Geology and Ground-Water Resources of Allen County, Kansas

By Don E. Miller

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DON E. MILLER *State Geological Survey of Kansas*

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ABSTRACT

Allen County lies within the Osage Plains section of the Central Lowlands physiographic province and includes an area of about 504 square miles. Rocks above the Precambrian basement have an average thickness of about 2,000 feet and are all sedimentary in origin. The consolidated deposits range in age from Cambrian through Pennsylvanian, and the unconsolidated deposits range in age from probable Tertiary through Quaternary. Only rocks of Pennsylvanian, Tertiary(?), and Quaternary age are exposed in the county. The exposed Pennsylvanian rocks have a regional dip to the northwest of about 12 to 15 feet per mile.

The most important bedrock aquifers are the shallow Pennsylvanian limestones and sandstones that have been weathered along joints, fractures, and bedding planes. Potable ground water is usually not found in the county below the base of the Kansas City Group, and in many places the boundary between fresh and saline water is much higher in the stratigraphic section.

Alluvial deposits having an average thickness of about 25 feet in the Neosho River valley should yield 10 to 100 gallons per minute of ground water to wells. Where saturated, Illinoisan terrace deposits should yield moderate amounts of water to wells. In much of the valley, semiartesian or artesian conditions probably prevail owing to a confining silt which overlies the permeable gravels.

Water from the Quaternary deposits is of good quality but is usually very hard. Water derived from shallow bedrock aquifers is generally higher in dissolved solids content and hardness than water from the Quaternary deposits.

INTRODUCTION

Purpose of Investigation

This investigation of the geology and ground-water resources of Allen County was made to determine the thickness, lithology, distribution, and hydrologic properties of the rocks containing fresh water (less than 1,000 parts per million dissolved solids).

The study was begun in the summer of 1963 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 and the Environmental Health Services of the Kansas State Department of Health.

Geography

Allen County extends from long 95°05′ W. to long 95°31′ W. and from lat 37°44′ N. to lat 38°02′ N., and includes an area of about 504 square miles. The county is bounded on the north by Anderson County, on the west by Woodson County, on the south by Neosho County, and on the east by Bourbon County (fig. 1).

Allen County lies within the Osage Plains section of the Central Lowlands physiographic province as defined by Schoewe (1949). The major topographic features are the southward-trending Neosho River valley and the scarped upland plains that bevel the gently dipping sedimentary rocks underlying the county.

The Neosho River and its tributaries drain almost all the county, with the exception of the eastern one-quarter, which is drained by the Little Osage and Marmaton Rivers and their tributaries. The latter two streams flow in a generally easterly direction into Bourbon County. The Neosho River in Allen County has an average gradient of about 1.5 feet per mile (Kansas Water Resources Board, 1961).

Allen County has a subhumid climate characterized by moderate precipitation, mild winters, and hot summers. The annual precipitation at Iola, as compiled from records of the U.S. Weather Bureau, is summarized in table 1.

Allen County was organized in 1855 with a settlement of what now is Iola. In 1964, the population of Allen County was 17,109, of which about 68 percent was urban. Iola, the largest town and the county seat, had a population of 7,360 in 1964. Other communities and their 1964 population are Humboldt, 2,484; LaHarpe, 596; Moran, 581; Gas City, 395; Elsmore, 129; Savonburg, 123; and Mildred, 58 (Kansas State Board of Agriculture, 1964).

Previous Investigations

The geology of Allen County and adjacent

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

TABLE 1.—Annual precipitation at Iola for the period 1930-65 (from published records of the U.S. Weather Bureau).

