Geology and Ground-Water Resources Of Miami County, Kansas

By Don E. Miller

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ABSTRACT

Miami County, Kansas, has an area of 592 square miles. It lies within the Osage Plains section of the Central Lowlands physiographic province. Rocks above the Precambrian basement are 2,000 to 2,500 feet thick and are of sedimentary origin. They include rocks of Cambrian, Ordovician, Silurian, Devonian, Mississippian, Pennsylvanian, and Neogene ages. Exposed Pennsylvanian and Neogene rocks are nearly 400 feet thick. The Pennsylvanian rocks have a regional dip to the northwest of about 20 feet per mile.

Recent alluvial deposits have a maximum thickness of about 55 feet in the Marais des Cygnes River valley and yield moderate supplies of ground water. Upper Pleistocene terrace deposits have a maximum thickness of 50 feet and yield moderate amounts of water. The most productive bedrock aquifers are Pennsylvanian limestones and sandstones that are near enough to the surface to have been weathered, thereby increasing their permeability. Water with less than 1,000 ppm dissolved solids occurs to a depth of about 200 feet in these bedrock aquifers.

Water from Neogene deposits is of good quality, except that it is moderately hard and may contain excessive amounts of iron. Bedrock aquifers yield water of good quality, but in most localities the water is moderately hard.

Data collected as a part of this investigation include records of 123 wells and springs, logs of 116 wells and test holes, and chemical analyses of 25 water samples.

INTRODUCTION

Purpose and Scope of Investigation

An investigation of the geology and ground-water resources of Miami County, Kansas, was made to determine the distribution, thickness, lithology, and hydrologic properties of the rocks containing fresh water. Rocks older than Pennsylvanian age in this County probably do not contain fresh water, and, therefore, they are considered only briefly in this report. Other mineral resources and the structural geology of the area are discussed briefly. Data regarding the quantity and quality of the ground water in the various aquifers are summarized.

The study of the geology and ground-water resources of Miami County was begun in the summer of 1960 by the State Geological Survey of Kansas and the U.S. Geological Survey in cooperation with the Division of Water Resources of the Kansas State Board of Agriculture.

Location and Extent of Area

Miami County, located in east-central Kansas, includes all or parts of 25 townships and constitutes an area of 592 square miles (Fig. 1).

Previous Investigations

The geology of Miami County and adjacent areas has been studied and described by many geologists. The first study dealing with the geology of the County was in 1865 by G. C. Swallow. Early stratigraphic studies by J. M. Jewett (1932) and by N. D. Newell (1935) contributed much to the overall knowledge of the geology of the area and to the stratigraphic nomenclature of the outcropping Pennsylvanian rocks. Jewett described the rocks in the subsurface of the County in 1954.

Other studies dealing with the area are listed in the references at the end of this report.

Methods of Investigation

This report is based on geologic and hydrologic data gathered during the spring and summer, 1960-62.

The geology includes detailed examination and description of numerous geologic sections as well as areal mapping (Pl. 1). Some of the geologic data from a report on the area by Newell (1935) are incorporated into this report.

Supplementary information on the geology and hydrology of the area was provided by inventorying wells and by drilling test holes. The samples collected in the course of drilling were later examined microscopically in the laboratory.

The base map on Plate 1 was compiled from aerial photographs obtained from the U.S. Department of Agriculture and from maps of the Soil Conservation Service and the State Highway Commission of Kansas. Areal geology was mapped on aerial photographs and on topographic maps and was transferred to a base map with a scale of 1:40,000.

Well-Numbering System

The well and test-hole designations used in this report give the locations of wells following the scheme of General Land Office surveys. The well number is composed of the township, the range, and the section number, followed by lowercase letters which indicate the subdivision

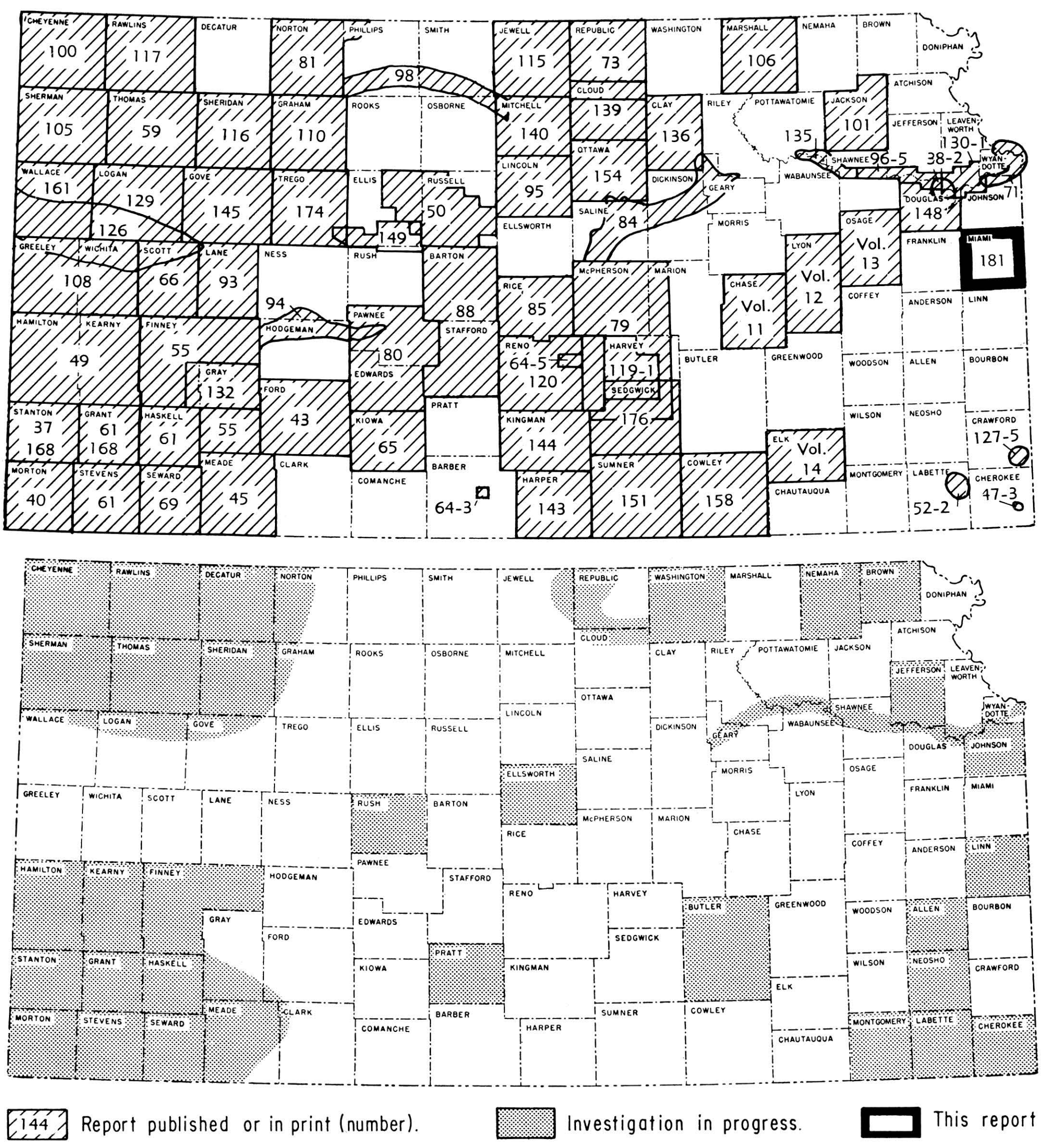

FIGURE 1.—Map of Kansas showing area described in this report, and other areas for which ground-water reports have been published by the State Geological Survey of Kansas or are in preparation.

of the section in which the well is located (Fig. 2). The first letter denotes the quarter section, the second letter denotes the quarter-quarter section, or 40-acre tract, and the third letter, when used, indicates the quarter-quarter-quarter section, or 10-acre tract. The 160-acre (quarter section), 40-acre, and 10-acre tracts are designated *a, b, c,* or *d,* in a counterclockwise direction, beginning in the northeast quarter.

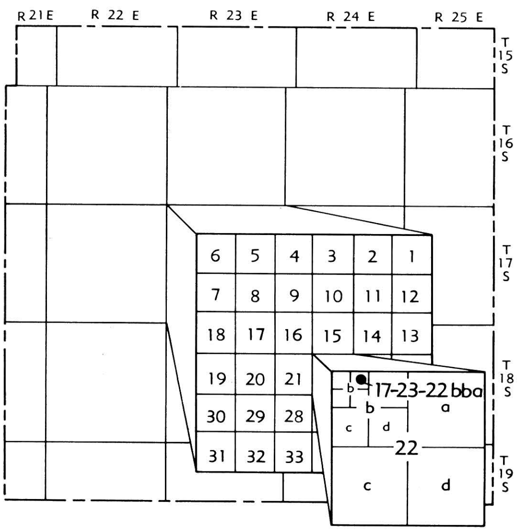

FIGURE 2.—Sketch of Miami County, Kansas, illustrating the well-numbering system used in this report. The well is in sec. 22, T 17 S, R 23 E.

Acknowledgments

The author expresses his appreciation to the many residents who supplied information concerning local geology, wells, and water supplies. Several drillers provided logs of wells that they had drilled in this area.

Geologists of the State Highway Commission of Kansas made available much geologic information, including profiles of several highway projects. Analyses of water samples collected during this investigation were made by H. A. Stoltenberg, Chief Chemist, of the Environmental Health Services of the Kansas State Department of Health.

Stratigraphic sections and other unpublished data on the geology and ground-water resources of the area collected by many other members of the Federal and State Geological Surveys were utilized in the preparation of this report, and their help is gratefully acknowledged.

The author acknowledges especially the assistance of J. M. Jewett, H. G. O'Connor, and S. M. Ball, who were particularly helpful and generous with their time.

The manuscript for this report has been reviewed critically by several members of the Federal and State Geological Surveys; by R. V. Smrha, Chief Engineer, and H. L. Mackey, Engineer, Division of Water Resources, Kansas State Board of Agriculture; and by J. L. Mayes, Chief Engineer, and B. F. Latta, Geologist, Environmental Health Services, Kansas State Department of Health.

A major part of the section of this manuscript dealing with the stratigraphy of the outcropping rocks was used in the preparation of a master's thesis (Miller, 1963) at the University of Kansas. Thanks are extended to staff members of the Geology Department for their assistance.

GEOGRAPHY

Topography and Drainage

Miami County lies within the Osage Plains section of the Central Lowlands physiographic province as defined by Schoewe (1949). The major topographic features are the southeast-trending Marais des Cygnes River valley and the gently sloping upland plains formed by erosion of the flat-lying sedimentary rocks underlying the County.

The Marais des Cygnes River and its tributaries drain the County except for the extreme northeastern part, which is drained by a few small streams flowing into the state of Missouri. The highest point in the County, which is about 1,150 feet above mean sea level, is 2.0 miles south and 2.5 miles east of Louisburg. The lowest point, which is about 790 feet above mean sea level, is along the Marais des Cygnes River at the south edge of the County. The Marais des Cygnes River has an average gradient of about 2.7 feet per mile in Miami County.

Climate

Miami County has a subhumid to humid climate characterized by moderate precipitation, reasonably mild winters, and fairly hot summers.

The mean annual precipitation at Paola, as compiled from records of the U.S. Weather Bureau, is summarized in Table 1.

TABLE 1.—Monthly and annual precipitation at Paola, Kansas, 1931-60. (From records of U.S. Weather Bureau.)

Month	Mean monthly precipitation, inches	
January	1.37	
February	1.32	
March	2.53	
April	3.58	184-day growing season (April–October)
May	4.86	
June	5.29	
July	4.68	
August	3.86	
September	3.72	
October	2.95	
November	1.87	
December	1.53	
Mean annual	37.56	

Population

Miami County was organized in 1855. In 1961 the County had a population of 19,820, of which about 53 percent was urban. Paola, the county seat, had a population of 4,782. Other communities in Miami County, and their 1961 populations, are: Osawatomie, 4,717; Louisburg, 888; and Fontana, 153 (Kansas State Board of Agriculture, 1961).

Agriculture and Industry

Agriculture is an important part of the economy of Miami County. According to the 1962 census of the State Board of Agriculture, there were 1,661 farms with a total of 126,035 acres under some type of cultivation. Crops produced in 1961 had a value of $5,678,150, while livestock and poultry produced had a value of $6,893,740.

Several small- to medium-sized industries are located in the larger communities of the County. For a complete listing by type of industry and number of employees, the reader is referred to the Kansas Industrial Development Commission Directory (1962).

GEOLOGY

Subsurface Stratigraphy[1]

Sedimentary rocks of Paleozoic and Neogene ages underlie Miami County. The Paleozoic rocks, of Pennsylvanian, Mississippian, Devonian, Silurian, Ordovician, and Cambrian ages, overlie Precambrian igneous and metamorphic rocks. The thickness of the Paleozoic rocks ranges from about 2,000 feet in the southeastern corner of the County to about 2,500 feet in the northwestern corner (Jewett, 1954, p. 290-292). The general thickness and character of the subsurface rocks are known from the study of well logs and samples of drill cuttings from oil and gas wells in the area.

A detailed discussion of the Paleozoic sequence of eastern Kansas was prepared by Lee (1943). More recently, Merriam and Kelly (1960) and Merriam and Smith (1961) prepared regional structural contour maps on the upper surfaces of Mississippian, Hunton, and Arbuckle rocks.

PRECAMBRIAN ROCKS

Quartzite, schist, slate, marble, porphyry, arkose, and granite have been reported in wells drilled into the Precambrian in Kansas. Wells drilled to the Precambrian at three localities in Miami County were reported to have encountered red arkose and granite (Cole, *et al.*, 1961).

The Precambrian surface slopes to the northwest across Miami County from about 1,200 feet below sea level in the southeastern corner to about 1,400 feet below sea level in the northwestern corner (Cole, 1962).

CAMBRIAN ROCKS

The Lamotte Sandstone of Late Cambrian age overlies Precambrian rocks throughout Miami County. It is a fine- to coarse-grained sandstone composed of quartz and feldspar and has a maximum thickness of about 100 feet (Jewett, 1954). The Bonneterre Dolomite, which overlies the Lamotte Sandstone, ranges in thickness from about 100 feet in the northwest corner to a somewhat greater thickness in the southeast corner and ranges in thickness from about 100 feet in the southwest corner to more than 150 feet in the northeast corner (Jewett, 1954).

CAMBRIAN AND ORDOVICIAN ROCKS

In Miami County the Arbuckle Group, of Early Ordovician and Late Cambrian ages, includes four recognizable formations. The Eminence Dolomite of Late Cambrian age is the lowestmost formation of the Arbuckle Group.

Lee (1943) differentiated the Ordovician part of the Arbuckle Group into three units: the Van Buren—Gasconade formations, the Roubidoux Formation, and the Jefferson City—Cotter dolomites. The Van Buren—Gasconade

[1] The stratigraphic nomenclature used in this report is that of the State Geological Survey of Kansas and does not necessarily follow the nomenclature of the U.S. Geological Survey.

sequence ranges in thickness from 150 feet in the southwest corner to about 200 feet in the northeast corner of the County. The Roubidoux ranges in thickness from about 100 feet in the southwest corner to about 80 feet in the northeast corner. The Jefferson City—Cotter sequence ranges in thickness from about 100 feet in the northeast corner to about 200 feet in the southwest corner. Arbuckle rocks in Miami County have an average thickness of 850 feet (Jewett, 1954).

ORDOVICIAN ROCKS

The Simpson Group and the overlying Viola Limestone of Middle Ordovician age are believed to be present only in northwestern Miami County. The upper part of the Simpson Group is composed of limestone, dolomite, and gray and green shale; the lower part is composed of well-rounded sandstone and gray shale. The maximum thickness of the Simpson Group in Miami County is about 100 feet. The thickness of the Viola Limestone ranges from 0 to about 200 feet (Jewett, 1954).

SILURIAN AND DEVONIAN ROCKS

In eastern Kansas undifferentiated Silurian and Devonian limestones and shales are commonly termed the "Hunton Group." According to Merriam and Kelly (1960), Hunton rocks of undetermined thickness occur in the northwest corner of Miami County.

DEVONIAN AND MISSISSIPPIAN ROCKS

Miami County lies on the northern flank of the Chautauqua Arch. Ordovician rocks, including the Viola Limestone, the Simpson Group, and the Arbuckle Group, are overstepped progressively to the southwest by the Chattanooga Shale, of Late Devonian and Early Mississippian ages. The Chattanooga is believed to be less than 50 feet thick in all parts of the County (Jewett, 1954). It is a silty and partly pyritiferous, greenish-gray, and dark-gray to black shale.

MISSISSIPPIAN ROCKS

Mississippian rocks in Miami County range from about 350 feet to slightly more than 450 feet, but they are thinner to the west and south. The Chouteau and Sedalia formations of Kinderhookian age, the Burlington Limestone of Osagian age, and the St. Louis, Salem(?), and Warsaw limestones of Meramecian age are believed to be present in the County (Lee and Girty, 1940). The Mississippian rocks in Miami County are chiefly limestone and dolomite.

PENNSYLVANIAN ROCKS

The Pennsylvanian rocks in Miami County belong to the Desmoinesian, Missourian, and Virgilian stages. The Desmoinesian Stage is composed of the Cherokee and Marmaton groups. The Missourian Stage consists of the Pleasanton, Kansas City, and Lansing groups. The Virgilian is made up of the Douglas, Shawnee, and Wabaunsee groups. Only rocks of the Missourian and Virgilian Stages are exposed; these are described in more detail in the following section.

Stratigraphy of Outcropping Rocks

Correlation of units discussed in this report on the basis of measured sections is shown on Plate 3. Decriptions of measured sections are at the end of the report.

PENNSYLVANIAN SYSTEM—MISSOURIAN STAGE

Pleasanton Group

TACKET FORMATION

The Tacket Formation (Jewett, *et al.,* 1965) is the oldest outcropping formation in Miami County (Pl. 1). It is composed of three units which are, in ascending order, a lower shale member, a middle limestone member, and an upper shale member. The Formation has an average thickness of 120 feet. It is a slope-forming unit, but it is poorly exposed along its outcrop in valleys in the southeastern part of the County.

Only about 25 feet of the upper shale member of the Tacket Formation is exposed in Miami County. This is predominantly of continental origin and is composed of olive-gray to grayish-orange sandy shale with thin, nodular limestone beds occurring locally.

A series of fine-grained, cross-bedded sandstone lenses ranging in thickness from 0 to 25 feet occurs in the upper part of the Tacket Formation at varying distances below the overlying Hertha Limestone. This sandstone is termed the "Knobtown" by drillers in the area. Study of the sandstone indicates that it consists of a number of separate lenses which were probably deposited by streams flowing across a surface of low relief (D. A. Hatcher, 1961, written communication).

Kansas City Group—Bronson Subgroup

HERTHA LIMESTONE

The Hertha Limestone (Adams, *et al.*, 1903) comprises in ascending order: the Critzer Limestone Member and the Mound City Shale Member, which are exposed only locally, and the Sniabar Limestone Member, which is the most persistent member of the Hertha in Miami County.

The Hertha is poorly exposed where it crops out along the valleys in the southeastern part of the County. In most localities it has a thickness of about 8 feet, but averages slightly more in the subsurface.

Structural contours drawn at the base of the Hertha (base of the Kansas City Group) show an irregular surface (Fig. 3). The local relief on this surface is probably the result of an initial irregularity at the time of deposition and subsequent regional movement of the rocks.

Critzer Limestone Member.—The Critzer Limestone Member (Jewett, 1932) was observed at only a few localities in Miami County. It is exposed in SE SE sec. 10, T 19 S, R 24 E, where it is composed of 1.0 foot of light olive-

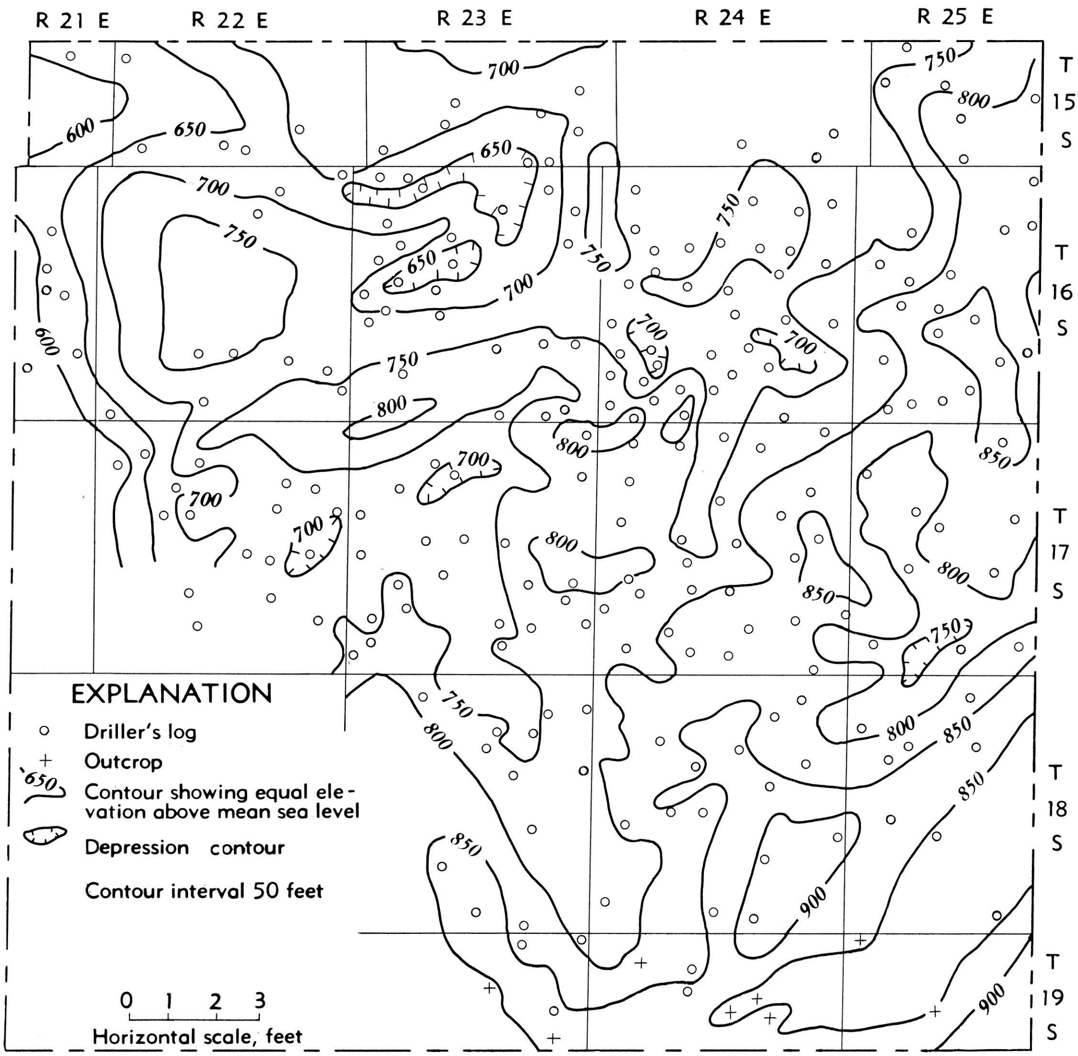

FIGURE 3.—Structural contour map on the base of the Kansas City Group in Miami County, Kansas. (Based on data from surface outcrops and from well logs in files of State Geological Survey of Kansas.)

gray, medium-grained, cherty limestone with abundant crinoid remains and some bryozoans.

Mound City Shale Member.—The Mound City Shale Member (Jewett, 1932) occurs only locally in Miami County. It is exposed at the location mentioned above in the description of the Critzer (SE SE sec. 10, T 19 S, R 24 E), where it consists of 0.4 foot of dusky-yellow, unfossiliferous sandy shale.

Sniabar Limestone Member.—The Sniabar Limestone Member (Jewett, 1932) is a medium- to coarse-grained, medium- to thick-bedded limestone with an average thickness of about 6 feet. It is the most lithologically variable unit in the lower part of the Kansas City Group. In NE SE sec. 34, T 18 S, R 24 E, it is oölitic at the top and contains chert in the lower part. In SE NW sec. 10, T 19 S, R 23 E, abundant hematite pebbles are found in a conglomerate composed of limestone phenoclasts in a calcareous matrix at or near the base of the Member. Insoluble residues of the conglomerate have a high percentage of oölitic and oömoldic chert. The conglomerate was probably derived from erosion of the Critzer Limestone Member, as it occurs at approximately the same stratigraphic position.

In most localities in Miami County the Sniabar Limestone Member is composed of two distinct limestone beds separated by a thin bed of shale. In NW SW sec. 33, T 18 S, R 24 E, the stratigraphic position of the shale is occupied by a breccia composed of angular limestone fragments. In the upper and lower limestone beds of the Sniabar, zones of bellerophontid gastropods are locally found. Algal encrustations are also quite common in the upper part of the Member.

LADORE SHALE

The Ladore Shale (Adams, *et al.,* 1904) is light-gray to olive-gray and weathers to a yellowish-gray. It is usually sandy; however, locally, as in SE NW sec. 10, T 19 S, R 23 E, it is calcareous and includes a thin limestone bed near the middle. The Ladore ranges in thickness from 1.2 feet in the NW SW sec. 33, T 18 S, R 24 E, to 11.4 feet in the NW NE sec. 19, T 18 S, R 24 E. The formation is unfossiliferous in Miami County, except for plant impressions in the sandy layers.

SWOPE LIMESTONE

The Swope Limestone (Newell, 1935) comprises two limestone members and one shale member, which are, in ascending order: Middle Creek Limestone Member, Hushpuckney Shale Member, and Bethany Falls Limestone Member. The Swope is well exposed along the streams in the southern part of Miami County but has no distinctive topographic expression. Throughout the County it has a thickness of about 34 feet and is easily distinguished from units above and below by the characteristic lithology of its members.

Middle Creek Limestone Member.—The Middle Creek Limestone Member (Newell, 1932) is a medium-gray to bluish-gray, fine-grained, dense limestone that commonly is seen in the outcrop as a single massive unit. It is brittle and has vertical joints 2 to 3 feet apart that form large, sharp-edged blocks. Locally, as in SE NW sec. 10, T 19 S, R 23 E, there are two limestone beds separated by a thin shale parting. The upper limestone has a thickness of 0.6 foot and the lower limestone of 1.8 feet. The thickness of the Middle Creek throughout most of the County is fairly constant, rarely more than 2.5 feet or less than 1.8 feet.

Hushpuckney Shale Member.—The Hushpuckney Shale Member (Newell, 1932) is named for Hushpuckney Creek, south of Fontana in Miami County. It consists of black fissile shale in the lower part and grayish sandy shale in the upper part. The Member has an average thickness of about 4 feet but attains a maximum thickness of 7.5 feet in NE NW sec. 6, T 19 S, R 25 E. At this location the lower 1.2 feet is black fissile shale and the upper 6.2 feet of the unit is yellowish-gray sandy shale. Where the Hushpuckney is relatively thin (3.9 feet), as in NW SW sec. 33, T 18 S, R 24 E, it appears that the thinning has been at the expense of the upper, sandy unit. Locally a thin bed of light olive-gray shale underlies the black shale.

The upper part of the Hushpuckney is fossiliferous, with chonetid brachiopods and a species of productid brachiopod being the most abundant forms.

Bethany Falls Limestone Member.—The uppermost member of the Swope Limestone, the Bethany Falls Limestone Member (Broadhead, 1866) ranges in thickness from about 13 feet near the SE cor. sec. 34, T 18 S, R 24 E, to about 28 feet in the SE NW sec. 10, T 19 S, R 23 E. It is a light-gray to light brownish-gray, medium-grained, medium- to thick-bedded sandy limestone containing numerous thin shale partings. In most areas the Member can be conveniently divided into two fairly distinct parts. The lower 12 to 16 feet of the Member contains fusulinids.

The upper part of the Member is cherty and locally has cross-bedded, pelletal limestone and (or) oölites in the extreme upper part (Fig. 4). Where the pelletal or oölitic limestone is present, the upper part locally contains vertical, tubular cavities containing iron-stained crystalline calcite. These cavities are 3 to 4 feet in length and 1 to 2 inches in diameter. The upper part of the Bethany Falls is the most variable in thickness, ranging from 0 to almost 14 feet. This irregularity is the result of thickening and thinning of the pelletal and oölitic part. The contact between the lower non-oölitic limestone and the oölitic limestone is quite uneven and possibly indicates a minor disconformity.

The Bethany Falls is a fossiliferous unit in which *Meekella, Derbyia, Antiquatonia,* and chonetid brachiopods are most common. *Triticites* is found locally in the lower part of the unit. Algae are quite abundant locally.

GALESBURG SHALE

The Galesburg Shale (Adams, *et al.,* 1903) in Miami County consists of greenish-gray to dusky-yellow, sandy to calcareous, blocky shale. Outcrops are restricted to stream valleys in the southern part of the County where the unit is poorly exposed. The Galesburg ranges in thickness from slightly less than 4 feet in the NE NW sec. 6, T 19 S, R 25 E, to about 12 feet in the NE SE sec. 34, T 18 S, R 24 E. It is usually thickest where the underlying Bethany Falls Limestone Member of the Swope Limestone is thin. Although not clearly evident on the outcrop, it appears possible that the oölitic upper part of the Bethany Falls locally was deposited concurrently with the lower part of the Galesburg Shale (Fig. 5). Whether the lateral change from limestone to shale is a gradual facies change or an interbedding of shale and limestone was not determined. The Galesburg is characteristically sparsely fossiliferous.

DENNIS LIMESTONE

The Dennis Limestone (Adams, *et al.,* 1903) forms prominent scarps and is well exposed in the southern part of the County. It has an average thickness of about 32 feet.

The Dennis in Miami County comprises two members, which, in ascending order, are: the

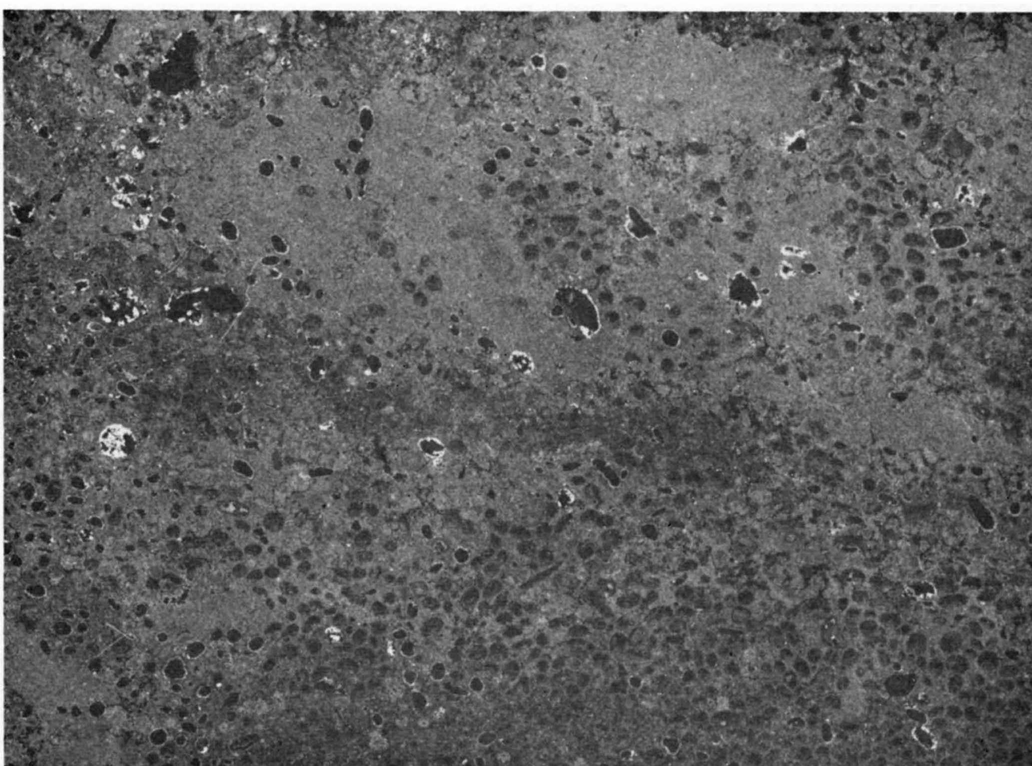

FIGURE 4.—Peel-print of the Bethany Falls Limestone Member of the Swope Limestone showing pelletal texture. Locality 56, SE SE NW sec. 10, T 19 S, R 23 E, ×4.

