	4.4
ROCA SHALE	
Shale, tannish-gray to gray, sandy	12.0
Limestone, earthy, very porous, boxwork structure	4.5
Shale, clayey, gray and tannish-gray, limy in middle part of unit	4.2
Shale, gray, laminated, platy to massive	13.0
	33.7
RED EAGLE LIMESTONE	
HOWE LIMESTONE MEMBER	
Limestone, single massive bed, gray, fossiliferous	0.9
BENNETT SHALE MEMBER	
Shale, gray, clayey to silty, flaky to blocky	1.3
Shale, black, fissile to platy; contains *Orbiculoidea* and conodonts	1.7
GLENROCK LIMESTONE MEMBER	
Limestone, single massive bed, silty, contains *Allorisma* and other pelecypods, fusulinids, productids, and bryozoans	1.2
Limestone, gray, shaly, weathers rubbly; contains brachiopods and crinoids	0.5
	5.6
JOHNSON SHALE	
Shale, dark-gray, silty, flaky	2.0
Limestone, shaly, discontinuous over short distances, contains bellerophontid gastropods	0.0 to 0.9
Shale, dark-gray, clayey to silty, platy to flaky	1.5
Limestone, gray, nodular to shaly; contains *Composita, Chonetes,* and crinoids	1.0
Shale, dark-gray, papery	1.0
	5.9

The Glenrock Limestone Member is about 1.5 feet thick. The upper 1 foot is a hard, massive, gray limestone containing many fossils. The lower 0.5 foot is a gray, silty limestone which weathers flaky and contains a brachiopod fauna and crinoids. The Glenrock yields no water to wells in Brown County.

The Bennett Shale Member is about 3 feet thick in Brown County. The upper part is a gray to dark-gray, calcareous clay shale which weathers flaky. The lower part of the Bennett is a black, fissile shale which contains *Orbiculoidea* and conodonts. The Bennett yields no water to wells in the area.

The Howe Limestone Member is a soft, silty, gray limestone about 1 foot thick. The unit consists of one massive bed which in the upper part contains fragments of brachiopods and many ostracodes. Locally, the Howe yields small quantities of water to wells.

ROCA SHALE

The Roca Shale is about 34 feet thick in Brown County. The upper part of the Roca is gray to tannish-gray sandy shale. The middle part is composed of very porous limestone having a boxwork structure. Below the porous limestone is a zone of limy shale. The lower part of the Roca is a gray, clayey, massive to flaky shale. The porous limestone in the middle part of the Roca is an important aquifer in northwestern Brown County. Yields up to 150 gpm may be obtained locally from this bed. South of the center of the County the porous limestone thins or is absent, and little or no water is obtained from the Roca.

GRENOLA LIMESTONE

The Grenola Limestone consists of five members which, in ascending order, are: the Sallyards Limestone, the Legion Shale, the Burr Limestone, the Salem Point Shale, and the Neva Limestone. The thickness of the Grenola in Brown County is about 28 to 30 feet.

The Sallyards Limestone Member is a hard, gray to tannish-gray fossiliferous limestone. The Sallyards generally consists of a single bed which weathers blocky. The Member ranges in thickness from 1 to 1.5 feet in the County and yields no water to wells in the area.

The Legion Shale Member is composed of gray and tannish-gray silty calcareous shale that contains a thin zone of black platy or fissile shale near the top. The Legion ranges in thickness from about 1.5 to 3 feet in the County. No water is obtained from the Legion in the area.

The Burr Limestone Member is poorly exposed in Brown County. Generally the Member is covered by colluvium and slump from the overlying beds. In adjacent areas the Burr consists of two or more beds of limestone separated by beds of shale. In Brown County only the lowermost limestone bed and an overlying shale were observed. This limestone bed is a hard, gray, fossiliferous limestone about 1 foot thick which weathers into small tannish-gray chips. The Burr yields no water to wells.

The Salem Point Shale Member is a silty, calcareous, greenish-gray to tannish-gray shale, which in Brown County ranges in thickness from about 4 to 8 feet. The Member is poorly exposed and does not yield water.

The Neva Limestone Member is about 13 feet thick in Brown County and consists of alternating beds of limestone and shale. Most of the limestone beds in the Neva are massive, somewhat porous, and fossiliferous. The uppermost bed of limestone is about 6 feet thick and consists of an upper soft, shaly, tannish-gray limestone underlain by a massive brownish-gray limestone about 4 feet thick. The limestones below the uppermost bed are gray. The shale beds are gray and tannish-gray and are silty, calcareous, and thin-bedded. A black fissile shale occurs in the lower part of the Neva in this area. The Neva Limestone Member yields small to moderate quantities of water to wells in western Brown County.

Section from the Morrill Limestone Member of the Beattie Limestone through the Neva Limestone Member of the Grenola Limestone in SE sec. 19, T 1 S, R 15 E, measured by R. C. Moore.

	Thickness, feet
BEATTIE LIMESTONE	
MORRILL LIMESTONE MEMBER	
Limestone, gray, weathers granular, hard, dense, fossiliferous; lower part light blue, weathers bluish-gray, fine-textured, earthy; contains an abundant molluscan fauna	0.9
Shale, greenish-gray	0.7
Limestone, white, soft, shaly	1.3
FLORENA SHALE MEMBER	
Shale, light-gray, very calcareous and fossiliferous	3.0
COTTONWOOD LIMESTONE MEMBER	
Limestone, white, soft, chalky, massive, weathers shelly; contains many fusulinids	5.5
	11.4
ESKRIDGE SHALE	
Shale, greenish-gray, calcareous, partly covered	28.0
	28.0
GRENOLA LIMESTONE	
NEVA LIMESTONE MEMBER	
Limestone, light tannish-gray, lower part single massive bed 4 feet thick, upper part soft, somewhat shaly	6.0
Shale, calcareous, grayish-brown	1.3

	Thickness, feet
Limestone, gray, impure, earthy, massive	1.4
Shale, greenish-gray, calcareous	0.8
Limestone, light- and dark-gray, impure, weathers blocky, very fossiliferous	0.4
Shale, soft, black, fissile	3.0
Shale, light- and dark-gray, hard, calcareous, grades to soft shaly limestone; contains *Orbiculoidea* and other brachiopods	0.9
Limestone, hard, dense, massive, light-gray	1.2
SALEM POINT SHALE MEMBER	
Shale, gray to tannish-gray, blocky	8.0
Base covered	23.0

ESKRIDGE SHALE

The Eskridge Shale is composed of varicolored shale with gray and tannish-gray being the dominant colors. Several persistent thin beds of limestone, generally less than 1 foot thick, occur in the Eskridge. The thickness in Brown County is about 30 feet. The Eskridge occupies the slope between the Grenola Limestone and the Beattie Limestone and is generally poorly exposed. Partial exposures are best seen in road ditches and stream banks. Coal occurs in the upper part of the Eskridge in Brown County (Moore, *et al.*, 1951). This coal is thin and discontinuous and not of commercial quality. The Eskridge yields no water to wells in the County.

BEATTIE LIMESTONE

The Beattie Limestone consists of three members which, in ascending order, are: the Cottonwood Limestone, the Florena Shale, and the Morrill Limestone. The Beattie is about 12 feet thick in Brown County.

The Cottonwood Limestone Member is a light-gray to white, massive limestone. The Member is best exposed in northwestern Brown County where it is about 5.5 feet thick. The Cottonwood in northern Kansas is not as hard as it is in the central part of Kansas and does not form the conspicuous bench strewn with large blocks of limestone so characteristic of the Member in the central part of the State. In Brown County the Cottonwood contains abundant fusulinids and scattered chert nodules. Solution channels are present in the Member and, in some localities small quantities of water are obtained from it.

The Florena Shale Member is a silty, very calcareous, light-gray to tannish-gray shale. The Florena is very fossiliferous, containing a mixed fauna in which *Chonetes* is especially abundant. The Florena is about 3 feet thick in northwestern Brown County but thickens to about 6 feet in the west-central part. The Florena yields no water to wells in the area.

The Morrill Limestone Member consists of two limestone beds separated by a shale bed. The upper limestone bed is a hard, dense, gray limestone containing brachiopods, and, upon weathering, the limestone has a granular appearance. The lower limestone bed is soft and weathers shaly. The intervening shale is gray to grayish-green. The Morrill is about 3 feet thick in Brown County and yields no water to wells in the area.

STEARNS SHALE

The Stearns Shale is poorly exposed in Brown County where it occupies the slope between the small benches formed by the Beattie Limestone and the Bader Limestone. The Stearns is about 15 feet thick in the County and is composed of gray and tannish-gray silty calcareous shale grading downward to gray-green shale. It commonly contains a thin limestone near the top. The Stearns yields no water to wells in the area.

BADER LIMESTONE

The Bader Limestone consists of three members which, in ascending order, are the Eiss Limestone, the Hooser Shale, and the Middleburg Limestone members. The Bader is about 25 feet thick in the County.

Section from Crouse Limestone through the Bader Limestone in SE NE SW sec. 25, T 1 S, R 14 E, measured by M. R. Mudge (slightly modified by Bayne).

	Thickness, feet
GLACIAL TILL	
Till, clayey, noncalcareous, brown, numerous small erratics	5±
CROUSE LIMESTONE	
Limestone, medium hard, tan to tannish-brown, massive, weathers tan and blocky	1.7
Limestone, medium hard, tan, thin-bedded; weathers shaly; fossiliferous	1.1
Shale, clayey, calcareous, tannish-gray, weathers tan and blocky; contains calcareous nodules	7.1
Limestone, medium hard, gray; weathers tan and blocky, cavernous, fossiliferous	1.3
	11.2
EASLY CREEK SHALE	
Shale, silty, calcareous, thin-bedded to blocky, light-gray to grayish-green, mottled with maroon in middle part, calcareous lenses in middle part and calcareous nodules in upper part	2.8
Shale, silty, calcareous, mostly blocky; some thin-bedded, alternating between gray, grayish-green and maroon	2.9
Shale, silty, calcareous, mostly thin-bedded, some blocky, inter-bedded gray, grayish-green and maroon beds somewhat thicker than overlying beds	7.2

	Thickness, feet
Shale, clayey, calcareous, grayish-green; weathers tan, thin-bedded, numerous calcareous lenses which weather cavernous ..	2.9
	15.8
BADER LIMESTONE	
MIDDLEBURG LIMESTONE MEMBER	
Limestone, hard, tannish-gray; weathers tan and blocky; cavernous and porous in upper part; many fossil fragments in upper part which weather faster than matrix and give the surface a porous appearance	1.1
Limestone, soft, tannish-gray; weathers tan and blocky to shaly in lower part	0.7
Limestone, hard, gray, massive; weathers tannish-gray; blocky near top and shaly in lower part; contains numerous high-spired gastropods in lower part; fossil fragments common throughout	2.0
HOOSER SHALE MEMBER	
Shale, silty, calcareous, tannish-gray, thin-bedded; weathers tan and blocky	1.6
Limestone, hard, dense, weathers light-gray	0.1
Shale, silty, calcareous, thin-bedded to blocky, grayish-green in upper part and tannish-gray in lower part; contains calcareous lenses in lower part	3.1
Shale, silty, calcareous, thin-bedded, maroon with grayish-green lenses; calcareous nodules at base	3.1
Shale, silty, calcareous, maroon	0.6
Shale, silty, calcareous, grayish-green	0.6
Limestone, hard, clayey, gray	0.2
Shale, silty, calcareous, tannish-gray	0.3
Shale, clayey, noncalcareous, grayish-green	0.2
EISS LIMESTONE MEMBER	
Limestone, soft, dolomitic, massive, tan, irregularly porous	2.9
Shale, silty and clayey, calcareous, tannish-gray; weathers tan, blocky	5.6
Limestone, medium hard, gray to light-gray, massive; weathers light-gray and shaly; abundant high-spired gastropods in lower part, very fossiliferous	1.6
	23.7
STEARNS SHALE	
Shale, silty to calcareous, thin-bedded to blocky, gray to grayish-green; lower part weathers cavernous	5.3
Base covered	5.3

The Eiss Limestone Member consists of two or more limestone beds separated by shale. The uppermost bed of limestone is dolomitic and generally massive and soft. The shale bed is silty, calcareous, and tannish gray. The lower bed of limestone is about 1 foot thick and is a gray silty to shaly, very fossiliferous limestone. A type of high-spired gastropod is especially abundant in the lower part. The Eiss is about 10 feet thick in Brown County and yields no water to wells in the area.

The Hooser Shale Member is a silty, calcareous shale. The unit is varicolored with grayish green and tannish gray dominant. One or more thin beds of limestone occur in the Hooser in Brown County. The Hooser is about 11 feet thick and yields no water to wells in the area.

The Middleburg Limestone Member is about 4 feet thick in Brown County and is composed of one or more beds of limestone, locally separated by a thin bed of shale. The limestone is medium hard and light-gray and weathers tannish gray. The uppermost limestone bed is porous. The lower bed of limestone is hard, massive, and very fossiliferous. A type of small high-spired gastropod is especially abundant in this bed. The Middleburg yields no water to wells in Brown County.

EASLY CREEK SHALE

The Easly Creek Shale is a silty, calcareous, varicolored shale. Gray and grayish green are the dominant colors; however, maroon shale occurs throughout the section, and tan shale is present in the lower part. Thin, limy zones occur in the middle and lower parts. The Easly Creek is not fossiliferous in Brown County. It ranges in thickness from 16 to 19 feet and does not yield water to wells.

CROUSE LIMESTONE

The Crouse Limestone is the uppermost rock of Permian age which crops out in Brown County. The Crouse consists of two limestone beds separated by a relatively thick bed of shale. The lower limestone bed is a hard, dense, massive, gray limestone about 1 foot thick and is fossiliferous throughout. The shale bed is clayey, calcareous, and tannish-gray. It is somewhat platy at the top and blocky in the lower part. This shale is about 6 feet thick. The upper limestone bed is about 3 feet thick and is a tannish-gray, earthy limestone which weathers porous. The Crouse yields no water to wells in Brown County.

QUATERNARY SYSTEM—PLEISTOCENE SERIES

The Pleistocene Epoch is the last of the major divisions of geologic time and has been called the "Ice Age" owing to the presence of continental glaciers in North America and elsewhere. The Pleistocene Series in Kansas has been divided into the Nebraskan, Kansan, Illinoisan, and Wisconsinan glacial stages and the Aftonian, Yarmouthian, Sangamonian, and Recent interglacial stages. Events in each of the periods of continental glaciation followed a cyclic repetition. Each cycle consists of a glacial and an interglacial stage. The cycle in a marginal belt around a glaciated area and ahead of an advancing glacier is characterized by a period of down-cutting in the valleys with some local deposition of sediments followed by a period of deposition of coarse material. Progressively finer heterogeneous material is deposited on the melting ice as the glacier retreates, and finally development of a soil profile occurs during the interglacial stages over a large area where surface conditions are relatively stable.

During the Nebraskan and Kansan stages, continental glaciers covered part of northeastern Kansas. The Kansan glacier covered all of Brown County, and deposits of this age occur in the County. The Nebraskan glacier probably entered the County, but no glacial deposits associated with this stage of glaciation were identified. Non-glacial Pleistocene deposits of pre-Kansan age are present in the County. The thickness of the Pleistocene rocks and their relation to the underlying Pennsylvanian and Permian rocks are shown on the cross sections on Plate 2.

Nebraskan and Aftonian Stages

Deposits of chert gravel containing some locally derived limestone gravel crop out in northwestern Brown County. Local deposits of similar lithology crop out and are found in test holes beneath glacial drift of Kansan age in eastern Brown County. Both of these deposits, because they occur below the drift and apparently do not contain glacial material, are considered to be of Nebraskan and Aftonian ages (Pl. 1). North and northwest of Morrill, numerous deposits of chert gravel occur in the highest topographic position, and in northeast Brown County similar gravel is present below lacustrine deposits in a deep channel. The deposits are generally less than 10 feet thick, and in northwest Brown County they lie above the water table and yield no water to wells. The gravel in the channel area in northeastern Brown County is as much as 20 feet thick. These deposits are saturated, and yields up to 100 gpm may be available in local areas although they are not utilized at present.

Kansan and Yarmouthian Stages

Several deposits associated with the glacier that covered Brown County during the Kansan Stage were identified during this study. These are glaciolacustrine deposits assigned to the Atchison Formation, glacial till or sediments laid down directly by the melting ice, and outwash deposits, or deposits laid down by meltwater flowing from the ice. These outwash deposits are in part equivalent to the Grand Island Formation.

Glaciolacustrine Deposits

Glaciolacustrine deposits composed of silt and very fine sand were present in several test holes in northeast Brown County. No outcrops of these deposits were observed in the County during the study, but in adjacent Atchison and Nemaha counties, similar deposits crop out. In these areas the deposits display bedding and staining by limonite on the bedding planes. In Atchison County these deposits have been named the Atchison Formation (Frye and Leonard, 1952). In Brown County the Atchison occurs near the base of a buried channel in the northeast part of the County (Pl. 2) and are overlain by glacial till or outwash material. It is believed that these deposits were laid down in relatively quiet water such as in a lake formed when the advancing ice blocked an old drainageway. Locally in this part of the County, the Atchison is underlain by a gravel of local origin which is believed to be of Nebraskan age. The Atchison Formation ranges in thickness from 0 to about 50 feet in Brown County. The Atchison Formation lies below the water table, and small supplies of water could be obtained, but no wells are known to obtain water from this Formation in the County.

Kansas Till and Outwash Deposits

The Kansas Till is a non-stratified glacial deposit consisting principally of clay but containing silt, sand, gravel, cobbles, and boulders deposited by the melting ice. Lenses of sand and gravel may be present at any horizon in the till. The unweathered till ranges from tannish gray to dark gray or bluish gray, and the weathered till is generally tannish brown or brown. The till contains fractures which dip at a steep angle and which have been filled with calcium carbonate and stained by limonite. Boulders are interspersed throughout the till and range widely in concentration over relatively short distances. The maximum thickness of till encountered in test holes in Brown County was about 115 feet.

Outwash deposits consisting of poorly-sorted to moderately-sorted silt, sand, and gravel are present in much of Brown County. This material was deposited by meltwater streams flowing away from the ice front and occurs both under and on top of till. These deposits range in thickness from 0 to about 100 feet. The outwash deposits appear to have been deposited in poorly defined channels which generally are not traceable more than short distances away from the outcrop area. One of the more prominent channels, about 1 mile west of Everest, is a north-south trending channel and may extend north and northwest to an area about 1 mile northeast of the community of Baker where outwash gravel is exposed in gravel pits. The material comprising this deposit is principally quartz sand; however, granitic and metamorphic rocks and boulders are also present. It is moderately well sorted but contains a small amount of silt and fine sand. The city of Everest obtains the municipal water supply from well 5-18-6dbb which was test-pumped at a rate of 250 gpm from these deposits.

In the area adjacent to Walnut Creek in west-central and northern Brown County and adjacent to Wolf River in east-central Brown County, numerous outcrops of outwash occur. An outwash deposit in SW NE sec. 32, T 2 S, R 16 E is exposed in a pit in a terrace adjacent to Walnut Creek. In this pit quartz sand is the most common material, but pebbles derived from glacial till and locally-derived material are also present. A molluscan fauna from the silt in this pit indicates a late Kansan age. All the outwash deposits except the chert gravel deposits of pre-Kansan age and the glaciolacustrine deposits of the Atchison Formation are considered in this report to be a part of the Grand Island Formation, although some are laid down directly on till and some occur in terrace position and may be somewhat younger.

Little water is ordinarily available to wells from the till, although in local areas, sand and gravel lenses incorporated in the till yield small quantities of water. The outwash deposits comprise the most important and widespread aquifer in Brown County. Yields ranging from a few gallons per minute to as much as 450 gpm are obtained. The major streams in the County have entrenched their valleys below the drift deposits in most of the area, and subsequent draining near the stream has made it difficult to obtain dependable water supplies from the drift in these areas. The changes in lithology and sorting which occur in glacial drift make it difficult to predict the availability of water from the drift; however, in a drift deposit 20 to 30 feet thick, one can expect one or more lenses of sand or gravel from which yields of several gallons per minute can be expected.

Illinoisan and Sangamonian Stages

Following the retreat of the Kansan glacier, erosion began on the till plain and most of the outwash deposits were laid down. During the Illinoisan Stage, erosion continued in the area, and a great quantity of material was removed (Pl. 2). It is probable that some deposition occurred during the Illinoisan, but quantitatively it was small, and the deposits were either removed during the Wisconsinan Stage or were not recognized in this study. A few discontinuous fluvial deposits in terrace position along Walnut Creek valley in north-central Brown County may be Illinoisan in age, but they are small in areal extent and are not shown on Plate 1.

In many local areas the upper surface of drift below the Wisconsinan loess is weathered. Part of this weathering could have occurred during Yarmouthian time when conditions were relatively stable, but it is believed that a soil formed during this period would have been largely removed by erosion during Illinoisan time and that the weathering is principally of Sangamonian age. Some loess and alluvial deposits of Illinoisan and Sangamonian age may be present in the County, but, with the exception of the fluvial deposits in Walnut Creek valley, they are not recognized. These deposits yield no water to wells in the area.

Wisconsinan and Recent Stages

During the early Wisconsinan time, many of the older deposits were eroded. The present stream system was established, and the streams entrenched their valleys to about their present level. This early eroding phase was followed by a period during which the valleys were partly filled with alluvial material, and loess derived from the valley trains from the Wisconsinan glaciers to the north was deposited in the uplands and on the valley walls.

The loess deposits (Pl. 1) may contain some loess of Illinoisan age, but are principally composed of early Wisconsinan loess (Peoria Formation) and late Wisconsinan loess (Bignell Formation). The Bignell and the Peoria loess can only be differentiated in this area through their contained molluscan fauna or, locally, by a zone which is leached of calcium carbonate at the top of the Peoria Formation. The maximum observed thickness of loess in Brown County was 86 feet. The loess is thickest in the northeast part of the County near the Missouri River and thins toward the west and southwest (Pl. 2). The loess is not an aquifer in the area.

The Wisconsinan and Recent alluvial deposits (Pl. 1) are composed of clay, silt, sand, and gravel. These deposits are generally poorly sorted, and relatively small supplies of water are obtained from them. The thickness of the Wisconsinan and Recent alluvial deposits ranges from only a few feet to about 55 feet.