Year	Annual precipitation, in inches	Year	Annual precipitation, in inches	Year	Annual precipitation, in inches	Year	Annual precipitation, in inches
1930	38.09	1940	35.18	1950	34.22	1960	35.62
1931	32.46	1941	51.44	1951	60.03	1961	53.31
1932	27.82	1942	43.45	1952	24.34	1962	34.99
1933	35.91	1943	41.86	1953	29.10	1963	16.20
1934	34.59	1944	48.98	1954	27.48	1964	33.49
1935	49.51	1945	44.28	1955	30.23	1965	31.48
1936	22.31	1946	29.60	1956	28.20		
1937	34.08	1947	40.31	1957	40.68		
1938	37.32	1948	43.14	1958	42.71		
1939	26.26	1949	43.27	1959	35.15	Mean	36.93

areas has been studied and described by many geologists. Principal workers and their subjects of investigation are listed in the Selected References section of this report.

Methods of Investigation

This report is based on geologic and hydrologic data collected and studied during 1963, 1964, and 1965.

The study of the geology included detailed examination and description of numerous stratigraphic sections as well as areal mapping (pl. 1). Geologic data in a report on the area by Moore and Elledge (1920) were restudied, and some of the data are incorporated in this report.

Supplementary information on the geology and ground-water hydrology of the county was obtained by an inventory of existing wells and by drilling test holes. The test holes were drilled with a truck-mounted power auger and a hydraulic-rotary drilling machine owned by the State Geological Survey. Samples collected in the course of drilling were later examined microscopically in the laboratory.

Areal geology was mapped on aerial photographs obtained from the U.S. Department of Agriculture, and then was transferred to a base map compiled from 7½-minute topographic quadrangles of the U.S. Geological Survey.

Data on the chemical quality of water were obtained from analyses of water samples analyzed by the laboratory of the Environmental Health Services of the Kansas State Department of Health.

Well-Numbering System

The locations of wells, test holes, and water-sampling points used in this report follow the scheme of General Land Office surveys. The well number is composed of township, range, and section numerals, followed by letters that indicate the subdivision of the section in which the well is located. The first letter denotes the quarter section (160-acre tract), the second letter denotes the quarter-quarter section (40-acre tract), and the third letter denotes the quarter-quarter-quarter section (10-acre tract). The 160-acre, 40-acre, and 10-acre tracts are designated *a*, *b*, *c*, and *d* in a counter-clockwise direction beginning in the northeast quadrant. For example, well 24-18E-22dcc is in the SW¼ SW¼ SE¼ sec. 22, T. 24 S., R. 18 E. (fig. 2). If two or more wells are in the same 10-acre tract, they are numbered serially in the order in which they were inventoried.

Acknowledgments

The author wishes to express his appreciation to the many residents of Allen County who sup-

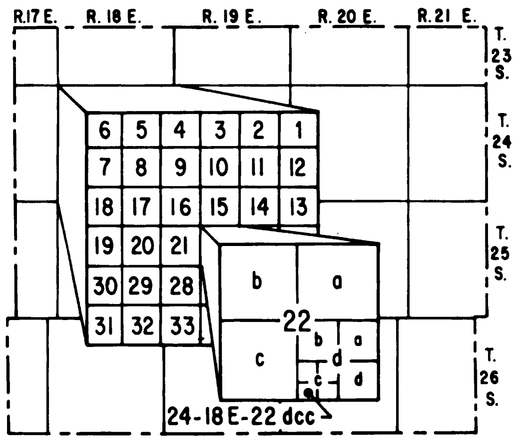


FIGURE 2.—Well-numbering system used in this report.

plied information concerning local geology, wells, and water supplies. Several drillers provided logs of wells that they had drilled in this area.

Mr. Virgil Burgat, Chief Geologist of the State Highway Commission of Kansas, provided geologic profiles of several highway projects in the county that were helpful in mapping and interpreting the geology. Mr. Carl Pate, Oilfield Research Laboratory, Chanute, Kans., provided many valuable analyses of water from oil- and gas-bearing rocks in the county.

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

Output from the IBM 7040 at The University of Kansas Computation Center, Richard G. Hetherington, Director, was used to facilitate the analysis of well and water-quality data.