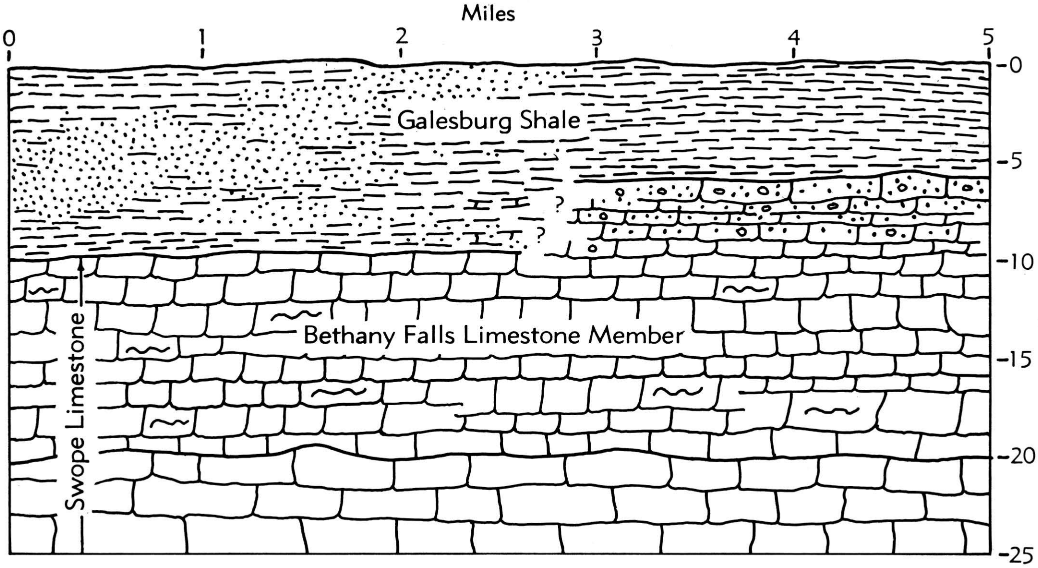

FIGURE 5.—Idealized section of relationship of the Bethany Falls Limestone Member (Swope Limestone) and the Galesburg Shale.

Stark Shale Member and the Winterset Limestone Member. A third member, the Canville Limestone Member, which is the lowermost member of the Dennis, is absent in Miami County outcrops but is present a short distance to the south in Linn County. A thin, impure, nodular limestone is seen locally, however, at this horizon in Miami County and may represent the Canville. This nodular limestone is exposed in NW NE sec. 19, T 18 S, R 24 E.

Stark Shale Member.—The lowermost member of the Dennis Limestone exposed in Miami County is the Stark Shale Member (Jewett, 1932). The lower part is black, fissile to very thin-bedded, carbonaceous shale. The upper part of the Stark consists of medium-olive to greenish-gray sandy shale and is about twice the thickness of the underlying black shale. Locally the olive and greenish-gray shale is absent, as in NE NW sec. 6, T 19 S, R 25 E, and the black shale is in contact with the overlying limestone. The thickness of the Stark ranges from 0.9 foot at the location mentioned above to almost 6 feet in NW NE sec. 19, T 18 S, R 24 E.

The Stark is fossiliferous in the upper, sandy part, with chonetid brachiopods being the most common type. The lower part is unfossiliferous except for rare inarticulate brachiopods.

Winterset Limestone Member.—The Winterset Limestone Member (Tilton and Bain, 1897) is the uppermost member of the Dennis Limestone. It is light gray to olive gray, medium grained, medium bedded and dense in the lower part and more fine grained in the middle part. The lower and middle parts of the Member characteristically contain shaly partings and much chert. The upper part is usually separated from the lower beds by a thin bed of calcareous gray shale, which in SW NE sec. 12, T 18 S, R 23 E attains a thickness of 1.5 feet. In NW SE sec. 27, T 18 S, R 23 E, two thin shales separated by 1.5 feet of soft, impure, wavy-bedded limestone are present. The upper part of the Winterset is dense, fine-grained, massive limestone. It contains an abundance of dark-gray chert and locally, as in NE NW sec. 27, T 18 S, R 24 E, is oölitic near the top. Commonly the oölite is restricted to the topmost 1 to 3 feet and does not characterize the entire upper part. The upper part of the Winterset is very fossiliferous and is characterized by numerous large productid brachiopods and locally by abundant gastropods (Fig. 6,*A*). *Triticites* is also very abundant in the upper part and is strikingly displayed in the dark chert nodules. The Winterset in Miami County has an average thickness of about 29 feet.

Kansas City Group—Linn Subgroup

CHERRYVALE SHALE

The Cherryvale Shale (Haworth and Bennett, 1908) comprises beds between the top of the Dennis Limestone and the base of the Drum

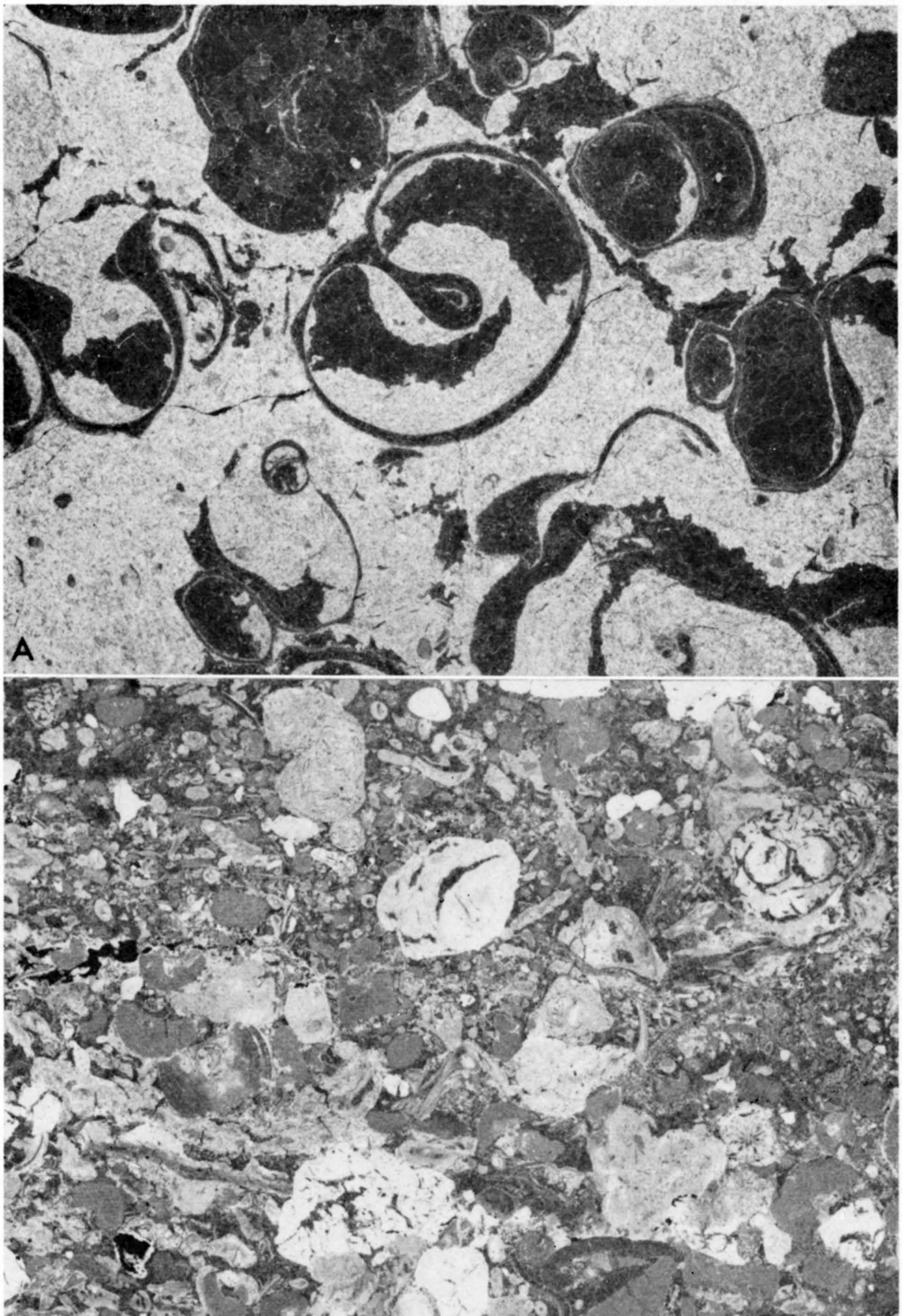

FIGURE 6.—*A*, Peel-print of upper part of the Winterset Limestone Member of the Dennis Limestone showing abundant gastropods. Note fine-grained texture of enclosing matrix; dark areas are secondary calcite. Locality 45, SW NW SE, sec. 27, T 18 S, R 23 E, ×4. *B*, Peel-print of the Westerville Limestone Member of the Cherryshale showing conglomeratic texture. Locality 51, SW SW NW sec. 7, T 18 S, R 24 E, ×4.

Limestone. It includes, in ascending order: the Fontana Shale Member, the Block Limestone Member, the Wea Shale Member, the Westerville Limestone Member, and the Quivira Shale Member. The Cherryvale has a great range in thickness in the subsurface, with a maximum of about 100 feet in the northeastern part of T 16 S, R 23 E, and a minimum of 40 feet in the extreme northeastern part of the County. At outcrops it has an average thickness of about 60 feet, but it is not well exposed.

Fontana Shale Member.—The Fontana Shale Member (Newell, 1935) is typically exposed in the vicinity of Fontana in southeastern Miami County. The Fontana is greenish-gray to olive-gray sandy shale. Locally a thin, nodular limestone occurs in the lower part, as in SW NE sec. 12, T 18 S, R 23 E. Where the limestone is absent, the interval is commonly marked by a thin layer of iron-stained calcareous shale. The Fontana has an average thickness of about 15 feet in Miami County. It is relatively unfossiliferous except for sparse chonetid brachiopods in the lower part.

Block Limestone Member.—The Block Limestone Member (Newell, 1935) is the lowermost limestone unit of the Cherryvale Shale and is named from exposures 0.25 mile east of the community of Block in southeastern Miami County. It is a bluish-gray to olive-gray medium-grained, thin-bedded fossiliferous limestone with numerous thin, fossiliferous shale partings. Insoluble residues from samples collected from the top of the unit show abundant oöliths and oömolds.

Triticites is the most characteristic fossil, but *Marginifera* and *Syringopora* also are abundant. The average thickness of the Member in Miami County is about 4 feet.

Wea Shale Member.—The Wea Shale Member (Newell, 1935), named from Wea Creek in northeastern Miami County, occupies the interval between the Block and the Westerville Limestone members. The Wea is characteristically olive-gray sandy shale containing sandstone beds locally near the base. The sandy layers are typically exposed in SW SW sec. 6, T 18 S, R 24 E. A thin bed of maroon shale occurs near the top of the Member at several exposures. Locally, pyritiferous nodules and limonite concretions occur in the Wea.

The Wea attains its greatest thickness in Miami County in SW NW sec. 16, T 17 S, R 24 E, where it is about 28 feet thick; the average thickness is about 18 feet. Fossils are rare in the Wea, but in SW NW sec. 7, T 18 S, R 25 E, plant impressions and carbonaceous smudges are found at its top. In places a very thin coal occurs near the top of the Member.

Westerville Limestone Member.—The Westerville Limestone Member (Bain, 1898) was studied at only a few scattered localities. In SW NW sec. 7, T 18 S, R 25 E, the Westerville is composed of about 2 feet of conglomeratic limestone containing abundant limonite nodules and quartz sand (Fig. 6,*B*). In SW NW sec. 16, T 17 S, R 24 E, the unit is composed of a 1-foot bed of yellowish-gray marly limestone. The different lithologies and the sporadic occurrence of the Westerville in Miami County may indicate a local disconformity at this horizon.

Quivira Shale Member.—The lower part of the Quivira Shale Member is composed of black, carbonaceous, fissile shale (Newell, 1935). It is characteristically exposed in a road cut in SW NW sec. 7, T 18 S, R 25 E. In SW SW sec. 24, T 18 S, R 24 E, the black fissile shale is absent and maroon clayey shale occurs at this horizon. Though these two types of rock occur in the same stratigraphic position, they have not been observed in the same outcrop. The black shale and the maroon shale are usually quite thin (0.5 to 1.0 foot) and rest directly on the Wea Shale Member in localities where the Westerville Limestone Member is missing. The upper part of the Quivera consists of olive-gray sandy shale. In NW SW sec. 25, T 18 S, R 22 E, a thin dark-gray fissile shale occurs directly below the overlying Drum Limestone. The dark shale probably represents the entire Quivira at this locality.

The Quivira has an average thickness of about 4 feet. It is unfossiliferous, except for sparse inarticulate brachiopods and conodonts in the black fissile shale.

DRUM LIMESTONE

The Drum Limestone (Adams, *et al.,* 1903) consists of a single massive bed of yellowish-gray to reddish-brown fine- to medium-grained limestone that is uniform in lithology and easily recognizable. Locally, as in NE NE sec. 6, T 17 S, R 24 E, the upper part weathers into thin slabs which show cross-bedding. The slabs are dark-brown, coarse-grained limestone and are separated by thin calcareous shale partings. The Drum is thickest where the cross-bedded upper part is present, and, at the location mentioned above, it has a thickness of about 8 feet. The thinnest outcrop of Drum measured in the County was 1.7 feet thick. The Member has poor topographic expression in Miami County.

The most characteristic feature of the Drum is the occurrence of abundant, small, white crinoid segments scattered throughout the limestone. Other fossils found in the Drum are *Neospirifer, Marginifera,* and *Composita,* and locally, as in NW SW sec. 25, T 18 S, R 22 E, the small sponge *Heliospongia.*

CHANUTE SHALE

The Chanute Shale (Haworth and Bennett, 1908) varies greatly in thickness and lithology over short lateral distances. It is about 8 feet thick near Paola and about 38 feet thick north of Block. The Chanute is characteristically yellowish-brown to greenish-gray sandy to clayey shale. It contains sandstone locally in the lower and middle parts and commonly in the upper part. In SW cor. sec. 6, T 17 S, R 23 E, sandstone rests directly on the underlying Drum Limestone (Pl. 3). In the northern part of T 19 S, R 22 E, where the sandstone is about 30 feet thick, there is very little shale in the Chanute. A few miles north, in NW SW sec. 25, T 18 S, R 22 E, the Chanute has 32 feet of shale and no sandstone. The Chanute Shale is a relatively unfossiliferous unit except for plant impressions found locally in the sandy layers.

Over a large area the Chanute contains the Thayer coal, which ranges in thickness from 0 to 0.5 foot. The coal is 11 to 15 feet above the base of the formation, and no coal occurs where the Chanute is thinner than 11 feet, or where sandstone occupies this interval, as it does in NW NE sec. 16, T 18 S, R 25 E. The Thayer occurs at differing stratigraphic positions in respect to the upper formational boundary. In SW NW sec. 7, T 18 S, R 25 E, a thin, nodular limestone overlying 8 feet of greenish-gray, clayey shale is found at the base of the formation. At the same stratigraphic position in NW NE sec. 33, T 16 S, R 23 E, there is a 2-foot bed of maroon shale overlying 6 feet of olive-green pyritiferous shale.

IOLA LIMESTONE

The Iola Limestone (Haworth and Kirk, 1894) comprises two limestone members and one shale member. They are, in ascending order: the Paola Limestone Member, the Muncie Creek Shale Member, and the Raytown Limestone Member. The Iola has an extensive outcrop area and lithologically is fairly consistent. It has an average thickness of about 10 feet north of the Marais des Cygnes River and about 12 feet south of the river.

Paola Limestone Member.—The Paola Limestone Member (Newell, 1932) is named for exposures north of Paola, and in most localities it is a single massive bed of dark-gray to brownish-gray, fine-grained, dense limestone with an average thickness of about 2.5 feet. In the southern part of the County, the Paola locally becomes more coarse grained and weathers into thin slabs. The contact with the underlying shale is fairly smooth, but the upper surface of the unit is very irregular or "hummocky" (Newell, 1935). Locally, iron-stained "worm tubes" extend downward 1 to 3 inches from the upper surface of the Paola.

The Paola is missing in several places in Miami County. In SW SW sec. 6, T 17 S, R 23 E, the Iola Limestone is 5.7 feet thick and the Paola Limestone Member is absent. A few miles east of Paola in NW NW sec. 24, T 17 S, R 23 E, the Iola is about 4.0 feet thick and the Paola Limestone Member is absent. Apparently the Paola is absent in these areas as a result of nondeposition over irregularities of the upper surface of the Chanute Shale (Fig. 7). The actual interface relationship of the Paola Limestone Member and the Chanute Shale around the areas of nondeposition was not observed. The Paola, however, does become more sandy when traced toward these areas.

Crinoid stems and small productid brachiopods are the most abundant fossils in the Paola Limestone Member. Encrusting algae of the *Osagia* type and bryozoans are quite common locally. Insoluble residues of samples from the Paola indicate that quartz sand was available only very locally during deposition of the unit; the bulk of the residue is fine silt, clay, and a small amount of pyrite.

Muncie Creek Shale Member.—The Muncie Creek Shale Member (Newell, 1932) is a very distinctive unit in Miami County. It is a bluish-gray to dusky-yellow sandy shale that has a dark-gray, carbonaceous, fissile facies locally, as in SE SE sec. 7, T 17 S, R 23 E. The average thickness of the Muncie Creek is about 0.5 foot.

The most diagnostic feature of the Muncie Creek is the presence of spherical or ellipsoidal phosphatic nodules ¼ to 1 inch in maximum diameter. The surface of these nodules weathers white or light gray, but the interior remains black or dark gray. Most of the nodules have small fossil fragments at their centers.

Many theories have been proposed as to the origin of phosphatic nodules in sediments. Blackwelder (1916) has said that ammonium phosphate generated by the decay of pelagic organisms might be the agent of precipitation of phosphatic nodules. Emigh (1958) states that

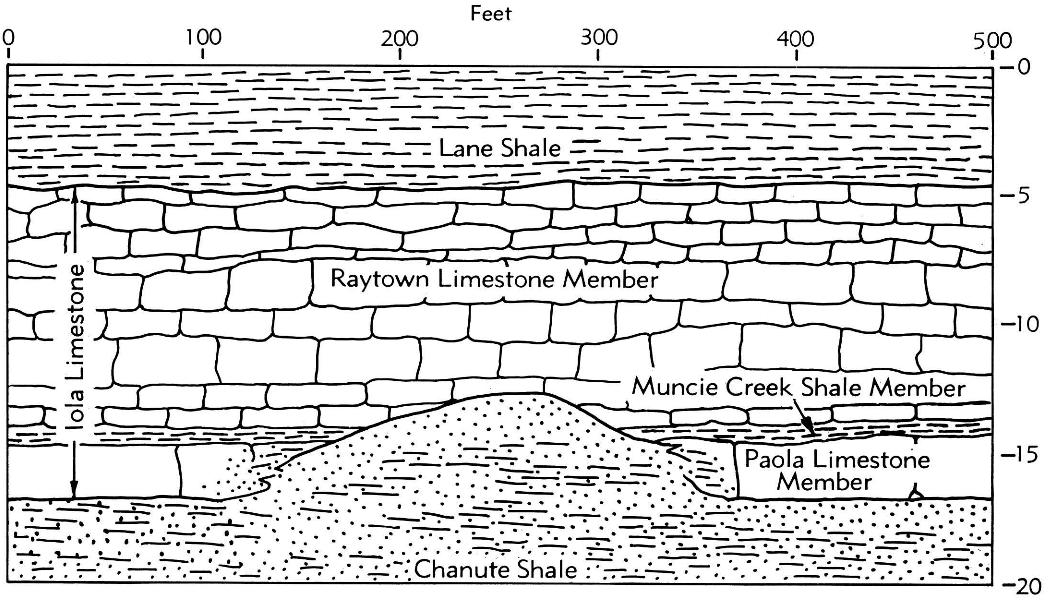

FIGURE 7.—Idealized section showing the relationship of the Iola Limestone and the Chanute Shale in areas of nondeposition of the Paola Limestone Member of the Iola Limestone.

phosphatic pellets or nodules in the Phosphoria Formation (Permian) in Idaho were originally nodules of calcium carbonate built around organic debris, which were replaced later by calcium phosphate. The latter theory probably explains the occurrence of the nodules in the Muncie Creek Shale Member.

Raytown Limestone Member.—The Raytown Limestone Member (Hinds and Greene, 1915) ranges in thickness from about 5 feet in SW SW sec. 29, T 17 S, R 24 E, to about 24 feet in SE SE sec. 7, T 17 S, R 23 E. It is a light olive-gray to light-gray medium- to coarse-grained limestone with numerous silty shale partings and abundant vugs lined with crystalline calcite. The Raytown is medium bedded in the northern part of Miami County but becomes progressively more thin bedded when traced toward the southern part of the County. In SE SE sec. 7, T 18 S, R 23 E, there are three thin limestone beds separated by shale which altogether have a thickness of 3.7 feet, and which occur about 4 feet above the main limestone bed of the Member. In the SE SE sec. 18, T 18 S, R 23 E, the upper limestones are thicker, better developed, and lie about 7 feet above the main limestone bed of the Raytown (Fig. 8).

Abundant large productid brachiopods occur in the Raytown, with *Echinaria* and *Linoproductus* being the most common. West and south of Osawatomie, small sponges resembling *Girtyocoelia* are present in the lower part of the Member. The coiled cephalopod *Knightoceras* was found in the upper part of the Member in SE SE sec. 9, T 16 S, R 23 E.

KANSAS CITY GROUP—ZARAH SUBGROUP

LANE SHALE

The Lane Shale (Haworth and Kirk, 1895) has considerable variation in lithology and thickness. In the western half of the County the Lane has an average thickness of about 80 feet and is an olive-gray to dusky-yellow silty to sandy shale and thin-bedded siltstone. In the eastern half it is an olive-gray to light-gray clayey shale with an average thickness of about 25 feet. The Lane ranges in thickness from about 16 feet in NE NE sec. 2, T 18 S, R 23 E to about 108 feet in SE sec. 7, T 16 S, R 23 E. The Lane is a slope-forming unit, and it produces a rounded topography.

Thin carbonaceous streaks 1/16- to ¼-inch thick are found locally in the Lane, but none is sufficiently continuous or thick enough to be termed a coal bed.

In SW SW sec. 17, T 17 S, R 22 E, there is a thin zone of light-gray, clayey shale containing laminae of reddish-brown calcareous silt just below the overlying Wyandotte Limestone. Pettijohn (1957) states that laminae of this type were probably deposited in deep, quiet waters and may indicate lower than normal salinity of the sea water. Newell (1935) reported that the laminated zone is quite common in the western part of the County. In SW NE sec. 27, T 18 S, R 22 E, a thin 0.4-foot-thick sandy, micaceous limestone replaces the laminated zone.

The Lane is essentially unfossiliferous except for sparse plant remains. Locally, as in SW SW sec. 5, T 17 S, R 25 E, there are small brachiopods and crinoid remains in the upper few feet of the formation.

WYANDOTTE LIMESTONE

The Wyandotte Limestone (Newell, 1932) comprises three limestone members and two shale members. They are, in ascending order: the Frisbie Limestone Member, the Quindaro Shale Member, the Argentine Limestone Member, the Island Creek Shale Member, and the Farley Limestone Member. The Wyandotte is a distinctive cuesta-forming formation which is well exposed in Miami County. It ranges in thickness from about 10 to 80 feet. The shale members are present only locally in Miami County. The absence of the shale members and the similarity in the lithology of the two upper limestone members makes identification of the units difficult.

Frisbie Limestone Member.—The Frisbie Limestone Member (Newell, 1932) is the most easily identifiable member of the Wyandotte. It is a light olive-gray to light brownish-gray, fine-grained, massive limestone. Locally, as in SW SW sec. 5, T 17 S, R 25 E, it is composed of 0.5 foot of limestone overlain by 0.2 foot of shale and 1.0 foot of limestone, but in SE NE sec. 27, T 17 S, R 25 E, it is composed of three limestones and two shales. At several localities, the Frisbie is absent or has undergone a facies change and is not recognizable. The Frisbie has an average thickness of about 2.5 feet. The maximum thickness noted was 3.6 feet in NE SE sec. 11, T 18 S, R 21 E.

Crinoid stems and small productid brachiopods are the most common fossils found in the Frisbie. The unit locally contains *Osagia*-like forms.

Quindaro Shale Member.—The Quindaro Shale Member (Newell, 1932) is a dusky-yellow to dark yellowish-orange, sandy shale. Locally, as in SW SW sec. 5, T 17 S, R 25 E, the lower part of the Quindaro is very dark gray. The Member is absent in many Wyandotte outcrops. The thickness ranges from 0 to about 3.3 feet.

The Quindaro is very fossiliferous with *Heterocoelia, Dielasma,* and *Phricodothyris* being the most common forms. Crinoid fragments and bryozoans are also abundant, and in SW SW sec. 5, T 17 S, R 25 E, sponges resembling *Heliospongia* are found.

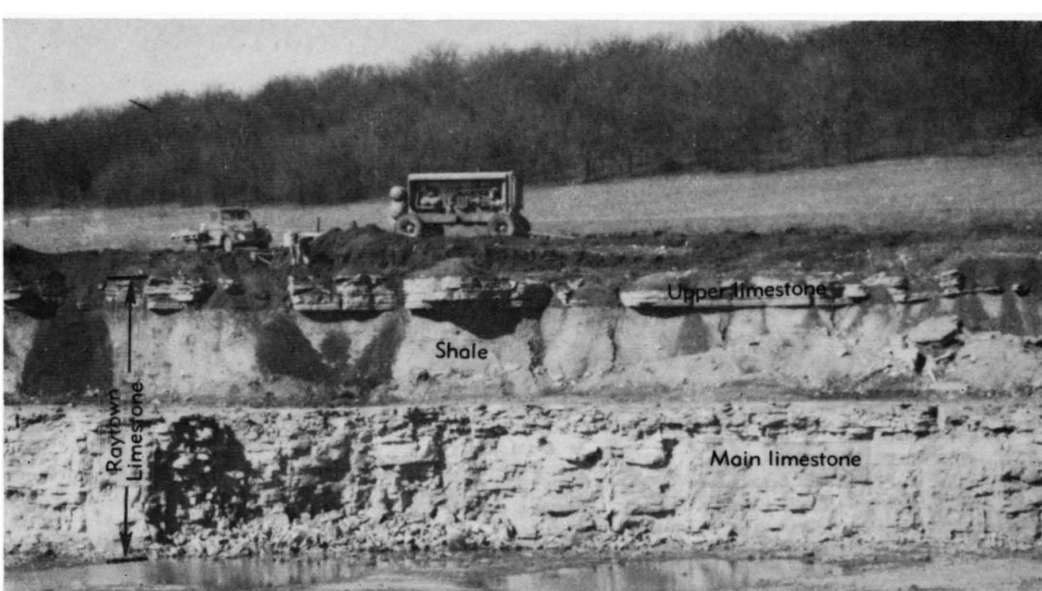

FIGURE 8.—Quarry exposure of the Raytown Limestone Member of the Iola Limestone, showing upper 3-foot limestone bed and 7-foot shale bed above the main limestone ledge of the Member, SE SE SE sec. 18, T 17 S, R 23 E.

Argentine Limestone Member.—The Argentine Limestone Member (Newell, 1932) is probably the most persistent member of the Wyandotte. Its identification in Miami County is primarily by stratigraphic position, as its lithology is similar to the Farley Limestone Member, which is normally the uppermost limestone member of the Wyandotte. Locally the Farley Limestone Member is missing and the Argentine Limestone Member is the uppermost member. The Argentine is a light olive-gray to grayish-orange, medium-grained, thin-bedded, locally cherty limestone, which weathers into thin fragments. In SE SE sec. 5, T 17 S, R 24 E, where the Frisbie Limestone Member and the Quindaro Shale Member are absent, the Argentine is very fractured.

The range in thickness of the Argentine Limestone Member is difficult to determine, but in SW SW sec. 1, T 16 S, R 24 E, where the overlying Island Creek Shale Member is present, about 37 feet of Argentine was measured.

The Argentine has a varied fauna with the brachiopods *Composita, Echinaria, Antiquatonia,* and *Phricodothyris* being most common. *Enteletes* is abundant west and south of Paola. The fusulinid *Triticites* is common locally.

Island Creek Shale Member.—The Island Creek Shale Member (Newell, 1932) was tentatively identified at only two localities in Miami County. In SW SW sec. 1, T 16 S, R 24 E, it has a thickness of 1.6 feet and is a grayish-orange clayey shale containing abundant gastropods. In NW NE sec. 4, T 16 S, R 25 E, there is 0.4 foot of gray clayey shale which is probably Island Creek.

Farley Limestone Member.—The Farley Limestone Member (Hinds and Greene, 1915), where present, is the uppermost member of the Wyandotte Limestone. It is a light olive-gray to pinkish-gray coarse-grained, wavy, thin- to thick-bedded limestone. In NW NE sec. 4, T 16 S, R 25 E, the Farley has a thickness of 15 feet, and the lower part of the Member is medium bedded and oölitic. Where the underlying Island Creek Shale Member is absent, the Farley rests directly on the Argentine Limestone Member. Only at two localities, where the Island Creek Shale Member is identified, is the base of the Farley Limestone Member identified with certainty.

The Farley contains much the same fauna as the Argentine Limestone Member, except for the presence of a few scattered *Aviculopecten* in the lowermost part, at localities where the Island Creek Shale Member is present.

BONNER SPRINGS SHALE

The Bonner Springs Shale (Newell, 1932) is the uppermost formation of the Kansas City Group. In the lower part it is a pale olive- to light-gray sandy shale which in places, as in NE SW sec. 8, T 16 S, R 23 E, grades laterally into a thin-bedded micaceous siltstone. It is an olive-gray to yellowish-brown clayey shale in the upper part.

Near the middle of the formation is a zone of varied lithology. In NE NW sec. 29, T 15 S, R 23 E, this zone is composed of about 4 feet of grayish-red clayey shale that appears to be barren of fossils. In NE NW sec. 16, T 16 S, R 24 E, the zone is composed of 0.7 foot of medium-gray clayey shale containing carbonaceous streaks, plant rootlets, and leaf impressions. In NW NW sec. 21, T 15 S, R 22 E, a 6-foot bed of olive-gray medium-grained, medium-bedded, calcareous sandstone is found in this interval.

In areas where the formation is primarily clayey shale, scattered limestone nodules are present. In NE NW sec. 29, T 15 S, R 23 E, a thin, argillaceous limestone bed about 1-foot thick is present 2.0 feet below the top of the formation. The limestone bed is very fossiliferous and contains abundant pelecypods, algae, brachiopods, gastropods, and bryozoan fragments.

The Bonner Springs ranges in thickness from 0.9 foot in NE NW sec. 30, T 16 S, R 24 E to 31.5 feet in NE SE sec. 19, T 15 S, R 23 E. The average thickness of the unit is about 20 feet.

Lansing Group

PLATTSBURG LIMESTONE

The Plattsburg Limestone (Broadhead, 1866) is the lowermost formation in the Lansing Group. It comprises two limestone members and one shale member, named, in ascending order, the Merriam Limestone Member, the Hickory Creek Shale Member, and the Spring Hill Limestone Member. The Plattsburg has an average thickness of about 16 feet. It is a scarp-forming unit and has an extensive area of outcrop (Pl. 1).