STRUCTURAL DEVELOPMENT

Much of the following discussion on structural development is based on the report, *Stratigraphy and Structural Development of the Forest City Basin* by Lee (1943).

Many unconformities are recognized in the Paleozoic rocks in northeastern Kansas. The most important of these are at the base of the Middle Ordovician St. Peter Sandstone, the base of the Devonian, the base of the Upper Devonian and Lower Mississippian, the Chattanooga Shale, and the top of the Mississippian. The erosion represented by each of these unconformities was preceded by important structural movement, and each period of erosion resulted in almost complete base leveling.

Prior to deposition of the St. Peter, northeastern Kansas had been an area of slow general uplift. During this period, many hundreds of feet of rock were deposited and, in turn, removed over minor flexures. It was on this base-leveled surface that the St. Peter Sandstone was deposited. At the end of the deposition of the St. Peter Sandstone, the pattern of structural movement changed, and the area began a general subsidence, marking the beginning, in Late Ordovician time, of the North Kansas basin. This basin was the dominant structural feature in northeastern Kansas until the end of Chattanooga time, although local deformations occurred in the area throughout this period.

The first movement along the Nemaha Anticline occurred during Early Mississippian time, resulting in folding of Lower Mississippian rocks over the anticline and the development of local parallel structures. This folding was slow and probably continued throughout the deposition of Mississippian rocks. The Nemaha Anticline bisected the North Kansas basin, forming the Salina basin on the west and an unnamed basin on the east. The folded rocks were then eroded to near base level. This was followed by renewed movement along the Nemaha Anticline which caused the re-elevation of the area west of the Anticline and the downwarping of the area east of the Anticline, forming the Forest City basin.

The Forest City basin was separated from the Cherokee basin of Oklahoma and southern Kansas by the Bourbon Arch, through Bourbon, Allen, and Coffey counties. Early Cherokee deposits in both the Forest City and Cherokee basins are abnormally thick and differ in lithology to the extent that the sandstones commonly found in the Cherokee basin are largely absent in the Forest City basin. In middle Cherokee time, the Bourbon Arch was topped, and the Forest City basin became an extension of the larger Cherokee basin.

Minor flexing of the area continued during Pennsylvanian and Permian time, although the Permian record is largely lost through later erosion. The westward dip of the surface rocks in the area occurred principally prior to Cretaceous time, but there has been some deformation and great elevation of the entire area since that time.

GROUND WATER

SOURCE AND PRINCIPLES OF OCCURRENCE

The source and principles of occurrence of ground water as related to Brown County are discussed on the following pages. The principles governing the occurrence of ground water have been discussed by many authors (Meinzer, 1923a; Moore, *et al.*, 1940) and the reader is referred to their reports for a more detailed discussion of the subject.

Water in the pores or interstices of rocks in the zone that is completely saturated is called *ground water*. In Brown County ground water is derived from precipitation in the form of rain or snow that falls on the County or in nearby areas. Part of the precipitation leaves as runoff discharged by streams, part evaporates, and part is transpired by vegetation. The part that escapes runoff, evaporation, or transpiration moves slowly downward through the soil and the underlying strata until it reaches the zone of saturation. After reaching the ground-water body, the water percolates through the rocks in a direction determined by the geology, topography, and geologic structure, until it is discharged by wells and springs, or by evaporation and transpiration in areas where the water table is relatively near the surface, or it is discharged directly into streams or other bodies of water.

The amount of water that can be stored in a water-bearing formation is dependent upon the porosity of the formation. *Porosity* is expressed as the ratio of the volume of interstices in the material to the total volume of the material. Saturated rocks of high porosity do not necessarily yield large quantities of water to wells; one rock may readily yield most of the water contained in its pores, but another having equal porosity but smaller pores may retain most of its contained water due to capillary attraction.

The quantity of water a water-bearing material will yield and the rate at which water will move through it are governed by its physical and hydrologic properties. Sediments are seldom homogeneous; their physical and hydrologic properties range widely, being governed by the size, shape, number, and degree of interconnection of the voids in the material. A water-bearing rock may have high porosity in relatively large voids, but, unless the voids are interconnected, little water can move through it, resulting in low permeability and transmissibility. Under such conditions a satisfactory well cannot be obtained.

Permeability may be defined as the capacity of rock to transmit water. The *field coefficient of permeability* of an aquifer may be expressed as the rate of flow of water at the prevailing temperature, in gallons a day, through a cross-sectional area having a thickness of 1 foot and a width of 1 mile for each foot per mile of hydraulic gradient. The coefficient of transmissibility is the field coefficient of permeability multiplied by the saturated thickness, in feet, of the aquifer.

The *water table* is the upper surface of the zone of saturation except where that surface is formed by an impermeable body. If the upper surface of the zone of saturation is formed by an impermeable body, no water table exists. The water level in a well drilled into saturated material under water-table conditions will stand in the well at the level at which it was first reached. When water is confined in a bed under pressure by an impermeable bed, artesian conditions exist. The water in a well drilled into an artesian aquifer will rise to a level higher than the level at which it was reached; if the pressure is great enough to lift the water above the land surface, the well will flow. In Brown County much of the water contained in the Pennsylvanian and Permian rocks is under some artesian pressure, but only one well was observed flowing at the surface. Well 4-16-17daa flowed at a rate of about one-half gallon per minute from the Pillsbury Shale and/or the Zeandale Limestone.

WATER TABLE AND MOVEMENT OF GROUND WATER

The factors that control the shape and slope of the water table are the topography of the land surface, the underlying bedrock, the transmissibility of the material through which it moves, the relative location of areas of recharge and discharge from the ground-water reservoir, and the relative rate of recharge and discharge.

In most areas the water table has the same general shape as the land surface but is more subdued in form and fluctuates in response to gain or loss of water in the aquifer. In some aquifers the fluctuation may be slow and of very little magnitude, but in others the response may be rapid, and fluctuations may be relatively large. Figure 5 shows the hydrographs of four wells in Brown County. Well 3-17-31bbb obtains water from Pennsylvanian limestone, and the other wells obtain water from glacial drift. The hydrographs of wells in the glacial drift are very similar and can be directly related to the weather cycle with lowering water level during periods of drought and rising water level in response to precipitation. Well 3-17-31bbb also can be correlated to the weather cycle, but the response to precipitation and periods of drought is much less than in the wells in glacial drift.

Contours on the water table are shown for part of Brown County on Plate 1. In the western part of the County, water is obtained principally from rocks of Pennsylvanian and Permian ages, and, because the water table is discontinuous or absent in this area, water-table contours are not shown. In the eastern part of the County, the contours are dashed through bedrock areas where the water table is discontinuous. In Brown County the shape of the water table is controlled largely by the topography and to some extent by the underlying bedrock. Most of the major streams have cut through the glacial drift. Discontinuous outcrops of bedrock occur along the valley walls, and alluvial deposits occur in the valley bottoms. Ground water moves in a 90-degree direction from any point on a contour, and it is apparent from the contours on Plate 1 that ground water moves toward and into nearly every stream of any size in the County. Near the valley walls the contours are more closely spaced. This in part indicates steeper topographic conditions but also indicates lower transmissibility of the less permeable bedrock and colluvium through which the water moves. In the upland areas largely underlain by glacial drift (Pl. 1), the contours are more widely spaced, reflecting the flatter upland topography and the more permeable material through which the water moves. In the valley alluvial deposits, water-table conditions exist, and locally this water table is continuous with the water table in the uplands. In those areas where bedrock is present in the valley walls, the water table is discontinuous.

DEPTH TO WATER

In Brown County the depth to water in the unconsolidated deposits is generally greatest in areas of the highest topography. The depth to water may determine in a given area the type of well or the type of pump used to obtain the water. In Brown County in areas where the depth to water is less than 25 feet, suction pumps are commonly used. In areas where the depth is below the level for efficient use of suction pumps, force or jet pumps are commonly used. In areas where the water table is shallow, many wells are dug or bored, but in areas where there is an appreciable depth to water, most wells are drilled.

The quantity of water discharged by evaporation and transpiration is closely related to the depth of water. In areas where the water table lies at a depth below the root systems of the vegetation, little water is transpired, and where the depth is more than a few feet, little water is evaporated directly from the zone of saturation or the capillary zone. In Brown County along the edges of many of the valleys (Pl. 2) and on the slope of many of the rounded hills in the drift area, the water table is at or near the surface. Seeps are present locally in these areas and much water is lost by evaporation and transpiration.

The depth to water in wells in Brown County is given in Table 6, and the depth to water in test holes in the glacial drift and valley alluvial deposits is given in Table 7. Depth to water in the glacial drift area is shown in Figure 6. The depth to water in wells given in Table 6

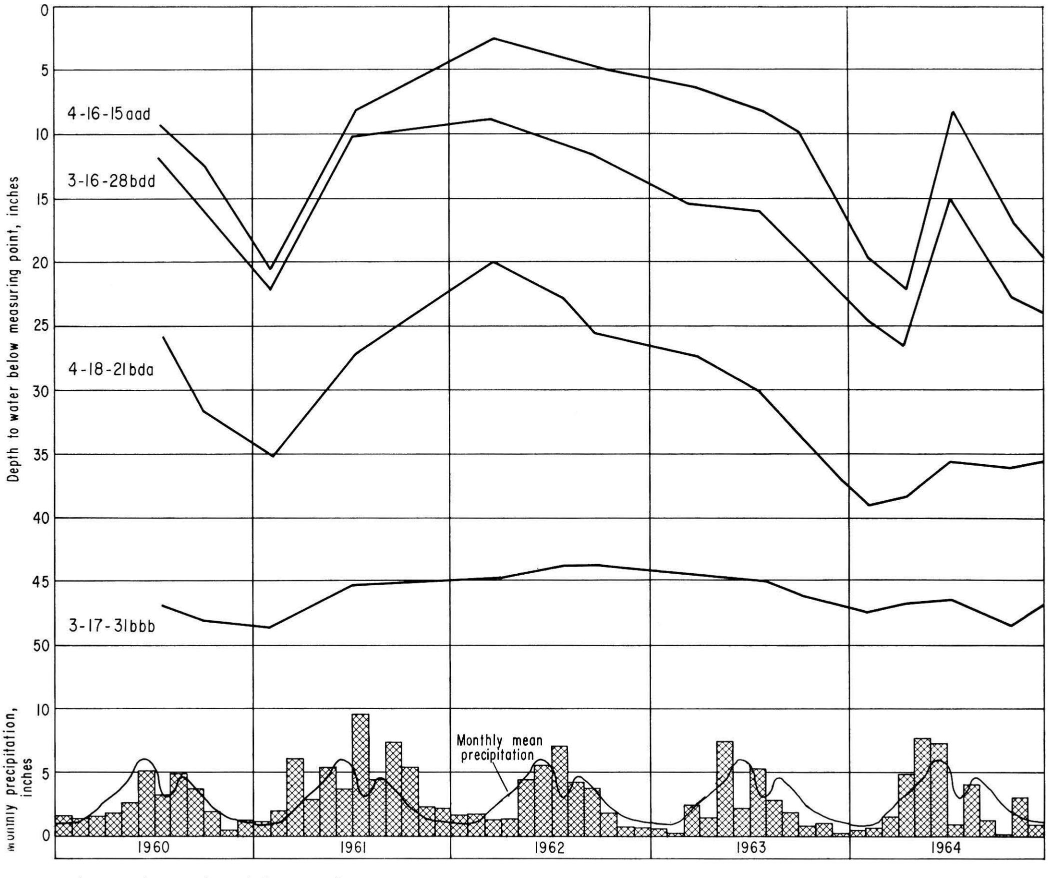

FIGURE 5.—Hydrographs of four wells in Brown County, Kansas, and monthly precipitation and monthly mean precipitation, 1960-64, at Horton, Kansas.

that obtain water from bedrock aquifers does not necessarily indicate the depth at which water was first reached in the well, since water in some of the bedrock aquifers occurs under artesian conditions and rises above the aquifer. Water in glacial drift and in alluvial deposits in the valleys occurs under water-table conditions. The depth to water in the County ranges from 0 to about 80 feet.

SATURATED THICKNESS OF GLACIAL DRIFT

Data on the saturated thickness of the glacial drift were obtained from test-hole information and are shown on Figure 6 and given in Table 7. The thickness of saturated material in a water-table aquifer has an important effect on the quantity of water available for use. In wells

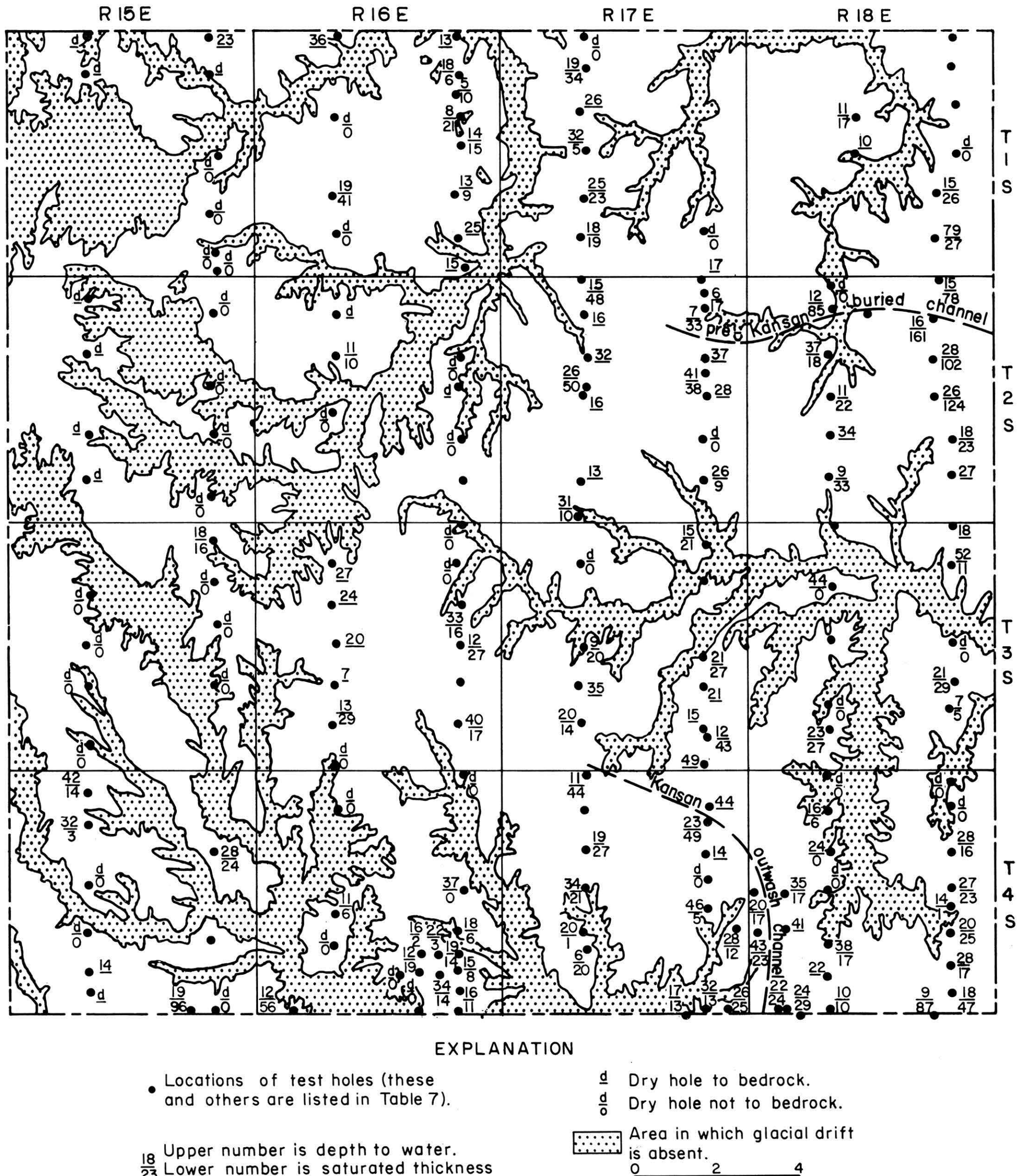

FIGURE 6.—Depth to water and saturated thickness in areas underlain by glacial drift, Brown County, Kansas.

having materials of equal permeability, the well with the greatest saturated thickness will have the largest potential yield. In Brown County the thickness of saturated material in the glacial drift area is an important factor in yield and reliability of wells from this aquifer. This material, although composed principally of fine materials, contains pockets or lentils of sand and gravel, and where 20 or 30 feet of saturated material is present, one or more of these permeable zones usually can be found in which a dependable water supply can be developed. In northwestern and western Brown County and adjacent to many of the streams in eastern Brown County, the drift is thin and dry or contains only a thin zone of saturation. In the eastern part of the County much of the area has a saturated thickness in excess of 20 feet; the maximum (161 feet) is in the northeastern part of the County.

AVAILABILITY OF GROUND WATER

Ground water is available in Brown County from glacial drift, alluvial deposits in valley areas, and bedrock aquifers. The glacial drift, occurring over much of the upland area of the County, is the most extensive and the most important of the aquifers. It ranges widely in thickness and lithology over short distances and, as these factors affect the availability of water from the drift, yields and dependability of wells in the drift range widely. Where the streams have cut through the drift and erosion has thinned the glacial deposits adjacent to these valleys, the drift is partly drained and is locally dry, resulting in either meager supplies or no water in these areas.

Moderate to large supplies of water are available from the drift in local areas in the County. The largest yields and most extensive supplies occur north of Hiawatha. The drift is thicker in this area and contains more outwash material than elsewhere. Yields may range up to 450 gpm in this area but more commonly are about 100 gpm or less. In an area just west of Everest, moderate supplies of water are available from channel deposits. These deposits are glacial outwash deposits and consist of moderately well-sorted sand and gravel occurring in a north-south trending channel (Fig. 6). Everest obtains water from these deposits in Atchison County. Well 5-18-6dbb was pumped at a rate of 250 gpm with 9 feet of drawdown during tests, but it is usually pumped at about 90 gpm. The channel in which these deposits occur is narrow and the areal extent of the aquifer is limited.

A pre-Kansan buried channel (Fig. 6) trending east-west just south of the line between Townships 1 and 2 in Ranges 17 and 18 is a potential source of moderate to large supplies of ground water. This channel locally contains pre-Kansan sand and gravel deposits in the basal part that are overlain by pro-glacial Kansan lacustrine deposits that are, in turn, overlain by Kansan glacial drift. The lacustrine deposits consist of very fine, bedded sand and some silt, as much as 50 feet thick. This sand is too fine to be successfully screened, and a well cannot be finished in it, but in the areas where it overlies sand and gravel deposits, a well screened in the lower sand and gravel could utilize the water stored in the lacustrine deposits.

In most of Brown County it is difficult to predict yields from wells in the glacial drift because the drift changes so markedly in lithology in short distances, but generally in the eastern part of the County adequate and dependable water supplies for domestic and stock use can be obtained.

Small quantities of water are generally available from alluvial deposits in the stream valleys in Brown County. The materials comprising these deposits are generally poorly sorted and contain much silt and clay intermixed with sand and gravel. This results in wells with small yields. The city of Reserve obtains water from alluvial deposits in Walnut Creek valley, and the city of Robinson obtains water from similar deposits in Wolf River valley. The yield from the municipal wells for these cities is about 20 gpm per well.

The quantity of water available to wells in Brown County from bedrock aquifers ranges widely, depending on local conditions and the individual aquifer. In eastern Brown County many wells obtain water from sandstone beds in the Wabaunsee Group. Yields of wells in sandstone aquifers in the County are generally small but dependable. Numerous springs occur along the walls of the major valleys in eastern Brown County. These springs issue from limestones of the Wabaunsee Group, and where these limestones are overlain by glacial drift, much of the flow of the springs is from water moving downward from the drift. Water moves through, and is discharged from, the limestone joints and solution channels. In a north-south-trending area in the central part of the County, rocks of the Admire Group and the upper part of the Wabaunsee Group are generally poor aquifers.

During periods of drought, water shortages occur in wells utilizing these aquifers; locally, however, dependable wells obtain water from thin sandstone beds.

In northwestern Brown County water is obtained from rocks in the lower part of the Council Grove Group. The Grenola Limestone, the Roca Shale, and the Long Creek Limestone Member of the Foraker Limestone are the principal aquifers. Yields ranging up to 250 gpm have been obtained from wells in this area; however, yields less than 100 gpm are common. South from the line between Townships 2 and 3, these aquifers are much less permeable and yields of only a few gpm are obtained. Water from the lower part of the Council Grove Group is generally high in sulfate, with an increase in concentration with depth. Numerous springs yielding water from these aquifers occur in the area west and northwest of Morrill, which obtains water from these aquifers in and just south of the city.

UTILIZATION OF GROUND WATER

In Brown County, ground water is used principally for domestic, stock, and public supplies. Only one industry uses ground water from privately owned wells, and irrigation is not practiced in the County.

Domestic and Stock Supplies

Nearly all water for domestic use and much of the water for stock use in rural areas in the County is obtained from privately owned wells. These range in depth from about 20 to 200 feet. There is no correlation between depth and location or source, for shallow wells and deep wells are found in all parts of the County. Most deep wells are drilled wells, and the shallow wells are about equally divided between dug and drilled wells, although nearly all new wells are drilled. Most domestic and stock wells are pumped at a low rate, although many are capable of yielding more water with the proper pump installation. Yields of domestic and stock wells in the County range from a few gallons per hour to about 40 gpm. In local areas where water shortages periodically occur, cisterns are used for supplemental water supplies. Many ponds have been constructed for stock use.

Public Supplies

Six cities in Brown County have public water supplies; five use ground water and one uses surface water.

The original water system for Everest was built in 1921. In 1934 water was obtained from four wells 60 to 65 feet deep located in the city. Water was obtained from glacial drift and the Bern Limestone. About 1955 better quality water was obtained from outwash channel deposits about 2 miles south of the city. Well 5-18-6dbb is 41 feet deep and was tested at a rate of 250 gpm. The well is normally pumped at a rate of 90 gpm. Analyses of water from well 4-18-29bda in the old well field and from the new well (5-18-6dbb) are given in Table 3. Storage is provided by an elevated steel tank with a capacity of 25,000 gallons. The average daily use is about 25,000 gallons. The water is chlorinated but receives no other treatment.