GEOLOGY[1]

Subsurface Stratigraphy

Sedimentary rocks of Paleozoic and Cenozoic age underlie Allen County. The Paleozoic rocks

[1] The classification and nomenclature of the rock units used in this report are those of the State Geological Survey of Kansas and differ somewhat from those of the U.S. Geological Survey.

are of Cambrian, Ordovician, Devonian, Mississippian, and Pennsylvanian age and overlie Precambrian igneous and metamorphic rocks. Paleozoic rocks in Allen County have an average thickness of about 2,000 feet (Jewett, 1954). The Cenozoic rocks are of Tertiary(?) and Quaternary age and have a maximum thickness of 35 feet. The general thickness and character of subsurface rocks are known from the study of well logs and samples of drill cuttings from oil and gas wells in the area.

PRECAMBRIAN ROCKS

Wells drilled to the Precambrian at two locations in Allen County are reported to have encountered schist and granite (Cole and others, 1961).

The Precambrian surface slopes to the west across Allen County from about 900 feet below sea level on the eastern edge to about 1,300 feet below sea level on the western edge (Cole, 1962).

CAMBRIAN ROCKS

In Allen County, Cambrian rocks are comprised of three formations: Lamotte (Reagan) Sandstone, Bonneterre Dolomite, and Eminence Dolomite. The Eminence Dolomite is the lowermost formation of the Cambrian and Ordovician Arbuckle Group. The total thickness of Cambrian rocks in Allen County is about 150 feet (Jewett, 1954).

ORDOVICIAN ROCKS

Ordovician rocks in Allen County are composed of four formations which are, in ascending order, the Gasconade Dolomite, Roubidoux Formation, Jefferson City Dolomite, and Cotter Dolomite. These formations are the upper four formations of the Cambrian and Ordovician Arbuckle Group and have an average composite thickness in Allen County of about 590 feet (Jewett, 1954).

DEVONIAN AND MISSISSIPPIAN ROCKS

Directly overlying rocks of the Arbuckle Group and underlying rocks of known Mississippian age is the Chattanooga Shale. This formation is believed to be less than 50 feet thick in all parts of Allen County (Jewett, 1954).

MISSISSIPPIAN ROCKS

The thickness of Mississippian limestone formations in Allen County averages about 300 feet. The Chouteau Limestone and Sedalia Dolomite of Kinderhookian age, the Burlington Limestone of Osagian age, and the Warsaw Limestone of Meramecian age are believed to be present in the county (Lee, 1940).

PENNSYLVANIAN ROCKS

The thickness of Pennsylvanian formations in Allen County averages about 895 feet (Jewett, 1954). Pennsylvanian rocks in the county are of Desmoinesian, Missourian, and Virgilian age. 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 Stage is made up of the Douglas, Shawnee, and Wabaunsee Groups. Only rocks of the Missourian and Virgilian Stages are exposed in Allen County, and only these are described in more detail in the following section.

Stratigraphy of Outcropping Rocks

Correlation of units discussed in this report is based on measured sections, sample logs, and drillers' logs. Figure 3 is a stratigraphic section parallel to the regional dip that shows the relationship of the units discussed.

PENNSYLVANIAN SYSTEM—MISSOURIAN STAGE

KANSAS CITY GROUP—BRONSON SUBGROUP

HERTHA LIMESTONE

The Hertha Limestone (Adams and others, 1903) is comprised of three members which are, in ascending order, the Critzer Limestone, Mound City Shale, and Sniabar Limestone Members. Of the three members, only the Mound City and the Sniabar crop out in Allen County.

The Hertha is the oldest outcropping formation in Allen County and is very poorly exposed along the valley of the Marmaton River in the southeastern part of the county. It has an average exposed thickness of about 12 feet. Figure 4 is a structure contour map, based on drillers' logs, drawn on the base of the Hertha.