Merriam Limestone Member.—The Merriam Limestone Member (Newell, 1932) usually is easily recognizable and is commonly seen as a single, massive bed of bluish-gray to light-gray, fine-grained, dense limestone.

The Merriam is locally composed of two distinct divisions. The lower division is a massive, bluish-gray to light-gray limestone and is the persistent part of the Member. In NE NE sec. 8, T 17 S, R 22 E, the lower division comprises all of the Merriam and is cross-bedded and oölitic. In NE NW sec. 30, T 16 S, R 24 E, the lower division is 3.6 feet thick and has a zone of black, fossiliferous chert 1.7 feet above the base (Pl. 3). Elsewhere, as in NW NW sec. 2, T 16 S, R 23 E, a zone containing abundant *Composita* occurs in the lower division. *Osagia*-like forms are usually present and in some places these constitute a large part of the limestone. The large pelecypod *Myalina* is abundant locally, and productid brachiopods are common in the lower part of the Member. The upper of these two divisions is light- to medium-gray, fine-grained, massive, locally cherty limestone. It is generally not very fossiliferous but usually contains abundant "worm tubes" on the upper surface. Locally the upper division is separated from the lower division by a thin shale bed, as in NE NW sec. 16, T 16 S, R 24 E. At this location the upper division is cherty and has abundant crinoid and bryozoan remains. The average thickness of the Merriam is about 3.5 feet. The thickness ranges from about 1 foot to about 9.5 feet.

Hickory Creek Shale Member.—The Hickory Creek Shale Member (Newell, 1932) is a yellowish-gray to orangish-gray, clayey, nodular, calcareous shale. It has an average thickness of slightly more than 2 feet, but locally it may be absent. A very thin, nodular limestone bed occurs near the middle of the Member in SW NW sec. 25, T 16 S, R 21 E, and in NE NE sec. 8, T 17 S, R 22 E, the entire Member is composed of nodular calcareous shale. The unit is fossiliferous with crinoid remains and bryozoans being the most common forms.

Spring Hill Limestone Member.—The Spring Hill Limestone Member (Newell, 1932) is a light olive-gray to yellowish-gray, fine- to coarse-grained, thin- to medium-bedded, sandy limestone. It contains chert locally and in SE SE sec. 27, T 16 S, R 22 E is oölitic at the top. In SE SE sec. 14, T 15 S, R 23 E, the Spring Hill has two shale partings and several thin wavy carbonaceous streaks. At several locations the Member has abundant fractures filled with iron-stained calcite crystals. In a quarry in NE NW sec. 27, T 15 S, R 22 E, the upper part of the Spring Hill is conglomeratic with abundant limonite pebbles, shale and ironstone fragments, and small abraded calcite crystals.

The Spring Hill ranges in thickness from 4 feet in SE SE sec. 8, T 16 S, R 23 E, to about 17 feet in SE NW sec. 7, T 17 S, R 22 E. Its thickness in the subsurface is variable and in places is more than 20 feet thick.

Triticites is common and *Osagia*-like forms are locally abundant. Echinoid spines are abundant locally in the Spring Hill, and Newell (1935) states that they are *Echinocrinus*. A zone of large Compositas is commonly found near the base of the unit. A zone containing *Enteletes* and *Marginifera* is usually associated with the carbonaceous streaks in the lower part of the Spring Hill. In SE NW sec. 7, T 17 S, R 22 E, the rock is made up principally of fenestrate bryozoan remains.

VILAS SHALE

The Vilas Shale (Adams, 1898) is grayish-olive to light-gray, sandy, and blocky. In the western part of the County it contains a considerable amount of moderate yellowish-brown siltstone and orangish-gray cross-bedded sandstone. In SE NW sec. 7, T 17 S, R 22 E, there is a 4-foot bed of calcareous cross-bedded sandstone 4 feet above the Plattsburg Limestone. The Vilas ranges in thickness from about 5 feet in SW NW sec. 31, T 15 S, R 23 E, to about 30 feet where State Highway 68 crosses the county line into Franklin County. It has few invertebrate megafossils, but plant remains are common in the sandy layers.

STANTON LIMESTONE

The Stanton Limestone (Haworth and Bennett, 1908) is the uppermost formation in the Lansing Goup. It comprises three limestone members and two shale members, which are, in ascending order, the Captain Creek Limestone Member, the Eudora Shale Member, the Stoner Limestone Member, the Rock Lake Shale Member, and the South Bend Limestone Member. The upper member was not measured because it is not exposed, and the remaining members are poorly exposed. Because of the scarcity of outcrops in which all members are recognizable, the thickness of the Stanton in Miami County is difficult to determine, but in adjacent counties it is about 35 feet.

Captain Creek Limestone Member.—The Captain Creek Limestone Member (Newell, 1935) is easily recognizable, both by its own distinct lithology and by the characteristic lithology of the units directly above and below. The lower part of the Captain Creek is medium gray and dense. The upper part is commonly a pale yellowish-brown to light-gray, medium-grained, thick-bedded, cherty limestone, which locally is sandy. At NW SE sec. 27, T 15 S, R 23 E, the upper part of the Member is oölitic. The chert is pale red and very pale blue and resembles medium-grained sand. It is finely disseminated and gives the upper part of the limestone a mottled appearance. At many of the exposures the upper part weathers into large, angular blocks.

The Member ranges in thickness from about 5 feet in NE SE sec. 26, T 16 S, R 21 E, to about 11 feet in NE NE sec. 8, T 17 S, R 22 E.

In NW SE sec. 27, T 15 S, R 23 E, a bed of bioclastic limestone 0.2-foot thick occurs at the base of the Captain Creek. The limestone contains brachiopods, crinoid stems, bryozoans, and what appear to be wood fragments replaced by calcium carbonate.

The Captain Creek contains abundant *Enteletes,* and the fusulinid *Triticites* is seen locally along the bedding planes.

Eudora Shale Member.—The Eudora Shale Member (Condra, 1930) is an olive-gray to light yellowish-brown, clayey, blocky shale with a thin layer of black, fissile shale near the middle. Locally, the black shale makes up 40 to 50 percent of the Member. The thickness of the Eudora ranges from about 5.5 feet in SW SW sec. 4, T 17 S, R 22 E, to about 11 feet in NE SE sec. 26, T 16 S, R 21 E. It is relatively unfossiliferous except for sparse inarticulate brachiopods, conodonts, and rare conularids, which occur in the black shale.

Stoner Limestone Member.—The Stoner Limestone Member (Condra, 1927) is poorly exposed and only in NW NW sec. 35, T 15 S, R 21 E was the full thickness of the Member seen. Newell (1935) states that the low relief on the upland surface underlain by the Stoner is due to the resistant nature of the Member. It is probable, however, that the Stoner in Miami County was at about base level when the upper Tertiary surface was formed (J. M. Jewett, 1962, oral communication). This factor may explain the scarcity of exposures of the Stoner as well as of other members of the Stanton in Miami County.

At the location mentioned above, the Stoner is about 19 feet thick and is comprised of the following sequence of units, in ascending order: (1) 13.3 feet of yellowish-gray, medium-grained, uneven- and medium-bedded limestone which contains fusulinids, crinoids, and algae; (2) a 0.5-foot bed of yellowish-brown, arenaceous shale; (3) a 2.4-foot bed of grayish-orange, sucrose-textured, uneven- and medium-bedded limestone; (4) a 1.1-foot bed of yellowish-gray coarse-grained, wavy- and thin-bedded limestone which contains abundant gastropods, pelecypods, and brachiopods; (5) a 0.3-foot dusky-yellow, banded shale parting; and (6) a 0.5-foot bed of light-gray sandy limestone containing pelecypods, brachiopods, and small sponges.

Rock Lake Shale and South Bend Limestone Members.—Only the lowermost part of the Rock Lake Shale Member (Condra, 1927) was seen in Miami County. In NW NW sec. 35, T 15 S, R 21 E, about 4 feet of badly weathered gray shale in the lower part of the unit is poorly exposed.

The South Bend Limestone Member is probably present as a 3- to 5-foot-thick sandy limestone in the subsurface in the northwestern part of the County, but it is not exposed and was not studied.

DOUGLAS GROUP

The nomenclature used here is the result of a redefinition of the lower boundary of the Douglas Group (Ball, 1963). The term "Pedee Group" was dropped from usage in Kansas by Ball, and the boundary of the Douglas Group was lowered to include all rocks to the top of the Lansing Group. The Weston Shale and the Iatan Limestone were reduced from formation to member rank, and the Stranger Formation was redefined to include rocks from the top of the Stanton Limestone to the base of the Haskell Limestone Member of the Lawrence Formation. The Lawrence Formation was redefined to include rocks between the base of the Haskell and the base of the Toronto Limestone Member of the Oread Limestone.

STRANGER FORMATION

Weston Shale Member.—The Weston Shale Member (Keyes, 1899) is the only member of the Stranger Formation identified in Miami County. It underlies the upland in the northwestern part of the County and is poorly exposed. It is composed of olive-gray to bluish-gray argillaceous shale, and limonite specks and nodules occur in it locally. The thickness of the Weston was not determined, but it is probably about 30 feet.

LAWRENCE FORMATION

Ireland Sandstone Member.—The only member of the Lawrence Formation identified in Miami County is the Ireland Sandstone Member (Moore, 1932). It underlies the surface in the extreme northwestern part of the County (Pl. 1). The Ireland is 13 feet thick in a test hole in the NE cor. sec. 22, T 15 S, R 21 E and is composed of fine to coarse silty, micaceous, quartz sand, with some fine to coarse gravel at the base.

NEOGENE SYSTEM—PLIOCENE AND PLEISTOCENE SERIES

Pre-Kansan (Pliocene?) Deposits

Upland chert gravels.—Locally deposits of chert gravel and silt are found in upland areas some distance from present drainage courses. These deposits are found at elevations about 200 feet above the flood plain of the Marais des Cygnes River and are sparsely scattered across bedrock surfaces. As the thickness of these deposits rarely exceeds 2 feet, they were not mapped and are not shown on Plate 1. They are probably Pliocene in age and reflect a surface across which eastward-trending streams flowed (Frye and Leonard, 1952).

Other deposits of Pliocene age are associated with or are near the present drainage course of the Marais des Cygnes River and are shown on Plate 1. They form a veneer, having a maximum thickness of about 6 feet, and lie on rocks of Pennsylvanian age at elevations 50 to 70 feet above the present flood plain of the river. The deposits are leached and oxidized and consist mainly of chert pebbles in a yellowish-tan sandy clay matrix.

The similarity of the weathered condition and topographic position of these deposits with respect to known Pliocene deposits found elsewhere indicates that they are probably of Pliocene age.

Kansan Stage

Deposits consisting of gravel and silt are found on valley walls and on low saddles along valley walls (Pl. 1). The similarity of the weathered condition and topographic position of these deposits to deposits of known Kansan age indicates that these deposits are also Kansan in age. They are scattered and occur at elevations that are 20 to 35 feet above the flood plain of the Marais des Cygnes River. Their maximum thickness is probably no more than 10 feet. They consist mainly of chert pebbles but contain some rounded limestone pebbles in a yellowish-tan sandy silt matrix. Individual pebbles range in diameter from 1 to 3 inches.

Illinoisan Stage

Fluvial deposits, which are Illinoisan in age, occur in the valleys of the streams in Miami County (Pl. 1). These Illinoisan deposits underlie a terrace which is about 8 feet above the flood plain at the terrace break and slopes up the valley wall to merge with the colluvium.

The deposits underlying the Illinoisan terrace are usually reddish-brown to yellowish-tan silt, which is locally sandy. Thin beds of gravel occur in places at the base of these deposits. The surface of the terrace is usually highly dissected.

Wisconsinan and Recent Stages

Deposits of Wisconsinan and Recent age consisting of sand, silt, and some gravel are found underlying the flood plain of the Marais des Cygnes River and its tributaries (Pl. 1). Due to their similar lithology these deposits were mapped as a unit.

The deposits consist of light-gray to tannish-gray silt with lenses of clay and fine to coarse sand. Gravel is present but is so sparse that it was rarely encountered in drill holes.

The surface of the alluvium is about 5 feet lower than the Wisconsinan terrace surface and is relatively flat and undissected. The maximum thickness of the Wisconsinan and Recent deposits in Miami County is about 55 feet (Pl. 2).

Structural Geology

A detailed analysis of the structural geology of Miami County is beyond the scope of this report. There are, however, certain features produced by regional and local structure which are easily seen in the exposed rocks, and these are described.

REGIONAL STRUCTURE

The Chautauqua Arch, which is a major pre-Mississippian structural element, indirectly affected the attitude of the Mississippian and Pennsylvanian rocks, in that the tectonic activity which caused the arch tilted the surface upon which these rocks were deposited.

Lee, *et al.* (1946) described a structural element they termed "the Ancestral Forest City Basin," the axis of which extends southward from southeastern Atchison County to southern Miami County. The Forest City Basin is the major post-Mississippian basin east of the Nemaha Anticline in northeastern Kansas. Originally it was both a topographic and a structural basin in which the earliest Pennsylvanian rocks of this part of Kansas were deposited (Lee and Payne, 1944).

Another important structural feature in eastern Kansas is the Prairie Plains monocline (Prosser and Beede, 1904). As a result of this post-Permian structure, the Pennsylvanian rocks in Miami County have a regional dip to the northwest of about 20 feet per mile. A structural contour map of Miami County (Fig. 3) using the base of the Kansas City Group as a datum plane shows many smaller anticlinal and synclinal structures superimposed upon the monocline.

LOCAL STRUCTURES

The Prairie Plains monocline in Miami County is marked by a number of small local structures. Within these structures there are local reversals of dip, or accentuation of normal regional dip. These structures partially control the drainage patterns.

Local reversal of the regional dip (northwest about 20 feet per mile) was seen at a number of places in Miami County. In the NW cor. sec. 2, T 17 S, R 22 E, the lower part of the Wyandotte Limestone and the upper part of the Lane Shale have a southward dip of about 3°. In the southern part of T 15 S, R 23 E, south of the community of Spring Hill, the rocks have a south-southeast dip.

A small northeast-trending anticline about 1 mile long is in sec. 33, T 16 S, R 22 E and sec. 4, T 17 S, R 22 E (Pl. 1). The northeast end of the anticline intercepts a northwest-trending syncline having a length of about three-fourths of a mile. An intermittent stream flows northeastward approximately along the axis of the anticline nearly to the east side of sec. 33, T 16 S, R 22 E, then turns southeastward and flows nearly along the axis of the syncline. The limbs of the structures have dips of as much as 12° locally. These structures affect rocks from the Lane Shale upward through the Captain Creek Limestone Member of the Stanton Limestone.

Another small anticlinal structure is in NW SW sec. 23, T 16 S, R 23 E. A minor flexure in the Iola Limestone, the axis of which trends northeast, is seen at this location. The regional dip is accentuated on the northwest limb of the structure. Two other small flexures occur in the Iola Limestone south of Louisburg along U.S. Highway 69.

The area around Somerset, in eastern Miami County, contains many anomalous structures. In SW SW sec. 33, T 16 S, R 24 E, an outlier of Wyandotte Limestone dips 5° to the southwest and the base of the unit is at an altitude of 970 feet above mean sea level. About 0.8 mile south of Somerset, in SE SE sec. 5, T 17 S, R 24 E, an outlier of Wyandotte dips northeastward at about 8° and the base is at an altitude of 920 feet (Fig. 9,*A*). South Wea Creek, east of Somerset, flows in a southwesterly direction from a point 1 mile east of Somerset until it reaches a point 1 mile south of town. At this point the stream changes direction and flows to the northwest. This change in direction of the stream is probably the result of a small local structure.

North of Somerset, in SE sec. 29 and in NE sec. 32, T 16 S, R 24 E, a structure affects rocks identified as Drum Limestone upward through Wyandotte Limestone (Fig. 10). A block of Wyandotte Limestone in the S SE sec. 29, and NW NE sec. 32, T 16 S, R 24 E, having an area of approximately 1,600 square yards, is exposed east of North Wea Creek. The base of this outlier of Wyandotte is 12 to 60 feet lower than beds of the Wyandotte one-quarter mile to the east. The southeast corner of this block has a dip of about 22° to the northwest and the southwestern part of the block dips to the northwest at about 15° (Fig. 9, *B*). The northwestern part of the limestone block, however, dips northeastward at 24°. The north side of the block dips north at about 10°. A small ravine, which probably marks a minor fault, cuts across the block in an east-west direction in sec. 29 and seems to mark the line where the direction of dip changes from northwesterly to northerly. It is probable that a north-northwest-trending fault, partly covered by alluvium, cuts along the west edge of the Wyandotte outlier. At this location, the Drum and Iola limestones either are faulted down to the east or dip northwestward under the alluvium of North Wea Creek.

Causes of Local Structures—The Miami County area has been depressed and raised many times during geologic time, and it is reasonable to assume that the amount of movement has not been uniform over the entire area. Gravitational gliding of the consolidated or partly consolidated sediments as a result of these regional movements could possibly produce structures like those in the vicinity of Somerset.

Some of these structures may be reflections of the original Precambrian surface. McQueen (1932) shows a high on the Precambrian surface underlying anomalies in the younger rocks in a cross section along the Missouri line in eastern Linn County. Differential compaction of sediments around Precambrian highs probably produced minor structures which are reflected in surface rocks.

It is possible that collapse of overlying sediments into openings produced by solution in the Mississippian limestones has produced a few of the minor structures seen at the surface.

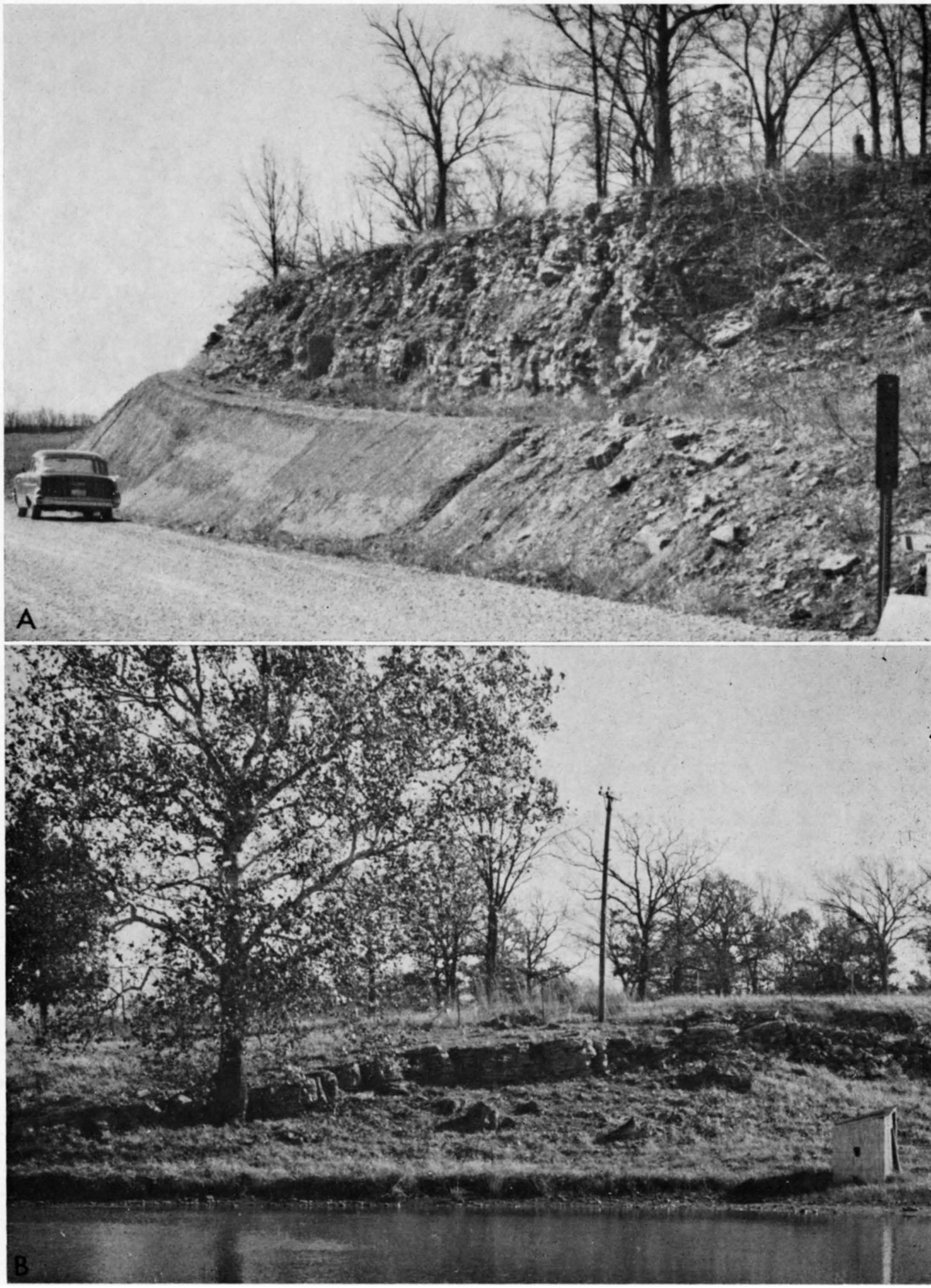

FIGURE 9.—*A*, Wyandotte Limestone overlying Lane Shale. Beds dip northeastward about 8°; SE SE sec. 5, T 17 S, R 24 E. *B*, Limestone bed in lower part of Wyandotte Limestone (overlapping Lane Shale) dipping 15° to the northwest. View toward northeast from top of Iola Limestone, which dips northwestward at about 5°; NE NW NE sec. 32, T 16 S, R 24 E.

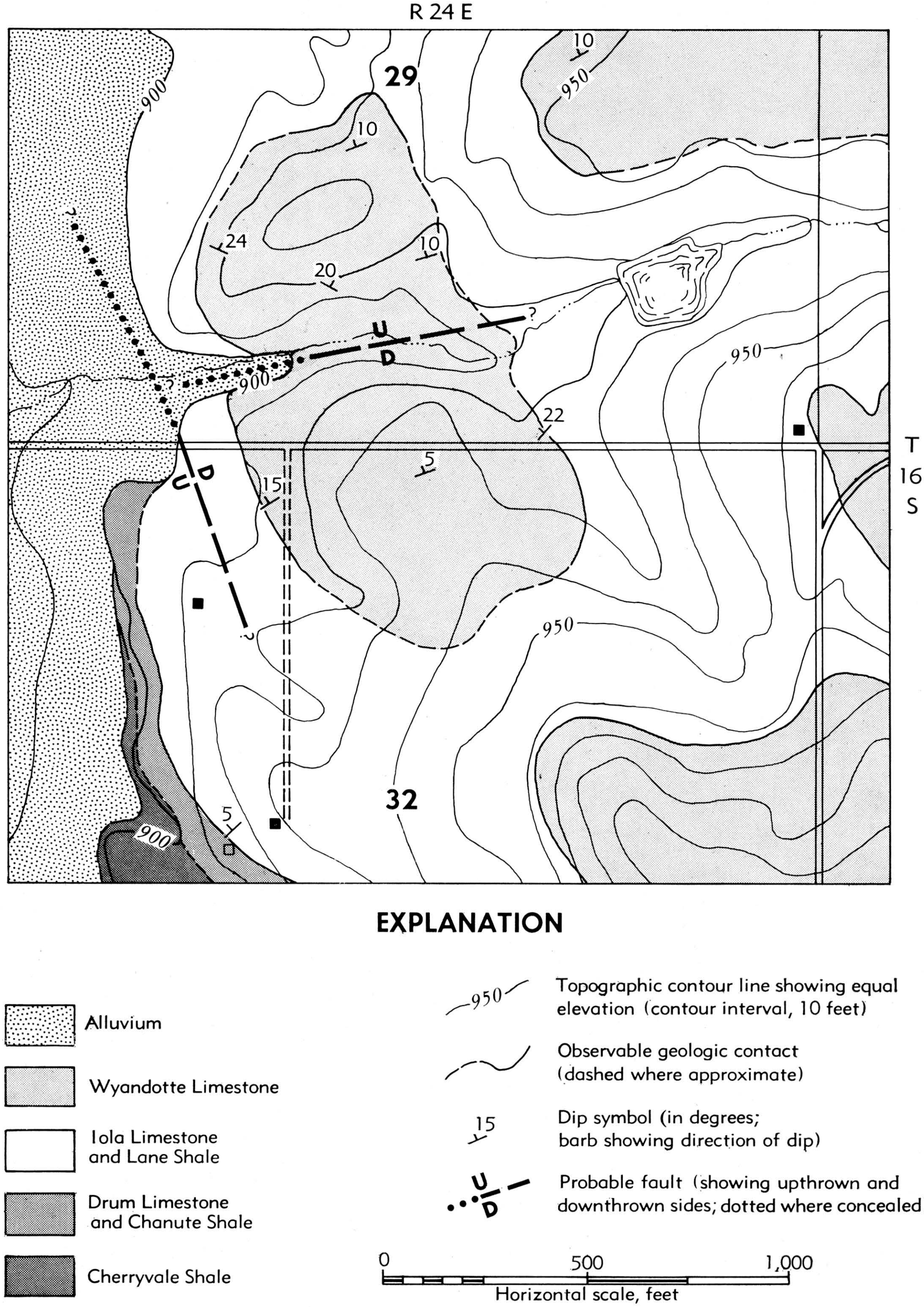

FIGURE 10.—Geologic map of a structurally deformed area north of Somerset in secs. 29 and 32, T 16 S, R 24 E, Miami County, Kansas.

MINERAL RESOURCES

Oil and Gas

Miami County was one of the first counties in Kansas to have gas and oil production. Some production was reported from wells drilled near Paola as early as 1860. In 1963, oil production from 1,092 wells in five fields amounted to 240,531 barrels.

All the fields had production from the "Squirrel sand" in the upper part of the Middle Pennsylvanian Cherokee Group at a depth of about 500 to 600 feet. Oil was produced also from the "Knobtown sand" and the Hepler Sandstone Member at depths of 300 to 400 feet, and from the "Peru sand" and "Bartlesville sand" at depths of about 400 and 700 feet.

Miami County produced more than 65,250,000 cubic feet of gas in 1963 from 15 wells. All summarized data here are from Hilpman, *et al.* (1964).

Limestone

Several limestones have been quarried and used for concrete and other aggregates, and crushed rock for road metal, riprap, subgrade, and embankment material. Limestones currently (1963) being quarried and crushed for aggregate and road metal are: the Bethany Falls Limestone Member of the Swope Limestone, Winterset Limestone Member of the Dennis Limestone, Iola Limestone, Wyandotte Limestone, and Plattsburg Limestone. These limestones are quarried where they are relatively thick, have desirable physical properties such as fairly high calcium content, medium hardness, and durability, and are near principal areas of use. The Stoner Limestone Member of the Stanton Limestone has been quarried in the extreme northwestern part of the County, where it is about 18 feet thick.

No quarries are operated in Miami County for the production of dimension stone, but several limestone beds have been quarried and the stone has been used locally for building purposes. The five limestones mentioned previously are probably the ones most used for building purposes.

Sand and Gravel

Sand and gravel is not currently being produced in Miami County. The last reported production was in 1955, when 8,683 short tons were produced (R. G. Hardy, 1964, personal communication).

The sand and gravel deposits are restricted to the valleys of the major streams and to the upland surfaces adjacent to these streams. The deposits are composed predominantly of quartz and chert but include 20 to 40 percent clay and silt.

Ceramic Materials

Deposits of shale and silt suitable for the manufacture of brick, tile, and light-weight constructional aggregate are abundant in Miami County (Norman Plummer and W. B. Hladik, 1964, personal communication). The deposits are Pennsylvanian in age and produce ceramics that are red or reddish brown. In the 1920's, material from the lower part of the Lane Shale from a pit just north of Paola, in SE NW sec. 9, T 17 S, R 23 E, was used to make brick. At several localities the shales of the Wea, Quivira, Lane, Bonner Springs, Vilas, and Weston are suitable for ceramic purposes.

GROUND-WATER RESOURCES

Principles of Occurrence

The following discussion of the occurrence of ground water has been adapted from Meinzer's report on the subject (1923), to which the reader is referred for a more detailed discussion. A general discussion of the principles of ground-water occurrence with special reference to Kansas has been presented by Moore (1940).

The rocks that make up the crust of the earth are not solid but have many openings, called *voids* or *interstices,* which may contain air, natural gas, oil, or water. The various kinds of rock differ from one another in the number, size, shape, and arrangement of these interstices; therefore, the occurrence of water in any region is determined by the geology of the region.

The interstices of rocks in Miami County range in size from pores of microscopic dimensions to openings several inches across. These openings can be classified as either *primary* or *secondary* interstices. Primary interstices are the spaces between rock grains formed during deposition of the rock. Secondary interstices are the joints, openings along bedding planes, and solution openings that were created in the rocks after deposition.

The quantity of water that a rock will hold is dependent upon the porosity of the rock.

Porosity is expressed as the percentage of the total volume of the rock that is occupied by interstices. If all the interstices of the rock are filled with water, the rock is then *saturated*. *Specific yield* is the amount of water that a saturated rock will yield under the force of gravity. The rate at which a rock will yield water to a well is determined by its permeability. Some beds of clay or shale may be very porous, but, because the interstices are small or poorly connected, they transmit little or no water and the rock is virtually impermeable.

SOURCE

Ground water is derived directly or indirectly from rain or snow which falls on the earth. Part of the precipitation leaves the area as surface runoff in streams, a part evaporates, and a part is transpired into the atmosphere by vegetation. Some of the precipitation, however, percolates downward through the soil and underlying strata until it reaches the zone of saturation. Water in the saturated zone below the surface of the earth is called *ground water*.

After reaching the zone of saturation, the water moves through the rocks in a direction determined by the lithology, the geologic structure, and the topography until it is discharged. Discharge may occur through wells and springs or into a stream or other body of water, or by evaporation and transpiration in areas where the saturated zone is relatively near the land surface.

If the upper surface of the zone of saturation is within a permeable rock (an *aquifer*), this surface is called the *water table*, and the water is said to be under *water-table conditions*. Ground water is said to be *confined* or *artesian water* if it occurs in permeable zones between relatively impermeable beds that confine the water under pressure. The level at which water stands in an open drill hole under artesian conditions does not represent the water table but rather the piezometric (or pressure) surface at that location.

ARTESIAN CONDITIONS

In Miami County, many of the wells drilled into the unweathered Pennsylvanian bedrock tap confined or artesian ground water. There are no flowing artesian wells in the County, but the hydrostatic pressure in many of the aquifers is sufficient to raise the water above the point at which it is first obtained in drilling the well. The hydrostatic pressure represents the difference in altitude between points of recharge to the artesian aquifer and the well, minus pressure losses caused by resistance to flow in the aquifer.

The many structurally low areas in the surface and near-surface rocks in Miami County are favorable for the occurrence of artesian water. Wells drilled in these areas would possibly yield more water and would be more dependable than wells drilled in adjacent structurally high areas.

WATER-TABLE CONDITIONS

The water table is not a level surface nor a static surface. It is similar, though on a modified scale, to the configuration of the surface topography. Where the water-bearing materials are nearly impermeable, the surface configuration of the land and of the water table will be similar. If the water-bearing materials are very permeable, the relief of the water table will be much lower than that of the land surface. Irregularities in the permeability of the water-bearing materials from place to place will cause irregularities in the water-table surface. The water table rises and falls in response to unequal additions to or withdrawals from water in the aquifer.

Plate 1 shows the locations and depth to water of wells and test holes for which data are given in Table 4 or in the *Logs of Wells and Test Holes* at the end of this report. No attempt was made to draw water-table contours for the area of outcrop of Pennsylvanian rocks, because in parts of the area the water is under artesian head and in other parts the water table is discontinuous. The water level in Pleistocene deposits in the valley fill is essentially continuous and usually is not under artesian head.

Recharge of Ground Water

Addition of water to an aquifer is known as ground-water recharge. The main source of recharge in Miami County is the precipitation which falls on the County. Some water enters the County by movement in the subsurface from adjacent areas, and some recharge is contributed by streams.