Hiawatha is the largest city in Brown County. The original water system for the city was built in 1887 when water was obtained from one dug well in a valley about 1 mile south of town. This well was the only source of supply until about 1912 when a spring (3-17-5aac) was improved and connected to the system. In 1921 another spring (2-16-36ddb) was improved and added to the system. Four additional wells located south of the city were added in the period between 1921 and 1945, and in 1947 two wells (1-17-32ccd and 2-17-5abd) were drilled about 4 miles north of the city. The present supply is obtained from five wells. In 1925 the average monthly pumpage was about 6,000,000 gallons, in 1935 about 7,000,000 gallons, in 1945 about 8,000,000 gallons, and in 1962 about 12,000,000 gallons. Storage is provided by a 500,000-gallon elevated steel tank located in the city and a 60,000-gallon underground concrete reservoir located about 2 miles north of the city. The water is good-quality, calcium-bicarbonate water (Table 3) and is chlorinated but receives no other treatment.

The present Horton water supply is obtained from Mission Lake at the northeast edge of the city. The original water supply was owned by a private water company which obtained water from wells in alluvial deposits in Delaware River valley at the southwest edge of the city. In 1928 the city took over the operation of the water system and drilled wells in the alluvium of Mission Creek at the east edge of the city. These wells and a small lake above the well field were used until Mission Lake was built on this creek in 1935. The average daily use in Horton is about 300,000 gallons. Storage is provided by an elevated steel tank of 250,000-gallon capacity.

The Morrill water supply is obtained from two wells drilled in 1951 about 1 mile south of the city. These wells are about 90 feet deep and yield water from the Grenola Limestone and the Roca Shale. The water is calcium-bicarbonate water and is hard but otherwise of good quality (well 1-15-35dcd, Table 3). The wells are pumped at a rate of about 100 gpm. Formerly the city obtained water from two wells in the southwest part of the city, but this water was high in sulfates (Table 3, well 1-15-26dcd), and the wells are no longer used except in an emergency. This water was obtained from the Long Creek Limestone Member of the Foraker Limestone. The average daily use is about 15,000 gallons and storage is provided by an elevated steel tank of 50,000-gallon capacity. The water is chlorinated but receives no other treatment.

The Reserve water supply is obtained from one well in alluvial deposits in Walnut Creek valley at the east edge of the city. This well (1-17-7cbc) yields about 20 gpm. Another well drilled in 1956 near the original well was used for a short time but is now abandoned. The water is hard but is otherwise of good quality (Table 3). The average daily use is about 10,000 gallons, and storage is provided by an elevated steel tank of 30,000-gallon capacity.

The city of Robinson obtains its water supply from two wells (3-18-4cdc1 and 3-18-9baa) in alluvial deposits in Wolf River valley at the south edge of the city. These wells normally yield about 20 gpm, but they are affected by drought conditions, and yields decline during long periods of drought. Well 3-18-4cac was formerly used for the water supply, but the yield was inadequate, and this well is now used only as a reserve-supply well. Storage is provided by an elevated steel tank having a capacity of 25,000 gallons. The average daily use is about 20,000 gallons.

INDUSTRIAL SUPPLIES

Only one industry in Brown County uses privately owned wells. The American Telephone and Telegraph Company uses water from wells 3-15-27cab1 and 3-15-27cab2 for cooling purposes in a cable relay station. The wells each produce about 10 gpm from the Foraker Limestone at a depth of about 100 feet. The analysis of a sample of water from well 3-15-27cab1 is given in Table 3.

Temperature

The temperature of ground water ordinarily receives little attention in the discussion of the quality of water or its suitability for use, but many industries prefer ground water for use in cooling systems because of its uniform temperature. The temperature of ground water at relatively shallow depths in an area is generally very near the mean annual temperature for that area (in Brown County, the mean annual temperature is 53.3°F).

CHEMICAL CHARACTER OF GROUND WATER

When water comes in contact with rocks that form the crust of the earth, it dissolves a part of the rock material. The type and composition of the rock through which it passes thus determines, to a large degree, the chemical character of such ground water. The more soluble minerals are taken into solution more easily and in greater concentration than the less soluble minerals.

The chemical character of ground water in Brown County is indicated by analyses of 37 samples of water from wells, test holes, and springs given in Table 3 and by 29 analyses shown on Figure 7. Of the 37 analyses, nine are of water from public-supply sources. Although not all the minerals present in the water were determined, those that commonly are present in sufficient quantity to adversely affect the quality of the water for domestic, industrial, and irrigation use are reported.

The mineral constituents listed in Table 3 are reported in parts per million (ppm) by weight. The concentration of minerals in water in equivalents per million (epm) can be computed by multiplying the ppm by the conversion factors given in Table 4. When expressed in equivalents per million, the sum of the anions is equal to the sum of the cations. In an analysis expressed in equivalents per million, unit concentrations of all ions are chemically equivalent.

Chemical Constituents in Relation to Use

The dissolved solids, hardness, iron, fluoride, nitrate, sulfate, and chloride in the samples of water from Brown County are summarized in Table 5 and briefly discussed in the following paragraphs.

DISSOLVED SOLIDS

The residue after water has been evaporated consists of mineral matter, some organic matter, and water of crystallization. The kind and quantity of minerals in the water determine its

TABLE 3.—Analyses of water from wells, springs, and test holes in Brown County, Kansas (in parts per million, except as otherwise indicated*). (Samples analyzed by H. A. Stoltenberg.)

Well number	Date of collection	Depth of well, feet	Geologic source	Temperature (°F)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids (residue at 180°C)	Hardness as $CaCO_3$† Carbonate	Hardness as $CaCO_3$† Noncarbonate	Specific conductance (micromhos at 25°C)	pH
1-15-13bcc	12-21-53	Spring	Long Creek Limestone Member of Foraker Limestone	....	....	0.13	101	34	20	....	420	37	15	0.3	37	454	344	48	....	....
21ddb	12-21-53	do	Grenola Limestone	....	....	.11	95	29	11	....	333	65	11	.3	28	406	273	83	....	....
23bcb	12-21-53	35.0	Long Creek Limestone Member of Foraker Limestone	....	....	.39	164	39	18	....	410	242	13	.2	2.4	684	336	232	....	....
26dcd	10-17-56	90.0	do	....	17	5.3	605	54	46	....	332	1,464	24	.6	1.8	2,378	272	1,460	....	7.4
26dda	12-21-53	65.0	Grenola Limestone	....	....	.33	97	32	13	....	359	16	16	.2	84	438	294	78	....	....
29ccb	4-18-62	50.0	do	54	16	.13	91	30	12	0.8	393	15	6.0	.2	32	397	322	28	690	....
35aaa	12-21-53	44.0	do	....	....	.62	131	39	10	....	356	22	44	.1	164	588	292	196	....	....
35dad	7-26-62	92.0	Grenola Limestone and Roca Shale	....	....	.09	100	31	3.7	....	354	35	11	.1	53	421	290	87	750	7.5
36daa	12-21-53	26.0	do	....	....	.22	104	30	12	....	415	30	7.0	.1	35	426	340	44	....	....
1-16-11aca	4-19-62	78.0	Wood Siding Formation	55	15	.54	75	13	10	.7	229	31	3.0	.3	38	299	188	52	520	....
29aaa	3-26-63	70.0	Admire Group	55	16	.83	162	38	16	1.7	346	28	48	.1	248	728	284	276	1,150	....
1-17-7ccb	6-13-61	38.0	Terrace deposits	....	21	.14	120	21	28	....	276	89	60	.2	53	528	226	160	890	7.0
22ccb	4-18-62	32.0	Glacial drift	54	20	.04	91	15	20	1.2	300	49	11	.5	23	378	246	42	630	....

32ccd	7-17-62	45.0	do	....	....	.08	74	13	8.3	....	268	13	7.0	.2	15	282	220	18	490	7.4
1-18-14ddd	4-18-62	15.0	Alluvium	55	15	.03	65	31	11	2.1	317	23	8.0	.3	26	337	260	30	610	....
2-15-27cdc	4-19-62	115.0	Grenola Limestone and Roca Shale	54	13	.04	108	47	27	3.1	422	82	28	.1	58	574	346	116	960	....
2-16-15bab	4-19-62	27.5	Wood Siding Formation	55	12	.10	85	16	24	.7	283	32	18	.2	49	376	232	46	640	....
2-17-5abc	3-28-61	97.0	Glacial drift	....	21	.01	67	13	14	....	256	14	11	.2	12	278	220	10	500	....
2-18-14cad	4-19-62	65.0	do	55	21	.01	58	9.6	14	1.2	183	10	10	.2	53	267	150	34	450	....
3-15-27cabl	3-26-63	100.0	Foraker Limestone	55	12	1.7	342	51	33	3.6	173	932	13	.6	2.2	1,475	142	921	1,650	....
3-16-10dda	3-26-63	50.0	Glacial drift	55	25	.26	83	19	34	1.2	285	26	22	.2	84	435	234	51	670	....
28bcd	4-19-62	40.0	do	54	21	.49	169	44	121	2.0	449	242	139	.4	80	1,039	368	234	1,660	....
3-17-14baa	4-19-62	Spring	Stotler Limestone	54	11	.05	62	10	12	6.3	198	28	9.0	.3	26	262	162	34	440	....
30bbb	3-26-63	42.0	Glacial drift	54	25	.07	66	28	33	1.4	346	15	12	.1	34	385	280	0	590	....
3-18-4abd	11-17-52	Spring	do	....	18	.14	41	7.4	14	....	115	26	11	.3	33	209	94	39	....	....
9baa	2- 1-60	28.7	Terrace deposits	....	....	.26	106	22	19	....	388	49	16	.4	4.9	428	318	37	740	7.3
22cda	4-18-62	40.0	Scranton Shale	54	22	.20	67	21	13	1.2	290	11	7.0	.2	33	318	238	16	540	....
4-15-33baa	4-20-62	Spring	Glacial drift	54	22	.05	78	22	76	.5	417	67	7.0	.2	31	509	285	0	830	....
4-16-17daa	4-19-62	125.0	Zeandale Limestone and Pillsbury Shale	....	5.0	.99	173	83	2,940	24	222	1,145	4,275	1.2	.4	8,756	182	590	14,880	....
29ccc	4-19-62	44.0	Terrace deposits	53	20	.10	147	28	20	1.2	393	41	49	.1	115	615	322	160	1,070	....
34aaa	3-26-63	69.0	Glacial drift	54	23	.15	94	42	22	1.4	305	18	40	.3	150	541	250	157	860	....
4-17-11aaa	3-26-63	75.0	do	55	25	.7	113	29	44	1.6	298	49	57	.2	155	621	244	157	940	....

TABLE 3.—Analyses of water from wells, springs, and test holes in Brown County, Kansas (*Concluded*).

Well number	Date of collection	Depth of well, feet	Geologic source	Temperature (°F)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids (residue at 180°C)	Hardness as $CaCO_3$† Carbonate	Hardness as $CaCO_3$† Noncarbonate	Specific conductance (micromhos at 25°C)	pH
21ccc	4-20-62	22.0	Pillsbury Shale	55	19	.17	112	16	44	1.2	317	58	49	.2	53	508	260	86	860	....
28cdd	7- 1-57	Lake	Surface water	....	....	.95	30	8.0	16	....	134	23	4.0	.2	3.5	156	108	0	273	8.0
4-18-10dcd	4-18-62	35.0	Glacial drift	54	21	.08	238	68	54	1.6	190	120	160	.4	567	1,324	156	718	2,080	....
29bda	10-10-49	64.0	Glacial drift and Bern Limestone	....	28	.08	115	31	68	....	326	72	102	.2	93	708	267	147	....	8.1
5-18-6dbb	2-21-61	41.0	Glacial drift	....	....	.02	65	20	31	....	325	16	7.0	.3	22	346	244	0	620	7.8

* One part per million is equivalent to one pound of substance per million pounds of water or 8.34 pounds per million gallons of water.
† Total hardness of water (carbonate hardness plus noncarbonate hardness): 0-60 ppm, soft; 61-120 ppm, moderately hard; 121-180 ppm, hard; 181-+ ppm, very hard.

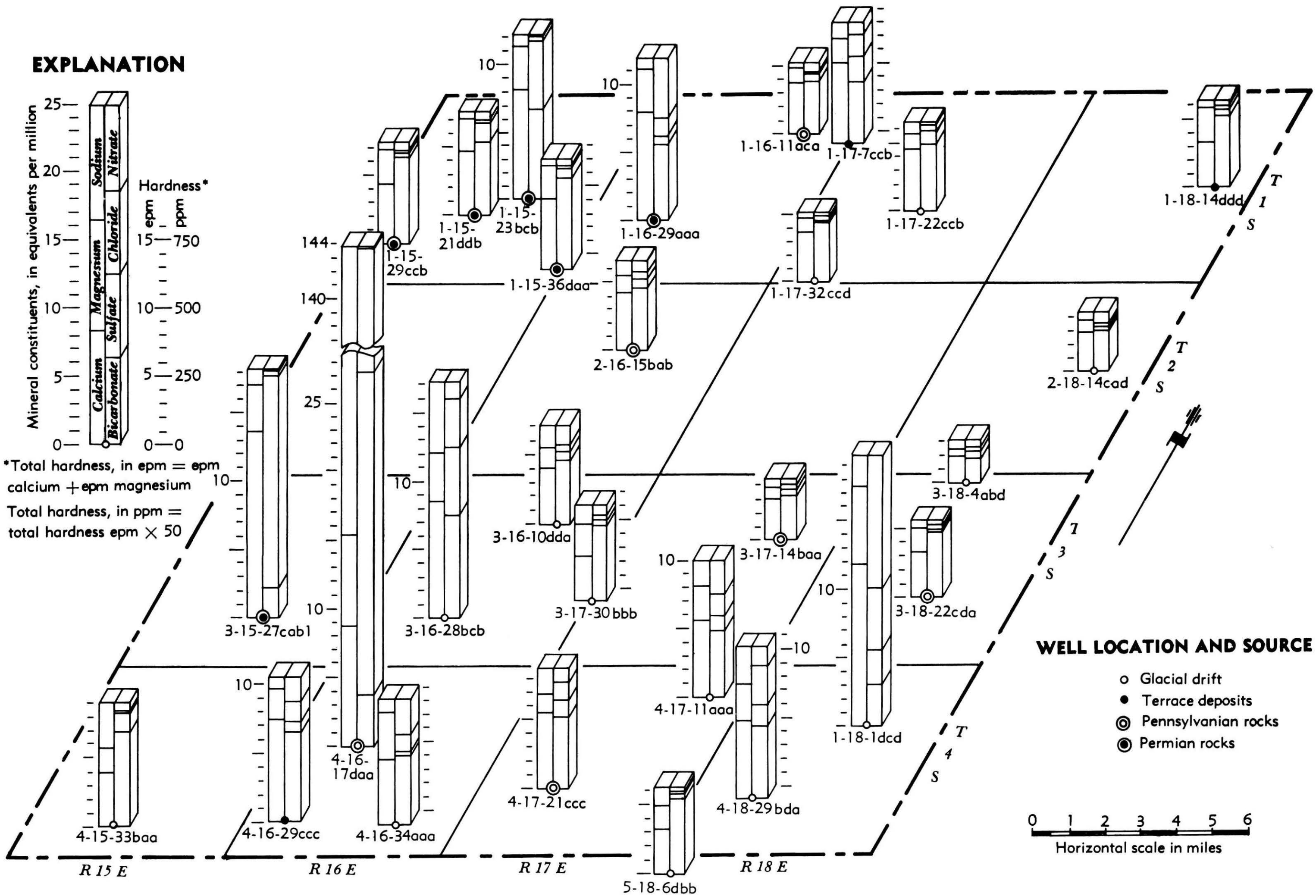

Figure 7.—Chemical character of water in Brown County, Kansas.

TABLE 4.—Factors for converting parts per million to equivalents per million.

Mineral constituent	Chemical symbol	Conversion factor
Calcium	Ca^{++}	0.0499
Magnesium	Mg^{++}	.0822
Sodium	Na^{+}	.0435
Carbonate	CO_3^{--}	.0333
Bicarbonate	HCO_3^{-}	.0164
Sulfate	SO_4^{--}	.0208
Chloride	Cl^{-}	.0282
Nitrate	NO_3^{-}	.0161
Fluoride	F^{-}	.0526

usability. Water containing less than 500 ppm of dissolved solids generally is satisfactory for domestic use. Water containing more than 1,000 ppm of dissolved solids may contain enough of certain constituents to cause a noticeable taste or to render it unsuitable for use in some other way (Table 5).

TABLE 5.—Dissolved mineral constituents in ground water, Brown County, Kansas.

Constituents	Number of samples	Range in concentration (ppm)
Dissolved solids		
	21	500 or less
	11	501 to 1,000
	5	more than 1,000
		Range: 156-8,756
Hardness		
	0	60 or less
	2	61 to 120
	3	121 to 180
	32	more than 180
		Range: 108-1,984
Iron		
	13	0.1 or less
	13	.11 to 0.3
	9	.31 to 1.0
	2	more than 1.0
		Range: 0.01-5.3
Fluoride		
	36	less than 1.0
	1	1.0 to 1.5
	0	more than 1.5
		Range: 0.1-1.2
Nitrate		
	21	45 or less
	9	46 to 90
	3	90 to 150
	4	more than 150
		Range: 0.4-567
Sulfate		
	25	50 or less
	9	51 to 250
	3	more than 250
		Range: 10-1,464
Chloride		
	33	100 or less
	3	101 to 250
	0	251 to 1,000
	1	1,001 to 5,000
		Range: 3-4,275

HARDNESS

The hardness of water, the property that generally receives the most attention, is commonly recognized by its effect when soap is used in the water; in a hard water the soap does not lather readily and leaves a curd on the water. Carbonate or "temporary" hardness is caused almost entirely by calcium and magnesium bicarbonate and may be removed by boiling. Boiling converts the bicarbonate ion to carbonate which is precipitated as calcium carbonate. These constituents combined with bicarbonates and sulfates are the active agents in the formation of scale in steam boilers or other containers in which water is evaporated. The non-carbonate or "permanent" hardness is caused by calcium and magnesium sulfates, nitrates, and some chloride salts and cannot be removed by boiling. Sodium chloride (common salt) does not contribute to hardness in water but is corrosive. Carbonate and non-carbonate hardness react to soap in the same manner. The carbonate hardness and the non-carbonate hardness are given in Table 3.

Water having a hardness less than 60 ppm is considered soft. Water having a hardness between 60 and 120 ppm may be termed moderately hard but for most purposes need not be softened. Water containing more than 120 ppm hardness is generally noticeably hard and for many uses may need to be softened. When municipal supplies are softened, generally, the hardness is decreased to about 100 ppm. In most softening processes, only the carbonate or "temporary" hardness is removed.

IRON

Next to hardness, iron is the most objectionable constituent in natural water. The quantity of iron present may differ greatly from place to place even in the same aquifer. If water contains more than 0.3 ppm of iron in solution, the iron, upon oxidation by exposure to air, may settle out as a reddish sediment. Iron may be present in sufficient quantity to give a disagreeable taste to water, stain cooking utensils and plumbing fixtures, and be objectionable in the preparation of food and beverages. Aeration, followed by settling or filtration, will remove iron from some water, but treatment with chemicals is required for others.

FLUORIDE

Although the quantity of fluoride present in natural water is relatively small in comparison to other common constituents, the amount present in water used by children should be known. Fluoride in water has been known to cause mottled enamel in the teeth, which may appear in children who, during the formation of the permanent teeth, habitually drink water containing more than 1.5 ppm of fluoride (Dean, 1936). A smaller quantity of fluoride in the drinking water (about 1.0 ppm) is likely to be beneficial by preventing or decreasing the incidence of caries in the permanent teeth of children (Dean, *et al.*, 1941). Fluoride is now added to many public water supplies in quantities sufficient to increase the total fluoride concentration to about 1 ppm.

NITRATE

Large amounts of nitrate in water may cause cyanosis in infants when the water is used for drinking or in the preparation of the food formula. Water containing less than 45 ppm of nitrate is generally regarded as safe, but water containing more than 90 ppm is regarded by the Kansas State Department of Health to be likely to cause severe, possibly fatal, cyanosis if used continuously (Metzler and Stoltenberg, 1950). Nitrate poisoning appears to be confined to infants in their first few months of life. Adults who drink the same water are not affected; however, breast-fed babies of mothers who drink such water may be affected. Also, cows that drink water containing excessive nitrate may produce milk high enough in nitrate to cause cyanosis in infants (U.S. Public Health Service, 1962).

The source of nitrates in natural water is not known. In Kansas, nitrate-bearing rocks sufficiently high in nitrate to contribute the quantities of nitrate which occur in water are not known to exist. Artificial fertilizers and certain legumes may contribute some nitrate in local areas, and seepage from sewage sources or barnyards may also contribute nitrates, but the quantities which have been pumped from wells known to be high in nitrate over several years' period would indicate a renewable source of the nitrates. Nitrate-fixing bacteria may be a principal source of nitrate. Nitrate produced in this manner could be carried down to the aquifer by seepage. Known occurrences of nitrate in Kansas seem to be more common in shallow wells and in aquifers of low transmissibility. The nitrates are commonly more concentrated at or near the water table. At present there is no economical way to remove nitrate from water, but proper construction of a well may materially reduce the amount of nitrate produced by the well. Such a well should be cased and sealed to a point well below the water table and screened and pumped at a low rate from the lowermost part of the aquifer.

SULFATE

Sulfates, when combined with calcium and magnesium, contribute most of the "permanent" hardness to a natural water, and the removal of these salts is both difficult and expensive. Sulfate, especially when combined with magnesium or sodium in excessive amounts (more than 500 ppm) in a domestic water supply, is undesirable because of the laxative effect on persons and animals when the water is used for drinking. A concentration of less than 250 ppm is recommended for human consumption, although a tolerance to the sulfates can be built up.

In Brown County, high concentrations of sulfates are commonly found in water from the Foraker Limestone and less commonly from the Roca Shale and Grenola Limestone (Fig. 7, Table 3).