Mound City Shale Member.—The Mound City Shale Member (Jewett, 1932) is seen at the NE¼ NE¼ sec. 10, T. 26 S., R. 21 E. It consists of 3 feet of yellowish-gray clayey shale. A thin (0.3 foot) dark-bluish-gray fossiliferous limestone occurs near the middle of the unit. In the sub-

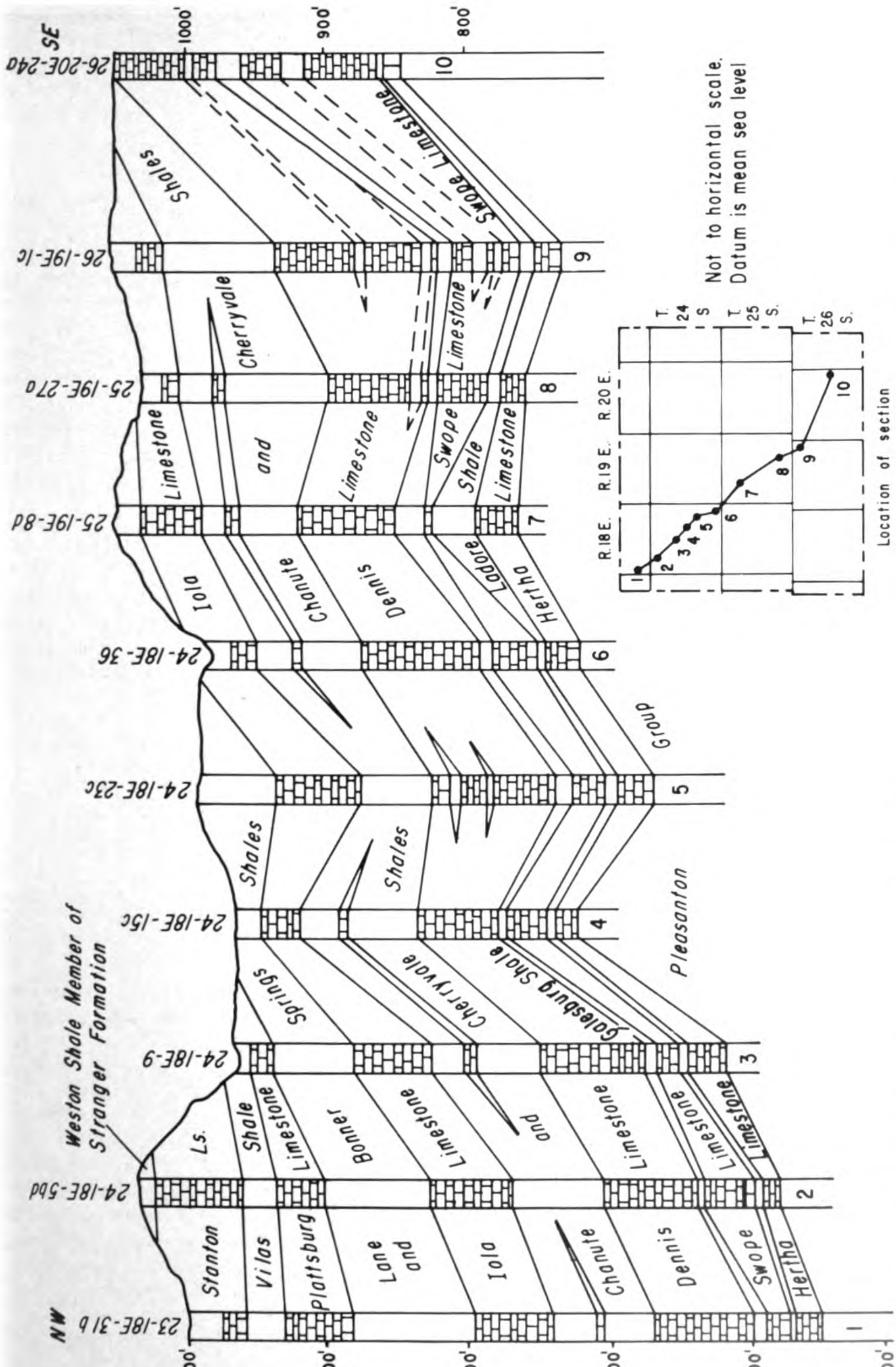
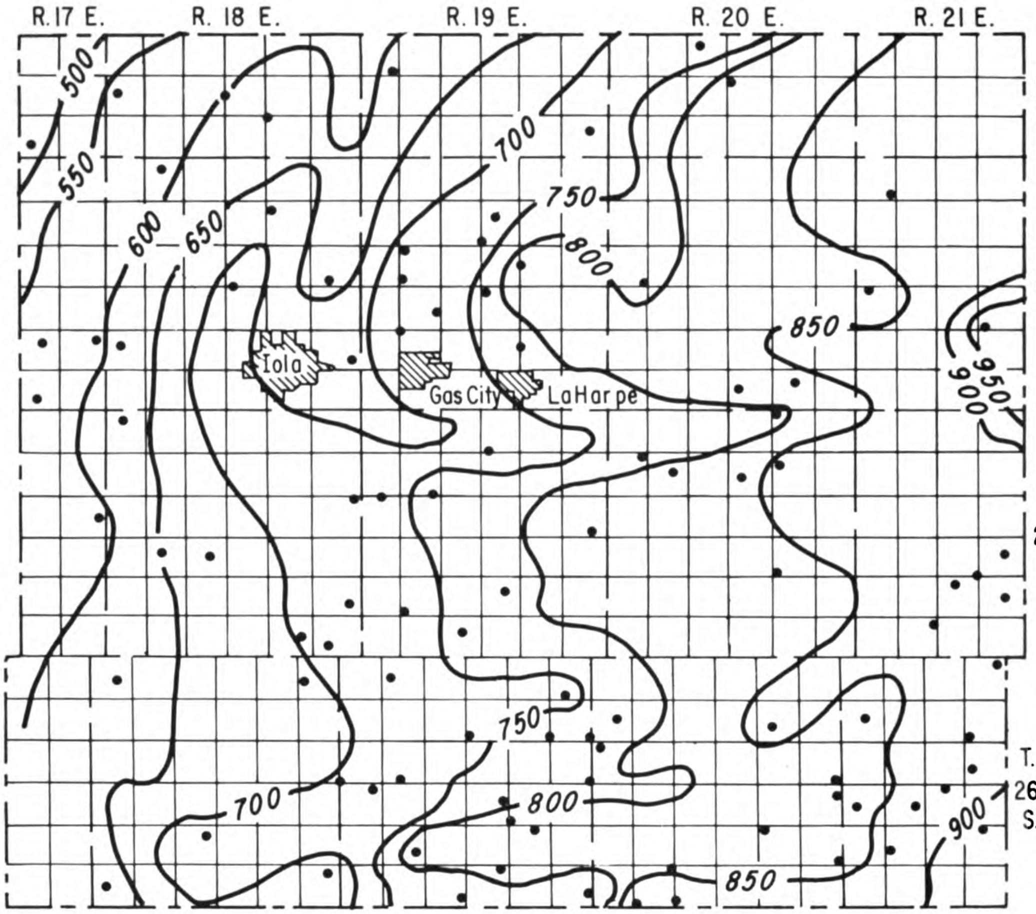