RECHARGE FROM PRECIPITATION

Only a small percentage of the water that falls as precipitation on Miami County reaches the ground-water reservoir. Most of it runs off as surface water or returns to the atmosphere through evaporation and transpiration. The rate of precipitation, type of soil, character of underlying rocks, amount and type of vegetation, and configuration of the topography all affect the rate and quantity of recharge.

Probably the most favorable conditions for recharge in Miami County occur in the alluvium and upper Pleistocene terrace deposits of the Marais des Cygnes River valley. In some localities the silt and clay of these deposits may retard recharge to some extent, but water levels in wells in the Marais des Cygnes valley rise relatively quickly after moderate to heavy rainfall.

Pennsylvanian rocks have diverse recharge characteristics because of local geologic, structural, and topographic conditions. In areas underlain by thick sequences of shale, recharge is very low, but where limestone or sandstone are exposed, conditions are favorable for substantial recharge. Over large areas of Miami County, limestones are at or near the surface and recharge probably occurs through fractures and joints in the rock. Fluctuations in the discharge of springs from limestone aquifers in the County coincide with wet or dry periods, indicating a considerable amount of recharge and rapid horizontal movement of water in these rocks. Precipitation entering small sinkholes in the upper part of the Wyandotte Limestone in eastern Miami County moves downward through solution channels and fractures and is largely discharged by springs in the same general area. It is reported that response to precipitation is so rapid in some of the springs discharging from limestones in eastern Miami County that the issuing water becomes turbid soon after a heavy rain.

RECHARGE FROM ADJACENT AREAS

Subsurface movement of water from outside the County is a relatively unimportant source of recharge to the ground-water reservoir. Some ground water probably moves into the County in the northeastern part along structural lows that trend southwest. Minor amounts of ground water probably enter along the eastern edge of the County from Missouri.

RECHARGE FROM STREAMS

Temporarily, during periods of high water in the Marais des Cygnes River, some water probably enters the alluvial aquifer from the stream. However, as soon as the stage of the stream drops below the level of the water table in the aquifer, the direction of water movement is reversed, and the water is discharged from the aquifer into the stream.

Discharge of Ground Water

In Miami County ground water is discharged by evaporation and transpiration, by seepage into streams, by subsurface movement to adjacent areas, and by springs and wells. The rate of natural discharge depends on climatic factors and the stage of the water table. Local differences in geology and topography cause more water to be discharged in some parts of the County than in others. Wells account for only a minor amount of the ground-water discharge.

DISCHARGE BY EVAPORATION AND TRANSPIRATION

More ground water is discharged by evaporation and transpiration than by all other means combined. Direct evaporation of ground water occurs where the water table is near the land surface. Ground water is also transpired by plants. In the stream valleys the roots of many plants penetrate the zone of saturation or the capillary fringe. The water table in the upland areas is relatively deep and discontinuous, and few of the plants take water from the ground-water reservoir.

DISCHARGE BY SEEPS AND SPRINGS

Ground water is discharged through springs and seeps along valley walls. Some of this discharge is evaporated directly into the atmosphere and some is transpired by plants during the growing season. The remaining water flows into streams and leaves the County as surface runoff. After the growing season, the amount of stream flow resulting from ground-water discharge increases, as the ground water that was previously intercepted by vegetation is then discharged into the streams.

DISCHARGE BY SUBSURFACE MOVEMENT

Subsurface movement of ground water into adjacent areas is relatively unimportant. The small amount of water that does leave the County in the subsurface probably does so through consolidated aquifers across the western and northern borders of the County, owing to the effect of the regional dip of the sediments.

DISCHARGE BY WELLS

Three types of wells are used to obtain water supplies. The type of well depends upon the use for which the well is intended, the geologic materials to be penetrated, the depth to water, and the depth to which the well is to be constructed or drilled. The following paragraphs describe briefly the three types of wells used in the County.

Dug Wells.—These are large-diameter wells ranging from 2.5 to 10 feet in diameter and are excavated with either hand tools or power equipment. These wells are usually cased with rock, but tile and concrete casing are also used. Most wells of this type penetrate the aquifer for only a short distance below the water table. Few dug wells are used in areas underlain by Pleistocene deposits. However, in the upland areas underlain by stratified deposits of Pennsylvanian age, there are many dug wells. This type of well is often desirable in both upland and valley areas as it provides additional storage space within the well, which compensates to some extent for the slow rate at which water drains into the well from deposits of low permeability. Another factor that makes dug wells desirable in areas underlain by Pleistocene deposits is the ease with which such a well can be constructed.

Driven Wells.—Driven wells are small-diameter wells consisting of 1¼- to 2-inch pipe having a screen attached to the bottom of the casing. The use of this type of well is limited to areas that are underlain by unconsolidated materials and in which the water table is relatively shallow. The pipe is driven into the aquifer so that the screen is below the water table. Owing to the silty and clayey texture of the Pleistocene deposits in Miami County, few driven wells yield more than 1 gpm (gallon per minute).

Drilled Wells.—Drilled wells in Miami County range in diameter from about 4 to 36 inches and are constructed with either percussion or rotary drilling machines. Decision as to the diameter of a well usually is based on the quantity of water needed. Wells drilled in unconsolidated deposits must be cased for their full depth and screened in the saturated zones. Wells drilled into the Pennsylvanian bedrock may be uncased except for a length of casing through the weathered surface rock. The surface casing prevents rock in the weathered zone from falling into the well and also seals out water from the surface and the weathered zone. Most domestic and stock wells in the County range in diameter from 4 to 8 inches. Their yields range from 1 to 3 gpm.

Availability of Ground Water

UNCONSOLIDATED ROCK AQUIFERS

Alluvium and Wisconsinan Terrace Deposits

MARAIS DES CYGNES RIVER VALLEY

Moderate quantities of ground water are available from Recent alluvium and terrace deposits in the Marais des Cygnes River valley. The extent of these deposits is shown on Plate 1. Logs of test holes indicate that these deposits have a maximum thickness of about 55 feet. The thickness of saturated water-bearing material ranges from 0 to about 46 feet.

The permeabilities of saturated alluvial and terrace deposits are probably relatively low, and only locally are there lenses of more permeable material. Specific capacities (yield in gpm per foot of drawdown) of wells drilled into this material are low to moderate. Movement of ground water through the unconsolidated deposits is probably slow, the hydraulic gradient being about 2 to 4 feet per mile. The water table in these deposits is relatively constant and does not fluctuate rapidly, as does the water table in the consolidated rocks. The storage coefficient[2] of the unconsolidated deposits is much higher than that of the consolidated rocks, and, where a sufficiently saturated section is present, relatively dependable domestic supplies can be developed. Yields of most of the wells in these deposits are 1 to 5 gpm, but one well has been reported to yield as much as 45 gpm. In general the water from these aquifers can be characterized as very hard calcium bicarbonate water with a high iron content. Chemical analyses of water from two wells in the terrace deposits of the Marais des Cygnes River are shown in Table 2.

OTHER STREAM VALLEYS

Tributaries of the Marais des Cygnes River contain alluvium and local terrace deposits, but these deposits are thin and yield only small water supplies to wells. The alluvium in these tributary valleys is composed of silty and clayey deposits ranging in thickness from 10 to 30 feet. The quality of ground water in these smaller valleys is reported to be generally satisfactory except for excessive hardness and iron content.

CONSOLIDATED ROCK AQUIFERS

Limestone and Shale Aquifers

Limestone and shale units are widespread over the County at or near the surface. Individual stratigraphic units are relatively uniform in thickness and composition and are laterally continuous. The unweathered limestones and shales are relatively impermeable and generally will not yield enough water to wells to provide an

[2] In nonartesian aquifers this is the approximate ratio of the volume of water a rock will yield by gravity to its own volume.

TABLE 2.—Analyses of water from typical wells in Miami County, Kansas (in parts per million, except as otherwise indicated*). (Samples analyzed by Howard 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)
15-21-35abb	8-16-62	23.2	Stanton Limestone	67	14	0.06	126	45	32	7.8	388	187	24	0.3	32	659	318	182	1,110
15-22-33bbb	7-18-62	49.2	Wyandotte Limestone	74	5.5	.08	74	30	34	4.7	300	68	15	.1	49	428	246	62	720
15-23-34bbb	7-18-62	18.5	Stanton Limestone	69	12	.21	54	11	41	19	229	85	8	.4	4	347	180	0	570
16-21-23aac	8-17-62	15	do	61	9.5	.20	100	8.9	28	.6	327	16	39	.1	6.2	369	268	18	660
16-22-15bbc	7-16-62	19.9	Wyandotte Limestone	65	14	.38	88	23	165	1.6	547	56	112	.2	28	757	314	0	1,270
34bca	8-17-62	Spring	Stanton Limestone	59	11	.05	89	18	15	1	344	28	7	.1	5.8	344	282	14	620
16-23-25dbc	7-19-62	86	Wyandotte Limestone	65	14	1.6	67	53	25	1.7	471	34	9	.2	.8	437	385	0	760
28ddc	7-24-62	135	Dennis Limestone	59	1.5	58	10	26	282	11	264	379	113	.4	.7	954	132	0	1,620
16-24-29ddc	7-19-62	20	Wyandotte Limestone and Lane(?) Shale	65	14	.75	138	11	13	2	425	43	15	.1	.4	446	348	42	730
16-25-18ddd	7-18-62	100	—	61	10	.07	136	12	4.7	.6	412	33	11	.1	10	420	338	51	630
17-21-12bcc	8-16-62	22	Plattsburg Limestone	67	7.5	.75	46	10	10	44	185	40	18	.3	17	284	154	4	500
17-22-26ccc	7-24-62	35	Cherryvale Shale	62	8	126	63	8	25	1.6	259	22	7	.1	1.8	264	190	0	450
17-24-20ccc	7-24-62	102	—	61	7.5	.34	61	20	11	2.3	215	48	16	.5	2.9	275	176	58	490
17-25-7cdd	7-25-62	23	Wyandotte Limestone and Lane(?) Shale	67	9.5	.18	117	16	5.8	2.2	366	62	4	.1	.8	397	300	58	590

18-21-13baa	8-16-62	38	Iola Limestone	60	10	1.5	107	90	78	6.6	337	337	75	.4	111	981	276	361	1,530
35caa	7-16-62	65	Chanute Shale	60	9.5	4.3	19	15	210	1.6	495	48	60	.6	36	643	109	0	1,070
18-22-26bbb	7-16-62	18	Iola Limestone and Chanute Shale	65	12	.65	182	49	97	2.4	259	59	415	.4	15	959	212	444	1,770
18-23-12aba	7-25-62	22	Dennis Limestone	63	10	.18	130	24	18	2.7	312	78	40	.1	80	534	256	167	920
23cbc	7-26-62	22	Recent alluvium and Wisconsinan terrace deposits	63	12	.13	150	16	14	10	405	71	25	.1	31	528	332	108	850
36da (city of Fontana)	3-11-63	50	do	—	15	3	114	13	17	.7	407	28	8	.1	1.8	398	338	4	680
18-25-33bbb	7-25-62	18.4	Dennis Limestone	72	13	1.4	286	42	33	12	305	325	127	.4	239	1,227	250	636	1,860
19-22-9ddd	7-26-62	80	Chanute Shale and Drum(?) Limestone	60	15	1.9	35	8	14	1	144	17	9	.1	4.2	174	118	2	310
19-23-15abb	7-26-62	52	Swope Limestone	65	10	.13	130	12	6.4	7.8	373	44	10	.1	27	431	306	68	690
19-24-4bbb	7-26-62	27	Dennis Limestone	67	8	3.1	123	46	30	14	315	244	39	.4	4.2	664	258	238	1,020
19-25-7dcd	7-25-62	25.5	do	70	9.5	.22	144	12	5.5	1.2	393	37	12	.1	49	464	322	87	820

* One part per million is equivalent to one pound of substance per million pounds of water or 8.33 pounds per million gallons of water.

adequate water supply. At or near the land surface weathering processes tend to increase or enlarge the open spaces within the rocks, especially along joints, fractures, and bedding planes, so that locally the rocks may yield 1 to 3 gpm of ground water to shallow wells.

The permeability of the weathered zone in limestone and shale differs greatly from place to place. Factors such as type and thickness of soil, vegetative cover, slope, and topographic position, as well as thickness and extent of the weathered zone have a marked influence on the amount of ground-water recharge and discharge in limestone and shale aquifers.

Probably all the limestones and shales between the base of the Kansas City Group and the top of the Weston Shale Member of the Stranger Formation yield water locally in variable amounts to wells in Miami County. Local differences in permeability, degree of weathering, distance from points of recharge, and structural attitude of the rocks govern the amount of water, if any, that will be discharged to wells.

The quality of water from the weathered limestone and shale aquifers is generally satisfactory for domestic use except for excessive hardness and iron content. The sanitary quality of ground water from such wells may be poor if the wells are not properly constructed or are located near sources of pollution.

Black fissile, carbonaceous shale occurs in the Swope and Dennis limestones, in the Cherryvale Shale, in the Stanton Limestone, and locally in the Iola Limestone. These black shales yield some water to wells and locally may be the principal aquifers for small domestic supplies. Wells 18-23-12ab and 19-23-15ab obtain water from black shales in the Dennis and Swope limestones, respectively, and are representative of wells obtaining water from black shales. The black shale facies of the Muncie Creek Shale Member of the Iola Limestone is only a few inches thick and is not an important source of water for wells.

Unconfirmed reports indicate that water in some of the pre-Pennsylvanian rocks is of better quality than the water obtained from lower Pennsylvanian rocks. The Hunton limestone of Silurian and Devonian ages is known to contain water of usable quality in parts of Brown and Doniphan counties in northeastern Kansas,[3] and the Arbuckle Group, of Cambrian and Ordovician ages, yields municipal water supplies in southeastern Kansas. No analyses of ground water from beds of pre-Kansas City age were obtained during this investigation.

[3] Water analyses on file in offices of U.S. Geological Survey, Ground-Water Branch, Lawrence, Kansas, and Kansas State Department of Health, Topeka, Kansas.

Sandstone Aquifers

Several of the shale units in Miami County contain relatively thin intraformational sandstones which locally yield 1 to 2 gpm of ground water to domestic wells. The sandstones have similar lithologic and hydrologic properties—chiefly very fine- to fine-grained micaceous, quartzose sandstone, with angular to subangular phenoclasts. Wells 17-23-24bbb and 18-22-12acc obtain water from sandstone in the Chanute Shale and are representative of wells obtaining water from sandstone aquifers (Table 5).

A small area of sec. 23, T 15 S, R 21 E, in the extreme northwestern part of the County, is underlain by about 20 feet of sandstone in the Lawrence Formation. This sandstone is similar in lithology and water-bearing characteristics to channel sandstones reported in Douglas County (O'Connor, 1960). No data as to quantity or quality of water from this aquifer in Miami County are available; however, in Douglas County wells in similar sandstone yield as much as 45 gpm and have permeabilities ranging from 18 to 343 gpd/ft^2.

Chemical Character of Ground Water

Water is often referred to as the universal solvent. Various gases and minerals are taken into solution by water as it falls through the air and as it percolates through materials in the earth. The kind and amount of impurities in ground water can be determined by chemical analysis. The corrosiveness, encrusting tendency, potability, and other properties can be predicted from the results of a quantitative analysis.

The analyses of 25 samples of water from wells and springs in Miami County are given in Table 2. Factors for converting parts per million of mineral constituents to equivalents per million are given in Table 3.

TABLE 3.—Factors for converting parts per million of mineral constituents to equivalents per million.

Cation	Conversion factor	Anion	Conversion factor
Ca^{++}	0.0499	HCO_3^-	0.0164
Mg^{++}	.0823	SO_4^{--}	.0208
Na^+	.0435	Cl^-	.0282
		NO_3^-	.0161
		F^-	.0526

QUALITY IN RELATION TO USE

Ground water from properly constructed wells will have good sanitary quality. The chemical content of the water also is important. Water to be used for drinking should not contain excessive amounts of iron, magnesium, chloride, sulfate, nitrate, or other undesirable constituents. Water to be used for cooking and washing should not have an excessive hardness and should not have a high bicarbonate content.

The quality of water in relation to use, with principal constituents and characteristics, acceptable concentrations, and range in concentrations in water in Miami County, is found in Table 4.

TABLE 4.—Quality of water in relation to use, Miami County, Kansas.

Constituents	Principal characteristics	Acceptable maximum concentration*	Range in concentration (ppm)
Dissolved Solids	Water high in dissolved solids may have a disagreeable taste or have a laxative effect. When water is evaporated the residue consists mainly of the minerals listed in Table 2.	500 ppm	174-1,227
Hardness	Hardness is caused by calcium and magnesium. Forms scale in vessels used in heating or evaporative processes. Hardness is commonly noticed by its effect when soap is used with the water. Carbonate hardness can be removed by boiling, noncarbonate hardness cannot.	120 ppm (easily detected) 200 ppm (sometimes softened for household use)	109-886
Iron (Fe)	Stains cooking utensils, plumbing fixtures, and laundry. Water may have a disagreeable taste.	0.3 ppm	0.06-126
Fluoride (F)	Fluoride concentrations of about 1 ppm in drinking water used by children during the period of calcification of teeth prevents or lessens the incidence of tooth decay. 1.5 ppm may cause mottling of the tooth enamel (Dean, 1936). Bone changes may occur with concentrations of 8-20 ppm.	1.5 ppm	0-0.6
Nitrate (NO_3)	Nitrate concentration of 90 ppm may cause cyanosis in infants (Metzler and Stoltenberg, 1950). Comly (1945) states that 45 ppm concentrations may be harmful to infants. Adverse effects from drinking high nitrate water are also possible in older children and adults.	45 ppm	0.4-239 (2 samples $>$90 ppm 3 samples $>$45 ppm)
Sulfate (SO_4)	Derived from solution of gypsum and oxidation of iron sulfides (pyrite, etc.). Concentrations of magnesium sulfate (Epsom salt) and sodium sulfate (Glauber's salt) may have a laxative effect on some persons.	250 ppm	16-379
Chloride (Cl)	Chloride in ground water may be derived from connate marine water in sediments, surface contamination, or solution of minerals containing chlorides.	250 ppm	4-415

* Concentrations as recommended by the Public Health Service, Drinking Water Standards, 1962.

SANITARY CONSIDERATIONS

The analyses of water (Table 2) show only the amount of dissolved solids and do not indicate the sanitary quality of the water. Well water may contain dissolved mineral matter that gives the water an objectionable taste even though it may be free of harmful bacteria and consequently safe for drinking. On the other hand, well water, good tasting and seemingly pure, may contain harmful bacteria. Excessive amounts of certain ions, such as chlorides or nitrates, may indicate pollution.

Recommendations for the location and construction of wells and suggestions for pump installations for the different types of wells can be obtained from the Kansas State Department of Health.

Utilization of Ground Water

In Miami County, ground water is used chiefly for domestic and stock supplies. In 1962, only one public-supply system (Fontana) obtained water from ground-water sources. Most industries use water from municipal supplies, but a few have their own surface-water supplies.

DOMESTIC AND STOCK SUPPLIES

Nearly all domestic and stock water supplies in rural areas are obtained from privately owned wells. In valley areas most supplies are obtained from driven, drilled, or dug wells, and in the upland areas from dug and drilled wells. In some upland areas where adequate ground-water supplies are difficult to obtain, cisterns are used as a source of domestic water on many farms. At many places in the County, ponds have been constructed for both domestic and stock water supplies.

PUBLIC SUPPLIES

Ground water is the source of supply for one public water system in Miami County. The community of Fontana, in southern Miami County, built its first public water supply in 1962. This supply is obtained from one well in alluvium and Wisconsinan terrace deposits in the Marais des Cygnes River valley about 2 miles northeast of the city. The well is 50 feet deep, 36 inches in diameter, gravel packed, and cased with 45 feet of 18-inch steel casing, and it has 5 feet of stainless steel screen set in the middle of the aquifer. The aquifer is reported to be 9.5 feet of silty gravel between the depths of 39 to 48.5 feet. The yield of the well is reported to be 45 gpm with 5 feet of drawdown.

The water is of satisfactory quality as is shown by an analysis in Table 3, although it is hard, and its iron content exceeds the maximum recommended for use by the U.S. Public Health Service (1962).

RECORDS OF WELLS AND SPRINGS

Information pertaining to 123 water wells and springs in Miami County is given in Table 5. Measured depths to water are given to the nearest 0.1 foot, whereas depths reported by the owner, tenant, or driller are given only to the nearest foot. Similarly, measured depths of wells are given to the nearest 0.1 foot and reported depths only to the nearest 1.0 foot.

TABLE 5.—Records of wells and springs in Miami County, Kansas.

* Well-numbering system described in text.
† Type of well: *Dr*, drilled well; *Du*, dug well; *Sp*, spring.
‡ Depth of well: Reported depths of wells given in feet below land surface; measured depths given in feet and tenths.
§ Type of casing: *C*, concrete; *GP*, galvanized-iron pipe; *R*, rock; *S*, steel.
|| Method of lift: *B*, bucket; *C*, centrifugal; *Cy*, cylinder; *J*, jet; *N*, none; *P*, pitcher; *T*, turbine.
Type of power: *E*, electric; *H*, hand; *W*, windmill.
\# Use of water: *D*, domestic; *M*, municipal; *N*, none; *S*, stock.
** Depth to water: Measured depths to water given in feet and tenths; reported depths in feet.
†† Altitude of land surface is approximate, determined from 10-foot contour on 7½-minute topographic maps.
‡‡ Chemical analysis given in Table 3.

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	Altitude of land surface, feet††	Remarks (Yield given in gallons per minute; drawdown in feet.)
15-21-23dcd	Robert H. Warren	Du	28.6	36	R	Shale	Weston Shale Member of Stranger Formation	Cy, H	N	7.8	7-18-60	±1,032	Reported inadequate in dry years.
25add	Oliver Neis	Du	21.2	48	R	Limestone, shale	Stanton Limestone	J, E	D, S	18.9	7-18-60	±1,031	do
25ddd	E. W. Otto	Du	20.2	36	R	Sandy shale	Vilas Shale	N	N	12.8	7-18-60	± 990	
35abb‡‡	J. E. Owing	Du	23.2	36	R	Limestone, shale,	Stanton Limestone	C, E	D	14.6	7-18-60	± 991	Reported inadequate in dry years.
15-22-22abd	Glenn Peer	Du	32.4	48	R	Limestone	Wyandotte Limestone	C, E	D	26.8	7-18-62	±1,025	Reported good well.
26cdc	Jay DeTar	Du	12	36	R	Shale	Lane Shale	J, E	D	3.3	2-16-61	± 945	
28bbb	R. M. Otis	Du	28.7	48	R	Limestone	Stanton Limestone	Cy, W	D, S	3.8	7-19-60	±1,030	Reported adequate well.
31aab	Alex Murdock	Du	31	48	R	Limestone, shale	Bonner Springs Shale and Wyandotte Limestone	Cy, W	D	3.6	7-18-60	± 960	
33bbb‡‡	Robert McDaniels	Du	49.2	108	R	Limestone	Wyandotte Limestone	J, E	D	42.5	7-18-62	± 960	Water from base of limestone at shale contact.
15-23-20ddd	Harold Hansen	Du	24.3	36	R	do	do	N	N	13.5	7-18-61	± 970	
26bda	Claude Leavell	Du	24.6	48	R	do	Plattsburg Limestone	J, E	D	21.5	8-2-60	±1,041	
29cba	Elmer Moll	Du	17.3	48	R	Limestone, shale	Plattsburg Limestone and Bonner Springs Shale	J, E	D	9.0	2-16-61	± 970	Spring at base of Plattsburg Limestone flows into well.
31caa	Robert Osborn	Du	23.0	36	R	Limestone	Plattsburg Limestone	N	N	10.6	7-18-62	± 991	
34bbb‡‡	H. G. Vochatzer	Du	18.5	48	R	do	Stanton Limestone	J, E	D	8.9	7-18-62	±1,064	
15-24-21aad	W. D. Pascal	Du	23.0	36	R	do	do	Cy, H	D	15.7	7-18-62	±1,080	
26bcc	Ella Heflebower	Du	25.1	36	R	do	do	J, E	D	20.0	8-2-60	±1,115	
29bcc	Lloyd Barkus	Du	47.0	48	R	do	Wyandotte Limestone	Cy, W	D	8.5	8-2-60	± 960	
15-25-20ccd	Ida Seck	Du	23.5	48	R	do	Plattsburg Limestone	Cy, H	D, S	4.4	8-3-60	±1,070	
27cba	Harold Beuser	Du	28.2	48	R	do	do	Cy, H	D, S	21.7	8-3-60	±1,065	
31ddd	William Seuferling	Dr	100+	8	S	....	....	N	N	45.1	8-3-60	±1,100	Water reported to be poor quality.
16-21-1ccd	Dale Burgoon	Du	16.5	48	R	Shale	Stranger Formation	Cy, H	D	5.3	2-16-61	±1,020	Water has a gassy odor.
23aac‡‡	Elmer Sieg	Du	15.0	48	R	Limestone(?)	Stanton Limestone	J, E	D	6.6	2-16-61	±1,020	
36cdc	C. Hamilton	Du	35	48	R	Limestone, sandstone(?)	Stanton Limestone and Vilas Shale	Cy, H	S	20.5	2-15-61	....	

TABLE 5.—Records of wells and springs in Miami 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	Altitude of land surface, feet††	Remarks (Yield given in gallons per minute; drawdown in feet.)
16-22-2dcb	M. A. Bell	Dr	180	8	S	Limestone, shale	Dennis Limestone	N	N	11.5	6-28-62	± 912	Water is poor quality.
8aaa	Charles Rodgers	Du	21	48	R	Limestone	Stanton Limestone	J, E	D, S	6.7	7-20-60	±1,037	Reported adequate well (1 to 3 gpm).
15bbc‡‡	J. H. Bucklew	Du	19.9	48	R	do	Wyandotte Limestone	Cy, H	D	13.3	7-20-60	± 951	
20bba	Jack Morgan	Du	16.0	72	R	do	Plattsburg Limestone	J, E	D	5.1	7-20-60	±1,015	
23dcb	Loyd Gates	Du	18.5	48	R	Shale	Lane Shale	Cy, H	D, S	13.8	7-20-60	± 950	Reported inadequate in dry years.
31-aaa	Basil Bourquin	Du	25.5	48	R	Limestone	Stanton Limestone	Cy, H	D	16.2	7-20-60	....	
34bca‡‡	Wilmer Rader	Sp	......	48	C	do	do	G	D, S	2.9	7-20-60	±1,050	Water from basal part of limestone.
16-23-3dad	Frank Yackle	Du	11.7	48	R	do	Wyandotte Limestone	N	N	2.4	8-1-60	±1,000	Water reported to be poor quality.
7daa	Lloyd White	Du	24.2	48	R	Limestone and sandstone(?)	Wyandotte Limestone and Lane Shale(?)	Cy, H	D	10.6	8-1-60	± 990	
12cdd	Roy Debrick	Du	14.9	36	R	Limestone	Wyandotte Limestone	J, E	D	8.2	8-1-60	±1,012	
19dba	David Coble	Du	21.6	48	R	Limestone and sandstone(?)	Iola Limestone and Chanute Shale(?)	J, E	D	13.0	7-24-62	± 913	
21bbc	Robert Cunningham	Du	15.0	48	R	Silt(?) and shale	Colluvium(?) and Lane Shale	Cy, H	D	11.0	8-1-60	± 890	
23bdc	Hugh Devine	Du	12.4	80	R	Limestone	Iola Limestone	Cy, H	D, S	4.6	8-1-60	± 930	
25dbc‡‡	Dale Everhart	Dr	86	8	S	do	Wyandotte Limestone	J, E	D, S	28.0	11-2-60	±1,075	
28ddc‡‡	Herbert Walters	Dr	135	8	S	Black shale	Dennis Limestone	N	N	8.8	11-2-60	± 930	
30ddc	Fred Witt	Du	45.0	48	R	Limestone and sandstone	Iola Limestone and Chanute Shale	Cy, H	N	20.2	8-1-60	± 911	Water reported to be poor quality.
16-24-2bad	Keith Dover	Du	21.9	48	R	Limestone	Stanton Limestone	J, E	D	11.6	7-18-62	±1,054	1 to 2 gpm.
4cad	E. Var Swanson	Du	10.9	48	R	do	do	Cy, H	N	2.4	8-2-60	±1,070	Water reported to be poor quality.
6dcd	Darrell Williams	Du	18.1	48	R	do	Plattsburg Limestone	Cy, H	D, S	10.0	8-2-60	±1,045	
10ddd	Tom Redman	Du	20.0	72	R	do	do	N	N	5.7	8-2-60	±1,030	
17adb	W. E. Nevius	Du	29.3	48	R	do	Wyandotte Limestone	Cy, W	D, S	8.3	8-2-60	±1,000	Water reported entering well at 17.0 ft. below land surface (approx. 1 gpm).
23aaa	E. J. Cheney	Du	35	72	R	Limestone and shale(?)	Wyandotte Limestone and Lane Shale(?)	J, E	D	26.3	7-19-62	±1,029	
24ccd	Cora Wortham	Du	54.6	48	R	Limestone	Wyandotte Limestone	Cy, W	D	31.4	8-2-60	±1,080	Water enters well at 26.5 below land surface (1 gpm).