CHLORIDE

Chloride salts are found in nature in abundance and are dissolved in widely varying quantities from many rock materials. They are found in sea water and in many ground waters at appreciable depths. Most oil-field brines contain considerable quantities of chloride. Small quantities of chloride have little effect on the suitability of water for ordinary uses. Only when it occurs in sufficient quantity to make the water unpalatable or corrosive to metal pipes or containers is it objectionable. Quantities of chloride permissible in irrigation water vary considerably with the crop being irrigated; however, water containing a high concentration of chloride is generally unsuitable for irrigation .

In the past, removal of chlorides from water has been both difficult and expensive; however, in recent years the removal of "salt" from water has been reduced in cost to a point where it is now economically feasible to do this in certain areas where no other water is available.

In Brown County, chlorides present no problems at the depths ordinarily reached by water-supply wells. Chloride concentrations are generally low in the glacial drift and alluvial aquifers; however, bedrock aquifers, which are low in chlorides at relatively shallow depths, may be high in chlorides at appreciable depth. Well 4-16-17daa yields water very high in chlorides from the Zeandale Limestone or the Pillsbury Shale, but other wells at shallower depths yield water of good quality from the same rocks (Table 3, 5).

SUMMARY OF GROUND-WATER CONDITIONS

Ground water is the principal source of supply for public, industrial, and domestic use in Brown County. Five public supplies are obtained from wells and one public supply is from a surface reservoir. Industrial use of ground water is small; only one company obtains water from privately owned wells. Almost all domestic supplies are obtained from wells, but locally, where ground-water shortages occur during periods of drought, cisterns are used for supplemental supplies. Much ground water is used for livestock, but many ponds have been constructed to furnish water for this purpose, also.

Ground water is available from three general sources in the County. The most extensive and most important aquifer is the glacial drift, which is present in a large part of the area. Relatively small quantities are available from the alluvial deposits in the valleys of the larger streams. Much water is obtained from bedrock aquifers in the area. The largest and most important bedrock supplies are obtained from the Permian rocks in western and northwestern Brown County. In this area little water is available from the glacial drift or the valley alluvium, both of which are thin.

In the glacial drift, water is obtained from sand and gravel lenses that occur throughout glacial till and from sand and gravel that occurs in outwash channels. Moderate to large quantities of water are available in a local area in northeastern Brown County from sand and gravel deposits in the lower part of pre-Kansan lacustrine deposits. Yields up to 450 gpm are obtained from wells in the glacial drift; however, more commonly the yield is less than 100 gpm and locally may be only a few gpm (Table 6).

The alluvial aquifers in the stream valleys are composed of silt, clay, sand, and gravel. These deposits are generally poorly sorted with silt and clay predominating, resulting in low yields from wells.

Small quantities of water are available from sandstone beds in the lower and middle part of the Wabaunsee Group. Springs occur locally along the outcrop of some of the limestones of the lower Wabaunsee. These are "contact" springs and are believed to obtain most of their water from overlying glacial drift. In the area underlain by rocks of the upper Wabaunsee and rocks of the Admire Group, little water is available, and periodic shortages occur in some areas. Rocks in the Council Grove Group of Permian age yield moderate to large quantities of water to wells in western and northwestern Brown County. The Foraker Limestone, Roca Shale, and Grenola Limestone are the principal aquifers in this area. Yields ranging up to 250 gpm are obtained from wells utilizing these combined aquifers; however, yields of less than 100 gpm are more common. South of the line between Townships 2 and 3, these rocks are less permeable, and the yields may be less than 10 gpm.

Water from wells in the County is generally hard but is suitable for most uses. In northwestern Brown County, the water from the Foraker Limestone is generally high in sulfates and locally, water from the Grenola Limestone and the Roca Shale is high in sulfate concentration. Chlorides ordinarily present no problem at the depth reached by most wells in the County, but at appreciable depths the Permian and Pennsylvanian rocks contain water high in chlorides. Water from many wells in the area is high in nitrate. The source of the nitrate in the water is not known. Nitrate concentrations are high in all areas in the County in all types of wells and in all aquifers.

RECORDS OF WELLS AND SPRINGS

Information on 130 wells and springs and one surface-water supply are given in Table 6. The number of wells and springs, listed according to use, are:

Domestic and stock wells and springs, *104*; public supply wells and springs, *23*; industrial wells, *2*; recreation, *1*; surface supply, *1*.

TABLE 6.—Records of wells, test holes, and springs in Brown County, Kansas.

Well number†	Owner or tenant	Type of well‡	Depth of well, feet§	Diameter of well, inches	Type of casing‖	Principal water-bearing unit		Method of lift**	Use of water††	Depth to water level below land surface, feet	Date of measurement	Height of land surface above mean sea level, feet	Remarks (Yield given in gallons per minute; drawdown in feet)
						Character of material	Geologic source						
1-15-5bbc	M. Broderick	Dr	65.0	6	GI	Limestone	Cottonwood Limestone Member of Beattie Limestone	Cy	D, S	59.41	9-13-62	1,100.0	
7dcc	H. Albee	Du	58.5	54	R	do	Grenola Limestone	Cy	D, S	56.40	9-11-62	1,222.0	
10aaa	J. P. Kauffman	Dr	60.0	6	GI	Limestone and shale	Grenola Limestone and Roca Shale	Cy	S	49.50	9-13-62	1,112.0	
13bcc*	C. Yoder	Sp	......	....	N	Limestone	Long Creek Limestone Member of Foraker Limestone	F	S	....	9-13-62	975.0	Flow, 5.
13bcd	do	Dr	93.0	8	S	do	do	J	D, S	65.05	9-13-62	1,040.0	
16cdb	W. Feek	Sp	......	....	N	do	Grenola Limestone	F	D, R	....	9-13-62	1,070.0	Sycamore Springs.
21ddb*	A. W. Wagner	Sp	......	....	N	do	do	F	S	....	9-13-62	1,070.0	
23bcb*	C. Reitz	Du	35.0	48	R	do	Long Creek Limestone Member of Foraker Limestone	Cy	D, S	29.48	9-13-62	1,035.0	
26dcd*	City of Morrill	Dr	90.0	8	S	do	do	T	PS	....	8-27-62	1,125.0	Used only as stand-by well. High in sulfate ion.
26dda*	G. Saylor	Dr	65.0	6	GI	do	Grenola Limestone	Cy	D	22.40	12-21-62	1,135.0	
28ddd	D. Snyder	Dr	125.0	6	GI	do	do	J	D, S	86,05	7-18-62	1,251.0	Poor well.
29ccb*	L. Bigler	Dr	50.0	6	GI	do	do	Cy	D, S	39.90	4-19-62	1,243.0	
35aaa*	R. B. Meyers	Du	44.0	48	R	do	do	Cy	D	15.46	12-21-53	1,121.0	
35aba	City of Morrill	Dr	90.0	8	S	do	Long Creek Limestone Member of Foraker Limestone	T	PS	21.56	8-27-62	1,122.0	Stand-by well.
35daa	do	Dr	91.0	8	S	Limestone and shale	Grenola Limestone and Roca Shale	T	PS	47.00	8-22-62	1,149.0	Yield, 150; 15 feet drawdown.
35dad*	do	Dr	92.0	8	S	do	do	T	PS	48.50	8-22-62	1,155.0	Yield, 100; 9 feet drawdown.
36daa*	A. Diehl	Du	26.0	48	R	do	do	Cy	S	4.05	12-21-53	1,091.0	
1-16-6aab	E. Fredrick	Dr	52.0	6	GI	Limestone	Long Creek Limestone Member of Foraker Limestone	Cy	N	32.10	9-13-62	1,040.0	Abandoned.
11aca*	James Oil Company	Dr	78.0	8	S	Sandstone	Wood Siding Formation	J	D	14.80	4-19-62	995.0	
12bbb	H. P. Clark	Du, Dr	200	36-6	GI, B	Sandy shale	Admire Group and Wood Siding Formation	Cy	D, S	31.0	7-27-62	990.0	
16ccc	E. Charles	Du	40.0	36	R	do	Admire Group	Cy	S	31.07	9-19-62	1,115.0	
26ccc	C. J. Harding	B	30.0	10	T	Sand and gravel	Glacial drift	Cy	....	11.95	9-19-62	1,050.0	Abandoned.
29aaa*	M. Byer	Du-Dr	70.0	40-6	R-GI	Sandy shale	Admire Group	Cy	D	22.00	3-26-63	1,098.0	

TABLE 6.—Records of wells, test holes, and springs in Brown County, Kansas (continued).

Well number†	Owner or tenant	Type of well‡	Depth of well, feet§	Diameter of well, inches	Type of casing‖	Principal water-bearing unit: Character of material	Principal water-bearing unit: Geologic source	Method of lift**	Use of water††	Depth to water level below land surface, feet	Date of measurement	Height of land surface above mean sea level, feet	Remarks (Yield given in gallons per minute; drawdown in feet)
31ddc	C. Stover	Du	25.0	48	R	do	do	Cy	S	18.46	9-19-62	1,062.0	
1-17-1bdd	L. Becker	Du	25.0	48	C	Sand and gravel	Glacial drift	Cy	D	18.96	9-11-62	952.0	Abandoned school.
4aaa	N. Hershberger	Du, Dr	32.0	48-6	R, GI	do	do	J	D, S	19.62	9-11-62	981.0	
7cbc	City of Reserve	Du	40	96	B	do	Terrace deposits	T	PS	7.00	7-27-62	912.0	Yield, 20.
7ccb*	do	Dr	38.0	8	S	do	do	T	PS	7.20	7-27-62	910.0	
10dda	L. Oswald	Du	23.0	50	R	do	Glacial drift	Cy	....	18.45	9-11-62	985.0	Poor well, abandoned.
15cdc	D. Davis	Dr	56.0	6	GI	do	do	Cy	S	24.52	9-18-62	1,040.0	
16ccb	J. Hart	Du	36.0	48	R	do	do	J	D, S	25.60	9-11-62	1,053.0	
22ccb*	H. Davis	Du	32.0	40	R	do	do	J	D, S	14.80	4-4-62	1,021.8	
32ccd*	City of Hiawatha	Du	45.0	168	S	do	do	T	PS	Flow	3-24-44	1,010.0	Yield 430, developed spring.
35baa	E. Klinefelter	Dr	31.0	6	GI	do	do	Cy	S	26.10	9-12-62	1,040.0	
1-18-3ccc	F. E. Hooper	Du	32.0	40	C	do	do	Cy	D	21.00	9-11-62	882.0	
5dcc	G. Brien	Dr	75.0	6	GI	do	do	J	D, S	32.20	7-17-62	916.0	Fair well.
14ddd*	W. Wehrman	Du	15.0	60	B	do	Alluvium	J, F	D, S	Flow	4-18-62	990.0	Developed spring.
16ddc	D. Reese	Dr	60.0	8	GI	do	Glacial drift	Cy	S	47.32	9-11-62	976	
18ccc1	E. Mueller	Dr	160.0	6	GI	do	do	N	N	21.06	7-17-62	978	Polluted, not used.
18ccc2	do	Dr	75.0	6	GI	do	do	J	D, S	45.00	7-17-62	1,001	Yield, 2.5.
34cdd	F. Moore	Dr	40.0	6	GI	do	do	J	D, S	31.00	9-11-62	1,060.0	Not adequate.
34ddc	U. Moore	Dr	70.0	8	S	do	do	Cy	S	60.50	9-11-62	1,093.0	Poor well.
2-15-3aba	A. H. Kruse	Du, Dr	80.0	48-6	C, GI	Limestone	Cottonwood Limestone Member of Beattie Limestone	J	D, S	40.20	7-18-62	1,198.0	Poor well.
19aaa	M. Franke	Dr	80.0	6	GI	Sand, gravel, and shale	Glacial drift and Cottonwood Limestone Member of Beattie Limestone	Cy	S	51.10	9-19-62	1,321.0	Poor well.
23aba	O. F. Duesing	Dr	50.0	6	GI	Sand, gravel, and limestone	Glacial drift and Grenola Limestone	Cy	D, S	36.01	9-19-62	1,172.0	Good well.
27cdc*	Fairview Drive Inn	Dr	115.0	8	S	Limestone and shale	Grenola Limestone and Roca Shale	J	D	78.00	7-23-62	1,228.5	Very good well.
31bdd	M. Chase	Dr	45.0	6	GI	Limestone	Grenola Limestone	Cy	S	35.00	9-20-62	1,204.0	
2-16-15bab*	W. Roch	Du	27.5	48	R	Sandstone	Wood Siding Formation	J	D, S	16.00	4-19-62	991.2	
20ccc	W. Anderson	Dr	35.0	6	GI	Limestone	Red Eagle Limestone	Cy	N	26.75	9-19-62	1,100.0	Abandoned.
34dcd	T. Hopp	Du	42.0	48	R	Sand and gravel	Glacial drift	Cy	S	29.48	10-30-62	1,132.0	

36ddb	City of Hiawatha	Du	20.0	96	B	do	do	T	PS	17.10	7-19-62	1,130.0	Yield, 150; drawdown, 3.
2-17-5abc*	do	Dr	97.0	18	S	do	do	T	PS	38.00	8-30-62	1,088	Yield, 450; drawdown, 6.
6daa	F. Stoltenberg	Dr	162	6	GI	Sandstone	Pillsbury Shale	J	D, S	....	4-30-62	1,068	Yield, 10±; chloride, 250 ppm.
22bbb	H. Middlebrook	Dr	26.5	6	GI	Sand and gravel	Glacial drift	Cy	S	14.52	9-12-62	1,106.5	
26ccc	C. Bierly	Dr	65.0	8	GI	do	do	Cy	N	44.25	9-19-62	1,092.0	Abandoned.
29cbb	City of Hiawatha	Du	35.0	96	B	do	do	Ce	PS	10.34	3-24-44	1,100.0	Yield, 100; abandoned prior to 1960.
29cdd	do	Du	35.0	132	B	do	do	Ce	PS	13.94	3-24-44	1,110.0	Yield, 80; drawdown, 3; abandoned.
29dbb	do	Du	33.0	120	B	do	do	Ce	PS	14.55	3-24-44	1,100.0	Yield, 90; drawdown, 3; abandoned.
31aac	do	Du	35.0	144	B	do	do	Ce	PS	24.12	3-24-44	1,104.0	Abandoned.
31ddc	do	Dr	50.0	16	S	do	do	T	PS	14.00	8-28-62	1,104.0	Yield 200.
32aba	M. Hughes	Dr	64.0	6	GI	do	do	Cy	S	....	6-2-46	1,098.0	
2-18-2cda	G. Steeley	Dr	200+	6	S	do	do	J	D, S	69.0	9-19-62	1,091.0	Very good well.
3aab	U. Moore	Dr	70.0	8	S	do	do	Cy, J	D, S	61.0	9-62	1,096.0	
3bab	C. Gibbons	Dr	70.0	8	GI	do	do	J	D, S	16.40	9-11-62	1,033.0	Good well.
7ccd	D. W. Kempton	Dr	60.0	6	GI	do	do	Cy	D, S	42.08	9-12-62	1,091.5	
14cad*	W. F. Winter	Dr	65.0	6	GI	do	do	Cy	D, S	21.25	4-18-62	1,085.5	
28ddc	L. M. Henry	Dr	20.0	6	GI	do	do	Cy	S	11.46	9-12-62	1,057.5	
3-15-4bab	J. Bruce	Dr	32.0	6	GI	Limestone	Cottonwood Limestone Member of Beattie Limestone	Cy	D, S	19.46	9-20-62	1,166.0	
11cbb	P. Cyphers	Dr	60.0	6	GI	do	Grenola Limestone	Cy	N	51.68	9-20-62	1,185.0	Abandoned well.
13ddc	L. Miller	Du	30.0	72	R	do	Foraker Limestone	Cy	S	14.86	9-20-62	1,171.0	
19cbc	J. Bindel	Du	26.0	48	R	do	Cottonwood Limestone Member of Beattie Limestone	Cy	S	11.24	9-20-62	1,202.0	
27cab1*	American Telephone and Telegraph Co.	Dr	100.0	6	S	do	Foraker Limestone	T	I	75.0	9-20-62	1,285.0	Yield, 10-13.
27cab2	do	Dr	90.0	6	S	do	do	T	I	65.0	9-20-62	1,275.0	Yield, 10-13.
31ccc	E. Whiteshell	Dr	60.0	6	GI	do	Grenola Limestone	Cy	S	42.20	9-20-62	1,180.0	
36abb	H. Wasserfallen	Sp	......	....	....	Sand and gravel	Glacial drift	Cy	S	Flow	9-21-62	1,130.0	Drift-bedrock contact spring.
3-16-5bbb	A. Brackhoft	Du	31.2	12	GI	do	Terrace deposits	J	D, S	13.19	7-13-60	1,035.5	Good well.
10dda*	Donald Pfister	Du	50.0	40	R	do	Glacial drift	J	D, S	36.50	3-26-63	1,172.0	
23bbc	School district	Dr	38.0	6	GI	do	do	Cy	D	24.09	10-30-62	1,172.0	
28bcd*	Powhattan community	Dr	40.0	12	GI	do	do	Cy	N	12.00	7-13-60	1,210.0	Abandoned in 1961, polluted.
3-17-1aaa	L. Lange	Dr	40.0	8	S	do	do	Cy	D, S	26.20	9-12-62	1,029.0	Poor well.
5aac	City of Hiawatha	Sp	......	....	....	do	do	Ce	PS	Flow	8-19-62	1,032	Yield, 140; improved spring.

TABLE 6.—Records of wells, test holes, and springs in Brown County, Kansas (concluded).

Well number†	Owner or tenant	Type of well‡	Depth of well, feet§	Diameter of well, inches	Type of casing‖	Principal water-bearing unit: Character of material	Principal water-bearing unit: Geologic source	Method of lift**	Use of water††	Depth to water level below land surface, feet	Date of measurement	Height of land surface above mean sea level, feet	Remarks (Yield given in gallons per minute; drawdown in feet)
10bbb	I. Warren	Dr	52.0	8	S	Sandstone	Pillsbury Shale	J	D, S	44.86	9-12-62	1,076.0	
11ccb	G. Kohler	Du, Dr	58.0	48-8	R-GI	do	do	Cy	D, S	32.55	9-12-62	1,023.0	
14baa*	L. A. Kosman	Sp	......	....	....	Limestone	Stotler Limestone	N	S	Flow	4-19-62	1,020.0	Yield, 3.
27bcb	M. Gregg	Dr	50.0	8	S	Sand and gravel	Glacial drift	Cy	D, S	37.09	9-19-62	1,135.0	
30bbb*	L. L. Aarstad	Dr	42.0	6	GI	do	do	J	D, S	23.10	3-26-63	1,151.0	
31bbb	Baker Community	Dr	75.0	12	GI	Sandstone	Wood Siding Formation	Cy	D, S	57.02	7-12-60	1,180.0	
3-18-1ccc	L. Erickson	Dr	55.0	6	GI	Sand and gravel	Glacial drift	Cy	D, S	46.40	9-21-60	1,051.0	
4abd*	G. Bragdon	Sp	......	....	....	do	do	N	S	Flow	11-17-52	1,001.0	Yield, 5.
4cac	City of Robinson	Du	40.0	192	B	do	Terrace deposits	T	PS	....	....	954.0	Low yield, not used in 1960-62.
4cdc1	do	Du	35.0	144	B	do	do	T	PS	....	....	953.0	Yield, 30±.
4cdc2	B. Benton	B	16.0	14	T	do	do	Cy	D	7.50	10-15-53	948.0	
9baa*	City of Robinson	Du	28.7	84	C	do	do	T	PS	18.27	10-15-52	954.5	Yield, 30±.
19bbc	C. B. Olsen	Dr	40.0	8	S	do	Glacial drift	J	D, S	16.81	9-21-62	1,095.0	
22cda*	L. Anderson	Du	40.0	48	R	Sandstone and shale	Scranton Shale	Cy	D, S	18.30	4-18-62	1,073.3	
32baa	M. Freeland	Dr	35.0	6	GI	Limestone	Bern Limestone	Cy	N	18.08	9-20-62	1,078.0	Abandoned school.
4-15-6bcc	I. W. Spiker	Dr	60.0	6	GI	Sand and gravel	Glacial drift	J	D, S	52.06	6-20-62	1,172.0	
19aaa	H. D. Zabel	Dr	36.0	6	GI	do	do	Cy	S	28.42	9-20-62	1,123.0	
24baa	Indian Land	B	16.0	16	GI	do	Alluvium	Ce	S	9.84	9-21-62	1,053.0	
31ccb	L. Achten	Dr	40.0	8	S	do	Glacial drift	Cy	D, S	26.83	9-20-62	1,160.0	
32aad1	A. S. Meyers	Du	40.0	36.0	R	do	do	J	D	32.40	8-16-60	1,175.0	Yield, 1.0.
32aad2	do	Dr	140.0	6	GI	Sand, gravel and sandstone	Glacial drift and Admire Group	Cy	S	41.0	8-16-60	1,182.0	Water reported very hard.
33baa*	D. Woodman	Sp	......	....	....	Sand and gravel	Glacial drift	N	S	Flow	4-20-62	1,140.0	
4-16-15aab	Mercier Community	Du	45.0	10	R	do	do	Cy	N	9.50	7-12-60	1,170.0	
17daa*	Brown County	Dr	125.0	4	N	Sandstone	Zeandale Limestone	N	N	Flow	4-19-62	1,044.0	Yield, 0.5; flowing core-drill hole.
26ddd1	V. Haug	Du	31.0	48	R	Sand and gravel	Glacial drift	J	D, S	18.26	7-15-60	1,112.0	
26ddd2	do	Dr	170.0	6	S	do	do	J	D, S	16.00	4-19-62	1,108.0	Bedrock at 32 feet; no additional water below drift.