FIGURE 3.—Generalized stratigraphic section parallel to the regional dip showing the relationship of the units discussed in this report.



EXPLANATION

Control point

— 750 —

Structure contour

Shows altitude of base of Hertha Limestone. Contour interval 50 feet. Datum is mean sea level

0 2 4 6 MILES

FIGURE 4.—Configuration of the base of the Kansas City Group (Hertha Limestone). Control points are from logs on file at the State Geological Survey of Kansas.

surface, at the NE¼ NE¼ sec. 24, T. 26 S., R. 20 E., the upper 1 foot of the Mound City is black fissile shale.

Sniabar Limestone Member.—The Sniabar Limestone Member (Jewett, 1932) is poorly exposed at the NE¼ NE¼ sec. 10, T. 26 S., R. 21 E., and is a bluish-gray to light-gray dense algal limestone. It is cherty with numerous shale partings. The Sniabar at this location is about 9 feet thick and is very fossiliferous. Individual fossil fragments are usually algal encrusted.

LADORE SHALE

The Ladore Shale (Adams and others, 1904) is about 15 feet thick in an exposure east of the county line (NW¼ SW¼ sec. 12, T. 26 S., R. 21 E.) in Bourbon County. It is not well exposed in Allen County but is about 2 to 3 feet thick in well 26-20E-24aaa. Throughout much of the subsurface of Allen County the formation averages about 5 feet thick.

The Ladore Shale was not observed at the surface in Allen County owing to the poor exposures in this part of the stratigraphic section. In the subsurface the Ladore is composed of tannish-gray arenaceous shale.

SWOPE LIMESTONE

The Swope Limestone (Newell, 1935) is comprised of two limestone members and one intercalated shale member. They are, in ascending order, the Middle Creek Limestone, Hushpuckney Shale, and Bethany Falls Limestone Members. The Swope is fairly well exposed along the streams in the southeastern corner and the northeastern corner of Allen County. It has no distinct topographic expression but is easily distinguished from units above and below because of the characteristic lithologies of its members. The Swope has an average thickness in Allen County of about 60 feet, with local thicknesses of 75 feet.

Section of Swope Limestone in a streambed and road cut from the SE¼ SE¼ SE¼ sec. 15 to the NE¼ NE¼ NE¼ sec. 22, T. 26 S., R. 21 E.

	Thickness, feet
Swope Limestone	
Bethany Falls Limestone Member	
Limestone, fine-grained, mottled dark-olive-gray and light-tannish-brown, unevenly bedded, unfossiliferous except for a few brachiopods and crinoid stems; contains some scattered chert	15.3
Limestone, fine-grained, brownish-gray	1.0
	16.3
Hushpuckney Shale Member	
Covered interval	3.1
Shale, black, hard, fissile, unfossiliferous	1.9
	5.0
Middle Creek Limestone Member	
Limestone, medium-dark-gray, hard, dense, brittle; contains some brachiopods	3.0
	3.0

Middle Creek Limestone Member.—The Middle Creek Limestone Member (Newell, 1935) is a dark-gray to bluish-gray dense fine-grained limestone that is usually seen on the outcrop as a single massive unit. It is brittle and fractures with a hackly to conchoidal surface. Locally, it comprises three limestone beds separated by thin shale partings. The lower limestone averages 0.5 foot in thickness, the lower shale averages 0.35 foot, the middle limestone averages 0.5 foot, the upper shale averages 0.8 foot, and the upper limestone averages 1.3 feet. The Middle Creek has an average thickness of about 3.5 feet.

Hushpuckney Shale Member.—The Hushpuckney Shale Member (Newell, 1935) has an average thickness in Allen County of about 5 feet. In the NE¼ NE¼ sec. 22, T. 26 S., R. 21 E., the lower 1.9 feet of the Hushpuckney is black, fissile, hard, and unfossiliferous. The upper 3.1 feet is yellowish-gray clayey calcareous shale with small gastropods in a zone located 2.0 feet from the top of the member. Other fossils in the upper 3.1 feet include chonetid and productid brachiopods.

Bethany Falls Limestone Member.—The Bethany Falls Limestone Member (Broadhead, 1865) is a light-olive-gray and medium-gray dense fine-grained mottled limestone. This very distinctive lithology makes the Bethany Falls easily identifiable. The Bethany Falls ranges in thickness from about 40 feet in the southeastern corner of Allen County to about 65 feet in the subsurface over much of the county.

The upper part of the Bethany Falls is occasionally cherty and oolitic. Locally, where the unit is thickest, thin (0.5-1 foot) beds of black fissile shale occur at about 20 feet and at about 30 feet above the base of the member.

The fusulinid *Triticites* is found locally in the lower part of the member and the brachiopods *Meekella, Derbyia,* and *Antiquatonia* are numerous. The brachiopod *Juresania* is found locally.

GALESBURG SHALE

The Galesburg Shale (Adams and others, 1903) ranges in thickness in Allen County from about 1 foot to almost 17 feet. Where the Galesburg is less than 6 feet thick, it is a yellowish-gray mottled slightly calcareous shale; where the thickness is greater, it is bluish gray and clayey in the lower part with yellowish-tan silty shale in the upper part. Locally, thin beds of coal and siltstone occur in the upper part.