26bbb	Steve Campbell	Sp	......	....	..	do	do	N	N	......	7-19-62	±1,030	Water flowing from base of limestone (1 to 2 gpm).
29ddc‡‡	Miami County	Du	20	144	R	do	Iola and Wyandotte(?) limestones	Cy, H	..	7.8	6-19-62	± 892	
30ddd	Virlin Snouffer	Du	28.0	38	R	Limestone and sandstone(?)	Iola Limestone and Chanute Shale(?)	Cy, H	D	10.4	8-2-60	± 950	
34dcb	Wagstaff Cattle Co.	Sp	5.6	40	R	Limestone	Wyandotte Limestone	J, E	D, S	3.4	8-2-60	± 980	Water flowing from from base of limestone (1 to 2 gpm).
16-25-7daa	Estle Fipps	Du	28.6	36	R	Shale and limestone(?)	Bonner Springs Shale and Wyandotte Limestone(?)	Cy, H J, E	D, S	15.6	7-18-62	±1,020	
11bab	R. E. Courtney	Du	17.3	36	R	Sandstone(?) and limestone	Chanute Shale(?) and Drum Limestone	N	N	8.7	8-3-60	± 990	Flowing spring short distance downslope from well (1 gpm).
15ddd	Robert Schulz	Du	42.0	36	R	Limestone and sandstone(?)	Iola Limestone and Chanute Shale(?)	Cy, H	D	25.3	8-3-60	±1,004	
18ddd‡‡	Elmer Williams	Dr	100	8	S	....	....	J, E	D, S	13.2	7-18-62	±1,064	
20bbb	Barbara Renner	Du	27.6	48	R	Limestone	Wyandotte Limestone	Cy, H	D	20.5	8-3-60	±1,064	
33aba	Vernon Dunn	Du	30.8	48	R	do	do	J, E	D	17.5	8-3-60	±1,022	
17-21-12bcc‡‡	John Beebe	Du	22	48	R	Limestone(?)	Plattsburg Limestone(?)	Cy, H	N	8.4	2-15-61	....	
36bbc	Elmer McKoon	Du	26.3	48	R	Sandy silt	Alluvium and terrace deposits	Cy, H	D	23.4	2-15-61	....	
17-22-7aaa	N. D. Straly	Du	28	48	R	Limestone	Stanton Limestone	J, E	D	3.2	7-2-60	....	Reported to be adequate well (1 to 3 gpm).
14aad	Frank McCaskey	Du	16.8	48	R	Limestone and shale(?)	Plattsburg Limestone and Bonner Springs Shale(?)	Cy, H	N	4.5	7-20-60	±1,072	
15aaa	Everett Oyster	Du	20.6	72	R	Limestone	Wyandotte Limestone	G	S	2.5	7-24-62	±1,000	2 gpm.
16dcc	John Whitaker	Du	18.1	48	R	do	do	P, H	D	16.0	7-20-60	±1,010	
26ccc‡‡	Otto Robinson	Dr	35.0	6	S	Sand(?) and Limestone(?)	Cherryvale Shale(?)	N	N	9.4	7-19-60	± 877	
29cdc	E. R. Feebeck	Du	43	36	R	do	Iola Limestone and Chanute Shale	B, H	D	31.7	7-20-60	....	
17-23-6dda	Matt Egidy	Du	35.6	36	R	Limestone(?)	Iola Limestone(?)	Cy, H	S	19.4	7-22-60	± 922	
11daa	Steven Russell	Du	23.6	72	R	Limestone and sandstone(?)	Iola Limestone and Chanute Shale(?)	J, E	D	5.6	7-19-62	± 903	
18add	Earl Croan	Du	26.6	48	R	do	do	Cy, H	D	21.3	7-22-60	± 912	
22bba	H. L. Cramer	Du	25	36	R	Limestone and sandstone	Iola Limestone and Chanute Shale	P, H	D	11.1	7-22-60	± 920	
24bbb	Frank Vohs	Du	21.8	36	R	Sandstone	Chanute Shale	T, E	S	14.2	7-22-60	± 945	

TABLE 5.—Records of wells and springs in Miami 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	Altitude of land surface, feet††	Remarks (Yield given in gallons per minute; drawdown in feet.)
17-23-25cbc	George Prothe	Du	14.8	28	R	Limestone(?) and sandstone	Iola Limestone and Chanute Shale	Cy, H	D	11.7	7-22-60	± 954	
27bcc	John H. Roman	Du	18.6	36	R	Limestone and shale(?)	Drum Limestone and Cherryvale Shale(?)	T, E	D	11.2	7-22-60	± 860	
30daa	Virgil Thomas	Du	13.2	36	R	Limestone(?)	Iola Limestone(?)	C, E	D	8.3	7-25-60	± 950	
17-24-8cbc	Floyd Bendorf	Du	28.4	48	R	Limestone and sandstone	Iola Limestone and Chanute Shale	Cy, H	D, S	22.6	7-29-60	± 965	Water flowing into well 21.0 ft. below land surface (½ gpm).
11bba	Robert Schmid	Du	15.5	36	R	Sandstone and shale	Chanute Shale	J, E	D	4.2	7-29-60	± 961	
16aad	Harvey Fort	Du	30	48	R	do	do	Cy, H	S	19.8	7-29-60	± 993	
20ccc‡‡	Jack Myers	Dr	102	8	S	....	....	T, E	D	49.3	7-24-62	±1,075	Reported yield ½ gpm.
24bcb	Joe Fisnosky	Du	21.8	48	R	Limestone	Wyandotte Limestone	J, E	D	17.5	7-29-60	±1,101	Reported to be poor well.
27cdd	Charles Kohlenberg	Sp	8.5	60	R	do	do	J, E	D	.5	7-29-60	±1,055	Spring is at base of limestone.
17-25-6dbb	George Stifter	Du	31.2	48	R	do	do	Cy, H	D	17.7	8-3-60	±1,020	
7cdd‡‡	Austin Studdard	Du	23.0	30	R	Limestone and shale	Wyandotte Limestone and Lane Shale	N	N	1.4	7-25-62	±1,000	Reported to be spring fed.
10aab	Gene Wilson	Du	40.0	48	R	Limestone	Wyandotte Limestone	J, E	D	27.8	8-3-60	±1,156	
19aaa	Centennial School Dist.	Du	21.6	48	R	do	do	Cy, H	D	16.2	8-3-60	±1,090	
27aab	Roy Arnett	Dr	28.6	8	S	do	do	N	N	20.6	8-3-60	±1,080	Well was plugged back from 578 ft. Water reported to be very poor quality.
32bbc	Helen Seachrest	Du	23.7	72	R	do	do	J, E	D	12.8	8-3-60	±1,090	
18-21-13baa‡‡	Donald Lash	Du	38.0	48	R	do	Iola Limestone	N	N	13.3	2-?-61	....	Reported to be poor well.
35caa‡‡	Charles Hay, Jr.	Dr	65	8	S	Sandstone	Chanute Shale	N	N	20	7-15-62	....	
36bdd	Charles Hay, Sr.	Dr	65	8	S	do	do	J, E	D, S	......	....	....	
36dbb	Clifford Miller	Dr	112	8	S	do	do	J, E	D	21.9	2-15-61	....	Reported to be adequate well (1 gpm).
18-22-8daa	Ora Farin	Du	34	48	R	Sandstone(?)	Chanute Shale(?)	Cy, H	D	12.9	7-26-60	± 960	
9cab	Dale McDowell	Dr	80	8	S	Shale	Cherryvale Shale	N	N	......	....	....	Plugged, log available.
12acc	John Rothwell	Du	34.0	60	R	Sandstone	Chanute Shale	J, E	D	28.2	7-26-60	....	
17cbc	Merle D. Stone	Dr	59	8	S	....	....	....	..	42	9-20-61	....	
19ddd	Elmer Smith	Du	18.0	48	R	Shale(?)	Lane Shale	J, E	D	4.4	7-26-60	....	
24cbb	Delton Deel	Du	24	48	R	Limestone and sandstone(?)	Iola Limestone and Chanute Shale(?)	Cy, H	D	22.8	7-26-60	....	

26bbb‡‡	Clarence Baker	Du	18	36	R	do	do	....	..	3.9	7-26-60	....	
18-23-7aaa	Kenneth Bird	Du	32	48	R	Limestone and shale	Drum Limestone and Cherryvale Shale	C, E	D	21.0	7-25-60	± 894	
12aba‡‡	Dale Block	Du	22	72	R	Black shale	Dennis Limestone	C, E	D, S	6.6	7-25-60	± 853	
15dcb	A. H. Osthoff	Du	20	72	R	Sandstone(?)	Chanute Shale(?)	C, E	D	7.7	7-25-60	± 893	
19add	John Gooden, Jr.	Du	41.0	36	R	do	do	J, E	D	17	7-26-60	....	
23cbc‡‡	Loren Winter	Du	22	36	R	Sand and silt	Alluvium and terrace deposits	J, E	D, S	7.9	7-26-60	± 827	
33bbc	Elwood Ludwig	Du	31.4	48	R	Limestone and sandstone(?)	Iola Limestone and Chanute Shale(?)	Cy, H	S	8.6	7-25-60	....	
36da‡‡	City of Fontana	Dr	50	18	S	Sand, silt and gravel	do	T, E	M	......	....	± 820	Reported yield 45 gpm with 5 ft. of drawdown.
18-24-5ddd	J. G. Deberick	Du	16.2	36	R	Limestone	Wyandotte Limestone	E, H	D	10.9	7-28-60	±1,035	
10daa	Merit Elliot	Du	21	48	R	do	Dennis Limestone	N	N	7	7-25-62	± 925	
12bba	John Hamlin	Du	20.5	36	R	Shale(?)	Cherryvale Shale(?)	J, E	D	9.2	7-28-60	±1,000	
22ccb	Rudy Weiss	Du	16	48	R	Black shale	Hushpuckney Shale Member of Swope Limestone	J, E	D	4.1	7-28-60	± 880	
25bba	Edmund Hopkins	Du	24.9	48	R	Limestone and sandstone	Iola Limestone and Chanute Shale	Cy, H	D	12.9	7-28-60	±1,010	
30bac	D. A. Tracey	Du	17.8	48	R	Limestone(?)	Dennis Limestone	J, E	D	15	7-28-60	± 895	
32add	B. Hildebrand	Du	19.8	36	R	Limestone and shale(?)	do	Cy, H	N	8.1	7-28-60	± 932	
18-25-10bbc	Frank Souders	Dr	52.1	8	GP	Limestone(?) and shale(?)	Iola Limestone(?) and Chanute Shale(?)	B, H	D	13.3	8-3-60	±1,043	Reported to be adequate well.
18dca	John Ala	Du	10	48	R	Limestone	Iola Limestone	J, E	D, S	2.7	2-16-61	±1,010	Probably fed by ground-water movement along base of Iola Limestone.
33bbb‡‡	Lester Gillogly	Du	18.4	36	R	Limestone(?)	Dennis Limestone(?)	Cy, H	S	5.1	7-25-62	± 983	
19-21-11caa	Lane Duncan	Du	34.7	48	R	Limestone	Wyandotte Limestone	B, H	D, S	16.5	7-27-60	....	
19-22-1ccc	J. A. Bell	Du	32	48	R	Sandstone(?)	Chanute Shale	Cy, H	S	4.9	7-27-60	....	
7aab	C. A. Hay	Du	16	48	R	Limestone	Wyandotte Limestone	N	..	3.5	7-27-60	....	½-1 gpm.
9ddd‡‡	Harold Weeks	Dr	80	8	S	Sandstone(?) and limestone	Chanute Shale(?) and Drum Limestone	N	N	34.4	11-2-60	....	
19-23-2ddc	Herman Housler	Du	30.6	48	R	Limestone and shale(?)	Dennis Limestone	J, E	D	9.6	7-28-60	± 905	
5ccc	Lester Wilson	Du	16.5	96	R	Sandstone(?)	Chanute Shale	Cy, H	S	3.6	7-28-60	....	
15abb‡‡	Robert Brocaw	Dr	52	10	S	Black shale	Swope Limestone	J, E	D	42.8	9-27-60	± 873	Reported to be poor well.
19-24-4bbb‡‡	Ival Karr	Du	27	48	R	Limestone	Dennis Limestone	Cy, H	D	14.9	7-26-62	± 940	
11cdd	Herchel Hoy	Du	21	72	R	do	Swope Limestone	N	N	2.5	7-26-62	± 900	
19-25-7dcd‡‡	Charles W. Atwood	Du	25.5	48	R	do	Dennis Limestone	J, E	D	14.4	7-25-62	± 965	
15aaa	Emmett Shannon	Du	25.5	36	R	do	do	J, E	D	7	7-25-62	± 981	

LOGS OF WELLS AND TEST HOLES

Given on the following pages are logs of 115 wells and test holes in Miami County drilled by the State Geological Survey of Kansas and local drillers. The letter (T) indicates elevation estimated from 7½-minute topographic maps.

15-21-22aaa.———Sample log of test hole in NE NE NE sec. 22, T 15 S, R 21 E, 45 feet west of section corner at edge of east-west road; augered December 5, 1960. Altitude of land surface, 1,058(T) feet; depth to water, 18.4 feet.

	Thickness, feet	*Depth, feet*
Soil	3	3
NEOGENE		
Pleistocene Series, undifferentiated		
Sand, very fine to medium, very silty, orangish-tan; some coarse sand in lower 1.0 foot	3	6
PENNSYLVANIAN		
Upper Pennsylvanian Series		
Virgilian Stage—Douglas Group		
Lawrence Formation		
Sand, fine to coarse, predominantly rounded quartz; micaceous; slightly cemented	14	20
Sand, fine to medium, very silty; some coarse gravel at base; slightly cemented	7	27
Stranger Formation		

15-21-24ccc.———Sample log of test hole in SW SW SW sec. 24, T 15 S, R 21 E, just east of underpass for interstate highway no. 35; augered December 5, 1960. Altitude of land surface, 1,018±(T) feet; dry hole.

	Thickness, feet	*Depth, feet*
NEOGENE		
Pleistocene Series, undifferentiated		
Silt, tan to dark-tan	5	5
Silt, sandy, tan	2.5	7.5
Silt, very sandy, brown; some very fine gravel	3.5	11
PENNSYLVANIAN		
Upper Pennsylvanian Series		

15-21-25aaa.———Sample log of test hole in NE NE NE sec. 25, T 15 S, R 21 E; augered December 5, 1960. Altitude of land surface, 1,021(T) feet; dry hole.

	Thickness, feet	*Depth, feet*
Soil	4.5	4.5
NEOGENE		
Pleistocene Series, undifferentiated		
Silt, dark-tan; with limonite specks	3.5	8.0
PENNSYLVANIAN		
Upper Pennsylvanian Series		
Missourian Stage—Douglas Group		
Stranger Formation		
Shale, weathered, calcareous, grayish-tan	....	....
Virgilian Stage—Douglas Group		
Stranger Formation		
Shale, weathered, clayey, greenish-tan	3	14

15-21-27aaa.———Sample log of test hole in NE NE NE sec. 27, T 15 S, R 21 E, in ditch; augered December 5, 1960. Altitude of land surface, 1,018(T) feet; dry hole.

	Thickness, feet	*Depth, feet*
NEOGENE		
Pleistocene Series, undifferentiated		
Silt, sandy, tan	6	6
Silt, sandy, calcareous, tan	5.5	11.5
Silt, sandy, tan	7.5	19
Silt, calcareous, tan; weathered shale	3	22
PENNSYLVANIAN		
Upper Pennsylvanian Series		
Missourian Stage—Douglas Group		
Stranger Formation		
Shale, reddish-brown, hard	1	23

15-21-35bdd.———Sample log of test hole in SE SE NW sec. 35, T 15 S, R 21 E; augered December 5, 1960. Altitude of land surface, 1,014(T) feet; dry hole.

	Thickness, feet	*Depth, feet*
NEOGENE		
Pleistocene Series, undifferentiated		
Silt, sandy, tan	3	3
Silt, very sandy, tan	8	11
Silt, calcareous, reddish-tan; with limestone pebbles	2	13
PENNSYLVANIAN		
Upper Pennsylvanian Series		
Missourian Stage—Lansing Group		
Stanton Limestone		

15-21-36abb.———Sample log of test hole in NW NW NE sec. 36, T 15 S, R 21 E; augered December 5, 1960. Altitude of land surface, 1,017(T) feet; dry hole.

	Thickness, feet	*Depth, feet*
NEOGENE		
Pleistocene Series, undifferentiated		
Silt, clayey, sandy, reddish-brown	4	4
PENNSYLVANIAN		
Upper Pennsylvanian Series		
Missourian Stage—Lansing Group		
Stanton Limestone		

15-22-13dcc.———Sample log of test hole in SW SW SE sec. 13, T 15 S, R 22 E; augered December 5, 1960. Altitude of land surface, 1,094(T) feet; dry hole.

	Thickness, feet	*Depth, feet*
NEOGENE		
Pleistocene Series, undifferentiated		
Silt, sandy, dark-tan	5	5
PENNSYLVANIAN		
Upper Pennsylvanian Series		
Missourian Stage—Douglas Group		
Stranger Formation		

15-22-27bbb.———Sample log of test hole in NW NW NW sec. 27, T 15 S, R 22 E; augered December 5, 1960. Altitude of land surface, 919(T) feet; depth to water, 6.8 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Pleistocene Series		
Recent Stage (alluvium)		
Silt, sandy, light-brown	17	17
Silt, sandy, tan	4	21
PENNSYLVANIAN		
Upper Pennsylvanian Series		
Missourian Stage—Kansas City Group		
Lane Shale		
Shale, weathered, tannish-green	1	22

15-22-28ddd.———Sample log of test hole in SE SE SE sec. 28, T 15 S, R 22 E; augered December 5, 1960. Altitude of land surface, 917(T) feet; depth to water, 17.2 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Pleistocene Series		
Wisconsinan and Recent stages (terrace deposits and alluvium, undifferentiated)		
Sand, very fine to fine, very silty, reddish-tan	21	21
Silt and sand, very fine to medium, tan	3	24
PENNSYLVANIAN		
Upper Pennsylvanian Series		
Missourian Stage—Kansas City Group		
Lane Shale		
Shale, gray	----	----

15-22-32dad.———Sample log of test hole in SE NE SE sec. 32, T 15 S, R 22 E; augered May 1961. Altitude of land surface, 920(T) feet; depth to water, 15.0 feet.

	Thickness, feet	Depth, feet
Road fill		
NEOGENE		
Pleistocene Series		
Recent Stage (alluvium)		
Silt, sandy, dark-tan	18	18
PENNSYLVANIAN		
Upper Pennsylvanian Series		
Missourian Stage—Kansas City Group		
Lane Shale		
Shale, gray	2	20

15-22-33abb.———Sample log of test hole in NW NW NE sec. 23, T 15 S, R 22 E; augered December 5, 1960. Altitude of land surface, 915(T) feet; depth to water, 18.0 feet.

	Thickness, feet	Depth, feet
Soil	4.5	4.5
NEOGENE		
Pleistocene Series		
Recent Stage (alluvium)		
Silt, slightly sandy, tanish-gray	6.5	11
Silt, sandy, dark-tan	5	16
Silt, slightly sandy, gray	2.5	18.5
PENNSYLVANIAN		
Upper Pennsylvanian Series		
Missourian Stage—Kansas City Group		
Lane Shale		
Shale, gray	4.5	23

15-23-16cdc.———Sample log of test hole in SW SE SW sec. 16, T 15 S, R 23 E; augered December 5, 1960. Altitude of land surface, 933(T) feet; depth to water, 8.4 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Pleistocene Series		
Recent Stage (alluvium)		
Silt and sand, very fine to medium, brown	33	33
PENNSYLVANIAN		
Upper Pennsylvanian Series		
Missourian Stage—Kansas City Group		
Lane Shale		

15-23-21ccc.———Sample log of test hole in SW SW SW sec. 21, T 15 S, R 23 E; augered May 1961. Altitude of land surface, 915(T) feet; depth to water, 4.0 feet.

	Thickness, feet	Depth, feet
Soil	3	3
NEOGENE		
Pleistocene Series		
Recent Stage (alluvium)		
Silt, sandy, dark-tan	10	13
Silt and sand, tan	10	23
PENNSYLVANIAN		
Upper Pennsylvanian Series		
Missourian Stage—Kansas City Group		
Lane Shale		
Shale, gray	1	24

15-24-18ccd.———Sample log of test hole in SE SW SW sec. 18, T 15 S, R 24 E, 200 feet north of house well; augered December 6, 1960. Altitude of land surface, 1,063(T) feet; dry hole.

	Thickness, feet	Depth, feet
NEOGENE		
Pleistocene Series, undifferentiated		
Silt, sandy, reddish-tan	3.5	3.5
Silt, sandy, dark reddish-brown; limestone pebbles at 7.5 feet	4.5	8.0
PENNSYLVANIAN		
Upper Pennsylvanian Series		
Missourian Stage—Lansing Group		
Stanton Limestone		

15-24-22add.———Sample log of test hole in SE SE NE sec. 22, T 15 S, R 24 E, 20 feet north of half section line; augered December 6, 1960. Altitude of land surface, 1,098(T) feet; dry hole.

	Thickness, feet	Depth, feet
NEOGENE		
Pleistocene Series, undifferentiated		
Silt, sandy, grayish-tan	3.5	3.5
Silt, slightly sandy, reddish-brown	5.0	8.5
PENNSYLVANIAN		
Upper Pennsylvanian Series		
Missourian Stage—Lansing Group		
Stanton Limestone		

	Thickness, feet	Depth, feet
Shale, weathered, calcareous, orangish-brown to reddish-brown and hard	3.0	11.5
Limestone, whitish-tan	....	....

15-25-20bbb.———Sample log of test hole in NW NW NW sec. 20, T 15 S, R 25 E; augered December 6, 1960. Altitude of land surface, 1,117(T) feet; dry hole.

	Thickness, feet	Depth, feet
NEOGENE		
Pleistocene Series, undifferentiated		
Silt, sandy, yellowish-tan	5	5
PENNSYLVANIAN		
Upper Pennsylvanian Series		
Missourian Stage—Lansing Group		
Stanton Limestone		
Shale, yellowish-tan	....	....

15-25-29aaa.———Sample log of test hole in NE NE NE sec. 29, T 15 S, R 25 E, 20 feet south of section corner; augered December 6, 1960. Altitude of land surface, 1,114(T) feet; dry hole.

	Thickness, feet	Depth, feet
NEOGENE		
Pleistocene Series, undifferentiated		
Sand, very silty, grayish-tan	8.5	8.5
PENNSYLVANIAN		
Upper Pennsylvanian Series		
Missourian Stage—Kansas City Group		
Bonner Springs Shale		
Shale, weathered, greenish-tan	3.0	11.5

16-21-3aaa.———Sample log of test hole in NE NE NE sec. 3, T 16 S, R 21 E; augered May 1961. Altitude of land surface, 1,038(T) feet; dry hole.

	Thickness, feet	Depth, feet
Soil	3	3
NEOGENE		
Pleistocene Series, undifferentiated		
Silt, sandy, tan; with carbonaceous specks and limonite	15	18
Silt, sandy, very fine to coarse and fine to medium gravel, yellowish-tan	5	23
Silt, clayey, greenish-tan	5	28
PENNSYLVANIAN		
Upper Pennsylvanian Series		
Virgilian Stage—Douglas Group		
Stranger Formation		
Shale, weathered, sandy, gray	5	33

16-21-10aaa.———Sample log of test hole in NE NE NE sec. 10, T 16 S, R 21 E; augered May 1961. Altitude of land surface, 1,006(T) feet; dry hole.

	Thickness, feet	Depth, feet
NEOGENE		
Pleistocene Series, undifferentiated		
Silt, sandy, tan; with red shale fragments and carbonaceous specks	5	5
PENNSYLVANIAN		
Upper Pennsylvanian Series		
Virgilian Stage—Douglas Group		
Stranger Formation		
Shale, reddish-brown	....	....

16-21-12bbb.———Sample log of test hole in NW NW NW sec. 12, T 16 S, R 21 E; augered May 1961. Altitude of land surface, 1,020(T) feet; dry hole.

	Thickness, feet	Depth, feet
Soil	3	3
NEOGENE		
Pleistocene Series, undifferentiated		
Silt, sandy, yellowish-tan	10	13
PENNSYLVANIAN		
Upper Pennsylvanian Series		
Virgilian Stage—Douglas Group		
Stranger Formation		
Shale, weathered, yellowish-tan; some very fine gravel and fine to coarse sand	7	20

16-21-15aaa.———Sample log of test hole in NE NE NE sec. 15, T 16 S, R 21 E; augered May 1960. Altitude of land surface, 986(T) feet; dry hole.

	Thickness, feet	Depth, feet
Soil	3	3
NEOGENE		
Pleistocene Series, undifferentiated		
Silt, slightly sandy, brown	5	8
Silt, slightly sandy, orangish-tan	5	13
PENNSYLVANIAN		
Upper Pennsylvanian Series		
Missourian Stage—Lansing Group		
Stanton Limestone		
Limestone, finely crystalline, tan		

16-21-24aaa.———Sample log of test hole in NE NE NE sec. 24, T 16 S, R 21 E; augered May 1961. Altitude of land surface, 1,051(T) feet; dry hole.

	Thickness, feet	Depth, feet
NEOGENE		
Pleistocene Series, undifferentiated		
Silt, brown to light-brown	3	3
Silt, clayey, tan and gray	5	8
PENNSYLVANIAN		
Upper Pennsylvanian Series		
Virgilian Stage—Douglas Group		
Stranger Formation		
Shale, tan and gray; limestone fragments and carbonaceous specks	1	9

16-22-2acc.———Sample log of test hole in SW SW NE sec. 2, T 16 S, R 22 E; augered May 1961. Altitude of land surface, 902(T) feet; depth to water, 7.0 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Pleistocene Series		
Recent Stage (alluvium)		
Sand, silty, brown	8	8

PENNSYLVANIAN
Upper Pennsylvanian Series
Missourian Stage—Kansas City Group
Iola Limestone

16-22-2dcb.———Drillers' log of water well in NW SW SE sec. 2, T 16 S, R 22 E; drilled by Carl Moore and Son for M. A. Bell, Paola, Kansas, September 15, 1961. Altitude of land surface, 912(T) feet; depth to water, 11.5 feet.

	Thickness, feet	*Depth, feet*
Soil	2	2
NEOGENE		
Pleistocene Series		
Recent Stage [colluvium (slope deposits)]		
Clay	4	6
Clay, sandy, yellow	17	23
PENNSYLVANIAN		
Upper Pennsylvanian Series		
Missourian Stage—Kansas City Group		
Iola Limestone		
Limestone, thin-bedded, "shell-rock"	3	26
Shale	3	29
Limestone	18	47
Chanute Shale		
Shale	7	54
Sand and shale, gray	17	71
Shale	7	78
Drum Limestone		
Limestone	4	82
Cherryvale Shale		
Shale	18	100
Limestone	3	103
Shale	3	106
Limestone	5	111
Shale	12	123
Limestone	2	125
Shale	10	135
Dennis Limestone		
Limestone, cherty; water at 5.0 from top	25	160
Shale, black	3	163
Galesburg Shale		
Shale	4	167
Swope Limestone	13	180

16-22-4cdd.———Sample log of test hole in SE SE SW sec. 4, T 16 S, R 22 E; augered May 1961. Altitude of land surface, 1,060(T) feet; dry hole.

	Thickness, feet	*Depth, feet*
Soil	3	3
NEOGENE		
Pleistocene Series, undifferentiated		
Silt, sandy, yellowish-tan; limonite specks and some blades of gypsum	3	6
PENNSYLVANIAN		
Upper Pennsylvanian Series		
Missourian Stage—Lansing Group		
Stanton Limestone		
Limestone, white calcite stringers and oölites	....	....

16-22-5cdd.———Sample log of test hole in SE SE SW sec. 5, T 16 S, R 22 E; augered May 1961. Altitude of land surface, 1,060(T) feet; dry hole.

	Thickness, feet	*Depth, feet*
Soil	3	3
NEOGENE		
Pleistocene Series, undifferentiated		
Silt, sandy, tan; carbonaceous specks	2	5
PENNSYLVANIAN		
Upper Pennsylvanian Series		
Virgilian Stage—Douglas Group		
Stranger Formation		

16-22-7bbb.———Sample log of test hole in NW NW NW sec. 7, T 16 S, R 22 E; augered May 1961. Altitude of land surface, 1,040(T) feet; dry hole.

	Thickness, feet	*Depth, feet*
Soil	3	3
NEOGENE		
Pleistocene Series, undifferentiated		
Silt, sandy, tan; more sandy in lower 2.0 feet	9	12
Sandy, very silty, tan	5	17
PENNSYLVANIAN		
Upper Pennsylvanian Series		
Virgilian Stage—Douglas Group		
Stranger Formation		
Shale (no return)	1	18

16-22-7cdd.———Sample log of test hole in SE SE SW sec. 7, T 16 S, R 22 E; augered May 1961. Altitude of land surface, 1,050(T) feet; dry hole.

	Thickness, feet	*Depth, feet*
Soil	3	3
NEOGENE		
Pleistocene Series, undifferentiated		
Silt, sandy, light-brown	2	5
Silt, tan	7	12
Silt, sandy, tan; some weathered shale	3	15
PENNSYLVANIAN		
Upper Pennsylvanian Series		
Virgilian Stage—Douglas Group		
Stranger Formation		

16-22-12ddd.———Sample log of test hole in SE SE SE sec. 12, T 16 S, R 22 E; augered May 1961. Altitude of land surface, 882(T) feet; depth to water, 9.1 feet.

	Thickness, feet	*Depth, feet*
Soil	3	3
NEOGENE		
Pleistocene Series		
Wisconsinan and Recent stages (terrace deposits and alluvium, undifferentiated)		
Silt, light-brown, sandy in lower 5.0 feet	10	13
Silt, sandy, tan; hematite specks in lower 5.0 feet	10	23
Sandy, very fine to medium, mostly very fine, silty, tan	4	27

PENNSYLVANIAN
Upper Pennsylvanian Series
Missourian Stage—Kansas City Group
Iola Limestone

16-22-28cbc.———Sample log of test hole in SW NW SW sec. 28, T 16 S, R 22 E; augered May 1961. Altitude of land surface, 1,100(T) feet; dry hole.

	Thickness, feet	*Depth, feet*
Soil	3	3
NEOGENE		
Pleistocene Series, undifferentiated		
Sand, very silty, very fine to fine, tan; small calcite crystals in lower 1.0 foot	5	8
PENNSYLVANIAN		
Upper Pennsylvanian Series		
Missourian Stage—Lansing Group		
Stanton Limestone		

16-22-30baa.———Sample log of test hole in NE NE NW sec. 30, T 16 S, R 22 E; augered May 1961. Altitude of land surface, 1,060(T) feet; dry hole.

	Thickness, feet	*Depth, feet*
Soil	2	2
NEOGENE		
Pleistocene Series, undifferentiated		
Sand, silty, tan	1	3
Sand, very fine to coarse; limonite and carbonaceous specks	5	8
Silt, sandy, reddish-tan; limonite and carbonaceous specks, with some caliche	5	13
PENNSYLVANIAN		
Upper Pennsylvanian Series		
Missourian Stage—Lansing Group		
Stanton Limestone		
Limestone and shale, red chert gravel	....	....

16-22-35aaa.———Sample log of test hole in NE NE NE sec. 35, T 16 S, R 22 E; augered May 1961. Altitude of land surface, 940(T) feet; dry hole.

	Thickness, feet	*Depth, feet*
Road fill	3	3
NEOGENE		
Pleistocene Series		
Recent Stage [colluvium (slope deposits)]		
Silt, sandy, grayish-brown; limonite specks; yellowish-tan and clayey in lower 8.0 feet	10	13
PENNSYLVANIAN		
Upper Pennsylvanian Series		
Missourian Stage—Kansas City Group		
Lane Shale		
Shale, light greenish-gray	....	....

16-23-5bbd.———Sample log of test hole in SE NW NW sec. 5, T 16 S, R 23 E; augered May 1961. Altitude of land surface, 905(T) feet; depth to water, 5.2 feet.

	Thickness, feet	*Depth, feet*
Soil	3	3
NEOGENE		
Pleistocene Series		
Recent Stage (alluvium)		
Silt, light-brown	5	8
Silt, sandy, light-brown	12	20
PENNSYLVANIAN		
Upper Pennsylvanian Series		
Missourian Stage—Kansas City Group		
Lane Shale		
Shale, gray	1	21

16-23-5cab.———Sample log of test hole in NW NE SW sec. 5, T 16 S, R 23 E; augered May 1961. Altitude of land surface, 898(T) feet; depth to water, 5 feet.

	Thickness, feet	*Depth, feet*
NEOGENE		
Pleistocene Series		
Recent Stage (alluvium)		
Silt, very sandy, dark-tan	3	3
Silt, slightly sandy, dark-tan	20	23
PENNSYLVANIAN		
Upper Pennsylvanian Series		
Missourian Stage—Kansas City Group		
Lane Shale		
Shale, weathered, gray	4	27

16-23-15dcb.———Sample log of test hole in NW SW SE sec. 15, T 16 S, R 23 E; augered May 1961. Altitude of land surface, 875(T) feet; depth to water, 3.2 feet.

	Thickness, feet	*Depth, feet*
NEOGENE		
Pleistocene Series		
Recent Stage (alluvium)		
Silt, slightly sandy, tan to yellowish-tan; limonite specks and more sandy in lower 10.0 feet	18	18
Silt, sandy, tan	10	28
PENNSYLVANIAN		
Upper Pennsylvanian Series		
Missourian Stage—Kansas City Group		
Drum Limestone		

16-23-18acc.———Sample log of test hole in SW SW NE sec. 18, T 16 S, R 23 E; augered May 1961. Altitude of land surface, 888(T) feet; depth to water, 7.0 feet.

	Thickness, feet	*Depth, feet*
Soil	3	3
NEOGENE		
Pleistocene Series		
Wisconsinan and Recent stages (terrace deposits and alluvium, undifferentiated)		
Silt, sandy, light-brown	5	8
Silt, sandy, tan; some limonite specks; some reddish-brown streaks in lower 5.0 feet	15	23
PENNSYLVANIAN		
Upper Pennsylvanian Series		
Missourian Stage—Kansas City Group		
Chanute Shale		

16-23-18bba.———Sample log of test hole in NE NW NW sec. 18, T 16 S, R 23 E; augered May 1961. Altitude of land surface, 888(T) feet; dry hole.