29ccc*	M. Hall	Dr	44.0	8	S	do	Terrace deposits	J	D, S	17.70	4-19-62	1,022.4	Yield, 7.
29cdc	do	Dr	32.0	6	GI	Sandy shale	Root Shale	N	N	28.00	4-19-62	1,040.0	Abandoned, very low yield.
31bcb	Bureau of Indian Affairs	Dr	40.0	6	GI	Sand and gravel	Glacial drift	Cy	D	30.69	9-21-62	1,122.0	
34aaa*	M. W. Hall	Dr	69.0	8	S	do	do	J	D, S	14.80	8-15-60	1,150.2	Good well; drilled 40 feet in shale.
4-17-7abb	R. Douthart	Du	24.5	48	R	do	do	Cy	S	7.05	10-30-62	1,122.0	
11aaa*	V. G. Knudson	Dr	75.0	6	S	do	do	J	D, S	47.50	3-26-63	1,159.5	
15cdc	S. White	Dr	32.0	8	GI	do	do	Cy	S	12.83	9-19-62	1,140.0	
17ada	H. C. Brown	Dr	50.8	6	T	do	do	Cy	D	35.91	5-27-61	1,135.0	
21ccc*	J. Peterson	Du	22.0	48	R	Sandstone	Pillsbury Shale	J	D, S	8.64	4-20-62	1,099.0	
28cdd*	City of Horton	Lake	......	....	....	....	(Surface water)	....	....	....	7-1-51	....	Water supply for city of Horton.
4-18-1aab	W. Kimmil	Dr	40.0	6	GI	Sand and gravel	Glacial drift	Cy	D	26.05	9-18-62	1,102.0	
4bcb	A. Madison	Dr	28.0	6	GI	do	Terrace deposits	Cy	D, S	10.06	9-9-62	1,025.0	
4ddc	H. Means	Dr	30.0	6	GI	do	do	Cy	S	12.21	9-18-62	1,028.0	
6ccc	A. Jacobson	Dr	50.0	6	GI	do	Glacial drift	Cy	D	35.06	9-18-62	1,150.0	
10dcd*	Ben Knudson	Du	35.0	40	B	do	do	Cy	S	28.85	4-18-62	1,148.5	
15ddd	M. Stanbarger	Dr	60.0	6	S	Sandstone	Scranton Shale	Cy	D	42.15	9-19-62	1,100.0	
29acc	City of Everest	Dr	66.0	8	C	Sand and limestone	Glacial drift and Bern Limestone	Cy	PS	22.90	7-14-60	1,147.0	Not used, city supply well number 1.
29bac	do	Du	61.0	120	R	do	do	Cy	PS	29.75	7-14-60	1,145.0	Not used, city supply well number 4.
29bad	do	Du	65	72	R	do	do	Cy	PS	30.0	7-14-60	1,153.0	Not used, city supply well number 3.
29bda*	do	Du	64.0	96	C	do	do	Cy	PS	25.95	7-14-60	1,145.0	Not used, city supply well number 2. Observation well.
5-18-3aba	F. C. Poutrie	Dr	40.0	6	GI	Sand and gravel	Glacial drift	Cy	D, S	13.65	9-19-62	1,143.0	
6bab	J. H. Nelson	Dr	91.5	6	S	do	do	Cy	D, S	43.70	8-9-60	1,127.0	Very good well.
6bda	do	Dr	44.0	8	GI	do	do	J	D, S	25.09	8-9-60	1,095.0	Do
6dbb*	City of Everest	Dr	41.0	18	S	do	do	T	PS	19.82	7-14-60	1,090.0	Yield, 90; city supply well number 5.

* Chemical analysis given in Table 3.
† Well-numbering system described in text (Fig. 2).
‡ *B*, bored; *Dr*, drilled; *Du*, dug; *Sp*, spring.
§ Measured in feet and tenths below land surface; reported depth given in feet.
|| *B*, brick; *C*, concrete; *GI*, galvanized iron; *N*, none; *R*, rock; *S*, steel; *T*, tile.
** *Ce*, centrifugal; *Cy*, cylinder; *F*, flow; *J*, jet; *T*, turbine.
†† *D*, domestic; *I*, industrial; *N*, none; *PS*, public service; *R*, recreation; *S*, stock.

TEST-HOLE DATA

The following table is a compilation of data obtained from logs of 246 test holes and auger holes and one well. These data were used in the preparation of the cross sections (Pl. 2) and in drawing the contours on the water table (Pl. 1).

TABLE 7.—Test-hole data, Brown County, Kansas.

Test-hole number	Depth, feet	Surface altitude, feet	Depth to water, feet	Depth to bedrock, feet	Saturated thickness of Pleistocene deposits, feet
1-15-2aaa	27.2	1,060.0	22.6	20.0	0
5aaa	28.0	1,164.0	Dry	19.0	0
5add	13.0	1,170.0	Dry	12.0	0
8aaa	21.2	1,213.0	Dry	21.0	0
11aad	17.0	995.0	Dry	12.0	0
12ccc	38.0	974.0	11.2	37.0	26
14add	37.0	972.5	11.0	33.0	22
17aaa	13.2	1,104.0	Dry	12.0	0
17dad	23.0	1,058.0	9.2	22.0	13
24bbb	35.0	1,074.0	Dry	32.0	0
26add	16.2	1,135.0	Dry	16.0	0
32aad	12.2	1,238.0	Dry	12.0	0
32dad	13.2	1,252.0	Dry	13.0	0
35daa	84.5	1,149.0	47.0	24.0	....
36bbc	33.0	1,095.0	9.2	28.0	19
36bcc	28.0	1,151.0	Dry	26.0	0
36ccc	21.2	1,147.0	Dry	21.0	0
1-16-2aaa	58.5	930.0	13.0	......	....
4bbb	38.5	972.0	35.5	38.0	2
5ddd	43.0	932.0	5.2	42.0	37
11aaa	24.0	985.0	18.0	23.5	6
11add	15.2	967.0	5.0	15.0	10
13bbb	29.0	1,002.0	8.0	28.5	21
13ccb	33.0	990.0	14.0	29.0	15
16bcb	25.0	1,060.0	Dry	22.0	0
26aaa	23.0	1,030.0	13.0	22.0	9
28ccc	23.0	1,074.0	Dry	21.0	0
28dcc	200.0	....	......	33.0	....
29aaa	61.0	1,098.0	18.5	60.0	41
33ccc	17.5	992.0	9.9	17.0	7
36bbb	58.5	997.0	25.0	......	....
36ccb	58.5	982.0	14.5	......	....
1-17-2aaa	60.0	921.0	35.4	59.0	24
4bbb	33.2	1,017.0	Dry	33.0	0
4ccc	58.0	1,003.0	19.3	53.0	34
8ddd	60.0	1,051.0	26.2	......	....
11aaa	22.2	907.0	15.7	22.0	6
14aaa	28.0	917.0	10.5	27.0	16
16ccc	40.0	1,034.0	31.8	37.0	5
23aab	35.2	925.0	10.4	35.0	25
23add	23.5	935.0	10.0	23.0	13
26ddd	37.2	1,046.0	Dry	37.0	0
28bbb	48.2	1,102.6	24.8	48.0	23
32aaa	37.1	1,078.0	17.5	37.0	19
1-18-2aaa	129.0	1,112.5	......	128.0	....
2ddd	60.0	1,008.0	Dry	......	....
4baa	58.0	859.0	8.9	56.0	47
9abb	50.0	943.0	25.8	47.0	21
12ccb	118.0	1,025.0	......	112.0	....
16abb	28.2	985.0	11.3	28.0	17
21abb	23.0	936.0	10.0	......	....
21dcc	42.3	924.0	7.4	42.0	35
23dcc	46.0	973.0	15.0	41.0	26
24bbb	4.5	1,002.0	Dry	4.0	0
28cdb	60.0	990.0	13.2	......	....
33bbb	37.0	934.0	4.1	36.0	32
33cbc	52.0	946.0	3.6	51.0	47
35abb	110.0	1,072.0	79.4	106.0	27
2-15-1ccc	21.2	1,172.0	Dry	21.0	0
5daa	16.2	1,285.0	Dry	16.0	0
9ccc	9.2	1,263.0	Dry	9.0	0
11ddd	24.0	1,082.0	9.5	22.0	12
14dda	21.0	1,175.0	Dry	20.0	0
16ccc	26.5	1,280.0	Dry	26.0	....
20ddd	18.2	1,287.0	Dry	18.0	0
24ccc	29.0	1,185.0	Dry	28.5	0
26daa	18.7	1,088.0	15.0	18.5	4
32aaa	11.2	1,251.0	Dry	11.0	0
32dda	9.6	1,210.0	Dry	9.5	0
35daa	19.5	1,188.0	Dry	18.5	0
2-16-1bcb	56.0	946.0	11.6	55.0	43
1bcc	54.5	946.0	6.0	53.5	48
9bbb	18.2	1,084.0	Dry	15.0	0
9ccc	25.0	1,049.0	11.3	21.0	10
12bcb	21.0	980.0	Dry	20.0	0
12ccc	20.0	1,042.0	Dry	18.5	0
14dda	38.5	1,025.0	Dry	13.5	0
20add	8.2	1,056.0	Dry	8.0	0
21ccc	8.2	1,021.0	Dry	8.0	0
25bbb	20.0	1,078.0	Dry	19.5	0
29dad	18.2	1,029.0	Dry	18.0	0
32aad	16.2	1,017.0	Dry	16.0	0
36bbb	36.0	1,130.0	......	35.0	....
36cbc	44.0	1,066.0	8.1	43.5	36
2-17-2aaa	33.0	1,072.0	16.7	......	....
2ada	24.0	1,025.0	6.1	23.0	17
2ddd	40.2	1,039.0	7.1	40.0	33
4ccc	60.0	1,072.0	16.0	......	....
5aaa	65.0	1,031.0	15.1	63.0	48
9ccc	60.0	1,100.0	31.0	......	....
11ddd	60.0	1,103.0	37.0	......	....
13ccc	60.0	1,102.0	27.6	......	....
14add	105.0	1,115.0	41.0	79.0	38
16cbc	81.0	1,128.0	26.0	76.0	50
16ccc	60.0	1,108.3	16.3	......	....
26aaa	23.0	1,046.0	Dry	20.0	0
26ddd	35.2	1,044.0	25.9	35.0	9
32aaa	60.0	1,118.0	12.8	......	....
32ddd	41.2	1,055.0	31.4	41.0	10
35dda	50.0	983.0	11.9	48.0	36
2-18-2abb	100.0	1,022.0	15.0	93.0	78
4bbc	38.0	988.0	Dry	37.0	0
4ccc	100.0	987.5	11.7	97.0	85
8ddd	60.0	1,017.0	37.0	55.0	18
11baa	188.0	1,058.0	15.7	177.0	161
14baa	145.0	1,085.0	28.0	130.0	102
14cdd	200.0	1,103.0	25.8	150.0	124
16ccc	35.0	1,042.0	10.8	33.0	22
21ccc	60.0	1,091.0	34.1	......	....
26aaa	42.0	1,065.0	18.0	41.0	23
26ddd	47.0	1,120.0	27.1	......	....
29ddd	42.2	1,069.0	8.7	41.0	33
3-15-1cbb	34.0	1,168.0	18.0	33.5	16
5ada	30.5	1,142.0	16.8	30.0	13
8dda	17.0	1,220.0	Dry	15.0	0
12bcc	24.0	1,190.0	Dry	23.5	0
13cbb	54.0	1,197.0	Dry	53.5	0
20aaa	15.2	1,204.0	Dry	15.0	0

TABLE 7.—Test-hole data, Brown County, Kansas.
(Concluded).

Test-hole number	Depth, feet	Surface altitude, feet	Depth to water, feet	Depth to bedrock, feet	Saturated thickness of Pleistocene deposits, feet
23daa	21.0	1,122.0	Dry	20.0	0
25bbb	29.0	1,143.0	Dry	28.5	0
26ddd	33.5	1,075.0	15.0	28.5	14
29aaa	15.2	1,182.0	Dry	15.0	0
32daa	24.2	1,193.0	Dry	24.0	0
3-16-1bbb	20.0	1,090.0	Dry	8.5	0
8aaa	60.0	1,193.0	27.6	......	....
11aaa	13.5	1,102.0	Dry	12.0	0
13bbb	53.5	1,148.0	32.9	48.5	16
17aaa	60.0	1,193.0	24.3	......	....
21bbb	60.0	1,205.0	19.9	......	....
21ccc	60.0	1,196.0	7.3	......	....
24bbb	39.0	1,143.0	11.5	38.5	27
25bbb	58.5	1,170.0	......	......	....
26ddd	57.2	1,163.0	39.5	57.0	17
29ddd	42.2	1,175.0	13.0	42.0	29
32ddd	18.2	1,155.0	Dry	18.0	0
3-17-2daa	38.2	1,062.0	14.6	38.0	21
8aaa	60.0	1,103.0	Dry	50.0	0
11aad	50.0	973.5	11.5	49.0	37
11add	38.2	1,025.0	......	38.0	....
14add	49.0	995.0	17.1	48.0	31
17aaa	25.0	1,073.0	Dry	5.0	0
20ddd	60.0	1,148.0	35.0	......	....
21bbb	33.5	1,088.0	9.0	28.5	20
23aad	52.0	1,085.0	21.0	48.0	27
26aaa	60.0	1,115.0	21.0	......	....
29ddd	38.5	1,109.0	20.0	33.5	14
35aaa	60.0	1,136.0	14.8	......	....
35ddd	60.0	1,138.0	48.8	......	....
36bcb	66.0	1,131.0	12.3	65.0	43
3-18-2aaa	50.0	1,074.0	18.0	......	....
4bbb	17.2	986.0	......	17.0	....
4ccb	57.0	954.0	9.6	56.0	46
9bbb	47.0	960.0	13.0	44.0	31
9bcc	47.0	1,035.0	44.2	43.0	0
11aaa	63.1	1,051.0	52.3	63.0	11
13ccc	17.1	1,030.0	Dry	17.0	0
14aad	46.0	931.0	4.5	45.0	40
16ccc	38.0	1,055.0	......	37.0	....
17aaa	52.0	970.0	10.7	51.0	40
23ddd	51.0	1,047.0	21.2	50.0	29
26daa	14.0	1,030.0	7.1	12.0	5
28bcc	13.1	1,061.0	Dry	13.0	0
33bbb	50.1	1,096.0	22.8	50.0	27
35daa	59.0	990.0	18.6	58.0	39
4-15-1bbb	31.0	1,067.0	15.0	28.5	14
2add	29.0	1,054.0	20.0	28.5	9
5daa	57.2	1,180.0	42.0	56.0	14
8add	35.5	1,174.0	31.8	35.0	3
13bbb	53.0	1,130.0	28.4	52.0	24
13ccc	30.0	1,040.0	8.1	28.0	20
17ddd	24.2	1,137.0	Dry	24.0	0
20dad	47.5	1,070.0	8.5	47.0	38
26ada	60.0	1,100.0	......	......	....
26ddd	57.0	1,054.0	7.5	50.0	42
29aaa	34.5	1,110.0	Dry	34.0	0
29ddd	60.0	1,154.5	14.3	......	....
32aad	34.2	1,173.0	33.7	......	....
33bcc	60.0	1,151.0	Dry	......	....
33ccc	48.0	1,109.0	45.4	46.0	1
35cdd	120.0	1,160.6	18.66	115.0	96
36ccc	22.2	1,129.0	Dry	22.0	0
4-16-1bbb	20.0	1,121.0	Dry	16.0	0
1ccc	45.0	1,070.0	26.6	31.0	4

Test-hole number	Depth, feet	Surface altitude, feet	Depth to water, feet	Depth to bedrock, feet	Saturated thickness of Pleistocene deposits, feet
9bbb	45.0	1,160.0	Dry	38.0	0
13ccc	38.0	1,139.0	36.8	34.0	0
17daa	55.0	1,043.0	13.5	35.0	21
20add	17.2	1,129.0	11.0	17.0	6
26aaa	25.0	1,089.0	18.0	24.0	6
26caa	25.2	1,126.0	22.3	25.0	3
26cbb	18.2	1,138.1	16.1	18.0	2
26daa	33.3	1,106.5	18.8	33.0	14
26ddd	23.2	1,106.7	15.4	23.0	8
29aad	25.2	1,112.0	Dry	22.0	0
30ccc	25.0	1,129.0	......	......	....
31ddd	77.0	1,124.1	11.6	68.0	56
33bbb	38.5	1,012.0	8.8	38.0	29
34baa	25.0	1,123.0	Dry	20.0	0
34ccd	28.5	1,120.0	13.4	28.0	15
35abb	25.0	1,120.0	......	19.0	....
35bbb	31.3	1,148.0	11.7	31.0	19
35cbb	17.2	1,134.0	Dry	17.0	0
35ccc	6.3	1,107.0	Dry	6.0	0
35cdd	20.0	1,125.8	11.3	17.0	6
35daa	48.2	1,135.5	34.3	48.0	14
35ddd	27.1	1,104.0	16.4	27.0	11
4-17-2ddd	60.0	1,151.0	44.0	......	....
4bbb	55.5	1,145.0	10.7	55.0	44
8aaa	51.5	1,170.0	......	51.0	....
9ccc	48.5	1,144.0	18.5	45.5	27
11ada	76.0	1,154.0	22.5	72.0	49
14aaa	60.0	1,158.0	14.3	......	....
14dda	15.0	1,089.0	......	12.0	....
16ccc	58.5	1,121.0	33.7	54.0	21
23add	51.2	1,136.0	45.5	51.0	5
24dcc	40.2	1,090.0	27.6	40.0	12
26ddc	27.0	1,039.0	17.9	24.0	6
28cbb	28.0	1,087.0	6.0	26.0	20
29aaa	21.5	1,106.0	20.2	21.0	1
32ddd	39.0	1,013.0	13.7	37.0	23
35ddd	47.0	1,115.0	32.0	45.0	13
36dcc	60.0	1,090.0	25.6	51.0	25
4-18-2ada	18.2	1,069.0	Dry	16.0	0
2ddd	19.0	1,101.0	Dry	17.0	0
5aaa	25.0	1,093.5	Dry	24.0	0
8aaa	22.2	1,109.0	16.3	22.0	6
9ccc	27.0	1,114.0	23.8	22.5	0
11ddd	45.0	1,118.0	27.8	44.0	16
14ddd	60.0	1,135.0	26.7	50.0	23
17ddd	29.1	1,107.5	Dry	29.0	0
19aaa	52.2	1,131.0	34.8	52.0	17
19bbb	37.2	1,101.0	19.6	37.0	17
19ccd	69.0	1,123.0	43.0	66.0	23
19ddd	60.0	1,139.0	41.0	......	....
23add1	32.0	1,063.0	9.7	27.0	17
23add2	17.0	1,075.0	14.0	15.0	1
26aaa	46.0	1,123.0	20.0	45.0	25
26dad	46.0	1,145.0	27.5	45.0	17
29ada	55.1	1,133.0	38.0	55.0	17
31ccc	60.0	1,119.0	49.0	......	....
31dcd	55.0	1,090.0	21.9	46.0	24
31ddd	55.0	1,113.0	23.9	53.0	29
32aaa	60.0	1,155.0	21.8	......	....
32ddd	19.6	1,111.0	10.1	19.5	10
35add	68.0	1,140.0	17.6	65.0	47
5-17-2abb	50.0	1,107.4	17.2	30.0	13
5-18-2aab	100.0	1,170.0	9.4	96.0	87
5bba	70.0	1,137.2	......	67.0	....

LOGS OF TEST HOLES

Data obtained from logs of 246 test holes and auger holes and one well (Table 7) were used in the preparation of the cross sections (Pl. 2) and in drawing the contours on the water table (Pl. 1).

The logs of 69 test holes and one well are representative of all the logs of wells and test holes which were used in the preparation of this report. The logs of 177 additional test holes and auger holes used in preparation of the report are not included in this bulletin, but are retained in the files of the U.S. Geological Survey and State Geological Survey of Kansas at Lawrence, Kansas, and may be consulted there.

1-15-5aaa.———Sample log of test hole in NE cor. sec. 5, T 1 S, R 15 E, 50 feet south and 10 feet west of center of road crossing; augered August 23, 1960. Altitude of land surface, 1,164.0 feet; dry hole.

	Thickness, feet	*Depth, feet*
Quaternary System		
Pleistocene Series		
Wisconsinan Stage		
Eolian silt deposits		
Silt, brown	6	6
Silt, light-brown	3	9
Kansan Stage		
Glacial drift		
Silt and clay, tan; contains some chert gravel	4	13
Silt, clayey, light-tan; contains much chert gravel	4	17
Gravel, clayey and silty, tannish-buff	2	19
Permian System		
Lower Permian Series		
Gearyan Stage		
Council Grove Group		
Shale, weathered, soft, gray	9	28

1-15-14add.———Sample log of test hole in SE SE NE sec. 14, T 1 S, R 15 E, 200 feet north of bridge in field entrance in line with fence; augered August 23, 1960. Altitude of land surface, 972.5 feet; depth to water, 11.0 feet.

	Thickness, feet	*Depth, feet*
Quaternary System		
Pleistocene Series		
Wisconsinan Stage		
Terrace deposits		
Silt, brown	10	10
Silt, sandy, gray	10	20
Silt, gray; interbedded fine to coarse sand	10	30
Silt, clay and gravel; few cobbles	3	33
Permian System		
Lower Permian Series		
Gearyan Stage		
Admire Group		
Shale, dark-gray	4	37

1-15-35daa.———Driller's log of test hole drilled by Layne-Western Co. in NE NE SE sec. 35, T 1 S, R 15 E. Altitude of land surface, 1,149.0 feet; depth to water, 47.0 feet.

	Thickness, feet	*Depth, feet*
Quaternary System		
Pleistocene Series		
Recent Stage		
Soil	6	6
Kansan Stage		
Clay, brown	10.5	16.5
Clay, brown, and boulders	1.5	18
Clay, brown	6	24
Permian System		
Lower Permian Series		
Gearyan Stage		
Council Grove Group		
Eskridge Shale		
Limestone	1	25
Shale, green; limestone streaks	8.1	33.1
Grenola Limestone		
Limestone, soft	3.4	36.5
Shale, green	4.0	40.5
Limestone, hard	1.5	42.0
Shale, green	2.5	44.5
Shale, blue	2.0	46.5
Limestone	0.5	47.0
Shale, brown	2.0	49.0
Shale, soft, gray	3.0	52.0
Shale, soft, blue	2.5	54.5
Limestone	1.5	56.0
Shale, blue	4.5	60.5
Limestone, soft	1.5	62.0
Roca Shale		
Shale, blue; limestone streaks	4.5	66.5
Shale, red	1.0	67.5
Red Eagle Limestone		
Limestone and green shale	12.5	80.0
Shale, black	4.5	84.5

1-16-2aaa.———Sample log of test hole in NE cor. sec. 2, T 1 S, R 16 E, 90 feet south and 10 feet west of center of "T" road; augered September 5, 1960. Altitude of land surface, 930.0 feet; depth to water, 13.0 feet.