DENNIS LIMESTONE

The Dennis Limestone (Adams and others, 1903) is well exposed in the southeastern and northeastern parts of the county. It has an average thickness of about 60 feet.

The Dennis Limestone is comprised of, in ascending order, the Canville Limestone, Stark Shale, and Winterset Limestone Members.

Section from Winterset Limestone Member of Dennis Limestone down into Bethany Falls Limestone Member of Swope Limestone measured by J. M. Jewett in the SE¼ SE¼ SW¼ sec. 33, T. 25 S., R. 21 E.

	Thickness, feet
Dennis Limestone	
Winterset Limestone Member	
Limestone, oolitic, cross-bedded; contains some chert	20.0±
Covered interval	6-10.0

	Thickness, feet
Limestone, blue to brownish-gray, weathers rough	5.0
	31-35.0±
STARK SHALE MEMBER	
Shale, gray to yellow	1.6
Shale, black, platy	3.0±
	4.6±
CANVILLE LIMESTONE MEMBER	
Limestone, gray, dense, earthy, may be partly covered	1.0
GALESBURG SHALE	
Covered interval	2-3.0
SWOPE LIMESTONE	
BETHANY FALLS LIMESTONE MEMBER	
Limestone, oolitic	5.0±
Limestone, brecciated, crumbly	6.0±
	11.0±

Canville Limestone Member.—The Canville Limestone Member (Jewett, 1932) is similar in lithology to the Middle Creek Limestone Member of the Swope Limestone. The Canville is a bluish-gray dense fine-grained massive limestone, which fractures with a hackly or conchoidal surface. It ranges in thickness from about 2 feet to almost 6 feet.

Stark Shale Member.—The Stark Shale Member (Jewett, 1932) is characteristically a black fissile very hard unfossiliferous shale in the lower 3 feet and a grayish-yellow clayey soft fossiliferous shale in the upper 1.5 feet. Locally, the upper lithology is absent and the entire interval is black and fissile.

The most common fossils in the upper part of the Stark are chonetid brachiopods. Inarticulate brachiopods are found locally in the lower part of the member.

Winterset Limestone Member.—The Winterset Limestone Member (Tilton and Bain, 1897) is light-gray to yellowish-gray medium-bedded fine- to medium-grained limestone in the upper part and medium- to coarse-grained limestone in the lower part. Shale partings, coarsely crystalline calcite, and algae are common in the lower part, and chert and crossbedded oolite are common in the upper part.

The Winterset Limestone Member is very fossiliferous in Allen County. Locally, as in the NW¼ NW¼ NE¼ sec. 16, T. 26 S., R. 20 E., the Winterset contains belemnoids, gastropods, pelecypods, trilobites, bryozoans, brachiopods, fusulinids, crinoids, and algae. The abundance of fossils and the increased total limestone thicknesses in the Dennis and Swope Limestones may indicate that they constituted part of a marine bank in Allen County.

The average thickness of the Winterset in Allen County is about 53 feet.

Kansas City Group—Linn Subgroup

CHERRYVALE SHALE

The Cherryvale Shale (Haworth and Bennett, 1908) includes three shale and two limestone members. They are, in ascending order, the Fontana Shale, Block Limestone, Wea Shale, Westerville Limestone, and Quivira Shale Members. The Cherryvale ranges in thickness from about 19 feet at the NW¼ NW¼ sec. 25, T. 26 S., R. 19 E., to about 80 feet in the subsurface in the northwestern corner of the county. The Cherryvale Shale and the overlying Drum Limestone and Chanute Shale have been mapped as one unit on plate 1.

Composite section from Cherryvale Shale down into Winterset Limestone Member of Dennis Limestone in a streambed and road cut in the SW¼ SW¼ NW¼ sec. 28, T. 23 S., R. 21 E.