	Thickness, feet	*Depth, feet*
Soil	3	3
NEOGENE		
Pleistocene Series		
Wisconsinan and Recent stages (terrace deposits and alluvium, undifferentiated)		
Silt, sandy, light-brown	5	8
Silt, sandy, tan	10	18
PENNSYLVANIAN		
Upper Pennsylvanian Series		
Missourian Stage—Kansas City Group		
Chanute Shale		
Shale, weathered, greenish-tan	5	23

16-23-18cdd.———Sample log of test hole in SE SE SW sec. 18, T 16 S, R 23 E; augered May 1961. Altitude of land surface, 872(T) feet; depth to water, 7.5 feet.

	Thickness, feet	*Depth, feet*
Soil	3	3
NEOGENE		
Pleistocene Series		
Recent Stage (alluvium)		
Sand, very fine to fine, very silty, light-brown	5	8
Silt, very sandy, brown	5	13
Sand, very fine to medium, some coarse, very silty, light-brown	5	18
Silt, sandy, tannish-gray	4	22
PENNSYLVANIAN		
Upper Pennsylvanian Series		
Missourian Stage—Kansas City Group		
Chanute Shale		

16-23-20dad.———Sample log of test hole in SE NE SE sec. 20, T 16 S, R 23 E; augered May 1961. Altitude of land surface, 868(T) feet; depth to water, 14.5 feet.

	Thickness, feet	*Depth, feet*
NEOGENE		
Pleistocene Series		
Wisconsinan and Recent stages (terrace deposits and alluvium, undifferentiated)		
Silt, light-brown to grayish-tan	3	3
Silt, slightly sandy, tan	5	8
Silt, sandy, yellowish-tan	10	18
Silt, sandy; carbonaceous and limonitic specks, weathered shale	5	23
PENNSYLVANIAN		
Upper Pleistocene Series		
Missourian Stage—Kansas City Group		
Chanute Shale		

16-23-20ddd.———Sample log of test hole in SE SE SE sec. 20, T 16 S, R 23 E; augered May 1961. Altitude of land surface, 866(T) feet; depth to water, 12.3 feet.

	Thickness, feet	*Depth, feet*
NEOGENE		
Pleistocene Series		
Recent Stage (alluvium)		
Silt, slightly sandy, yellowish-tan	27	27
PENNSYLVANIAN		
Upper Pleistocene Series		
Missourian Stage—Kansas City Group		
Chanute Shale		
Shale, gray	3	30

16-23-21cbb.———Sample log of test hole in NW NW SW sec. 21, T 16 S, R 23 E; augered May 1961. Altitude of land surface, 872(T) feet; depth to water, 8.4 feet.

	Thickness, feet	*Depth, feet*
Soil	3	3
NEOGENE		
Pleistocene Series		
Wisconsinan and Recent stages (terrace deposits and alluvium, undifferentiated)		
Silt, sandy, gray, with limestone pebbles	5	8
Silt, sandy, tan to orangish-tan	5	13
PENNSYLVANIAN		
Upper Pennsylvanian Series		
Missourian Stage—Kansas City Group		
Chanute Shale		
Shale, weathered, sandy, grayish-tan	5	18

16-23-22cbc.———Sample log of test hole in SW NW SW sec. 22, T 16 S, R 23 E; augered May 1961. Altitude of land surface, 872(T) feet; depth to water, 3.5 feet.

	Thickness, feet	*Depth, feet*
Soil	3	3
NEOGENE		
Pleistocene Series		
Recent Stage (alluvium)		
Silt, dark-tan; some very fine sand	10	13
(No return from auger)	5	18
Silt, sandy, dark-tan; limonite specks and weathered shale fragments	9	27
PENNSYLVANIAN		
Upper Pennsylvanian Series		
Missourian Stage—Kansas City Group		
Cherryvale Shale		

16-23-25dbc.———Drillers' log of water well in SW NW SE sec. 25, T 16 S, R 23 E; drilled by Carl Moore and Son for Dale Everhart, Paola, Kansas, in 1954. Altitude of land surface, 1,075(T) feet; depth to water, 24.9 feet.

	Thickness, feet	*Depth, feet*
Soil	2	2
NEOGENE		
Pleistocene Series, undifferentiated		
Clay	15	17
PENNSYLVANIAN		
Upper Pennsylvanian Series		
Missourian Stage—Lansing Group		
Plattsburg Limestone		
Limestone	3	20
Missourian Stage—Kansas City Group		
Bonner Springs Shale		
Shale	7	27

	Thickness, feet	*Depth, feet*
Wyandotte Limestone		
Limestone (water obtained at this level)	31	58
Lane Shale		
Shale	20	78
Iola Limestone		
Limestone	8	86

16-23-28cdd.———Sample log of test hole in SE SE SW sec. 28, T 16 S, R 23 E; augered May 1961. Altitude of land surface, 862(T) feet; depth to water, 16.3 feet.

	Thickness, feet	*Depth, feet*
Soil	3	3
NEOGENE		
Pleistocene Series		
Wisconsinan and Recent stages (terrace deposits and alluvium, undifferentiated)		
Silt, sandy, light-brown	5	8
Silt, sandy, tan	10	18
Silt, sandy, light-brown; with weathered shale fragments	5	23
PENNSYLVANIAN		
Upper Pennsylvanian Series		
Missourian Stage—Kansas City Group		
Cherryvale(?) Shale		

16-23-28ddc.———Drillers' log of water well in SW SE SE sec. 28, T 16 S, R 23 E; drilled by Mr. Bunch for Herbert Walters, Paola, Kansas, 1954. Altitude of land surface, 930(T) feet; depth to water, 8.8 feet.

	Thickness, feet	*Depth, feet*
Soil and clay	8	8
PENNSYLVANIAN		
Upper Pennsylvanian Series		
Missourian Stage—Kansas City Group		
Chanute Shale		
Sandstone	3	11
Shale, green	27	38
Drum Limestone		
Limestone, hard	4	42
Cherryvale Shale		
Shale, gray	8	50
Limestone	2	52
Shale, light-gray	18	70
Limestone	14	84
Shale, gray	16	100
Dennis Limestone		
Limestone	24	124
Shale, gray	3	127
Shale, black; water	4	131
Limestone	4	135

16-23-32ddc.———Sample log of test hole in SW SE SE sec. 32, T 16 S, R 23 E; augered May 1961. Altitude of land surface, 854(T) feet; depth to water, 12.4 feet.

	Thickness, feet	*Depth, feet*
Soil	3	3
NEOGENE		
Pleistocene Series		
Recent Stage (alluvium)		
Silt, sandy to very sandy, light-brown	20	23
PENNSYLVANIAN		
Upper Pennsylvanian Series		
Missourian Stage—Kansas City Group		
Chanute Shale		
Shale, weathered, gray	4	27

16-23-33ccc.———Sample log of test hole in SW SW SW sec. 33, T 16 S, R 23 E; augered May 1961. Altitude of land surface, 863(T) feet; depth to water, 12.4 feet.

	Thickness, feet	*Depth, feet*
Soil	3	3
NEOGENE		
Pleistocene Series		
Recent Stage (alluvium)		
Silt, grayish-tan; some sand in lower 10.0 feet	15	18
Silt, sandy, gray; some weathered shale	10	28
PENNSYLVANIAN		
Upper Pennsylvanian Series		
Missourian Stage—Kansas City Group		
Chanute Shale		

16-23-36cdd.———Sample log of test hole in SE SE SW sec. 36, T 16 S, R 23 E; augered May 1961. Altitude of land surface, 1,038(T) feet; dry hole.

	Thickness, feet	*Depth, feet*
NEOGENE		
Pleistocene Series, undifferentiated		
Silt, slightly sandy, reddish-tan	3	3
PENNSYLVANIAN		
Upper Pennsylvanian Series		
Missourian Stage—Kansas City Group		
Wyandotte Limestone		

16-24-13cbb.———Sample log of test hole in NW NW SW sec. 13, T 16 S, R 24 E; augered May 1961. Altitude of land surface, 954(T) feet; depth to water, 9.2 feet.

	Thickness, feet	*Depth, feet*
NEOGENE		
Pleistocene Series		
Recent Stage (alluvium)		
Silt, sandy, brown; some chert fragments in lower 9.0 feet	12	12
PENNSYLVANIAN		
Upper Pennsylvanian Series		
Missourian Stage—Kansas City Group		
Lane Shale		
Shale, gray and reddish-tan	1	13

16-24-15dda.———Sample log of test hole in NE SE SE sec. 15, T 16 S, R 24 E; augered May 1961. Altitude of land surface, 947(T) feet; depth to water, 12.5 feet.

	Thickness, feet	*Depth, feet*
NEOGENE		
Pleistocene Series		
Recent Stage (alluvium)		
Silt, sandy, grayish-tan to tan; caliche in lower 3.0 feet	11	11
Silt, sand, and fine to coarse gravel, reddish-brown; limonitic	2	13

	Thickness, feet	*Depth, feet*
PENNSYLVANIAN		
Upper Pennsylvanian Series		
Missourian Stage—Kansas City Group		
Lane Shale		
Shale; with limestone and chert	1	14

16-24-16dcd.———Sample log of test hole in SE SW SE sec. 16, T 16 S, R 24 E; augered May 1961. Altitude of land surface, 930(T) feet; depth to water, 7.3 feet.

	Thickness, feet	*Depth, feet*
Soil	3	3
NEOGENE		
Pleistocene Series		
Recent Stage (alluvium)		
Silt, light-brown	4	7
Silt, sandy; some limestone pebbles	6	13
Silt, sandy; shale and limestone fragments, small fragments of carbonized wood; clams, snails, algae (charophytes), and ostracods	1	14
PENNSYLVANIAN		
Upper Pennsylvanian Series		
Missourian Stage—Kansas City Group		
Lane Shale		

16-24-29add.———Sample log of test hole in SE SE NE sec. 29, T 16 S, R 24 E; augered May 1961. Altitude of land surface, 912(T) feet; depth to water, 8.6 feet.

	Thickness, feet	*Depth, feet*
NEOGENE		
Pleistocene Series		
Recent Stage (alluvium)		
Silt, dark-brown; with light-green shale fragments	2	5
Silt, sandy, light-brown	8	13
Silt, sandy, brown; chert gravel, brown; light-green shale fragments; tannish-white limestone gravel	0.5	13.5
PENNSYLVANIAN		
Upper Pennsylvanian Series		
Missourian Stage—Kansas City Group		
Lane Shale		

16-24-32abb.———Sample log of test hole in NW NW NE sec. 32, T 16 S, R 24 E; augered May 1961. Altitude of land surface, 895(T) feet; depth to water, 7.8 feet.

	Thickness, feet	*Depth, feet*
Soil	2	2
NEOGENE		
Pleistocene Series		
Recent Stage (alluvium)		
Silt, slightly sandy, light-brown	11	13
PENNSYLVANIAN		
Upper Pennsylvanian Series		
Missourian Stage—Kansas City Group		
Chanute Shale		
Shale, weathered, gray	5	18
Shale, hard, gray	2	20

17-22-26ccc.———Drillers' log of water well in SW SW SW sec. 26, T 17 S, R 22 E; drilled by George H. Swank for Otto Robinson, Kansas City, Missouri, June 1960. Altitude of land surface, 877(T) feet; depth to water, 9.4 feet.

	Thickness, feet	*Depth, feet*
Soil and clay	12	12
NEOGENE		
Pleistocene Series, undifferentiated		
Gravel(?)	2	14
PENNSYLVANIAN		
Upper Pennsylvanian Series		
Missourian Stage—Kansas City Group		
Drum Limestone		
Limestone, blue	2	16
Cherryvale Shale		
Shale, white	4	20
Sand, blue [limestone(?)]	4	24
Limestone, white	11	35

17-22-31ccc.———Sample log of test hole in SW SW SW sec. 31, T 17 S, R 22 E; augered June 1961. Altitude of land surface, 855(T) feet; depth to water, 5.7 feet.

	Thickness, feet	*Depth, feet*
NEOGENE		
Pleistocene Series		
Wisconsinan and Recent stages (terrace deposits and alluvium, undifferentiated)		
Silt, sandy, tan	5	5
Silt, sandy, reddish-tan	18	23
Gravel, coarse; silt, tan; and gray shale fragments	1	24
PENNSYLVANIAN		
Upper Pennsylvanian Series		
Missourian Stage		

17-22-32ddd.———Sample log of test hole in SE SE SE sec. 32, T 17 S, R 22 E; augered June 1961. Altitude of land surface, 849(T) feet; depth to water, 11.7 feet.

	Thickness, feet	*Depth, feet*
NEOGENE		
Pleistocene Series		
Recent Stage (alluvium)		
Silt and sand, very fine to fine, yellowish-tan; light-brown in lower 15.0 feet with less sand in lower 10.0 feet	23	23
Silt; with chert and limestone gravel	1	24
PENNSYLVANIAN		
Upper Pennsylvanian Series		
Missourian Stage—Kansas City Group		
Cherryvale Shale		
Limestone	....	....

17-23-3abb.———Sample log of test hole in NW NW NE sec. 3, T 17 S, R 23 E; augered May 1961. Altitude of land surface, 962(T) feet; dry hole.

	Thickness, feet	*Depth, feet*
NEOGENE		
Pleistocene Series, undifferentiated		
Silt and sand, very fine, tan	9	9

	Thickness, feet	Depth, feet
PENNSYLVANIAN		
Upper Pennsylvanian Series		
Missourian Stage—Kansas City Group		
Lane Shale		
Shale, blue-gray	1	10

17-23-9cbd.———Sample log of test hole in SE NW SW sec. 9, T 17 S, R 23 E; augered May 1961. Altitude of land surface, 852(T); depth to water, 8.1 feet.

	Thickness, feet	Depth, feet
Soil	2	2
NEOGENE		
Pleistocene Series		
Recent Stage (alluvium)		
Silt, sandy, light-brown	11	13
Silt, sandy, tan; very fine to medium limestone and chert gravel in lower 4.0 feet	9	22
PENNSYLVANIAN		
Upper Pennsylvanian Series		
Missourian Stage—Kansas City Group		
Cherryvale Shale		
Shale, gray	1	23

17-23-12daa.———Sample log of test hole in NE NE SE sec. 12, T 17 S, R 23 E; augered May 1961. Altitude of land surface, 872(T) feet; depth to water, 8.3 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Pleistocene Series		
Recent Stage (alluvium)		
Sand and silt, fine to coarse, tan	12	12
Sand, very fine to coarse, very silty, tan	6	18
PENNSYLVANIAN		
Upper Pennsylvanian Series		
Missourian Stage—Kansas City Group		
Cherryvale Shale		
Shale, gray	1	19

17-23-13bbb.———Sample log of test hole in NW NW NW sec. 13, T 17 S, R 23 E; augered May 1961. Altitude of land surface, 865(T) feet; depth to water, 6.0 feet.

	Thickness, feet	Depth, feet
Soil	4	4
NEOGENE		
Pleistocene Series		
Wisconsinan and Recent stages (terrace deposits and alluvium, undifferentiated)		
Silt, sandy, tan	3	7
Silt, sandy, light-brown; with limestone fragments	6	13
PENNSYLVANIAN		
Upper Pennsylvanian Series		
Missourian Stage—Kansas City Group		
Chanute Shale		

17-23-13bcd.———Sample log of test hole in SE SW NW sec. 13, T 17 S, R 23 E; augered May 1961. Altitude of land surface, 860(T) feet; depth to water, 12.4 feet.

	Thickness, feet	Depth, feet
Soil	3	3
NEOGENE		
Pleistocene Series		
Recent Stage (alluvium)		
Silt, sandy, light-brown	5	8
Silt, sandy, yellowish-tan	15	23
Silt, sandy, dark-tan; calcareous	1	24
PENNSYLVANIAN		
Upper Pennsylvanian Series		
Missourian Stage—Kansas City Group		
Cherryvale Shale		

17-23-17abc.———Sample log of test hole in SW NW NE sec. 17, T 17 S, R 23 E; augered May 1961. Altitude of land surface, 853(T) feet; depth to water, 8.8 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Pleistocene Series		
Recent Stage (alluvium)		
Silt, sandy, brown	8	8
Silt, very sandy, tan	19	27
PENNSYLVANIAN		
Upper Pennsylvanian Series		
Missourian Stage—Kansas City Group		
Cherryvale Shale		
Shale, dark-gray	1	28

17-23-17bba.———Sample log of test hole in NE NW NW sec. 17, T 17 S, R 23 E; augered May 1961. Altitude of land surface, 860(T) feet; depth to water, 15.4 feet.

	Thickness, feet	Depth, feet
Soil	5	5
NEOGENE		
Pleistocene Series		
Recent Stage (alluvium)		
Silt, sandy, dark-tan	5	10
Silt, sandy, yellowish-tan	3	13
Sand, silty, yellowish-tan	4	17
PENNSYLVANIAN		
Upper Pennsylvanian Series		
Missourian Stage—Kansas City Group		
Cherryvale Shale		

17-23-20ada.———Sample log of test hole in NE SE NE sec. 20, T 17 S, R 23 E; augered May 1961. Altitude of land surface, 850(T) feet; depth to water, 8.5 feet.

	Thickness, feet	Depth, feet
Soil	4	4
NEOGENE		
Pleistocene Series		
Recent Stage (alluvium)		
Silt, sandy, yellowish-tan; darker in lower 6.0 feet	9	13
PENNSYLVANIAN		
Upper Pennsylvanian Series		
Missourian Stage—Kansas City Group		
Cherryvale Shale		
Limestone	....	....

17-23-22cbc.———Sample log of test hole in SW NW SW sec. 22, T 17 S, R 23 E; augered May 1961. Altitude of land surface, 845(T) feet; depth to water, 4.5 feet.

	Thickness, feet	*Depth, feet*
Soil	3	3
NEOGENE		
Pleistocene Series		
Recent Stage (alluvium)		
Silt, sandy, brown	15	18
Sand, silty, yellowish-tan	9	27
PENNSYLVANIAN		
Upper Pennsylvanian Series		
Missourian Stage—Kansas City Group		
Cherryvale Shale		

17-23-22dbc.———Sample log of test hole in SW NW SE sec. 22, T 17 S, R 23 E; augered May 1961. Altitude of land surface, 850(T) feet; depth to water, 18.0 feet.

	Thickness, feet	*Depth, feet*
Road fill	13	13
NEOGENE		
Pleistocene Series		
Recent Stage (alluvium)		
Silt, sandy, dark-tan to tan	22	35
PENNSYLVANIAN		
Upper Pennsylvanian Series		
Missourian Stage—Kansas City Group		
Cherryvale Shale		

17-23-23bbb.———Sample log of test hole in NW NW NW sec. 23, T 17 S, R 23 E; augered May 1961. Altitude of land surface, 847(T) feet.

	Thickness, feet	*Depth, feet*
Soil	5	5
NEOGENE		
Pleistocene Series		
Recent Stage (alluvium)		
Silt, sandy, dark-tan; some fine to coarse gravel in lower 5.0 feet	15	20
PENNSYLVANIAN		
Upper Pennsylvanian Series		
Missourian Stage—Kansas City Group		
Cherryvale Shale		

17-24-1bab.———Sample log of test hole in NW NE NW sec. 1, T 17 S, R 24 E; augered May 1961. Altitude of land surface, 938(T) feet; depth to water, 10.1 feet.

	Thickness, feet	*Depth, feet*
Road fill	3	3
NEOGENE		
Pleistocene Series		
Recent Stage (alluvium)		
Silt and sand, fine to medium sand; light-brown	9	12
PENNSYLVANIAN		
Upper Pennsylvanian Series		
Missourian Stage—Kansas City Group		
Chanute Shale		
Shale, gray	2	14

17-24-3ada.———Sample log of test hole in NE SE NE sec. 3, T 17 S, R 24 E; augered May 1961. Altitude of land surface, 925(T) feet; depth to water, 4.5 feet.

	Thickness, feet	*Depth, feet*
NEOGENE		
Pleistocene Series		
Recent Stage (alluvium)		
Silt, sandy, reddish-tan	18	18
PENNSYLVANIAN		
Upper Pennsylvanian Series		
Missourian Stage—Kansas City Group		
Cherryvale Shale		
Shale, gray	2	20

17-24-4cbb.———Sample log of test hole in NW NW SW sec. 4, T 17 S, R 24 E; augered May 1961. Altitude of land surface, 895(T) feet; depth to water, 13.5 feet.

	Thickness, feet	*Depth, feet*
Road fill	5	5
NEOGENE		
Pleistocene Series		
Recent Stage (alluvium)		
Silt, sandy, dark grayish-tan	4	9
Silt, sandy, tan	4	13
Silt, sandy, light-brown; some fine chert gravel	5	18
PENNSYLVANIAN		
Upper Pennsylvanian Series		
Missourian Stage—Kansas City Group		
Chanute(?) Shale		
Shale, gray	1	19

17-24-5cbb.———Sample log of test hole in NW NW SW sec. 5, T 17 S, R 24 E; augered May 1961. Altitude of land surface, 880(T) feet; depth to water, 8.1 feet.

	Thickness, feet	*Depth, feet*
NEOGENE		
Pleistocene Series		
Recent Stage (alluvium)		
Silt, light-brown; some sand in lower 4.0 feet	7	7
Silt, light reddish-tan	11	18
Silt, tan; calcareous; some gravel	1	19
PENNSYLVANIAN		
Upper Pennsylvanian Series		
Missourian Stage—Kansas City Group		
Cherryvale(?) Shale		

17-24-7caa.———Sample log of test hole in NE NE SW sec. 7, T 17 S, R 24 E; augered May 1961. Altitude of land surface, 884(T) feet; depth to water, 13.4 feet.

	Thickness, feet	*Depth, feet*
Soil	3	3
NEOGENE		
Pleistocene Series		
Wisconsinan and Recent stages (terrace deposits and alluvium, undifferentiated)		
Silt, very sandy, tannish-gray	5	8
Sand, fine to coarse, mostly fine, silty, yellowish-tan; some white chert and less coarse sand in lower 10.0 feet	15	23

	Thickness, feet	Depth, feet
PENNSYLVANIAN		
Upper Pennsylvanian Series		
Missourian Stage—Kansas City Group		
Cherryvale(?) Shale		
Shale, greenish-gray	0.5	23.5

17-25-6cdd.———Sample log of test hole in SE SE SW sec. 6, T 17 S, R 25 E; augered May 1961. Altitude of land surface, 965(T) feet; dry hole.

	Thickness, feet	Depth, feet
Soil	2	2
NEOGENE		
Pleistocene Series		
Recent Stage [colluvium (slope deposits)]		
Silt, sandy, brown	6	8
Silt, tan	1	9
PENNSYLVANIAN		
Upper Pennsylvanian Series		
Missourian Stage—Kansas City Group		
Iola Limestone		

18-21-1aab.———Sample log of test hole in NW NE NE sec. 1, T 18 S, R 21 E; augered June 1961. Depth to water, 6.0 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Pleistocene Series		
Recent Stage (alluvium)		
Silt, sandy, light-brown	5	5
Silt, sandy; pieces of white sandstone and chert gravel; some limestone pebbles	8	13
Silt and sand, very fine to medium, tan; less sandy, calcareous limestone fragments in the lower 6.0 feet	16	29
PENNSYLVANIAN		
Upper Pennsylvanian Series		
Missourian Stage—Kansas City Group		
Iola(?) Limestone		

18-21-35caa.———Drillers' log of water well in NE NE SW sec. 35, T 18 S, R 21 E; drilled by George H. Swank for Charles E. Hay, Jr., Lane, Kansas, April 20, 1961. Depth to water 20.0 feet.

	Thickness, feet	Depth, feet
Soil	8	8
PENNSYLVANIAN		
Upper Pennsylvanian Series		
Missourian Stage—Kansas City Group		
Lane(?) Shale		
Shale, limy, yellow	4	12
Iola(?) Limestone		
Limestone, blue	16	28
Chanute Shale		
Shale, blue	2	30
Sand, blue; water	8	38
Drum Limestone		
Limestone, blue	9	47
Cherryvale Shale		
Shale, blue	18	65

18-21-36bdd.———Drillers' log of water well in SE SE NW sec. 36, T 18 S, R 21 E; drilled by George H. Swank for Charles Hay, Sr., Lane, Kansas, April 26, 1961.

	Thickness, feet	Depth, feet
Soil	4	4
PENNSYLVANIAN		
Upper Pennsylvanian Series		
Missourian Stage—Kansas City Group		
Lane(?) Shale		
Shale, limy, yellow; water	6	10
Sand, yellow	2	12
Iola(?) Limestone		
Limestone, blue	5	17
Chanute(?) Shale		
Sand, blue; water	5	22
Shale, blue	5	27
Drum(?) Limestone		
Limestone, blue	8	35
Cherryvale(?) Shale		
Shale, sandy, blue	25	60
Limestone, blue	5	65

18-22-2ddb.———Sample log of test hole in NW SE SE sec. 2, T 18 S, R 22 E; augered May 1961. Altitude of land surface, 852(T) feet; depth to water, 8.8 feet.

	Thickness, feet	Depth, feet
Road fill	4	4
NEOGENE		
Pleistocene Series		
Recent Stage (alluvium)		
Silt, sandy, brown	9	13
Silt, sandy, yellowish-tan	6	19
Sand, silty, yellowish-tan; fine gravel in lower 4.0 feet	14	33
(No return on auger)	5	38
PENNSYLVANIAN		
Upper Pennsylvanian Series		
Missourian Stage—Kansas City Group		
Cherryvale Shale		

18-22-4bbc.———Sample log of test hole in SW NW NW sec. 4, T 18 S, R 22 E; augered June 1961. Altitude of land surface, 847(T) feet; depth to water, 11.5 feet.

	Thickness, feet	Depth, feet
Soil	3	3
NEOGENE		
Pleistocene Series		
Recent Stage (alluvium)		
Silt, sandy, grayish-brown	10	13
Silt, sandy, tan	20	33
Silt, grayish-tan; fine to medium, chert and limestone gravel; green shale fragments and carbonaceous specks	10	43
Silt, sandy, yellowish-tan; some fine gravel	1	44
PENNSYLVANIAN		
Upper Pennsylvanian Series		
Missourian Stage—Kansas City Group		
Cherryvale(?) Shale		

18-22-4daa.———Sample log of test hole in NE NE SE sec. 4, T 18 S, R 22 E; augered June 1961. Altitude of land surface, 858(T) feet; depth to water, 15.3 feet.

	Thickness, feet	*Depth, feet*
Soil	3	3
NEOGENE		
Pleistocene Series		
Wisconsinan and Recent stages (terrace deposits and alluvium, undifferentiated)		
Silt and sand, very fine to medium, yellowish-tan	5	8
Silt, sandy, yellowish-tan	15	23
Silt, sandy, tan	3	26
PENNSYLVANIAN		
Upper Pennsylvanian Series		
Missourian Stage—Kansas City Group		
Cherryvale(?) Shale		

18-22-6aba.———Sample log of test hole in NE NW NE sec. 6, T 18 S, R 22 E; augered June 1961. Depth to water, 12.5 feet.

	Thickness, feet	*Depth, feet*
Soil	3	3
NEOGENE		
Pleistocene Series		
Wisconsinan and Recent stages (terrace deposits and alluvium, undifferentiated)		
Silt, sandy, clayey, dark-tan; reddish silt streaks and gray silt streaks with carbonaceous specks in lower 3.0 feet	5	8
Silt, sandy, yellowish-tan; white limestone chips and chert gravel in lower 5.0 feet	10	18
PENNSYLVANIAN		
Upper Pennsylvanian Series		
Missourian Stage—Kansas City Group		
Chanute(?) Shale		

18-22-9cab.———Drillers' log of water well in NW NE SW sec. 9, T 18 S, R 22 E; drilled by George H. Swank for Dale McDowell, Osawatomie, Kansas, 1952.

	Thickness, feet	*Depth, feet*
Soil	4	4
NEOGENE		
Pleistocene Series		
Wisconsinan and Recent stages (terrace deposits and alluvium, undifferentiated)		
Clay	16	20
PENNSYLVANIAN		
Upper Pennsylvanian Series		
Missourian Stage—Kansas City Group		
Cherryvale Shale		
Shale, blue	11	31
Sandstone, blue(?) (possible crystalline limestone)	6	37
Shale, blue; (water obtained at this level)	5	42
Dennis Limestone		
Limestone, white	20	62
Galesburg Shale		
Shale, blue	5	67
Swope Limestone		
Limestone, white	13	80

18-22-10aaa.———Sample log of test hole in NE NE NE sec. 10, T 18 S, R 22 E; augered June 1961. Altitude of land surface, 845(T) feet; depth to water, 3.8 feet.

	Thickness, feet	*Depth, feet*
Soil	8	8
NEOGENE		
Pleistocene Series		
Recent Stage (alluvium)		
Silt, sandy, grayish-tan	5	13
Silt, tan	5	18
Silt, reddish-tan	10	28
Sand, very fine to coarse, silty, reddish-tan	0.5	28.5
PENNSYLVANIAN		
Upper Pennsylvanian Series		
Missourian Stage—Kansas City Group		
Cherryvale(?) Shale		

18-22-10abb.———Sample log of test hole in NW NW NE sec. 10, T 18 S, R 22 E; augered June 1961. Altitude of land surface, 847(T) feet; depth to water, 14.9 feet.

	Thickness, feet	*Depth, feet*
Soil	10	10
NEOGENE		
Pleistocene Series		
Recent Stage (alluvium)		
Silt, sandy, tan	8	18
Sand, very fine to coarse, and gravel, very fine to medium, very silty, yellowish-tan	3	21
PENNSYLVANIAN		
Upper Pennsylvanian Series		
Missourian Stage—Kansas City Group		
Cherryvale(?) Shale		

18-22-10bbb.———Sample log of test hole in NW NW NW sec. 10, T 18 S, R 22 E; augered June 1961. Altitude of land surface, 849(T) feet; depth to water, 14.1 feet.

	Thickness, feet	*Depth, feet*
Soil	3	3
NEOGENE		
Pleistocene Series		
Recent Stage (alluvium)		
Silt, sandy, reddish-brown to yellowish-tan	5	8
Sand, very fine to medium, some coarse, very silty, yellowish-tan; fine to coarse gravel in lowermost 1.0 foot	11	19
PENNSYLVANIAN		
Upper Pennsylvanian Series		
Missourian Stage—Kansas City Group		
Cherryvale(?) Shale		

18-22-12caa.———Sample log of test hole in NE NE SW sec. 12, T 18 S, R 22 E; augered June 1961. Altitude of land surface, 840(T) feet; depth to water, 15.2 feet.

	Thickness, feet	*Depth, feet*
Road fill	3	3

	Thickness, feet	Depth, feet
NEOGENE		
Pleistocene Series		
Recent Stage (alluvium)		
Silt, sandy, dark-tan; with limonite specks and white limestone pebbles; some caliche	15	18
Silt, sandy, yellowish-tan; with large angular sand grains; limonite, caliche and a dark glassy mineral in the lower 5.0 feet	10	28
Silt, sandy, light yellowish-tan	20	48
Silt, limestone gravel and sand; some shale particles	3	51
PENNSYLVANIAN		
Upper Pennsylvanian Series		
Missourian Stage—Kansas City Group		
Cherryvale Shale		

18-22-14abb.———Sample log of test hole in NW NW NE sec. 14, T 18 S, R 22 E; augered May 1961. Depth to water, 12.1 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Pleistocene Series		
Wisconsinan and Recent stages (terrace deposits and alluvium, undifferentiated)		
Silt and sand, tan to reddish-tan; more red in the lower 5.0 feet	8	8
Sand, silty, yellowish-tan; some fine gravel in the lowermost 1.0 foot	6	14
PENNSYLVANIAN		
Upper Pennsylvanian Series		
Missourian Stage—Kansas City Group		
Cherryvale(?) Shale		

18-22-14abd.———Sample log of test hole in SE NW NE sec. 14, T 18 S, R 22 E; augered May 1961. Depth to water, 13.2 feet.