	Thickness, feet	*Depth, feet*
Quaternary System		
Pleistocene Series		
Wisconsinan Stage		
Eolian silt deposits		
Silt, brown	3.5	3.5
Silt, reddish-brown	5	8.5
Silt, tannish-brown	5	13.5
Illinoisan(?) Stage		
Terrace deposits		
Silt, clayey, tannish-brown; contains much fine to coarse sand	5	18.5
Clay, tannish-brown	5	23.5
Clay, silty, tan	5	28.5
Silt, tannish-brown; much fine to coarse sand	10	38.5
Silt, clayey, tan and gray	20	58.5

1-16-4bbb.———Sample log of test hole in NW cor. sec. 4, T 1 S, R 16 E, 50 feet east and 10 feet south of center of "T" road; augered September 2, 1960. Altitude of land surface, 972.0 feet; depth to water, 35.5 feet.

	Thickness, feet	Depth, feet
QUATERNARY SYSTEM		
PLEISTOCENE SERIES		
Wisconsinan Stage		
Eolian silt deposits		
Silt, clayey, brown	6	6
Silt, tannish-brown	6	12
Kansan Stage		
Glacial drift		
Silt, reddish-brown; contains some coarse gravel	8	20
Silt, tan	10	30
Silt, clayey, brown; contains some fine to coarse gravel	7	37
Clay, buff	1	38
PENNSYLVANIAN SYSTEM		
UPPER PENNSYLVANIAN SERIES		
Virgilian Stage		
Wabaunsee Group		
Shale, gray	0.5	38.5

1-16-5ddd.———Sample log of test hole in SE cor. sec. 5, T 1 S, R 16 E, on west road shoulder opposite section corner; augered September 2, 1960. Altitude of land surface, 932.0 feet; depth to water, 5.2 feet.

	Thickness, feet	Depth, feet
QUATERNARY SYSTEM		
PLEISTOCENE SERIES		
Wisconsinan Stage		
Terrace deposits		
Silt, dark-gray grading to brown	6	6
Silt, grayish-brown	7	13
Clay, very silty, brown	7	20
Clay, tough, grayish-brown	15	35
Silt, clayey, grayish-brown; much sand and gravel fine to coarse	7	42
PENNSYLVANIAN SYSTEM		
UPPER PENNSYLVANIAN SERIES		
Virgilian Stage		
Wabaunsee Group		
Shale, dark bluish-gray	1	43

1-16-11aaa.———Sample log of test hole in NE cor. sec. 11, T 1 S, R 16 E, 30 feet south and 10 feet west of center of crossroad; augered September 5, 1960. Altitude of land surface, 985.0 feet; depth to water, 18.0 feet.

	Thickness, feet	Depth, feet
QUATERNARY SYSTEM		
PLEISTOCENE SERIES		
Wisconsinan Stage		
Eolian silt deposits		
Silt, dark grayish-brown	3.5	3.5
Silt, brown	5	8.5
Kansan Stage		
Glacial drift		
Clay, brown	2	10.5
Clay, tannish-brown	3	13.5
Clay, buff	5	18.5
Clay, silty, tannish-brown	5	23.5
PERMIAN SYSTEM		
LOWER PERMIAN SERIES		
Gearyan Stage		
Admire Group		
Shale, gray	0.5	24.0

1-16-26aaa.———Sample log of test hole in NE cor. sec. 26, T 1 S, R 16 E, 30 feet south and 6 feet west of center of crossroad; augered September 5, 1960. Altitude of land surface, 1,030.0 feet; depth to water, 13.0 feet.

	Thickness, feet	Depth, feet
QUATERNARY SYSTEM		
PLEISTOCENE SERIES		
Wisconsinan Stage		
Eolian silt deposits		
Silt, clayey, dark-brown	3	3
Silt, clayey, dark reddish-brown	5	8
Kansan Stage		
Glacial drift		
Silt, dark-brown; contains much fine to coarse sand and gravel	4	12
Sand and gravel, fine to coarse, very silty, brown	8	20
Silt, clayey, tan	2	22
PERMIAN SYSTEM		
LOWER PERMIAN SERIES		
Gearyan Stage		
Admire Group		
Shale, gray	1	23

1-16-28dcc.———Sample log of well in SW SW SE sec. 28, T 1 S, R 16 E, drilled May 27, 1957, for Forrest Lydick.

	Thickness, feet	Depth, feet
QUATERNARY SYSTEM		
PLEISTOCENE SERIES		
Kansan Stage		
Glacial drift		
Silt, black	5	5
Clay, silty, light-gray	8	13
Clay, sandy, reddish-brown	12	25
Clay, sandy, tan to greenish-tan	8	33
PERMIAN SYSTEM		
LOWER PERMIAN SERIES		
Gearyan Stage		
Admire Group		
Janesville Shale		
West Branch Shale Member		
Shale, greenish-tan	5	38
Shale, yellow	2	40
Shale, light bluish-gray	3	43
Falls City Limestone		
Shale and limestone, very dark-gray, and hard zones	9	52
Onaga Shale		
Hawxby Shale Member		
Shale, bluish-gray	10	62
Aspinwall Limestone Member		
Shale and limestone, hard, light-gray	4	66
Towle Shale Member		
Shale, greenish-gray	6	72
Limestone, brown, and gray shale interbedded	3	75
Shale, red	5	80
Shale, olive-drab and gray	2.5	82.5
PENNSYLVANIAN SYSTEM		
UPPER PENNSYLVANIAN SERIES		
Virgilian Stage		
Wabaunsee Group		
Wood Siding Formation		
Brownville Limestone Member		
Limestone, gray	2.5	85
Pony Creek Shale Member		
Shale, bluish-gray to greenish-gray	3	88

	Thickness, feet	Depth, feet
Shale, red	4	92
Shale, gray	1	93
Grayhorse Limestone Member		
Limestone, hard, brown	3.5	96.5
Plumb Shale Member		
Shale, red	8.5	105
Nebraska City Limestone Member		
Limestone, brown	1	106
Root Shale		
French Creek and Friedrich Shale members		
Shale, gray	2	108
Coal	1	109
Shale, clayey at top, platy in lower part, dark-gray	21	130
Shale, bluish-gray	21	151
Stotler Limestone		
Grandhaven Limestone Member		
Limestone, medium-hard, brown	5	156
Dry Shale Member		
Shale, red	4	160
Shale, bluish-black	15	175
Dover Limestone Member		
Limestone	0.5	175.5
Shale, bluish-gray	2.5	178
Limestone, hard, blue	2	180
Pillsbury Shale		
Shale, sandy, reddish-brown	10	190
Shale, bluish-gray	10	200

1-16-29aaa.———Sample log of test hole in NE cor. sec. 29, T 1 S, R 16 E, 60 feet west and 10 feet south of center of crossroad; augered September 2, 1960. Altitude of land surface, 1,098.0 feet; depth to water, 18.5 feet.

	Thickness, feet	Depth, feet
QUATERNARY SYSTEM		
PLEISTOCENE SERIES		
Wisconsinan Stage		
Eolian silt deposits		
Silt, black	4	4
Silt, clayey, grayish-brown	2	6
Silt, tannish-brown	7	13
Silt, reddish-brown	5	18
Silt, tan	3	21
Kansan Stage		
Glacial drift		
Clay, silty, brown; contains much fine to medium sand	10	31
Clay, tough, gray; some fine to coarse gravel and sand in lenses	19	50
Clay, silty, grayish-brown; some gravel	10	60
PERMIAN SYSTEM		
LOWER PERMIAN SERIES		
Gearyan Stage		
Admire Group		
Janesville Shale		
Shale, gray	1	61

1-16-36bbb.———Sample log of test hole in NW cor. sec. 36, T 1 S, R 16 E, 30 feet south and 9 feet west of center of crossroad; augered September 6, 1960. Altitude of land surface, 997.0 feet; depth to water, 25.0 feet.

	Thickness, feet	Depth, feet
QUATERNARY SYSTEM		
PLEISTOCENE SERIES		
Wisconsinan Stage		
Eolian silt deposits		
Silt, brown	4	4
Kansan Stage		
Glacial drift		
Clay, silty, reddish-brown and gray	4	8
Clay, silty, reddish-brown; contains caliche pebbles	10	18
Clay, reddish-brown	5	23
Silt, clayey, reddish-brown; contains fine to medium sand	20.5	43.5
Clay, silty, gray and tan	5	48.5
Clay, silty, gray; contains fine sand	5	53.5
Clay, silty, gray and tan, much coarse gravel	5	58.5

1-17-4ccc.———Sample log of test hole in SW cor. sec. 4, T 1 S, R 17 E, 50 feet north and 8 feet east of center of crossroad; augered October 19, 1960. Altitude of land surface, 1,003.0 feet; depth to water, 19.3 feet.

	Thickness, feet	Depth, feet
QUATERNARY SYSTEM		
PLEISTOCENE SERIES		
Wisconsinan Stage		
Eolian silt deposits		
Silt, brown	6	6
Kansan Stage		
Glacial drift		
Silt and clay, grayish-brown	2	8
Silt, clayey, brown	4	12
Clay, silty, reddish-brown; contains fine sand	4	16
Silt, clayey, tannish-brown; contains fine sand	10	26
Sand, fine to medium; contains much tan silt	6	32
Sand, fine to coarse and fine gravel; very silty, tan	10	42
Clay, dark-gray; contains coarse gravel throughout	11	53
PENNSYLVANIAN SYSTEM		
UPPER PENNSYLVANIAN SERIES		
Virgilian Stage		
Wabaunsee Group		
Shale, bluish-gray	5	58

1-17-14aaa.———Sample log of test hole in NE cor. sec. 14, T 1 S, R 17 E, 50 feet south and 8 feet west of center of crossroad; augered September 16, 1960. Altitude of land surface, 917.0 feet; depth to water, 10.5 feet.

	Thickness, feet	Depth, feet
QUATERNARY SYSTEM		
PLEISTOCENE SERIES		
Wisconsinan Stage		
Terrace deposits		
Silt, reddish-brown	6	6
Silt, tan, very sandy, fine	3	9
Silt, clayey; contains some fine sand	2	11
Sand, fine to medium	12	23
Silt and clay, soft, tannish-gray	4	27
PENNSYLVANIAN SYSTEM		
UPPER PENNSYLVANIAN SERIES		
Virgilian Stage		
Wabaunsee Group		
Shale, gray	1	28

1-17-28bbb.———Sample log of test hole in NW cor. sec. 28, T 1 S, R 17 E, on south road shoulder 200 feet east of highway; augered October 20, 1960. Altitude of land surface, 1,102.6 feet; depth to water, 24.8 feet.

	Thickness, feet	Depth, feet
QUATERNARY SYSTEM		
PLEISTOCENE SERIES		
Wisconsinan Stage		
Eolian silt deposits		
Silt, brown	16	16
Kansan Stage		
Glacial drift		
Clay, brown; contains some fine to coarse sand	2	18
Clay, brown	4	22
Clay, tannish-brown, and fine to coarse gravel	6	28
Clay, light-tan; some fine sand	10	38
Clay, silty, tan, and fine to coarse sand and gravel	10	48
PENNSYLVANIAN SYSTEM		
UPPER PENNSYLVANIAN SERIES		
Virgilian Stage		
Wabaunsee Group		
Limestone, hard	0.2	48.2

1-18-2aaa.———Sample log of test hole in NE cor. sec. 2, T 1 S, R 18 E, at north side of road in center of curve; drilled November 16, 1962. Altitude of land surface, 1,112.5 feet.

	Thickness, feet	Depth, feet
QUATERNARY SYSTEM		
PLEISTOCENE SERIES		
Wisconsinan Stage		
Eolian silt deposits		
Silt, black	3	3
Silt, tannish-brown	17	20
Silt, tannish-brown	40	60
Silt, light-brown	26	86
Kansan Stage		
Glacial drift		
Clay, tan and gray; contains some fine to coarse sand and gravel	14	100
Clay, tan and gray; contains lenses of fine to coarse sand and gravel; partly cemented sand in lower part	10	110
Clay, sandy, fine, reddish-tan, some fine to coarse gravel	18	128
PENNSYLVANIAN SYSTEM		
UPPER PENNSYLVANIAN SERIES		
Virgilian Stage		
Wabaunsee Group		
Scranton Shale		
Shale, light-gray	1	129

1-18-4baa.———Sample log of test hole in NE NE NW sec. 4, T 1 S, R 18 E, 30 feet west and 10 feet south of center of "T" road; augered September 19, 1960. Altitude of land surface, 859.0 feet; depth to water, 8.9 feet.

	Thickness, feet	Depth, feet
QUATERNARY SYSTEM		
PLEISTOCENE SERIES		
Wisconsinan Stage		
Terrace deposits		
Silt, sandy, dark-gray	5	5
Silt, clayey, dark-gray to black	10	15
Silt, soft, gray	10	25
Silt, dark-gray	10	35
Sand and gravel, fine to coarse, much black silt	19	54
Gravel, very coarse and large cobbles; much gray clay	2	56
PENNSYLVANIAN SYSTEM		
UPPER PENNSYLVANIAN SERIES		
Virgilian Stage		
Wabaunsee Group		
Shale, sandy, dark-gray	2	58

1-18-12ccb.———Sample log of test hole in NW SW SW sec. 12, T 1 S, R 18 E, 125 feet east of section line on north road shoulder; drilled November 7, 1962. Altitude of land surface, 1,025.0 feet.

	Thickness, feet	Depth, feet
QUATERNARY SYSTEM		
PLEISTOCENE SERIES		
Wisconsinan Stage		
Eolian silt deposits		
Silt, black	3	3
Silt, tannish-brown	32	35
Silt, reddish-tan	15	50
Silt, tan	18	68
Kansan Stage		
Glacial drift		
Clay, gray and dark-gray	4	72
Clay, light-gray mottled tannish-brown and much fine to coarse sand and gravel	10	82
Clay, gray and tan, some fine to coarse sand and gravel	18	100
Clay, gray, contains some fine to coarse sand and gravel; large cobbles near base	12	112
PENNSYLVANIAN SYSTEM		
UPPER PENNSYLVANIAN SERIES		
Virgilian Stage		
Wabaunsee Group		
Scranton Shale		
Shale, bluish-gray	6	118

1-18-21dcc.———Sample log of test hole in SW SW SE sec. 21, T 1 S, R 18 E, on east road shoulder 150 feet north of east-west road; augered September 20, 1960. Altitude of land surface, 924.0 feet; depth to water, 7.4 feet.

	Thickness, feet	Depth, feet
QUATERNARY SYSTEM		
PLEISTOCENE SERIES		
Wisconsinan Stage		
Terrace deposits		
Silt, brown, and fine to coarse sand and gravel	5	5
Sand, fine	3	8
Silt, gray; contains much very fine sand	9	17
Silt, clayey, soft, gray	13	30
Silt, tan, and fine to coarse sand	12	42
PENNSYLVANIAN SYSTEM		
UPPER PENNSYLVANIAN SERIES		
Virgilian Stage		
Wabaunsee Group		
Limestone, hard	0.3	42.3

1-18-28cdb.———Sample log of test hole in NW SE SW sec. 28, T 1 S, R 18 E, in lowest part of gravel pit southwest of road entrance; augered September 20, 1960. Altitude of land surface, 990.0 feet; depth to water, 13.2 feet.

	Thickness, feet	Depth, feet
QUATERNARY SYSTEM		
PLEISTOCENE SERIES		
Kansan Stage		
Glacial drift		
Sand and gravel, fine to coarse, silty; some cobbles	7	7
Sand, fine to coarse, brown stained; some fine gravel	9	16
Sand, fine to coarse and fine gravel	2	18
Clay, gray	1	19
Sand, fine to coarse and fine gravel	1	20
Silt, clayey, black; fine to coarse sand and gravel	10	30
Gravel, fine to coarse and cobbles; much gray clay	7	37
Clay, gray	23	60

1-18-35abb.———Sample log of test hole in NW NW NE sec. 35, T 1 S, R 18 E, 25 feet east of a power pole in triangle formed by road curve; drilled November 8, 1962. Altitude of land surface, 1,072.0 feet; depth to water, 79.4 feet.

	Thickness, feet	Depth, feet
QUATERNARY SYSTEM		
PLEISTOCENE SERIES		
Wisconsinan Stage		
Eolian silt deposits		
Silt, tan	10	10
Kansan Stage		
Glacial drift		
Clay, gray and tan, some brown mottling	11	21
Clay, gray mottled brown; contains much fine to coarse sand and gravel	33	54
Clay, dark-gray; contains much fine sand and a little fine gravel	16	70
Clay, dark-gray; contains much fine sand	36	106
PENNSYLVANIAN SYSTEM		
UPPER PENNSYLVANIAN SERIES		
Virgilian Stage		
Wabaunsee Group		
Scranton Shale		
Shale, gray; contains thin limestone beds	4	110

2-15-11ddd.———Sample log of test hole in SE cor. sec. 11, T 2 S, R 15 E, next to fence 150 feet west of road; augered August 24, 1960. Altitude of land surface, 1,082.0 feet; depth to water, 9.5 feet.

	Thickness, feet	Depth, feet
QUATERNARY SYSTEM		
PLEISTOCENE SERIES		
Wisconsinan Stage		
Terrace deposits		
Silt, dark grayish-brown	7	7
Clay, gray	1	8
Silt, tan	4	12
Silt, gray	5	17
Silt, sandy, gray	2	19
Silt, sandy, tan	3	22
PERMIAN SYSTEM		
LOWER PERMIAN SERIES		
Gearyan Stage		
Council Grove Group		
Shale, tannish-brown	2	24

2-15-26daa.———Sample log of test hole in NE NE SE sec. 26, T 2 S, R 15 E, on west road shoulder 25 feet south of bridge; augered August 29, 1960. Altitude of land surface, 1,088.0 feet; depth to water, 15.0 feet.

	Thickness, feet	Depth, feet
QUATERNARY SYSTEM		
PLEISTOCENE SERIES		
Wisconsinan Stage		
Terrace deposits		
Silt, light-gray	3.5	3.5
Clay, silty, dark-brown	3	6.5
Silt, gray; contains much fine to coarse sand and gravel	2	8.5
Silt, clayey, dark-gray; contains some fine to coarse sand and gravel	2	10.5
Clay, buff	3	13.5
Silt, gray; and interbedded tan clay	5	18.5
PERMIAN SYSTEM		
LOWER PERMIAN SERIES		
Gearyan Stage		
Council Grove Group		
Johnson Shale		
Shale, gray	0.2	18.7

2-16-9ccc.———Sample log of test hole in SW cor. sec. 9, T 2 S, R 16 E, 50 feet east and 8 feet north of center of crossroad; augered September 1, 1960. Altitude of land surface, 1,049.0 feet; depth to water, 11.3 feet.

	Thickness, feet	Depth, feet
QUATERNARY SYSTEM		
PLEISTOCENE SERIES		
Kansan Stage		
Glacial drift		
Silt, dark-gray	6	6
Clay, dark-brown	1	7
Silt, reddish-brown	3	10
Silt, dark-brown	3	13
Clay, brown	3	16
Silt, buff; contains much fine to coarse sand and gravel, some cobbles	5	21
PERMIAN SYSTEM		
LOWER PERMIAN SERIES		
Gearyan Stage		
Admire Group		
Onaga Shale		
Shale, clayey, dark-gray	4	25

2-16-36bbb.———Sample log of test hole in NW cor. sec. 36, T 2 S, R 16 E, on east road shoulder 600 feet south of section corner; augered September 7, 1960. Altitude of land surface, 1,130.0 feet.

	Thickness, feet	Depth, feet
QUATERNARY SYSTEM		
PLEISTOCENE SERIES		
Wisconsinan Stage		

	Thickness, feet	Depth, feet
Eolian silt deposits		
Silt, brown, grading to tannish-brown	3.5	3.5
Silt, tannish-brown	5	8.5
Kansan Stage		
Glacial drift		
Clay, silty, reddish-brown	5	13.5
Clay, silty and sandy, brown	15	28.5
Sand, fine to coarse, silty, tannish-brown	6.5	35
PERMIAN SYSTEM		
LOWER PERMIAN SERIES		
Gearyan Stage		
Admire Group		
Shale, sandy, tannish-gray	1	36

2-17-2ada.———Sample log of test hole in NE SE NE sec. 2, T 2 S, R 17 E, ¼ mile south of section corner, 25 feet south and 50 feet west of a bridge; drilled November 14, 1962. Altitude of land surface, 1,025.0 feet; depth to water, 6.1 feet.

	Thickness, feet	Depth, feet
QUATERNARY SYSTEM		
PLEISTOCENE SERIES		
Wisconsinan and Recent stages		
Valley fill		
Silt, black	5	5
Kansan Stage		
Glacial drift		
Clay, light-gray; contains some fine sand	4	9
Sand and gravel, fine to coarse, some cobbles	3	12
Clay, tan and gray; contains very fine sand	4	16
Clay, dark-gray; contains fine to coarse sand and gravel	7	23
PENNSYLVANIAN SYSTEM		
UPPER PENNSYLVANIAN SERIES		
Virgilian Stage		
Wabaunsee Group		
Emporia Limestone		
Limestone, hard, gray	1	24

2-17-5aaa.———Sample log of test hole in NE cor. sec. 5, T 2 S, R 17 E, 75 feet west and 8 feet south of center of crossroad; augered October 20, 1960. Altitude of land surface, 1,031.0 feet; depth to water, 15.1 feet.

	Thickness, feet	Depth, feet
QUATERNARY SYSTEM		
PLEISTOCENE SERIES		
Kansan Stage		
Glacial drift		
Silt, brown	3	3
Silt, dark-brown, and fine to coarse sand and fine to medium gravel	4	7
Silt, brown	5	12
Silt, sandy, brown; some coarse gravel	4	16
Sand, fine to coarse and fine gravel	11	27
Clay, dark-gray; contains some coarse gravel throughout	14	41
Clay, dark-gray; some fine to coarse gravel	16	57
Gravel, fine to coarse and some fine to coarse sand, clayey	6	63
PENNSYLVANIAN SYSTEM		
UPPER PENNSYLVANIAN SERIES		
Virgilian Stage		
Wabaunsee Group		
Shale, bluish-gray	2	65

2-17-14add.———Sample log of test hole in SE SE NE sec. 14, T 2 S, R 17 E, in west road ditch 200 feet north of ½-mile line; drilled November 15, 1962. Altitude of land surface, 1,115.0 feet; depth to water, 41.0 feet.