	Thickness, feet	Depth, feet
Soil	3	3
NEOGENE		
Pleistocene Series		
Recent Stage (alluvium)		
Silt, slightly sandy, grayish-brown	10	13
Silt, sandy, light-brown	15	28
Silt, sandy, grayish-tan; with chert and limestone fragments in the lower 5.0 feet	15	43
PENNSYLVANIAN		
Upper Pennsylvanian Series		
Missourian Stage—Kansas City Group		
Cherryvale(?) Shale		

18-22-17cbc.———Drillers' log of water well in SW NW SW sec. 17, T 18 S, R 22 E; drilled by George H. Swank for Merle D. Stone, Osawatomie, Kansas, September 20, 1961. Depth to water 42 feet.

	Thickness, feet	Depth, feet
Soil	6	6
NEOGENE		
Pleistocene Series		
Recent Stage (alluvium)		
Silt, yellow	21	27
PENNSYLVANIAN		
Upper Pennsylvanian Series		
Missourian Stage—Kansas City Group		
Cherryvale Shale		
Shale, blue	8	35
Sand, blue	5	40
Shale, blue	6	46
Dennis Limestone		
Limestone, blue	6	52
Limestone, white	7	59

18-22-18add.———Sample log of test hole in SE SE NE sec. 18, T 18 S, R 22 E; augered June 1961. Depth to water, 9.3 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Pleistocene Series		
Recent Stage (alluvium)		
Silt, sandy, brown	3	3
Silt, sandy, tan; fine to medium gravel in lower 5.0 feet	30	33
PENNSYLVANIAN		
Upper Pennsylvanian Series		
Missourian Stage—Kansas City Group		
Cherryvale(?) Shale		

18-22-18ddd.———Sample log of test hole in SE SE SE sec. 18, T 18 S, R 22 E; augered June 1961. Depth to water, 12.7 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Pleistocene Series		
Wisconsinan and Recent stages (terrace deposits and alluvium, undifferentiated)		
Silt, sandy, dark-tan	8	8
Silt, slightly sandy, tannish-gray	15	23
Silt and sand, fine to coarse	1	24
PENNSYLVANIAN		
Upper Pennsylvanian Series		
Missourian Stage—Kansas City Group		
Cherryvale(?) Shale		

18-23-2ccc.———Sample log of test hole in SW SW SW sec. 2, T 18 S, R 23 E; augered June 1961. Altitude of land surface, 836(T) feet; depth to water, 10.8 feet.

	Thickness, feet	Depth, feet
Soil	3	3
NEOGENE		
Pleistocene Series		
Wisconsinan and Recent stages (terrace deposits and alluvium, undifferentiated)		
Silt, sandy, light-brown	15	18
Sand, very fine to fine, very silty, orangish-tan; fine to coarse gravel in lower few feet	19	37
PENNSYLVANIAN		
Upper Pennsylvanian Series		
Missourian Stage—Kansas City Group		
Cherryvale(?) Shale		

18-23-3dcd.———Sample log of test hole in SE SW SE sec. 3, T 18 S, R 23 E; augered June 1961. Altitude of land surface, 831(T) feet; depth to water, 10.7 feet.

	Thickness, feet	*Depth, feet*
Soil	3	3
NEOGENE		
Pleistocene Series		
Recent Stage (alluvium)		
Silt, sandy, light-brown	25	28
Silt, sandy, tan	5	33
Silt, sandy, brown; with limestone, chert and quartz gravel in the lowermost 1.0 foot	6	39
PENNSYLVANIAN		
Upper Pennsylvanian Series		
Missourian Stage—Kansas City Group		
Cherryvale(?) Shale		

18-23-9dda.———Sample log of test hole in NE SE SE sec. 9, T 18 S, R 23 E augered June 1961. Altitude of land surface, 830(T) feet; depth to water, 5.8 feet.

	Thickness, feet	*Depth, feet*
NEOGENE		
Pleistocene Series		
Recent Stage (alluvium)		
Silt, sandy, brown	18	18
Silt, slightly sandy, brown; with carbonaceous specks in lower 17.0 feet	22	40
PENNSYLVANIAN		
Upper Pennsylvanian Series		
Missourian Stage—Kansas City Group		
Dennis Limestone		
Winterset Limestone Member		

18-23-10bab.———Sample log of test hole in NW NE NW sec. 10, T 18 S, R 23 E; augered June 1961. Altitude of land surface, 839(T) feet; depth to water, 16.0 feet.

	Thickness, feet	*Depth feet*
Soil	3	3
NEOGENE		
Pleistocene Series		
Wisconsinan and Recent stages (terrace deposits and alluvium, undifferentiated)		
Silt, sandy, yellowish-tan; with carbonaceous specks; very sandy in lower 5.0 feet	20	23
PENNSYLVANIAN		
Upper Pennsylvanian Series		
Missourian Stage—Kansas City Group		
Cherryvale(?) Shale		

18-23-12dcc.———Sample log of test hole in SW SW SE sec. 12, T 18 S, R 23 E; augered June 1961. Altitude of land surface, 833(T) feet; dry hole.

	Thickness, feet	*Depth feet*
NEOGENE		
Pleistocene Series		
Recent Stage [colluvium (slope deposits)]		
Silt, sandy, brown	4	4
Silt, dark-brown; chert and limestone gravel at base	1	5
PENNSYLVANIAN		
Upper Pennsylvanian Series		
Missourian Stage—Kansas City Group		
Hertha Limestone		

18-23-13bbb.———Sample log of test hole in NW NW NW sec. 13, T 18 S, R 23 E; augered June 1961. Altitude of land surface, 838(T) feet; depth to water, 8.7 feet.

	Thickness, feet	*Depth, feet*
Soil	4	4
NEOGENE		
Pleistocene Series		
Wisconsinan and Recent stages (terrace deposits and alluvium, undifferentiated)		
Silt, sandy, tan	5	5
Silt, sandy, yellowish-tan; with limestone gravel at base	10	19
PENNSYLVANIAN		
Upper Pennsylvanian Series		
Missourian Stage—Kansas City Group		
Hertha(?) Limestone		

18-23-14aab.———Sample log of test hole in NW NE NE sec. 14, T 18 S, R 23 E; augered June, 1961. Altitude of land surface, 831(T) feet; depth to water, 8.8 feet.

	Thickness, feet	*Depth, feet*
Soil	3	3
NEOGENE		
Pleistocene Series		
Recent Stage (alluvium)		
Silt, sandy, tan	3	6
Silt, sandy, brown	6	12
Silt, light-brown; with very fine, orange-tan sand streaks	6	18
Silt, dark-tan; some sand	20	38
Silt, sandy, tan	8	46
PENNSYLVANIAN		
Upper Pennsylvanian Series		
Missourian Stage—Kansas City Group		
Hertha(?) Limestone		

18-23-14abb.———Sample log of test hole in NW NW NE sec. 14, T 18 S, R 23 E; augered June 1961. Altitude of land surface, 836(T) feet; depth to water, 10.8 feet.

	Thickness, feet	*Depth, feet*
NEOGENE		
Pleistocene Series		
Recent Stage (alluvium)		
Silt, sandy, brown	3	3
Silt, grayish-brown; some fine sand	10	13
Silt, sandy, yellowish-tan; more coarse material in the lower 15.0 feet	20	33
PENNSYLVANIAN		
Upper Pennsylvanian Series		
Missourian Stage—Kansas City Group		
Hertha(?) Limestone		

18-23-16aab.———Sample log of test hole in NW NE NE sec. 16, T 18 S, R 23 E; augered June 1961. Altitude of land surface, 845(T) feet; depth to water, 7.7 feet.

	Thickness, feet	Depth, feet
Soil	3	3
NEOGENE		
Pleistocene Series		
Recent Stage (alluvium)		
Silt, sandy, light-yellowish-brown	3	6
Silt, sandy, yellowish-tan	9	15
Sand, very fine to very coarse, very silty, yellowish-tan	4	19
PENNSYLVANIAN		
Upper Pennsylvanian Series		
Missourian Stage—Kansas City Group		
Swope Limestone		
Bethany Falls(?) Limestone Member		

18-23-24adb.———Sample log of test hole in NW SE NE sec. 24, T 18 S, R 23 E; augered June 1961. Altitude of land surface, 831(T) feet; depth to water, 8.5 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Pleistocene Series		
Recent Stage (alluvium)		
Silt, sandy, tan; less sand and darker in lower 36.0 feet	54	54
PENNSYLVANIAN		
Upper Pennsylvanian Series		
Missourian Stage—Kansas City Group		
Ladore(?) Shale		
Shale, weathered, gray; sand and gravel at top	0.5	54.5

18-23-24bdb.———Sample log of test hole in NW SE NW sec. 24, T 18 S, R 23 E; augered June 1961. Altitude of land surface, 837(T) feet; depth to water, 8.1 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Pleistocene Series		
Wisconsinan and Recent stages (terrace deposits and alluvium, undifferentiated)		
Silt, sandy, brown	3	3
Silt and sand, very fine, yellowish-tan	20	23
Silt, very sandy; with abundant gravel	1	24
PENNSYLVANIAN		
Upper Pennsylvanian Series		
Missourian Stage—Kansas City Group		
Hertha(?) Limestone		

18-23-24cbc.———Sample log of test hole in SW NW SW sec. 24, T 18 S, R 23 E; augered June 1961. Altitude of land surface, 835(T) feet; depth to water, 7.6 feet.

	Thickness, feet	Depth, feet
Soil	3	3
NEOGENE		
Pleistocene Series		
Recent Stage (alluvium)		
Silt, sandy, dark-tan	5	8
Silt, sandy, tan; limestone gravel in the lower 2.0 feet	13	21
PENNSYLVANIAN		
Upper Pennsylvanian Series		
Missourian Stage—Kansas City Group		
Hertha(?) Limestone		

18-23-25bbb.———Sample log of test hole in NW NW NW sec. 25, T 18 S, R 23 E; augered June 1961. Altitude of land surface, 828(T) feet; depth to water, 15.8 feet.

	Thickness, feet	Depth, feet
Soil	3	3
NEOGENE		
Pleistocene Series		
Recent Stage (alluvium)		
Silt, sandy, tan	5	8
Silt, sandy, yellowish-tan	26	34
PENNSYLVANIAN		
Upper Pennsylvanian Series		
Missourian Stage—Kansas City Group		
Ladore(?) Shale		

18-23-36adb.———Sample log of test hole in NW SE NE sec. 36, T 18 S, R 23 E; augered June 1961. Altitude of land surface, 826(T) feet; depth to water, 3.6 feet.

	Thickness, feet	Depth, feet
Road fill	3	3
NEOGENE		
Pleistocene Series		
Wisconsinan and Recent stages (terrace deposits and alluvium, undifferentiated)		
Silt, sandy, tan; small fragments of white limestone	15	18
Silt, sandy, grayish-brown; some fine gravel, both limestone and chert	25	43
PENNSYLVANIAN		
Upper Pennsylvanian Series		
Missourian Stage—Kansas City Group		
Ladore Shale		
Shale, weathered, some limestone gravel	2	45
Shale, hard	..	..

18-24-30dcc.———Sample log of test hole in SW SW SE sec. 30, T 18 S, R 24 E; augered June 1961. Altitude of land surface, 822(T) feet; depth to water, 6.9 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Pleistocene Series		
Recent Stage (alluvium)		
Silt, sandy, tan	3	3
Silt, brown; some very fine sand	25	28
Silt, very sandy, light-brown; some limestone fragments in lower 4.0 feet	24	52
PENNSYLVANIAN		
Upper Pennsylvanian Series		
Missourian Stage—Pleasanton Group		

18-24-31bdb.———Sample log of test hole in NW SE NW sec. 31, T 18 S, R 24 E; augered June 1961. Altitude of land surface, 823(T) feet; depth to water, 5.8 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Pleistocene Series		
Wisconsinan and Recent stages (terrace deposits and alluvium, undifferentiated)		
Silt, sandy, tan	8	8
Silt, sandy, tan; with orange and gray streaks	10	18
Silt, sandy, clayey, grayish-tan; with some fine gravel	25	43
PENNSYLVANIAN		
Upper Pennsylvanian Series		
Missourian Stage—Pleasanton Group		

19-22-9ddd.———Drillers' log of water well in SE SE SE sec. 9, T 19 S, R 22 E; drilled by George H. Swank for Harold Weeks, Des Moines, Iowa, 1952. Depth to water, 34.4 feet.

	Thickness, feet	Depth, feet
Soil	2	2
NEOGENE		
Pleistocene Series, undifferentiated		
Clay	6	8
PENNSYLVANIAN		
Upper Pennsylvanian Series		
Missourian Stage—Kansas City Group		
Chanute Shale		
Sandstone, brown	14	22
Shale, blue	6	28
Coal	0.5	28.5
Shale, blue	3.5	32
Shale, light-gray	10	42
Drum Limestone		
Limestone, blue (water obtained at base of formation)	5	47
Cherryvale Shale	33	80

19-23-10cad.———Sample log of test hole in SE NE SW sec. 10, T 19 S, R 23 E; augered June 1961. Altitude of land surface, 824(T) feet; depth to water, 7.1 feet.

	Thickness, feet	Depth, feet
Road fill	3	3
NEOGENE		
Pleistocene Series		
Recent Stage (alluvium)		
Silt, sandy, dark-tan	30	33
PENNSYLVANIAN		
Upper Pennsylvanian Series		
Missourian Stage—Pleasanton Group		
Tacket Formation		
Shale, greenish-gray; with very fine to fine gravel at top	1	34

19-23-15abb.———Drillers' log of water well in NW NW NE sec. 15, T 19 S, R 23 E; drilled by Robert Brocaw, Fontana, Kansas, May 1960. Altitude of land surface, 873(T) feet; depth to water, 43.7 feet.

	Thickness, feet	Depth, feet
PENNSYLVANIAN		
Upper Pennsylvanian Series		
Missourian Stage—Kansas City Group		
Swope Limestone		
Limestone	32	32
Shale, black	2	34
Limestone, blue	2	36
Ladore Shale		
Shale, gray	5	41
Hertha Limestone		
Limestone, gray	6	47
Missourian Stage—Pleasanton Group		
Tacket Formation		
Shale, gray	5	52

19-24-6ccc.———Sample log of test hole in SW SW SW sec. 6, T 19 S, R 24 E; augered June 1961. Altitude of land surface, 821(T) feet; depth to water, 6.8 feet.

	Thickness, feet	Depth, feet
Soil	3	3
NEOGENE		
Pleistocene Series		
Recent Stage (alluvium)		
Silt, sandy, brownish-gray; lighter in color in the lower 15.0 feet	30	33
Silt, sandy, yellowish-tan	6	39
PENNSYLVANIAN		
Upper Pennsylvanian Series		
Missourian Stage—Pleasanton Group		
Tacket Formation		
Shale, gray	1	40

19-24-10cdd.———Sample log of test hole in SE SE SW sec. 10, T 19 S, R 24 E; augered June 1961. Altitude of land surface, 821(T) feet; depth to water, 4.7 feet.

	Thickness, feet	Depth, feet
Road fill	3	3
NEOGENE		
Pleistocene Series		
Recent Stage (alluvium)		
Silt, sandy, brown; gypsum blades in lower 5.0 feet	15	18
PENNSYLVANIAN		
Upper Pennsylvanian Series		
Missourian Stage—Pleasanton Group		
Tacket Formation		
Shale, weathered, gray	8	26

19-24-14cbb.———Sample log of test hole in NW NW SW sec. 14, T 19 S, R 24 E; augered June 1961. Altitude of land surface, 823(T) feet; depth to water, 5.3 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Pleistocene Series		
Recent Stage (alluvium)		
Silt, clayey, tan	3	3
Silt, slightly sandy, yellowish-tan	5	8
Silt, sandy, tan	15	23
Silt, slightly sandy, grayish-tan	6	29
PENNSYLVANIAN		
Upper Pennsylvanian Series		
Missourian Stage—Pleasanton Group		
Tacket Formation		
Shale, gray	1	30

19-25-9ccc.———Sample log of test hole in SW SW SW sec. 9, T 19 S, R 25 E; augered June 1961. Altitude of land surface, 853(T) feet; depth to water, 6.0 feet.

	Thickness, feet	Depth, feet
NEOGENE		
Pleistocene Series		
Recent Stage (alluvium)		
Silt, sandy, gray	3	3
Silt, sandy, tan	23	26
PENNSYLVANIAN		
Upper Pennsylvanian Series		
Missourian Stage—Pleasanton Group		
Tacket Formation		

19-25-16bab.———Sample log of test hole in NW NE NW sec. 16, T 19 S, R 25 E; augered June 1961. Altitude of land surface, 843(T) feet; depth to water, 7.8 feet.

	Thickness, feet	Depth, feet
Soil	3	3
NEOGENE		
Pleistocene Series		
Recent Stage (alluvium)		
Silt, light-brown; some very fine to medium sand in the lower 10.0 feet	20	23
PENNSYLVANIAN		
Upper Pennsylvanian Series		
Missourian Stage—Pleasanton Group		
Tacket Formation		
Shale, gray to grayish-tan	1	24

19-25-16bcb.———Sample log of test hole in NW SW NW sec. 16, T 19 S, R 25 E; augered June 1961. Altitude of land surface, 840(T) feet; depth to water, 14.4 feet.

	Thickness, feet	Depth, feet
Soil	3	3
NEOGENE		
Pleistocene Series		
Recent Stage (alluvium)		
Silt, dark-tan	15	18
Silt, grayish-tan	14	32
PENNSYLVANIAN		
Upper Pennsylvanian Series		
Missourian Stage—Pleasanton Group		
Tacket Formation		

MEASURED SECTIONS

The following measured sections are arranged by geographic location. The color terminology used in the descriptions was determined with the aid of the Rock-Color Chart (Geological Society of America, 1951), which uses the Munsell system of dividing all colors into three basic components: hue, value, and chroma. The symbol (5Y7/2), for example, indicates a color in the middle of the yellow range of high value (almost white) and low chroma (pale, approaching gray). The corresponding name of this symbol is yellowish-gray. Shades of gray are indicated by the symbol *N* followed by the value. Additional measured sections for the County are available for examination in the open files of the State Geological Survey of Kansas and the Ground-Water Branch, U.S. Geological Survey, in Lawrence, Kansas.

Locality 2. SW NW NW sec. 21, T 15 S, R 22 E.

	Thickness, feet
PLATTSBURG LIMESTONE	
SPRING HILL LIMESTONE MEMBER	
Limestone, coarse-grained, thick-bedded, light brownish-gray (5YR6/1); fusulinids, corals, and a few productid brachiopods	13.2
BONNER SPRINGS SHALE	
Shale, sandy, blocky-bedded, olive-gray (5Y6.5/1)	11.0
Sandstone, medium-grained, limy, micaceous, light olive-gray (5Y6/1); small brachiopods; scattered carbonaceous specks	5.9
Covered	11.3
Total Bonner Springs Shale measured	28.2
WYANDOTTE LIMESTONE	
Limestone, fine- to coarse-grained, thick-bedded, light brownish-gray (5YR6/1); large brachiopods and algae; lower part covered	13.6

Locality 3. SE SE sec. 26, T 15 S, R 22 E.

	Thickness, feet
PLATTSBURG LIMESTONE	
SPRING HILL LIMESTONE MEMBER	
Limestone, medium-grained, thin-bedded, pale yellowish-brown (10YR6/2); algae, *Composita*, and crinoid fragments	4.0+
BONNER SPRINGS SHALE	
Shale, clayey, blocky, light grayish-olive (10Y5/2); partly covered	17.4
WYANDOTTE LIMESTONE	
ARGENTINE LIMESTONE MEMBER	
Limestone, fine- to coarse-grained, silty, medium-bedded, grayish-orange-pink (5-YR7/2) to dark yellowish-gray (5Y7/1); very badly fractured; some hematite, abundant large crystals of calcite	7.2

	Thickness, feet
FRISBIE LIMESTONE MEMBER	
Limestone, fine- to medium-grained, thin- to medium-bedded, light brownish-gray (5YR6/1) to light olive-gray (5Y6/1)	3.0
Total Wyandotte Limestone measured	10.2
LANE SHALE	
Shale, clayey, blocky, medium light-gray (N6) with moderate reddish-brown (10-R4/6) spots; carbonaceous impressions; partly covered	19.2
Siltstone, very thin-bedded, moderate olive-brown (5Y4/4) to dusky-yellow (5Y-6/4); plant impressions	8.9
Sandstone, fine- to very fine-grained, medium- to thick-bedded, very dark yellowish-orange (10YR5/6); plant impressions	4.2
Siltstone and shale, very thin-bedded, moderate olive-brown (5Y4/4) to dusky-yellow (5Y6/4); plant impressions	10.6
Covered	39.0
Total Lane Shale measured	81.9

Locality 4. NE NW sec. 27, T 15 S, R 22 E, quarry exposure.

	Thickness, feet
PLATTSBURG LIMESTONE	
SPRING HILL LIMESTONE MEMBER	
Limestone, conglomeratic, thin- to medium-bedded, pale yellowish-brown (10YR6/2); many limonite, calcite, shale and ironstone fragments; some small brachiopods and gastropods	2.1
Limestone, fine- to coarse-grained, thin- to medium-bedded, very pale brown (5YR6/2); very fractured with calcite fillings; brachiopods, crinoids, bryozoans and *Osagia*	13.3
Limestone, medium-grained, medium-bedded, grayish-orange-pink (5YR7/2)	3.0
Total Spring Hill Limestone Member measured	18.4
BONNER SPRINGS SHALE	
Shale, clayey, blocky, mottled, moderate yellowish-brown (10YR5/4) to moderate reddish-brown; partly covered	15.6
Covered	17.4
Total Bonner Springs Shale measured	33.0

Locality 9. SW SW NW sec. 25, T 16 S, R 21 E.

	Thickness, feet
PLATTSBURG LIMESTONE	
SPRING HILL LIMESTONE MEMBER	
Limestone, medium-grained, bedding thin and irregular, pale yellowish-brown (10YR6/2); badly fractured, algal, with crinoid remains; poorly exposed	2.1
HICKORY CREEK SHALE MEMBER	
Shale, silty, moderate yellowish-brown (10YR5/4) to dark yellowish-orange (10YR6/6); 0.1-foot bed of soft limestone in middle of shale	1.2
MERRIAM LIMESTONE MEMBER	
Limestone, fine-grained, massive yellowish-gray (5Y8/1); algal, with *Phricodothyris* and echinoid spines	1.0
Total Plattsburg Limestone measured	4.3
BONNER SPRINGS SHALE	
Shale, blocky, light olive-gray (5Y5/2)	5.5
Limestone(?), shaly, nodular, dark yellowish-orange (10YR6/6) to dark yellowish-brown (10YR4/2)	.7
Shale, silty, blocky, grayish-red (5R4/2)	2.8
Shale, silty, blocky, dark greenish-gray (5GY4/1)	2.0+
Total Bonner Springs Shale measured	11.0

Locality 10. SW SW sec. 26 and SE SE sec. 27, T 16 S, R 22 E.

	Thickness, feet
VILAS SHALE	
Covered	6.0+
PLATTSBURG LIMESTONE	
SPRING HILL LIMESTONE MEMBER	
Limestone, medium- to coarse-grained, oölitic at top, thin- to thick-bedded, light-gray (N7) to yellowish-gray (5Y8/1); cherty, with fusulinids and brachiopods *(Composita?)*	13.7
HICKORY CREEK SHALE MEMBER	
Shale, silty, blocky, grayish-orange (10-YR7/4)	1.0
MERRIAM LIMESTONE MEMBER	
Limestone, fine-grained, thin- to medium-bedded, light olive-gray (5Y6/1); *Osagia?*	5.1
Total Plattsburg Limestone measured	19.8
BONNER SPRINGS SHALE	
Shale, clayey, greenish-gray (5GY6/1); small brachiopods and bryozoan fragments	5.5
WYANDOTTE LIMESTONE	
ARGENTINE LIMESTONE MEMBER	
Limestone, coarse-grained, thin-bedded, light olive-gray (5Y6/1); large productids and crinoid remains	12.7
FRISBIE LIMESTONE MEMBER	
Limestone, medium-grained, massive, light olive-gray (5Y6/1) to medium light-gray (N6)	3.1
Total Wyandotte Limestone measured	15.8
LANE SHALE	
Shale, sandy, blocky, light-gray (N7) to light olive-gray (5Y6/1); several thin siltstone streaks, lower part covered	10.0+

Locality 12. SE sec. 7 and SW sec. 8, T 16 S, R 23 E; composite road cut and quarry exposure.

	Thickness, feet
PLATTSBURG LIMESTONE	
SPRING HILL LIMESTONE MEMBER	
Limestone, medium- to coarse-grained, thin- to medium-bedded, pale yellowish-brown (10YR6/2); fusulinids and *Enteletes*	4.0
HICKORY CREEK SHALE MEMBER	
Shale, flaky, grayish-orange (10YR7/4)	1.0
MERRIAM LIMESTONE MEMBER	
Limestone, fine-grained, thick-bedded and massive, yellowish-gray (5Y7/2) to light brownish-gray (5YR6/1); *Osagia?*	2.1
Total Plattsburg Limestone	7.1
BONNER SPRINGS SHALE	
Shale, blocky-bedded, moderate yellowish-brown (10YR5/4), dusky-red (5R3/4) at base	6.2
Siltstone, thin-bedded, grayish-orange (10-YR7/4); plant remains	5.1
Total Bonner Springs Shale measured	11.3
WYANDOTTE LIMESTONE	
ARGENTINE LIMESTONE MEMBER	
Limestone, fine-grained, thin-bedded at bottom, remainder thick-bedded, pale olive-gray (5Y7/1); some chert; large *Linoproductus*, crinoid remains, and algae.	15.8
LANE SHALE	
Shale and siltstone, sandy, blocky to massive, micaceous	108.6
IOLA LIMESTONE	
RAYTOWN LIMESTONE MEMBER	
Limestone, medium-grained, medium- and even-bedded, grayish-orange-pink (5-YR7/2); algal; very fossiliferous	10.3
MUNCIE CREEK SHALE MEMBER	
Shale, silty, flaky, dusky-yellow (5Y6/4); phosphatic nodules	.7
PAOLA LIMESTONE MEMBER	
Limestone, fine-grained, thick-bedded and massive, light brownish-gray (5YR6/1); algal	2.4
Total Iola Limestone measured	13.4
CHANUTE SHALE	

Locality 13. SE SE NW sec. 22, T 16 S, R 23 E.

	Thickness, feet
LANE SHALE	
Shale, poorly exposed	4.0+
IOLA LIMESTONE	
RAYTOWN LIMESTONE MEMBER	
Limestone, fine- to medium-grained, thin- to medium-bedded, light olive-gray (5Y6/1); small shale partings throughout, limonite specks; algal; crinoid remains, gastropods and abundant brachiopods	7.0
MUNCIE CREEK SHALE MEMBER	
Shale, silty, flaky, olive-gray (5Y4/1); some limonite, small white phosphate nodules; many small fossils	.4
PAOLA LIMESTONE MEMBER	
Limestone, fine-grained, thick-bedded and massive, light olive-gray (5Y6/1) to light brownish-gray (5YR6/1), weathers to a dusky yellow (5Y6/4); top is very hummocky; limonite specks, algal; with *Chonetes*	2.4
Total Iola Limestone measured	9.8
CHANUTE SHALE	
Shale, clayey, blocky, upper 2.5 feet is soft, limonitic, greenish-gray (5G6/1), lower 3.3 feet is hard, dark-gray (N3) with disseminated limonite, coal fragments	5.8+

Locality 17. SE NE NW sec. 30, T 16 S, R 24 E, quarry exposure.

	Thickness, feet
PLATTSBURG LIMESTONE	
SPRING HILL LIMESTONE MEMBER	
Limestone, coarse-grained, medium-bedded, yellowish-gray (5Y8/1), weathers moderate yellowish-brown (10YR5/4); abundant hematite and crystalline calcite; fusulinids, brachiopods, algae, and *Enteletes*	9.1
HICKORY CREEK SHALE MEMBER? (covered)	2.0
MERRIAM LIMESTONE MEMBER	
Limestone, medium-grained, massive, soft, medium light-gray (N6); band of black chert 1.7 feet from base; bryozoans and fossil fragments in the chert	3.6
Total Plattsburg Limestone measured	14.7
BONNER SPRINGS SHALE	
Shale, flaky to blocky, hard, light-gray (N7)	.9
WYANDOTTE LIMESTONE	
FARLEY AND ARGENTINE LIMESTONE MEMBERS, UNDIFFERENTIATED	
Limestone, medium-grained, thick-bedded, massive, yellowish-gray (5Y8/1); some algae	14.7
Limestone, medium- to coarse-grained, thin- to medium-bedded, yellowish-gray (5-Y7/2) to dark olive-gray (5Y4/1); productids and spirifers (base covered)	6.3
Total Wyandotte Limestone measured	21.0

Locality 23. SE SE SW sec. 35, T 17 S, R 22 E.

	Thickness, feet
IOLA LIMESTONE	
RAYTOWN LIMESTONE MEMBER	
Limestone, fine- to medium-grained, medium-bedded, very pale yellowish-brown (10YR7/2); *Echinaria*	5.4
MUNCIE CREEK SHALE MEMBER	
Shale, flaky, very pale yellowish-brown (10YR7/2)	.5
PAOLA LIMESTONE MEMBER	
Limestone, very fine-grained, thick-bedded and massive, light olive-gray (5Y5/2); hacky fracture, small brachiopods	2.4
Total Iola Limestone measured	8.3
CHANUTE SHALE	
Shale, sandy, blocky-bedded, olive-gray (5Y5/2)	3.4
Coal	.4
Underclay, gypsum	.2
Shale, clayey, blocky-bedded, medium-dark-gray (N4)	11.2
Total Chanute Shale measured	15.2

	Thickness, feet
DRUM LIMESTONE	
Limestone, fine- to medium-grained, thick-bedded and massive, yellowish-gray (5Y7/2); abundant crinoid stems	2.7
CHERRYVALE SHALE	
WEA AND QUIVERA SHALE MEMBERS, UNDIFFERENTIATED	
Shale, clayey, blocky to papery, greenish-gray (5GY6/1) with grayish-red (5R4/2) and light olive-gray (5Y5/1) streaks, lower 2.0 feet is medium gray (N5); plant impressions, base covered	8.6

Locality 24. SW cor. sec. 6 and NW cor. sec. 7, T 17 S, R 23 E.

	Thickness, feet
WYANDOTTE LIMESTONE	
FARLEY AND ARGENTINE LIMESTONE MEMBERS	
Limestone, fine-grained, dense, medium-bedded, light-olive-gray (5Y6/1); limonite specks, partly covered	12.9
LANE SHALE	
Shale, sandy, clayey, brownish-orange (10YR6/4); thin siltstone beds scattered throughout, partly covered	39.9
IOLA LIMESTONE	
PAOLA AND RAYTOWN LIMESTONE MEMBERS, UNDIFFERENTIATED	
Limestone, medium- to coarse-grained, dense, medium-bedded, light olive-gray (5Y6/1), red specks at bottom; upper part fine-grained, yellowish-gray (5Y-8/1), partly covered	5.7
CHANUTE SHALE	
Shale, silty, blocky-bedded, light-gray (N7), weathers with a reddish stain, small black specks, lower part covered	5.3
Sandstone, very fine to fine-grained, medium-bedded, dark yellowish-gray (5Y-6/2)	1.0
Sandstone, fine- to medium-grained, thin-bedded, yellowish-gray (5Y6/2)	1.2
Sandstone, very fine to fine-grained, thick-bedded and massive, dusky-yellow (5Y-6/4); micaceous	1.9
Sandstone, fine-grained, pale yellowish-brown (10YR6/2)	.8
Sandstone, fine-grained, very thin-bedded, moderate yellowish-brown (10YR5/4); each layer is separated by films of carbonaceous material	3.3
Total Chanute Shale measured	13.5
DRUM LIMESTONE	
Limestone, fine-grained, sandy, hard, medium-light-gray (N6); some mica near upper contact, lower part covered	1.0

Locality 25. SE SE SE sec. 7, T 17 S, R 23 E, quarry exposure.

	Thickness, feet
IOLA LIMESTONE	
RAYTOWN LIMESTONE MEMBER	
Limestone, coarse-grained, yellowish-gray (5Y7/2); sparsely fossiliferous	0.8
Shale, flaky, dark yellowish-orange (10YR6/6)	.9
Limestone, coarse-grained, yellowish-gray (5Y7/2)	.7
Shale, flaky, dark yellowish-orange (10-YR6/6)	.6
Limestone, coarse-grained, yellowish-gray (5Y7/2)	.7
Shale, flaky, yellowish-gray (5Y7/2) to grayish-yellow (5Y8/4); calcareous, numerous horn corals	3.8
Limestone, fine-grained, hard, very dense, medium-bedded, medium-olive-gray (5-Y5/1); algal with *Antiquatonia, Derbyia,* and *Dielasma*	4.3
Limestone, fine-grained, thin- to medium-bedded, dark-yellowish-gray (5Y7/1)	1.9
Limestone, fine-grained, thick-bedded, dark-yellowish-gray (5Y7/1); beds are lens-shaped	2.1
Limestone, fine-grained, medium-bedded, very light-gray (N8); numerous shale partings, algal	7.8
Limestone, silty, soft, light-gray to medium-light-gray (N6.5); composed mostly of fossil fragments	.5
Total Raytown Limestone Member measured	24.1
MUNCIE CREEK SHALE MEMBER	
Shale, hard and fissile, dark-gray (N3); sparse phosphatic nodules in upper part, abundant pyrite particles, *Lingula* and some worm trails?	.5
PAOLA LIMESTONE MEMBER	
Limestone, fine-grained, medium-olive-gray (5Y5/1); top contact hummocky, lower part covered	1.5
Total Iola Limestone measured	26.1

Locality 28. SE sec. 20, T 17 S, R 23 E, along north-south road.

	Thickness, feet
IOLA LIMESTONE	
Limestone, covered, rubble at surface	
CHANUTE SHALE	
Shale, silty, blocky-bedded, dusky-yellow (5Y6/4), weathers to dark grayish-yellow (5Y7/4); partly covered	28.7
DRUM LIMESTONE	
Limestone, fine-grained, dense, medium-bedded, yellowish-gray (5Y7/2), weathers moderate yellowish brown (10YR-5/4); abundant crinoid stems	2.7
CHERRYVALE SHALE	
QUIVIRA SHALE MEMBER	
Shale, silty, blocky-bedded, dusky-yellow (5Y6/4); many thin dark yellowish-orange (10YR6/6) siltstone streaks	25.5
WESTERVILLE LIMESTONE MEMBER	
Limestone, fine-grained, hard, dense, light olive-gray (5Y5/2), weathers grayish yellow (5Y8/4); crinoid fragments	.6
WEA SHALE MEMBER	
Shale, silty, blocky-bedded, dusky-yellow (5Y6/4)	5.7
Total Cherryvale Shale measured	31.8

Locality 30. SE SW SW sec. 31, T 17 S, R 23 E.

	Thickness, feet
IOLA LIMESTONE	
RAYTOWN LIMESTONE MEMBER	
Limestone, fine- to medium-grained, dense, medium-bedded, light-olive-gray (5Y-6/1) to yellowish-gray (5Y7/2); abundant calcite crystals, algal in lower part, gastropods and small brachiopods	10.7
CHANUTE SHALE	
Shale, clayey, grayish-orange (10YR7/4); mostly covered	32.7
DRUM LIMESTONE	
Limestone, coarse-grained, thin-bedded, flaggy, light olive-gray (5Y6/1); very fossiliferous	1.2
Shale, calcareous, light olive-gray (5Y6/1); limestone streaks with crinoid stems	.5
Limestone, fine-grained, dense, hard, thick-bedded and massive, light brownish-gray (5YR6/1), weathers moderate-brown (5YR4/4); abundant crinoid stems	2.3
Total Drum Limestone measured	4.0

Locality 31. SE NW NW to SW SE NW sec. 1, T 17 S, R 24 E.

	Thickness, feet
WYANDOTTE LIMESTONE	
ARGENTINE LIMESTONE MEMBER	
Limestone, medium- to coarse-grained, thin- to medium-bedded, light-olive-gray (5Y6/1); very cherty in upper 2.6 feet, fusulinids, brachiopods and crinoid stems, upper part covered	5.7
LANE SHALE	
Shale, silty, blocky-bedded, grayish-orange (10YR7/4) to light-bluish-gray (5B7/1)	50.3
IOLA LIMESTONE	
RAYTOWN LIMESTONE MEMBER	
Limestone, fine- to medium-grained, medium-bedded, light-olive-gray (5Y6/1); algal	7.7
MUNCIE CREEK SHALE MEMBER	
Shale, silty, flaky, dusky-yellow (5Y6/4); phosphatic nodules	.35
PAOLA LIMESTONE MEMBER	
Limestone, fine-grained, thick-bedded and massive, medium-yellowish-brown (10-YR5/2); worm borings?, brachiopods	2.7
Total Iola Limestone measured	10.75
CHANUTE SHALE	
Covered	12.0

Locality 32. SE SE SE sec. 5, T 17 S, R 24 E.

	Thickness, feet
WYANDOTTE LIMESTONE	
FARLEY AND ARGENTINE LIMESTONE MEMBERS, UNDIFFERENTIATED	
Limestone, fine- to medium-grained, thick-bedded, light olive-gray (5Y6/1); fractures filled with calcite, cherty, has *Enteletes* and algae	8.5
Limestone, fine- to medium-grained, thin- and wavy-bedded, very light olive-gray (5Y7/1), cherty, *Antiquatonia*	5.5
Limestone, medium-grained, thick-bedded, yellowish-gray (5Y8/1); cherty, *Antiquatonia*	7.3
Total Wyandotte Limestone measured	21.3
LANE SHALE	
Shale, clayey, blocky-bedded in upper part to fissile in lower part, olive-gray (5Y-3/2) to dark-gray (N3); some siltstone, limonite streaks	20.1

Locality 33. NW SW NW sec. 16, T 17 S, R 24 E.

	Thickness, feet
IOLA LIMESTONE	
PAOLA LIMESTONE MEMBER	
Limestone, fine-grained, medium-bedded, yellowish-gray (5Y7/2); algal, partly covered	2.3+
CHANUTE SHALE	
Shale, clayey, blocky-bedded, light olive-gray (5Y5/2); abundant plant remains	4.1
Sandstone, fine-grained, massive; dark-yellowish-orange (10YR6/6), weathers moderate yellowish brown (10YR5/4); plant remains	11.1
Shale, clayey, blocky-bedded, medium-gray (N5)	2.0
Coal, black (N1), with medium-olive-gray (5Y5/1) underclay	.4
Shale, silty, blocky-bedded, light olive-gray (5Y5/2) to dusky-yellow (5Y6/4); calcareous nodules in lower 5.0 feet	11.2
Total Chanute Shale measured	28.8
DRUM LIMESTONE	
Limestone, fine-grained, massive, light olive-gray, weathers moderate reddish brown (10R4/6); gastropods, crinoid stems	3.1
CHERRYVALE SHALE	
QUIVIRA SHALE MEMBER	
Shale, clayey, blocky-bedded, upper 2 feet grayish-black (N2) with moderate greenish-yellow (10Y7/4) spots, remainder is pale olive (10Y6/2); plant remains	16.1
WESTERVILLE LIMESTONE MEMBER	
Limestone, coarse-grained, medium- to thick-bedded, yellowish-gray (5Y7/2); crinoid stems, weathered very deeply	1.1
WEA SHALE MEMBER	
Shale, silty, blocky-bedded, moderate-yellowish-brown (10YR5/4) to light olive-gray (5Y5/2)	19.4
Covered	10.0
Total Cherryvale Shale measured	46.6

Locality 34. SW SW SW sec. 29 and SE SE SE sec. 30, T 17 S, R 24 E.

	Thickness, feet
WYANDOTTE LIMESTONE	
ARGENTINE LIMESTONE MEMBER	
Limestone, medium-grained, soft, medium-bedded, very light-gray (N8) to grayish-orange-pink (5YR7/2); crinoid stems	5.1

	Thickness, feet
LANE SHALE	
Shale, sandy, flaky- to blocky-bedded, pale olive (10Y6/2)	24.1
IOLA LIMESTONE	
RAYTOWN LIMESTONE MEMBER	
Limestone, medium to coarse, medium-bedded, light olive-gray (5Y6/1); large productids and algae	5.1
MUNCIE CREEK SHALE MEMBER	
Shale, flaky, dusky-yellow (5Y6/4); phosphatic nodules	.2
PAOLA LIMESTONE MEMBER	
Limestone, fine-grained, thick-bedded and massive, medium-light-gray (N6); top surface hummocky, algal	2.1
Total Iola Limestone measured	7.4
CHANUTE SHALE	
Shale, sandy, blocky- to flaky-bedded, greenish-gray (5GY6/1)	37.4
DRUM LIMESTONE	
Limestone, coarse-grained, light brownish-gray (5YR6/1); abundant crinoid stems, base covered	2.0

Locality 35. SW SW SW sec. 5, T 17 S, R 25 E.

	Thickness, feet
WYANDOTTE LIMESTONE	
ARGENTINE LIMESTONE MEMBER	
Limestone, medium- to coarse-grained, thin-bedded in upper 5.0 feet, lower 2.0 feet is thick bedded, light olive-gray (5Y6/1), cherty, *Antiquatonia* and other small brachiopods, sparse fusulinids	7.0
QUINDARO SHALE MEMBER	
Shale, sandy, upper third is dark yellowish-orange (10YR6/6), middle third is dark gray (N3), lower third is grayish-olive (10Y4/2); upper half has abundant crinoid stems, bryozoans, spirifers and other small brachiopods, *Heliospongia?*	3.3
FRISBIE LIMESTONE MEMBER	
Limestone, fine-grained, medium-bedded, medium (N5) to dark yellowish-gray (5Y6/2), 0.2-foot shale parting 0.5 foot from base of limestone, crinoid stems and small brachiopods	1.7
Total Wyandotte Limestone measured	12.0
LANE SHALE	
Shale, silty, blocky-bedded, medium-light-gray (N6) to medium-gray (N5); partly covered	65.7

Locality 36. SW SE SW sec. 17, T 17 S, R 25 E, quarry exposure.

	Thickness, feet
WYANDOTTE LIMESTONE	
FARLEY-ARGENTINE LIMESTONE MEMBER	
Limestone, medium-grained with abundant large calcite crystals, thin- to medium-bedding, yellowish-gray (5Y7/2), weathers dusky yellow (5Y6/4; very large chert nodules throughout, 0.6 to 1.0 foot in diameter	28.4
Covered	4.0
FRISBIE LIMESTONE MEMBER	
Limestone, fine-grained, thick-bedded and massive, light-olive-gray (5Y5/2); *Enteletes, Linoproductus,* bryozoans, and a few fusulinids	2.6
Total Wyandotte Limestone measured	35.0
LANE SHALE	
Shale, clayey, light olive-gray (5Y5/2); scattered limestone stringers, base not exposed	3.0

Locality 40. SW NW sec. 17, T 18 S, R 22 E.

	Thickness, feet
LANE SHALE	
Covered	6.0+
IOLA LIMESTONE	
RAYTOWN LIMESTONE MEMBER	
Limestone, medium- to coarse-grained, thick-bedded, light-gray (N7) to yellowish-gray (5Y8/1); weathers into angular blocks, some spirifers and *Echinaria*	12.2
MUNCIE CREEK SHALE MEMBER	
Shale, silty, flaky, yellowish-gray (5Y7/2); phosphatic nodules	.2
PAOLA LIMESTONE MEMBER	
Limestone, fine-grained, thick-bedded and massive, medium-gray (N5); top hummocky, contains worm borings; *Heterocoelia?*	2.1
Total Iola Limestone measured	14.5
CHANUTE SHALE	
Shale, sandy, blocky-bedded, light grayish-olive (10Y5/2) with reddish-brown (10-R4/4) streaks; a few plant impressions, mostly covered	10.0

Locality 44. SW SW NE sec. 12, T 18 S, R 23 E, quarry exposure.

	Thickness, feet
CHERRYVALE SHALE	
FONTANA SHALE MEMBER	
Covered	4.0+
DENNIS LIMESTONE	
WINTERSET LIMESTONE MEMBER	
Limestone, fine- to medium-grained, thin- to medium-bedded and wavy, medium-light-gray (N6) to medium-olive-gray (5Y5/1); weather medium yellowish orange (10YR7/6); abundant fusulinids, *Antiquatonia, Linoproductus,* bryozoans, and crinoid remains; some dark-gray oölitic (N3) chert	5.3
Shale, clayey, blocky-bedded to fisssile, olive-gray (5Y4/1) to dark-gray (N3)	1.1
Limestone, fine- to medium-grained, thick-bedded and massive, medium-light-gray (N6); dark-gray oölitic (N3) chert; bryozoans and crinoid stems	2.8
Shale, clayey, blocky-bedded, olive-black (5Y2/1)	1.5
Limestone, fine- to medium-grained, medium- to thick-bedded, light-gray (N7); algal, *Derbyia*	4.6
Shale, silty, thinly laminated, olive-gray (5Y4/1)	.6

	Thickness, feet
Limestone, coarse-grained, thick-bedded, light-gray (N7); abundant calcite crystals and some oölites; crinoids and *Neospirifer sp.*	10.6
Covered	3.0
Limestone, medium- to coarse-grained, wavy-bedded, medium-light-gray (N6); marly, very fossiliferous	.6
STARK SHALE MEMBER	
Shale, blocky-bedded, dark greenish-gray (5GY4/1); *Chonetes, Myalina,* base covered	1.3
Total Dennis Limestone measured	31.4

Locality 47. NW NW NE sec. 19, T 18 S, R 24 E.

	Thickness, feet
DENNIS LIMESTONE	
WINTERSET LIMESTONE MEMBER	
Limestone, medium- to coarse-grained, thin- to medium-bedded, light-gray (N7) to light olive-gray (5Y6/1); oölitic, cherty; bryozoans and *Triticites?* partly covered	29.7
STARK SHALE MEMBER	
Shale, top half is sandy, blocky-bedded, greenish-gray (5GY6/1), bottom half is hard, fissile, grayish-black (N2)	6.0
Limestone, marly, light olive-gray (5Y6/1), remnant of Canville? Limestone Member of Dennis Limestone	.2
Total Dennis Limestone measured	35.9
GALESBURG SHALE	
Shale, sandy, blocky-bedded, greenish-gray (5GY6/1); *Chonetes*	5.1
SWOPE LIMESTONE	
BETHANY FALLS LIMESTONE MEMBER	
Limestone, medium- to coarse-grained, dense, uneven, thin- to thick-bedded, light olive-gray (5Y6/1) to light-gray (N7); chert in the upper part; crinoid stems, bryozoans, and *Derbyia*	15.1
HUSHPUCKNEY SHALE MEMBER	
Shale, top half is sandy, blocky-bedded, light olive-gray (5Y6/1), lower half is black (N1), fissile	5.5
MIDDLE CREEK LIMESTONE MEMBER	
Limestone, fine-grained, thick-bedded and massive, moderate bluish-gray (5B5/1); *Chonetes* and *Derbyia*	1.4
Total Swope Limestone measured	22.0
LADORE SHALE	
Shale, clayey, blocky-bedded, medium-gray (N5) and light olive-gray (5Y6/1); *Chonetes* and *Derbyia*; partly covered	11.4
HERTHA LIMESTONE	
Limestone, coarse-grained, thick-bedded and massive, medium-olive-gray (5Y5/1); crinoid stems and a few bellerophontid gastropods; base covered	4.2

Locality 48. NW NE NW sec. 27, T 18 S, R 24 E, stream bank exposure.

	Thickness, feet
DENNIS LIMESTONE	
WINTERSET LIMESTONE MEMBER	
Limestone, fine- to medium-grained, thin- to medium-bedded and uneven, medium-gray (N5); cherty and oölitic, *Composita* and *Derbyia*	6.4
Limestone, fine-grained, thin-bedded and uneven, light-gray (N7); chert in lower 5.0 feet; algal, with crinoid remains and *Dielasma*	10.5
Limestone, medium-grained, thick and unevenly bedded, light-gray (N7); algal with abundant productid brachiopods	11.3
Covered, some black (N1) shale fragments	9.2
Total Dennis Limestone measured	37.4
SWOPE LIMESTONE	
BETHANY FALLS LIMESTONE MEMBER	
Limestone, coarse-grained, massive, light olive-gray (5Y6/1); very oölitic and crossbedded	4.7
Limestone, coarse-grained, thin-bedded, medium-light-gray (N6); shale partings, *Antiquatonia*	6.1
Limestone, medium- to coarse-grained, medium- to thick-bedded and uneven, light-gray (N7) to light-olive-grey (5Y-6/1); shale partings, cherty, worm borings?, crinoid stems and *Chonetes*	8.5
HUSHPUCKNEY SHALE MEMBER	
Shale, hard, fissile, black (N1); some fish scales?, base covered	3.0
Total Swope Limestone measured	22.3

Locality 50. NE SE sec. 34, T 18 S, R 24 E, composite stream bank exposure and quarry exposure.

	Thickness, feet
DENNIS LIMESTONE	
WINTERSET LIMESTONE MEMBER	
Limestone, coarse-grained, thick-bedded, light olive-gray (5Y6/1); some oölites; algae, crinoid stems, and *Composita*	5.2
STARK SHALE MEMBER	
Shale, silty, blocky-bedded, medium-olive-gray (5Y4/2) with abundant fossils in upper half, hard, fissile, black (N1) in lower half	3.4
Total Dennis Limestone measured	8.6
GALESBURG SHALE	
Covered	5.0
SWOPE LIMESTONE	
BETHANY FALLS LIMESTONE MEMBER	
Covered	6.8
Limestone, medium- to coarse-grained, medium- to thick-bedded, light olive-gray (5Y6/1) to light-gray (N7); bryozoans, crinoid stems, partly covered	13.2
HUSHPUCKNEY SHALE MEMBER	
Shale, upper part is clayey, blocky-bedded, olive-gray (5Y4/1) and lower part is fissile, black (N1); middle portion covered	4.7
MIDDLE CREEK LIMESTONE MEMBER	
Limestone, fine-grained, massive, medium-dark-gray (N4); algal	1.8
Total Swope Limestone measured	26.5

	Thickness, feet
LADORE SHALE	
Covered	4.6
HERTHA LIMESTONE	
Limestone, medium- to coarse-grained, thin- to medium-bedded, olive-gray (5Y4/1) to light-gray (N7); crinoid stems; base covered	5.1

Locality 57. NE SE SE sec. 10, T 19 S, R 24 E.

	Thickness, feet
SWOPE LIMESTONE	
BETHANY FALLS LIMESTONE MEMBER	
Limestone, medium-grained, medium-bedded, very light-brownish-gray (5YR-7/1); cherty, mostly covered	19.7
HUSHPUCKNEY SHALE MEMBER	
Covered	5.1
Shale, fissile, grayish-black (N2)	.9
MIDDLE CREEK LIMESTONE MEMBER	
Limestone, fine-grained, massive, light-olive-gray (5Y6/1)	2.6
Total Swope Limestone measured	28.3
LADORE SHALE	
Covered	3.7
HERTHA LIMESTONE	
Limestone, medium-grained, massive, light-olive-gray (5Y6/1) at top, light-brownish-gray (5YR6/1) at base; bryozoans, and algae	4.3
Shale, flaky, dusky-yellow (5Y6/4)	.4
Limestone, coarse-grained, massive, yellowish-gray (5Y7/2); crinoid stems	1.2
Total Hertha Limestone	5.9
PLEASANTON GROUP	
Shale, clayey, blocky-bedded, olive-gray (5Y5/2)	5.2
Limestone, sandy, nodular, olive-gray (5Y5/2)	.5
Shale, clayey, blocky-bedded, medium-olive-gray (5Y4/2)	6.0
Sandstone, fine-grained, dusky-yellow (5Y-6/4); plant impressions	1.0
Shale, sandy, blocky-bedded, dark grayish-yellow (5Y7/4)	5.1
Sandstone, fine-grained, thin- to medium-bedded, grayish-orange (10YR7/4); plant impressions	5.7
Shale, sandy, blocky-bedded, light olive-gray (5Y6/1) to light-gray (N7); micaceous; plant remains; base covered	20.0
Total Pleasanton Group measured	43.5

Locality 58. NE NE NW sec. 6, T 19 S, R 25 E, composite section along east-west road.

	Thickness, feet
DENNIS LIMESTONE	
WINTERSET LIMESTONE MEMBER	
Limestone, covered	22.8
STARK SHALE MEMBER	
Shale, hard, fissile, black (N1)	1.0
Total Dennis Limestone measured	23.8
GALESBURG SHALE	
Shale, silty, blocky-bedded, dusky-yellow (5Y6/4); plant remains	3.8
SWOPE LIMESTONE	
BETHANY FALLS LIMESTONE MEMBER	
Limestone, medium-grained, thin- to medium-bedded, upper quarter is very light-gray (N8), upper middle quarter is pale olive (10Y6/2), lower middle quarter is yellowish-gray (5Y7/2), lower quarter is light brownish-gray (5YR7/2); bryozoans, crinoid stems, and *Antiquatonia*	19.5
HUSHPUCKNEY SHALE MEMBER	
Shale, upper 6.2 feet is silty, flaky dusky-yellow (5Y6/4), lower 1.2 feet is hard, fissile, dark-gray (N3)	7.4
MIDDLE CREEK LIMESTONE MEMBER	
Limestone, fine-grained, massive, medium-gray (N5)	2.0
Total Swope Limestone measured	28.9
LADORE SHALE	
Shale, silty, paper-thin, olive-gray (5Y6/1)	1.7
HERTHA LIMESTONE	
Limestone, coarse-grained, medium- to thick-bedded, light brownish-gray (5Y-R6/1); limonite specks; algae, *Pulcratia*, bellerophontid gastropods, sparse horn corals	3.7

Locality 59. NE NE NW sec. 16, T 19 S, R 25 E.

	Thickness, feet
SWOPE LIMESTONE	
HUSHPUCKNEY SHALE MEMBER	
Shale, fissile, black (N1); mostly covered	1.3
MIDDLE CREEK LIMESTONE MEMBER	
Limestone, fine-grained, massive, medium-bluish-gray (5B5/1)	1.6
Total Swope Limestone measured	2.9
LADORE SHALE	
Covered	5.1
HERTHA LIMESTONE	
Limestone, fine- to medium-grained, thin- to thick-bedded, light-brown (5YR6/4); top bed is algal with *Derbyia*, lower bed is crinoidal with *Composita*	3.2
Shale, silty, medium light-gray (N6)	.4
Limestone, earthy, massive, olive-gray (5Y4/1); crinoid remains	1.0
Total Hertha Limestone measured	4.6
PLEASANTON GROUP	
Shale, clayey, blocky, medium-olive-gray (5Y5/1); plant impressions	6.2
Limestone, nodular, brownish-gray (5YR-4/1)	.3
Shale, silty, blocky-bedded, grayish-orange (10YR7/4)	62.0
Total Pleasanton Group measured	68.5

REFERENCES

ADAMS, G. I., 1898, Physiography of southeastern Kansas: Kansas Univ. Quart. 7, p. 87-102.

————, GIRTY, G. H., and WHITE, DAVID, 1903, Stratigraphy and paleontology of the upper Carboniferous rocks of the Kansas section: U.S. Geol. Survey Bull. 211, 123 p.

————, HAWORTH, ERASMUS, and CRANE, W. R., 1904, Economic geology of the Iola quadrangle, Kansas: U.S. Geol. Survey Bull. 238, 83 p.

BAIN, H. F., 1898, Geology of Decatur County, Iowa: Iowa Geol. Survey, v. 8, p. 255-309.

BLACKWELDER, ELIOT, 1916, The geologic role of phosphorus: Am. Jour. Sci., v. 42, p. 285-298.

BROADHEAD, G. C., 1866, Coal measures in Missouri: St. Louis Acad. Sci. Trans., v. 2, p. 311-333.

COLE, V. B., 1962, Configuration on top of Precambrian rocks in Kansas: Kansas Geol. Survey Oil and Gas Inv. 26.

————, MERRIAM, D. F., FRANKS, P. C., HAMBLETON, W. W., and HILPMAN, P. L., 1961, Wells drilled into Precambrian rock in Kansas: Kansas Geol. Survey Bull. 150, 169 p.

COMLY, H. H., 1945, Cyanosis in infants caused by nitrate in well water: Am. Med. Assoc. Jour., v. 129, p. 112-116.

CONDRA, G. E., 1927, The stratigraphy of the Pennsylvanian System in Nebraska: Nebraska Geol. Survey Bull. 1, 291 p.

————, 1930, Correlation of the Pennsylvanian beds in the Platte and Jones Point sections of Nebraska: Nebraska Geol. Survey Bull. 3, 57 p.

DEAN, H. T., 1936, Chronic endemic dental fluorosis: Am. Med. Assoc. Jour., v. 109, p. 1269-1272.

EMIGH, G. D., 1958, Petrology, mineralogy, and origin of phosphate pellets in the Phosphoria Formation: Idaho Bur. Mines and Geology Pamph. 114, 60 p.

FARQUHAR, O. C., 1957, The Precambrian of Kansas: Kansas Geol. Survey Bull. 127, pt. 3, 73 p.

FRYE, J. C., and LEONARD, A. B., 1952, Pleistocene geology of Kansas: Kansas Geol. Survey Bull. 99, 230 p.

HILPMAN, P. L., OROS, M. O., BEENE, D. L., and GOEBEL, E. D., 1964, Oil and gas developments in Kansas during 1963: Kansas Geol. Survey Bull. 172, 180 p.

HAWORTH, ERASMUS, 1895, The stratigraphy of the Kansas coal measures: Kansas Univ. Quart. 3, p. 271-290.

————, and BENNETT, JOHN, 1908, History of geological field work [in Kansas]: Kansas Univ. Geol. Survey, v. 9, p. 42-56.

————, and KIRK, M. Z., 1894, A geologic section along the Neosho River from the Mississippian Formation of the Indian Territory to White City, Kansas; and along the Cottonwood River from Wyckoff to Peabody: Kansas Univ. Quart. 2, p. 104-115.

HINDS, HENRY, and GREENE, F. C., 1915, The stratigraphy of the Pennsylvanian Series in Missouri: Missouri Bur. Geology and Mines, v. 13, 407 p.

JEWETT, J. M., 1932, Brief discussion of the Bronson Group in Kansas: Kansas Geol. Soc., 6th Ann. Field Conf. Guidebook, p. 99-103.

————, 1954, Oil and gas in eastern Kansas: Kansas Geol. Survey Bull. 104, 397 p.

KANSAS INDUSTRIAL DEVELOPMENT COMMISSION, 1962, Directory of Kansas Manufacturers and products, 1926-63: Div. of Econ. Research, Topeka, Kan.

KANSAS STATE BOARD OF AGRICULTURE, 1962, Kansas agriculture: 45th Ann. Rept., 96 p.

KEYES, C. R., 1899, The Missourian Series of the Carboniferous: Am. Geologist, v. 23, p. 298-316.

LEE, WALLACE, 1939, Relation of thickness of Mississippian limestone in central and eastern Kansas to oil and gas deposits: Kansas Geol. Survey Bull. 26, 42 p.

————, 1940, Subsurface Mississippian rocks of Kansas, with report on fossils of Mississippian age from well cores in western Kansas, by G. H. Girty: Kansas Geol. Survey Bull. 33, 114 p.

————, 1943, The stratigraphy and structural development of the Forest City Basin in Kansas: Kansas Geol. Survey Bull. 51, 142 p.

————, GROHSKOPF, J. G., GREENE, F. C., HERSHEY, H. G., HARRIS, S. E., JR., and REED, E. C., 1946, The structural development of the Forest City Basin in Missouri, Kansas, Iowa, and Nebraska: U.S. Geol. Survey Oil and Gas Inv., Prelim. Map 48.

————, and Payne, T. G., 1944, McLouth gas and oil field, Jefferson and Leavenworth counties, Kansas: Kansas Geol. Survey Bull. 53, 195 p.

McQueen, H. S., 1932, Insoluble residues as a guide in stratigraphic studies: Missouri Bur. Geol. & Mines, Bienn. Rept. State Geologist (1929-1930), p. 102-131.

Meinzer, O. E., 1923, The occurrence of ground water in the United States, with a discussion of principles: U.S. Geol. Survey Water-Supply Paper 489, 321 p.

Merriam, D. F., 1960, Preliminary regional structural contour map on top of Mississippian rocks in Kansas: Kansas Geol. Survey Oil and Gas Inv. 22.

————, and Kelley, T. E., 1960, Preliminary regional structural contour map on top of "Hunton" rocks (Silurian-Devonian) in Kansas: Kansas Geol. Survey Oil and Gas Inv. 23.

————, and Smith, Polly, 1961, Preliminary regional structural contour map on top of Arbuckle rocks (Cambrian-Ordovician) in Kansas: Kansas Geol. Survey Oil and Gas Inv. 25.

Metzler, D. F., and Stoltenberg, H. A., 1950, The public health significance of high nitrate waters as a cause of infant cyanosis and methods of control: Kansas Acad. Sci. Trans., v. 53, no. 2, p. 194-211.

Miller, Don E., 1963, Stratigraphy of the outcropping Pennsylvanian rocks in Miami County, Kansas: unpub. Master's thesis, Dept. Geology, Univ. Kansas.

Moore, R. C., 1932, A reclassification of the Pennsylvanian System in the northern Mid-Continent region: Kansas Geol. Soc., 6th Ann. Field Conf. Guidebook, p. 79-98.

————, 1935 [1936], Stratigraphic classification of the Pennsylvanian rocks of Kansas: Kansas Geol. Survey Bull. 22, 256 p.

————, 1940, Ground-water resources of Kansas, with chapters by Lohman, S. W., Frye, J. C., Waite, H. A., McLaughlin, T. G., and Latta, Bruce: Kansas Geol. Survey Bull. 27, 112 p.

Newell, N. D., 1935, The geology of Johnson and Miami counties, Kansas: Kansas Geol. Survey Bull. 21, pt. 1, 150 p.

O'Connor, H. G., 1960, Geology and ground-water resources of Douglas County, Kansas: Kansas Geol. Survey Bull. 148, 200 p.

————, 1963, Changes in Kansas stratigraphic nomenclature: Am. Assoc. Petroleum Geologists Bull., v. 47, no. 10, p. 1873-1877.

Pettijohn, F. J., 1957, Sedimentary rocks: Harper & Bros., New York, 718 p.

Prosser, C. S., and Beede, J. W., 1904, Description of the Cottonwood Falls quadrangle [Kans.]: U.S. Geol. Survey Geol. Atlas, Folio 109, 6 p.

Rock-Color Chart Committee, 1951, Rock-color chart: Geol. Soc. America.

Runnels, R. T., and Schleicher, J. A., 1956, Chemical composition of eastern Kansas limestones: Kansas Geol. Survey Bull. 119, pt. 3, p. 81-103.

Schoewe, W. H., 1944, Coal resources of the Kansas City Group, Thayer Bed, in eastern Kansas: Kansas Geol. Survey Bull. 52, pt. 3, p. 81-136.

————, 1949, The geography of Kansas, pt. 2, Physical geography: Kansas Acad. Sci. Trans., v. 52, p. 261-333.

Swallow, G. C., and Hawn, F., 1865, Report of the geological survey of Miami County, Kansas: Kansas City, Mo., 24 p.

Tilton, J. L., and Bain, H. F., 1897, Geology of Madison County, Iowa: Iowa Geol. Survey, v. 7, p. 489-539.

U.S. Dept. Commerce, Weather Bureau, Climatological data, Kansas: annual summaries 1931-60.

U.S. Dept. Health, Education, and Welfare, 1962, Public Health Service drinking water standards—1962: Public Health Service Pub. 956, 61 p.

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