	Thickness, feet	Depth, feet
QUATERNARY SYSTEM		
PLEISTOCENE SERIES		
Kansan Stage		
Glacial drift		
Silt, black	3	3
Clay, gray and tan	2	5
Clay, light-gray	7	12
Clay, tannish-gray; contains much fine to coarse sand and gravel and caliche	10	22
Clay, tannish-gray; much fine to coarse sand and gravel	15	37
Sand and gravel, fine to coarse, some gray clay	13	50
Sand and gravel, fine to coarse	17	67
Clay, dark-gray; contains fine sand	12	79
PENNSYLVANIAN SYSTEM		
UPPER PENNSYLVANIAN SERIES		
Virgilian Stage		
Wabaunsee Group		
Zeandale Limestone		
Shale, dark-gray	20	99
Limestone, hard, gray	2	101
Shale, gray	4	105

2-17-16cbc.———Sample log of test hole in SW NW SW sec. 16, T 2 S, R 17 E, 50 feet east and 50 feet north of center of drive to highway material yard; drilled November 5, 1962. Altitude of land surface, 1,128.0 feet; depth to water, 26.0 feet.

	Thickness, feet	Depth, feet
QUATERNARY SYSTEM		
PLEISTOCENE SERIES		
Wisconsinan Stage		
Eolian silt deposits		
Silt, very dark-gray	3	3
Clay, silty, grayish-green	4	7
Kansan Stage		
Glacial drift		
Clay, gray mottled tannish-brown	5	12
Clay, tannish-brown, and some gray clay	11	23
Clay, gray, some tan clay	8	31
Clay, light-gray, some tan clay and caliche	4	35
Clay, tan	11	46
Clay, tan and gray; contains fine to coarse sand	14	60
Sand and gravel, fine to coarse; contains some gray clay	16	76
PENNSYLVANIAN SYSTEM		
UPPER PENNSYLVANIAN SERIES		
Virgilian Stage		
Wabaunsee Group		
Pillsbury Shale		

	Thickness, feet	Depth, feet
Shale, light-gray, weathered brown	3	79
Shale, light-gray	2	81

2-17-26ddd.———Sample log of test hole in SE cor. sec. 26, T 2 S, R 17 E, 75 feet north and 8 feet west of center of road crossing; augered September 15, 1960. Altitude of land surface, 1,044.0 feet; depth to water, 25.9 feet.

	Thickness, feet	Depth, feet
QUATERNARY SYSTEM		
PLEISTOCENE SERIES		
Wisconsinan Stage		
Eolian silt deposits		
Silt, brown	6	6
Silt, light-brown	2	8
Silt, tannish-brown	8	16
Kansan Stage		
Glacial drift		
Silt, clayey, brown to tan; contains much fine to coarse sand and gravel	9	25
Sand and gravel, fine to coarse, silty, tan	7	32
Silt, brown, and some fine to coarse sand	3	35
PENNSYLVANIAN SYSTEM		
UPPER PENNSYLVANIAN SERIES		
Virgilian Stage		
Wabaunsee Group		
Bern Limestone (Wakarusa Limestone Member)		
Limestone, hard, bluish-gray	0.2	35.2

2-18-2abb.———Sample log of test hole in NW NW NE sec. 2, T 2 S, R 18 E, in ditch at southeast corner of road crossing; drilled November 8, 1962. Altitude of land surface, 1,022.0 feet; depth to water, 15.1 feet.

	Thickness, feet	Depth, feet
QUATERNARY SYSTEM		
PLEISTOCENE SERIES		
Wisconsinan and Recent stages		
Valley deposits, undifferentiated		
Silt, black	6	6
Silt, gray	5	11
Kansan Stage		
Glacial drift		
Clay, very dark-gray	15	26
Clay, tan, and some gray clay, mottled brown; contains much fine sand	7	33
Clay, dark-gray, much fine sand	7	40
Clay, dark-gray, much fine sand and some fine to coarse gravel	25	65
Sand and gravel, fine to coarse cobbles near top	18	83
Sand, fine to medium, and some fine to coarse gravel	10	93
PENNSYLVANIAN SYSTEM		
UPPER PENNSYLVANIAN SERIES		
Virgilian Stage		
Wabaunsee Group		
Scranton Shale		
Shale, weathered, reddish-brown	3	96
Shale, gray	4	100

2-18-4ccc.———Sample log of test hole in SW cor. sec. 4, T 2 S, R 18 E, on north road shoulder 75 feet east of center of road; drilled November 14, 1962. Altitude of land surface, 987.5 feet; depth to water, 11.7 feet.

	Thickness, feet	Depth, feet
QUATERNARY SYSTEM		
PLEISTOCENE SERIES		
Kansan Stage		
Glacial drift		
Clay, grayish-brown; contains some fine to coarse sand and gravel	6	6
Clay, gray mottled brown, some coarse gravel	14	20
Clay, gray mottled brown, some fine sand	8	28
Atchison Formation		
Sand, very fine	50	78
Nebraskan Stage		
Sand and gravel, fine to coarse	3	81
Sand and gravel, coarse, some carbonized wood	5	86
Sand and gravel, coarse (drills very rough)	11	97
PENNSYLVANIAN SYSTEM		
UPPER PENNSYLVANIAN SERIES		
Virgilian Stage		
Wabaunsee Group		
Scranton Shale		
Limestone, gray	1	98
Shale, dark-gray	2	100

2-18-11baa.———Sample log of test hole in NE NE NW sec. 11, T 2 S, R 18 E, in north road ditch 500 feet west of center of highway; drilled November 9, 1962. Altitude of land surface, 1,058.0 feet; depth to water, 15.7 feet.

	Thickness, feet	Depth, feet
QUATERNARY SYSTEM		
PLEISTOCENE SERIES		
Wisconsinan Stage		
Eolian silt deposits		
Silt, brown	3	3
Silt, tannish-brown	5	8
Silt, tan	4	12
Kansan Stage		
Glacial drift		
Clay, sandy, fine, brown	2	14
Clay, sandy, gray and brown, some fine gravel	8	22
Clay, tan; contains much fine to coarse sand and gravel	14	36
Clay, dark-gray, very sandy	2	38
Sand and gravel, fine to coarse	7	45
Clay, dark-gray; contains much coarse gravel	4	49
Sand and gravel, fine to coarse	7	56
Clay, dark-gray and brown; contains some coarse gravel	10	66
Gravel, fine to coarse, and fine to coarse sand, some cobbles	22	88
Clay, dark-gray	12	100
Sand and gravel, loosely cemented, fine to coarse	26	126
Atchison Formation		
Clay, gray, and fine sand	14	140
Sand, fine to very fine	28	168
Clay, gray	9	177

	Thickness, feet	Depth, feet
PENNSYLVANIAN SYSTEM		
UPPER PENNSYLVANIAN SERIES		
Virgilian Stage		
Wabaunsee Group		
Scranton Shale		
Shale, light bluish-gray	11	188

2-18-14baa.———Sample log of test hole in NE cor. NW sec. 14, T 2 S, R 18 E, south ditch 200 feet west of road crossing; drilled November 12, 1962. Altitude of land surface, 1,085.0 feet; depth to water, 28.0 feet.

	Thickness, feet	Depth, feet
QUATERNARY SYSTEM		
PLEISTOCENE SERIES		
Wisconsinan Stage		
Eolian silt deposits		
Silt, reddish-brown	10	10
Silt, tannish-brown	10	20
Silt, buff	15	35
Kansan Stage		
Glacial drift		
Clay, gray	10	45
Clay, gray mottled brown	3	48
Gravel and sand, fine to coarse	3	51
Clay, gray mottled brown; contains thin streaks of cemented fine to coarse sand and gravel	14	65
Clay, dark-gray, and much fine to coarse sand	12	77
Clay, dark-gray; contains thin streaks of fine to coarse sand and gravel	5	82
Sand and gravel, fine to coarse, some gray clay and cobbles	6	88
Clay, dark-gray and fine to coarse gravel	4	92
Sand and gravel, fine to coarse, clayey	5	97
Atchison Formation		
Sand, fine	11	108
Clay, silty, dark-gray; contains much fine sand	12	120
Nebraskan Stage		
Clay, gray; contains fine to coarse sand and gravel; some cobbles	10	130
PENNSYLVANIAN SYSTEM		
UPPER PENNSYLVANIAN SERIES		
Virgilian Stage		
Wabaunsee Group		
Scranton Shale		
Shale, sandy, soft, gray	15	145

2-18-14cdd.———Sample log of test hole in SE cor. SW sec. 14, T 2 S, R 18 E, 135 feet west and 4 feet north of center of road crossing; drilled November 13, 1962. Altitude of land surface, 1,103.0 feet; depth to water, 25.8 feet.

	Thickness, feet	Depth, feet
QUATERNARY SYSTEM		
PLEISTOCENE SERIES		
Wisconsinan Stage		
Eolian silt deposits		
Silt, greenish-gray	10	10
Silt, tannish-brown	10	20
Silt, tan	2	22
Silt, buff	8	30
Silt, tan	10	40
Kansan Stage		
Glacial drift		
Clay, buff	2	42
Clay, gray mottled with tan	8	50
Clay, gray mottled with tan; fine to coarse sand and gravel	15	65
Sand and gravel, fine to coarse, and some tan clay	20	85
Clay, light-buff; contains much fine sand	5	90
Atchison Formation		
Sand, fine	20	110
Nebraskan Stage		
Clay, brown, and fine to coarse sand and gravel	40	150
PENNSYLVANIAN SYSTEM		
UPPER PENNSYLVANIAN SERIES		
Virgilian Stage		
Wabaunsee Group		
Scranton Shale		
Shale, gray; contains thin limestone beds	14	164
Shale, sandy, gray	36	200

2-18-16ccc.———Sample log of test hole in SW cor. sec. 16, T 2 S, R 18 E, 30 feet north and 20 feet east of center of crossroad; augered September 21, 1960. Altitude of land surface, 1,042.0 feet; depth to water, 10.8 feet.

	Thickness, feet	Depth, feet
QUATERNARY SYSTEM		
PLEISTOCENE SERIES		
Kansan Stage		
Glacial drift		
Silt, brown; contains some fine sand	6	6
Silt, tannish-brown; contains much fine to coarse sand and gravel	7	13
Sand and gravel, fine to coarse, silty	3	16
Sand, fine to coarse	7	23
Sand, fine	5	28
Sand and gravel, fine to coarse	5	33
PENNSYLVANIAN SYSTEM		
UPPER PENNSYLVANIAN SERIES		
Virgilian Stage		
Wabaunsee Group		
Auburn Shale	2	35

2-18-29ddd.———Sample log of test hole in SE cor. sec. 29, T 2 S, R 18 E, in west road ditch 150 feet north of center of crossroad; augered September 21, 1960. Altitude of land surface, 1,069.0 feet; depth to water, 8.7 feet.

	Thickness, feet	Depth, feet
QUATERNARY SYSTEM		
PLEISTOCENE SERIES		
Wisconsinan Stage		
Eolian silt deposits		
Silt, reddish-brown	10	10

	Thickness, feet	Depth, feet
Kansan Stage		
Glacial drift		
Silt, tannish-brown; contains much fine sand	8	18
Silt, buff, and fine sand	9	27
Silt, brown	5	32
Clay, gray and brown	9	41
PENNSYLVANIAN SYSTEM		
UPPER PENNSYLVANIAN SERIES		
Virgilian Stage		
Wabaunsee Group		
Shale, weathered, dark-gray to black	1	42
Limestone, hard	0.2	42.2

3-15-1cbb.———Sample log of test hole in NW NW SW sec. 1, T 3 S, R 15 E, on east road shoulder at half-mile line; augered August 29, 1960. Altitude of land surface, 1,168.0 feet; depth to water, 18.0 feet.

	Thickness, feet	Depth, feet
QUATERNARY SYSTEM		
PLEISTOCENE SERIES		
Kansan Stage		
Glacial drift		
Silt, brown	3.5	3.5
Silt, sandy, reddish-brown	5	8.5
Silt, tan; contains some fine to coarse sand and gravel	5	13.5
Clay, buff	10	23.5
Silt, clayey, buff and gray	5	28.5
Clay, buff to light-gray	5	33.5
PERMIAN SYSTEM		
LOWER PERMIAN SERIES		
Gearyan Stage		
Council Grove Group		
Grenola Limestone		
Limestone, grayish-white	0.5	34

3-15-26ddd.———Sample log of test hole in SE cor. sec. 26, T 3 S, R 15 E, on west road shoulder 63 feet north of crossroad; augered August 30, 1960. Altitude of land surface, 1,075.0 feet; depth to water, 15.0 feet.

	Thickness, feet	Depth, feet
QUATERNARY SYSTEM		
PLEISTOCENE SERIES		
Wisconsinan Stage		
Terrace deposits		
Silt, dark-gray	3.5	3.5
Clay, reddish-brown	5	8.5
Clay, gray	5	13.5
Silt, brown	10	23.5
Clay, dark-gray	5	28.5
PERMIAN SYSTEM		
LOWER PERMIAN SERIES		
Gearyan Stage		
Council Grove Group		
Foraker Limestone		
Shale, gray	5	33.5

3-16-8aaa.———Sample log of test hole in NE cor. sec. 8, T 3 S, R 16 E, 30 feet west and 8 feet south of center of crossroad; augered September 1, 1960. Altitude of land surface, 1,193.0 feet; depth to water, 27.6 feet.

	Thickness, feet	Depth, feet
QUATERNARY SYSTEM		
PLEISTOCENE SERIES		
Wisconsinan Stage		
Eolian silt deposits		
Silt, dark-brown	4	4
Silt, reddish-brown	3	7
Kansan Stage		
Glacial drift		
Clay, gray mottled with brown	2	9
Silt, clayey, brown	8	17
Clay, brown	2	19
Clay, gray	5	24
Silt, brown	8	32
Silt, brown; contains much fine to coarse gravel	4	36
Silt, very sandy, buff; contains cobbles from 41-43 feet, drills very rough	7	43
Silt and clay, brown	11	54
Clay, silty, tannish-brown; large cobbles near base	6	60

3-16-13bbb.———Sample log of test hole in NW cor. sec. 13, T 3 S, R 16 E, 30 feet south and 8 feet east of center of crossroad; augered September 7, 1960. Altitude of land surface, 1,148.0 feet; depth to water, 32.9 feet.

	Thickness, feet	Depth, feet
QUATERNARY SYSTEM		
PLEISTOCENE SERIES		
Wisconsinan Stage		
Eolian silt deposits		
Silt, brown	3.5	3.5
Silt, tannish-brown	5	8.5
Kansan Stage		
Glacial drift		
Silt, clayey, tan	3.5	12.0
Clay, silty, buff	8	20.0
Sand and gravel, fine to coarse, silty, tan	11.5	31.5
Clay, reddish-brown	2	33.5
Sand, fine to coarse, silty, light-tan	15	48.5
PERMIAN SYSTEM		
LOWER PERMIAN SERIES		
Gearyan Stage		
Admire Group		
Onaga Shale		
Shale, gray	5	53.5

3-16-26ddd.———Sample log of test hole in SE cor. sec. 26, T 3 S, R 16 E, 150 feet north and 8 feet west of center of crossroad; augered September 12, 1960. Altitude of land surface, 1,163.0 feet; depth to water, 39.5 feet.

	Thickness, feet	Depth, feet
QUATERNARY SYSTEM		
PLEISTOCENE SERIES		
Wisconsinan Stage		
Eolian silt deposits		
Silt, clayey, dark-brown	4	4
Silt, brown	3	7
Kansan Stage		
Clay, brown and gray	10	17
Clay, tannish-gray	9	26
Clay, gray, tough; contains fine to coarse gravel	6	32
Silt, reddish-brown	4	36
Silt, brown; contains lenses of fine to coarse sand and gravel	5	41

	Thickness, feet	*Depth, feet*
Silt, tan, and fine sand; some gravel in lower part	7	48
Clay, gray	9	57
PERMIAN SYSTEM		
LOWER PERMIAN SERIES		
Gearyan Stage		
Admire Group		
Shale, hard, gray	0.2	57.2

3-17-2daa.———Sample log of test hole in NE NE SE sec. 2, T 3 S, R 17 E, 50 feet south and 8 feet west of center of crossroad; augered September 15, 1960. Altitude of land surface, 1,062.0 feet; depth to water, 14.6 feet.

	Thickness, feet	*Depth, feet*
QUATERNARY SYSTEM		
PLEISTOCENE SERIES		
Kansan Stage		
Glacial drift		
Silt, reddish-brown; contains much fine to coarse sand	5	5
Silt, reddish-brown	6	11
Silt, buff, and interbedded fine sand	5	16
Sand, fine	6	22
Sand, fine to coarse, and tan silt	4	26
Silt and clay, gray mottled brown	12	38
PENNSYLVANIAN SYSTEM		
UPPER PENNSYLVANIAN SERIES		
Virgilian Stage		
Wabaunsee Group		
Auburn Shale		
Shale, hard, gray	0.2	38.2

3-17-20ddd.———Sample log of test hole in SE cor. sec. 20, T 3 S, R 17 E, 25 feet west and 8 feet north of center of crossroad; augered October 24, 1960. Altitude of land surface, 1,148.0 feet; depth to water, 35.0 feet.

	Thickness, feet	*Depth, feet*
QUATERNARY SYSTEM		
PLEISTOCENE SERIES		
Wisconsinan Stage		
Eolian silt deposits		
Silt, dark-brown	3.5	3.5
Silt, brown	5	8.5
Kansan Stage		
Glacial drift		
Clay, brown	10	18.5
Clay, dark-brown	5	23.5
Silt, brown	5	28.5
Sand, fine, silty, tan	10	38.5
Sand, fine to medium, and much tan silt	5	43.5
Silt, very sandy, tan	10	53.5
Silt, tan, and fine sand	6.5	60

3-17-36bcb.———Sample log of test hole in NW SW NW sec. 36, T 3 S, R 17 E, on east road shoulder 100 feet south of end of a hedge row; drilled November 15, 1962. Altitude of land surface, 1,131.0 feet; depth to water, 12.3 feet.

	Thickness, feet	*Depth, feet*
QUATERNARY SYSTEM		
PLEISTOCENE SERIES		
Recent Stage		
Silt, black	5	5
Kansan Stage		
Glacial drift		
Clay, dark-gray	11	16
Clay, light-gray	9	25
Clay, light-gray, mottled tan; contains some fine to coarse sand and gravel	3	28
Clay, tan; contains much fine to coarse sand and gravel	22	50
Clay, tan; contains much fine to coarse sand and gravel and cobbles	15	65
PENNSYLVANIAN SYSTEM		
UPPER PENNSYLVANIAN SERIES		
Virgilian Stage		
Wabaunsee Group		
Emporia Limestone		
Limestone, very hard, dark-gray	1	66

3-18-2aaa.———Sample log of test hole in NE cor. sec. 2, T 3 S, R 18 E, on west road shoulder 75 feet north of crossroad; augered October 17, 1960. Altitude of land surface, 1,074.0 feet; depth to water, 18.0 feet.

	Thickness, feet	*Depth, feet*
QUATERNARY SYSTEM		
PLEISTOCENE SERIES		
Kansan Stage		
Glacial drift		
Silt, dark-brown	5	5
Silt, brown	4	9
Silt, clayey, gray	3	12
Silt, brown	4	16
Silt, tan; fine to medium sand	5	21
Sand, fine to coarse, silty, tan	7	28
Silt, tan, very sandy	9	37
Silt, clayey, tan; and fine to coarse sand and gravel	8	45
Clay, gray; and fine to coarse sand and gravel	5	50

3-18-9bbb.———Sample log of test hole in NW cor. sec. 9, T 3 S, R 18 E, at corner of road 600 feet north of NE corner of cemetery; augered September 22, 1960. Altitude of land surface, 960.0 feet; depth to water, 13.0 feet.

	Thickness, feet	*Depth, feet*
QUATERNARY SYSTEM		
PLEISTOCENE SERIES		
Wisconsinan Stage		
Terrace deposits		
Silt, dark-gray	5	5
Silt, dark-brown	2	7
Silt, brown	9	16
Silt, tan	9	25
Silt, clayey, dark-gray to black	7	32
Clay, silty, chocolate-brown	8	40
Sand and gravel, fine to coarse; contains much clay	4	44
PENNSYLVANIAN SYSTEM		
UPPER PENNSYLVANIAN SERIES		
Virgilian Stage		
Wabaunsee Group		
Shale, gray	3	47

3-18-14aad.———Sample log of test hole in SE NE NE sec. 14, T 3 S, R 18 E; drilled October 17, 1960. Altitude of land surface, 931.0 feet; depth to water, 4.5 feet.

	Thickness, feet	Depth, feet
QUATERNARY SYSTEM		
PLEISTOCENE SERIES		
Wisconsinan Stage		
Terrace deposits		
Silt, dark-gray	5	5
Silt, dark gray-brown, some medium gravel	8	13
Silt, dark-brown	17	30
Silt, dark-brown	13	43
Silt, grayish-brown; contains much coarse gravel	2	45
PENNSYLVANIAN SYSTEM		
UPPER PENNSYLVANIAN SERIES		
Virgilian Stage		
Wabaunsee Group		
Shale, dark-gray	1	46

3-18-16ccc.———Sample log of test hole in SW cor. sec. 16, T 3 S, R 18 E, 50 feet east and 8 feet north of center of crossroad; augered September 22, 1960. Altitude of land surface, 1,055.0 feet.

	Thickness, feet	Depth, feet
QUATERNARY SYSTEM		
PLEISTOCENE SERIES		
Wisconsinan Stage		
Eolian silt deposits		
Silt, dark-brown	6	6
Silt, brown	1	7
Silt, tannish-brown	5	12
Kansan Stage		
Glacial drift		
Sand, very fine, silty, tan	8	20
Sand, very fine; contains a little tan silt	14	34
Clay, dark-gray, and fine sand	3	37
PENNSYLVANIAN SYSTEM		
UPPER PENNSYLVANIAN SERIES		
Virgilian Stage		
Wabaunsee Group		
Shale, limy, gray	1	38

3-18-33bbb.———Sample log of test hole in NW cor. sec. 33, T 3 S, R 18 E, 75 feet south and 12 feet east of center of crossroad; augered September 22, 1960. Altitude of land surface, 1,096.0 feet; depth to water, 22.8 feet.

	Thickness, feet	Depth, feet
QUATERNARY SYSTEM		
PLEISTOCENE SERIES		
Wisconsinan Stage		
Eolian silt deposits		
Silt, reddish-brown	7	7
Silt, brown	4	11
Kansan Stage		
Glacial drift		
Clay, silty, dark-brown	2	13
Clay, gray and brown	3	16
Silt, brown	1	17
Clay, gray	5	22
Clay, silty, grayish-brown	1	23
Clay, silty, tan; contains much fine to coarse sand and gravel	5	28
Sand, fine to coarse, very silty, tan	8	36
Clay, gray, and fine to coarse gravel	1	37
Clay, dark-brown; fine to coarse sand and gravel	13	50
PENNSYLVANIAN SYSTEM		
UPPER PENNSYLVANIAN SERIES		
Virgilian Stage		
Wabaunsee Group		
Emporia Limestone		
Limestone, hard, gray	0.1	50.1

4-15-1bbb.———Sample log of test hole in NW cor. sec. 1, T 4 S, R 15 E, 90 feet east of crossroad on south road shoulder; augered August 30, 1960. Altitude of land surface, 1,067.0 feet; depth to water, 15.0 feet.

	Thickness, feet	Depth, feet
QUATERNARY SYSTEM		
PLEISTOCENE SERIES		
Wisconsinan Stage		
Terrace deposits		
Silt, dark-gray	3.5	3.5
Silt, clayey, gray	10	13.5
Silt, clayey, reddish-brown	5	18.5
Silt, dark-gray	5	23.5
Silt, tan	5	28.5
PERMIAN SYSTEM		
LOWER PERMIAN SERIES		
Gearyan Stage		
Council Grove Group		
Foraker Limestone		
Shale, gray	2.5	31

4-15-5daa.———Sample log of test hole in NE NE SE sec. 5, T 4 S, R 15 E, on east road shoulder at tree near half-mile line; augered August 17, 1960. Altitude of land surface, 1,180.0 feet; depth to water, 42.0 feet.

	Thickness, feet	Depth, feet
QUATERNARY SYSTEM		
PLEISTOCENE SERIES		
Wisconsinan Stage		
Eolian silt deposits		
Silt, black grading to brown	5	5
Silt, tan	2	7
Silt, brown	2	9
Kansan Stage		
Glacial drift		
Clay, gray mottled with brown	5	14
Silt, clayey, tannish-buff; contains some gravel	6	20
Silt, clayey, sandy, with caliche, tan	7	27
Silt, tan	11	38
Silt, buff	9	47
Silt and clay and interbedded gravel and cobbles	9	56
PERMIAN SYSTEM		
LOWER PERMIAN SERIES		
Gearyan Stage		
Council Grove Group		
Grenola Limestone		
Shale, gray, and thin limestone beds	1	57
Limestone, hard, white	0.2	57.2

4-15-13bbb.———Sample log of test hole in NW cor. sec. 13, T 4 S, R 15 E, in triangle on road to east; augered August 26, 1960. Altitude of land surface, 1,130.0 feet; depth to water, 28.4 feet.

	Thickness, feet	*Depth, feet*
QUATERNARY SYSTEM		
PLEISTOCENE SERIES		
Kansan Stage		
Glacial drift		
Silt, gray and brown	5	5
Silt, clayey, brown	2	7
Silt, reddish-brown	2	9
Clay, gray and brown	7	16
Silt, clayey, very sandy, reddish-brown	3	19
Sand, fine to coarse, silty, reddish-brown; some gravel	3	22
Clay, tan	3	25
Clay, tan, brown, and fine to coarse gravel	6	31
Clay, brown	14	45
Clay, gray and brown; contains some gravel	7	52
PERMIAN SYSTEM		
LOWER PERMIAN SERIES		
Gearyan Stage		
Admire Group		
Shale, dark-gray	1	53

4-15-20dad.———Sample log of test hole in SE NE SE sec. 20, T 4 S, R 15 E, on west road shoulder 600 feet south of half-mile line; augered August 16, 1960. Altitude of land surface, 1,070.0 feet; depth to water, 8.5 feet.

	Thickness, feet	*Depth, feet*
QUATERNARY SYSTEM		
PLEISTOCENE SERIES		
Wisconsinan Stage		
Terrace deposits		
Silt, black to dark-gray	7	7
Silt, grayish-brown	2	9
Silt, brown to tannish-brown	14	23
Silt, dark-gray	12	35
Silt, clayey, black	10	45
Clay, black; contains very coarse gravel and cobbles	2	47
PERMIAN SYSTEM		
LOWER PERMIAN SERIES		
Gearyan Stage		
Council Grove Group		
Shale, dark-gray	0.5	47.5

4-15-33ccc.———Sample log of test hole in SW cor. sec. 33, T 4 S, R 15 E, on east road shoulder at north end of field; augered August 16, 1960. Altitude of land surface, 1,109.0 feet; depth to water, 45.4 feet.

	Thickness, feet	*Depth, feet*
QUATERNARY SYSTEM		
PLEISTOCENE SERIES		
Wisconsinan Stage		
Terrace deposits		
Silt, grayish-brown	6	6
Silt, clayey, gray	6	12
Silt, tan; contains some gravel	6	18
Silt, tan, and light-gray clay; contains some gravel	5	23
Silt, clayey, grayish-brown	6	29
Silt, clayey, gray; contains some gravel	6	35
Clay, gray to dark-gray; contains some gravel	11	46
PERMIAN SYSTEM		
LOWER PERMIAN SERIES		
Gearyan Stage		
Council Grove Group		
Shale, gray	2	48

4-15-35cdd.———Sample log of test hole in SE SE SW sec. 35, T 4 S, R 15 E, on north road shoulder 0.45 mile east of section corner; drilled November 30, 1948. Altitude of land surface, 1,160.6 feet; depth to water, 18.66 feet.

	Thickness, feet	*Depth, feet*
QUATERNARY SYSTEM		
PLEISTOCENE SERIES		
Kansan Stage		
Glacial drift		
Clay and silt, compact, dark-gray	4	4
Clay, tan, and fine to medium sand	2	6
Clay, pinkish-gray	5	11
Clay, tan and light-gray	9	20
Clay, tan, and fine sand; some limestone gravel	5	25
Clay, tan and gray, some fine sand	9	34
Clay, tan, and fine to coarse sand	16	50
Clay, tan; contains some fine to coarse gravel	23.5	73.5
Sand and gravel, fine to coarse; clayey at top, blue	6.5	80
Sand and gravel, fine to coarse	15	95
Clay, sandy, bluish-gray	11	106
Sand, medium to coarse	9	115
PERMIAN SYSTEM		
LOWER PERMIAN SERIES		
Gearyan Stage		
Admire Group		
Shale, light-gray, and thin limestone zones	5	120

4-16-26daa.———Sample log of test hole in NE NE SE sec. 26, T 4 S, R 16 E, 20 feet south and 6 feet west of center of road at half-mile line; augered August 15, 1960. Altitude of land surface, 1,106.5 feet; depth to water, 18.8 feet.

	Thickness, feet	*Depth, feet*
QUATERNARY SYSTEM		
PLEISTOCENE SERIES		
Wisconsinan Stage		
Eolian silt deposits		
Silt, black grading to tannish-brown	5	5
Kansan Stage		
Glacial drift		
Silt, brown; contains some fine sand	7	12
Sand, fine to coarse; contains much silt	9	21
Sand, fine to coarse; contains some tan silt	5	26
Silt, gray, very sandy	7	33

	Thickness, feet	Depth, feet
PENNSYLVANIAN SYSTEM		
UPPER PENNSYLVANIAN SERIES		
Gearyan Stage		
Wabaunsee Group		
Wood Siding Formation		
Shale, hard, gray	0.3	33.3

4-16-35bbb.———Sample log of test hole in NW cor. sec. 35, T 4 S, R 16 E, 30 feet south and 6 feet east of center of road crossing; augered August 15, 1960. Altitude of land surface, 1,148.5 feet; depth to water, 11.7 feet.

	Thickness, feet	Depth, feet
QUATERNARY SYSTEM		
PLEISTOCENE SERIES		
Wisconsinan Stage		
Eolian silt deposits		
Silt, black grading to gray	5	5
Kansan Stage		
Glacial drift		
Clay, gray, mottled with brown	2	7
Silt, brown	5	12
Clay, gray and brown	6	18
Silt, brown; contains some embedded gravel	12	30
Sand, fine to coarse	1	31
PERMIAN SYSTEM		
LOWER PERMIAN SERIES		
Gearyan Stage		
Admire Group		
Onaga Shale		
Shale, gray	0.3	31.3

4-16-35ddd.———Sample log of test hole in SE cor. sec. 35, T 4 S, R 16 E, 10 feet north and 40 feet west of center of road crossing; augered August 15, 1960. Altitude of land surface, 1,104.0 feet; depth to water, 16.4 feet.

	Thickness, feet	Depth, feet
QUATERNARY SYSTEM		
PLEISTOCENE SERIES		
Wisconsinan Stage		
Eolian silt deposits		
Silt, black to brown	3	3
Silt, reddish-brown to tan	6	9
Kansan Stage		
Glacial drift		
Sand, fine to very fine, reddish-brown	5	14
Sand, fine to coarse, some gray silt	6	20
Sand and gravel, fine to coarse, silty	7	27
PENNSYLVANIAN SYSTEM		
UPPER PENNSYLVANIAN SERIES		
Virgilian Stage		
Wabaunsee Group		
Wood Siding Formation		
Brownville Limestone Member		
Limestone, hard, white	0.1	27.1

4-17-11ada.———Sample log of test hole in NE SE NE sec. 11, T 4 S, R 17 E, in west road ditch 200 feet south of railroad; drilled November 16, 1962. Altitude of land surface, 1,154.0 feet; depth to water, 22.5 feet.

	Thickness, feet	Depth, feet
QUATERNARY SYSTEM		
PLEISTOCENE SERIES		
Kansan Stage		
Glacial drift		
Silt, black	2.5	2.5
Clay, gray	4.5	7
Clay, gray mottled tannish-brown	15	22
Clay, grayish-green	3	25
Clay, gray, with some brown mottling	20	45
Clay, tan; contains much fine to coarse sand and gravel	17	62
Sand and gravel, fine to coarse	2	64
Clay, tan	3	67
Clay, gray, mottled with tan, much fine to coarse sand and gravel	5	72
PENNSYLVANIAN SYSTEM		
UPPER PENNSYLVANIAN SERIES		
Virgilian Stage		
Wabaunsee Group		
Willard Shale		
Shale, gray	2	74
Emporia Limestone		
Limestone, hard, gray	2	76

4-17-16ccc.———Sample log of test hole in SW cor. sec. 16, T 4 S, R 17 E; augered September 8, 1960. Altitude of land surface, 1,121.0 feet; depth to water, 33.7 feet.

	Thickness, feet	Depth, feet
QUATERNARY SYSTEM		
PLEISTOCENE SERIES		
Wisconsinan Stage		
Eolian silt deposits		
Silt, dark-brown	5	5
Silt, light-brown	5.5	10.5
Kansan Stage		
Glacial drift		
Clay, silty, tan	7.5	18
Silt, sandy, yellowish-tan; contains much limestone gravel from 21.0 feet	3.5	21.5
Silt, very sandy, tan	5.5	27
Silt, clayey, reddish-tan	10	37
Silt, light-brown	2	39
Sand, fine to coarse, silty, tan	6	45
Silt, clayey, dark-brown	2	47
Clay, silty, light-brown	7	54
PENNSYLVANIAN SYSTEM		
UPPER PENNSYLVANIAN SERIES		
Virgilian Stage		
Wabaunsee Group		
Stotler Limestone		
Shale, sandy, gray	4.5	58.5

4-17-23add.———Sample log of test hole in SE SE NE sec. 23, T 4 S, R 17 E, in west road ditch at half-mile line; augered September 13, 1960. Altitude of land surface, 1,136.0 feet; depth to water, 45.5 feet.

	Thickness, feet	Depth, feet
QUATERNARY SYSTEM		
PLEISTOCENE SERIES		
Wisconsinan Stage		
Eolian silt deposits		
Silt, dark-gray and brown	7	7
Silt, light-brown	8	15

	Thickness, feet	Depth, feet
Kansan Stage		
Glacial drift		
Clay, tough, tannish-brown	11	26
Silt, clayey, gray	6	32
Clay, gray	5	37
Silt, clayey, gray	4	41
Clay, silty, gray; much fine to coarse gravel	5	46
Clay, silty, reddish-brown	3	49
Clay, reddish-tan	2	51
PENNSYLVANIAN SYSTEM		
UPPER PENNSYLVANIAN SERIES		
Virgilian Stage		
Wabaunsee Group		
Zeandale Limestone (Tarkio Limestone Member)		
Limestone, hard, gray	0.2	51.2

4-17-32ddd.———Sample log of test hole in SE SE SE sec. 32, T 4 S, R 17 E, 600 feet west and 10 feet north of center of "T" road; augered September 30, 1960. Altitude of land surface, 1,013.0 feet; depth to water, 13.7 feet.

	Thickness, feet	Depth, feet
QUATERNARY SYSTEM		
PLEISTOCENE SERIES		
Wisconsinan Stage		
Terrace deposits		
Silt, black, grading to dark-gray	6	6
Silt, dark grayish-brown	6	12
Silt, brown	8	20
Silt, gray	16	36
Gravel, fine to coarse, very silty	1	37
PENNSYLVANIAN SYSTEM		
UPPER PENNSYLVANIAN SERIES		
Virgilian Stage		
Wabaunsee Group		
Shale, gray	2	39

4-17-36dcc.———Sample log of test hole in SW SW SE sec. 36, T 4 S, R 17 E, 6 feet north of center of road 200 feet east of half-mile line; augered October 25, 1960. Altitude of land surface, 1,090.0 feet; depth to water, 25.6 feet.

	Thickness, feet	Depth, feet
QUATERNARY SYSTEM		
PLEISTOCENE SERIES		
Wisconsinan Stage		
Eolian silt deposits		
Silt, dark-brown	5	5
Silt, brown	6	11
Kansan Stage		
Glacial drift		
Clay, grayish-brown	5	16
Silt, sandy, dark-brown	5	21
Silt, tannish-brown; contains some fine to coarse sand and gravel	6	27
Sand, fine to coarse, and interbedded tan silt	4	31
Sand, fine to medium, silty, tan; contains some fine to coarse gravel	11	42
Sand and gravel, fine to coarse, hard, compact	9	51
PENNSYLVANIAN SYSTEM		
UPPER PENNSYLVANIAN SERIES		
Virgilian Stage		
Wabaunsee Group		
Shale, bluish-gray	9	60

4-18-8aaa.———Sample log of test hole in NE cor. sec. 8, T 4 S, R 18 E, 50 feet west and 6 feet south of center of crossroad; augered September 22, 1960. Altitude of land surface, 1,109.0 feet; depth to water, 16.3 feet.

	Thickness, feet	Depth, feet
QUATERNARY SYSTEM		
PLEISTOCENE SERIES		
Wisconsinan Stage		
Eolian silt deposits		
Silt, dark-brown	4	4
Silt, brown	3	7
Silt, grayish-brown	4	11
Silt, tannish-brown	5	16
Kansan Stage		
Glacial drift		
Silt, tan, and fine to coarse sand and gravel	2	18
Silt, brown, and much fine sand	3	21
Gravel, fine to coarse, and tan clay	1	22
PENNSYLVANIAN SYSTEM		
UPPER PENNSYLVANIAN SERIES		
Virgilian Stage		
Wabaunsee Group		
Limestone, hard	0.2	22.2

4-18-11ddd.———Sample log of test hole in SE cor. sec. 11, T 4 S, R 18 E, in west road ditch at top of a hill 300 feet north of section corner; augered October 6, 1960. Altitude of land surface, 1,118.0 feet; depth to water, 27.8 feet.

	Thickness, feet	Depth, feet
QUATERNARY SYSTEM		
PLEISTOCENE SERIES		
Wisconsinan Stage		
Eolian silt deposits		
Silt, brown	10	10
Silt, reddish-brown	3	13
Kansan Stage		
Glacial drift		
Silt, brown, and fine to coarse sand and gravel	8	21
Clay, gray	1	22
Silt, tan	6	28
Silt, clayey, dark-gray; contains some medium sand	8	36
Silt, brown; contains some fine to coarse sand	8	44
PENNSYLVANIAN SYSTEM		
UPPER PENNSYLVANIAN SERIES		
Virgilian Stage		
Wabaunsee Group		
Shale and thin limestone beds, gray	1	45

4-18-19aaa.———Sample log of test hole in NE cor. sec. 19, T 4 S, R 18 E, 250 feet west and 8 feet north of center of crossroad; augered October 26, 1960. Altitude of land surface, 1,131.0 feet; depth to water, 34.8 feet.

	Thickness, feet	Depth, feet
QUATERNARY SYSTEM		
PLEISTOCENE SERIES		
Kansan Stage		
Glacial drift		
Silt, brown	6	6
Clay, brown and gray	4	10
Clay, gray	10	20
Clay, light-gray	7	27
Silt, clayey, light-gray; contains some fine to medium sand	13	40
Silt, light-gray and tan, very sandy; contains some fine to coarse gravel and cobbles from 42-44 feet	7	47
Sand and gravel, fine to coarse, and interbedded tan silt	5	52
PENNSYLVANIAN SYSTEM		
UPPER PENNSYLVANIAN SERIES		
Virgilian Stage		
Wabaunsee Group		
Limestone, hard	0.2	52.2

4-18-26aaa.———Sample log of test hole in NE cor. sec. 26, T 4 S, R 18 E, in west road ditch 100 feet south of crossroad; augered October 5, 1960. Altitude of land surface, 1,123.0 feet; depth to water, 20.0 feet.

	Thickness, feet	Depth, feet
QUATERNARY SYSTEM		
PLEISTOCENE SERIES		
Wisconsinan Stage		
Eolian silt deposits		
Silt, brown	6	6
Kansan Stage		
Glacial drift		
Clay, brown	5	11
Clay, gray	2	13
Silt, tan; some fine sand and cobbles at 19 and 25 feet	13	26
Silt, clayey, brown; much fine to coarse sand and gravel and cobbles throughout interval	14	40
Clay, gray and fine to coarse sand and gravel and cobbles throughout interval	5	45
PENNSYLVANIAN SYSTEM		
UPPER PENNSYLVANIAN SERIES		
Virgilian Stage		
Wabaunsee Group		
Shale, limy, gray	1	46

4-18-29ada.———Sample log of test hole in NE SE NE sec. 29, T 4 S, R 18 E, in triangle at road leading to Everest; augered September 26, 1960. Altitude of land surface, 1,133.0 feet; depth to water, 38.0 feet.

	Thickness, feet	Depth, feet
QUATERNARY SYSTEM		
PLEISTOCENE SERIES		
Wisconsinan Stage		
Eolian silt deposits		
Silt, dark grayish-brown	4	4
Silt, brown	7	11
Kansan Stage		
Glacial drift		
Clay, compact, tough, grayish-brown	7	18
Silt, brown	4	22
Clay, grayish-brown	6	28
Silt, gray	4	32
Clay, gray	8	40
Silt, clayey, gray	3	43
Silt, buff; contains some fine to coarse sand	3	46
Clay, gray; contains fine to coarse sand, some gravel and cobbles	9	55
PENNSYLVANIAN SYSTEM		
UPPER PENNSYLVANIAN SERIES		
Virgilian Stage		
Wabaunsee Group		
Limestone, hard	0.1	55.1

4-18-31ddd.———Sample log of test hole in SE cor. sec. 31, T 4 S, R 18 E, 75 feet west and 10 feet north of center of crossroad; augered October 25, 1960. Altitude of land surface, 1,113.0 feet; depth to water, 23.9 feet.

	Thickness, feet	Depth, feet
QUATERNARY SYSTEM		
PLEISTOCENE SERIES		
Wisconsinan Stage		
Eolian silt deposits		
Silt, black to dark-gray	6	6
Silt, dark-brown	2	8
Kansan Stage		
Glacial drift		
Silt, very clayey, light-brown	7	15
Silt, clayey, gray and buff; contains much fine sand	3	18
Silt, clayey and sandy, grayish-brown	4	22
Silt, light-gray, and fine to medium sand	4	26
Clay, light-gray, and streaks of fine to coarse sand	4	30
Sand, fine to coarse; some fine to coarse gravel at top of interval, silty, tan	6	36
Sand, fine to coarse, very silty, tan	9	45
Clay, dark-gray to black; contains fine to coarse sand in streaks	8	53
PENNSYLVANIAN SYSTEM		
UPPER PENNSYLVANIAN SERIES		
Virgilian Stage		
Wabaunsee Group		
Shale, grayish-green	2	55

4-18-35add.———Sample log of test hole in SE SE NE sec. 35, T 4 S, R 18 E, on west road shoulder at half-mile line; augered October 5, 1960. Altitude of land surface, 1,140.0 feet; depth to water, 17.6 feet.

	Thickness, feet	Depth, feet
QUATERNARY SYSTEM		
PLEISTOCENE SERIES		
Wisconsinan Stage		
Eolian silt deposits		
Silt, dark-gray	3	3
Silt, brown	5	8

	Thickness, feet	Depth, feet
Kansan Stage		
Glacial drift		
Clay, gray and brown	5	13
Clay, gray	3	16
Clay, grayish-brown, and some medium gravel	2	18
Silt, grayish-brown	4	22
Silt, brown	5	27
Silt, gray and brown	4	31
Silt, very sandy, soft; contains some gravel	9	40
Clay, gray; contains streaks of fine to coarse sand and gravel; some cobbles	25	65
PENNSYLVANIAN SYSTEM		
UPPER PENNSYLVANIAN SERIES		
Virgilian Stage		
Wabaunsee Group		
Auburn Shale		
Shale, gray	3	68

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