	Thickness, feet
CHERRYVALE SHALE	
Sandstone, fine-grained, tan, medium-bedded; contains abundant limonite specks	2.0
Shale, olive-gray to dusky-yellow; contains abundant plant impressions	21.2
Shale, dark-gray, platy	2.2
Limestone, sandy, dark-gray to brownish-gray, nodular	0.2
Shale, clayey, dark-reddish-brown with olive-green spots; contains soft ironstone pebbles	5.8
Shale, mostly covered; sandstone layers interbedded with sandy shale	39.4
	70.8
DENNIS LIMESTONE	
WINTERSET LIMESTONE MEMBER	
Limestone, fine- to medium-grained, light-gray to tannish-gray, thin- to medium-bedded; algal with *Echinaria, Linoproductus;* fusulinids near center, oolitic at top	13.8
Shale, dark-gray to black, fissile	0.5
Limestone, medium-grained, light-olive-gray, massive; contains calcite crystals, algae, *Linoproductus, Echinaria,* and bryozoans. Lower part covered	3.8
	18.1

Fontana Shale Member.—The Fontana Shale Member (Newell, 1935) is yellowish-gray to light-gray sandy shale. Limonite specks are common in the upper part of the unit. The Fontana is sparsely fossiliferous, with chonetid brachiopods being most common.

The Fontana ranges in thickness from about 5 to about 45 feet, and the unit is thickest in the northern and northwestern parts of Allen County.

Block Limestone Member.—The Block Limestone Member (Newell, 1935) is a yellowish-tan dense medium-grained algal limestone.

Locally, the unit contains calcite crystals. The Block has an average thickness of about 2 feet and is usually a single thin nodular limestone bed.

Wea Shale Member.—The Wea Shale Member (Newell, 1935) is poorly exposed in Allen County and is characteristically an olive-gray to dusky-yellow platy shale, but locally the lower 2 to 3 feet is dark-gray fissile shale. Plant impressions and carbonaceous smudges are common.

The Wea ranges in thickness from about 4 feet in the southern part to almost 24 feet in the northern part of the county.

Westerville Limestone Member.—The Westerville Limestone Member (Bain, 1898) was studied at only one locality. In the NE¼ NE¼ sec. 25, T. 26 S., R. 19 E., the Westerville is composed of 1.2 feet of light-olive-gray to brownish-gray fine- to coarse-grained limestone. The unit is very fossiliferous and many of the fossils have fillings of dark-gray limestone.

The Westerville is absent in parts of Allen County, possibly as a result of nondeposition. The unit is probably lens shaped and thins out within short distances.

Quivira Shale Member.—The Quivira Shale Member (Newell, 1935) is an olive-gray to dusky-yellow clayey shale with limonite stains where the underlying Westerville is present. Where the Westerville is absent, the unit is called the undifferentiated Wea and Quivira Members and is characteristically yellowish gray and sandy.

At the NE¼ NE¼ sec. 25, T. 26 S., R. 19 E., the Quivira Shale Member is 2.3 feet thick. The combined Wea and Quivira attains thicknesses of about 30 feet.

DRUM LIMESTONE

The Drum Limestone (Adams and others, 1903) consists of a single massive bed of olive-gray to yellowish-gray dense medium-grained limestone. The unit usually weathers light yellowish brown. It has an average thickness of about 3 feet in outcrops but is thicker in the subsurface of northwestern Allen County.

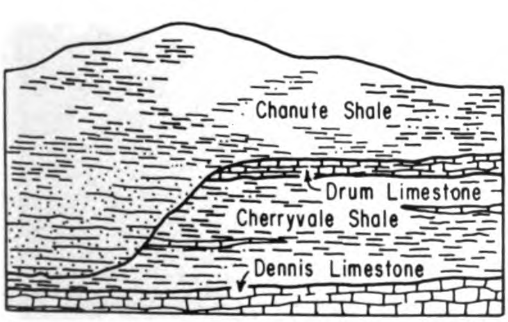


FIGURE 5.—Effect of post-Drum Limestone channeling which occurred prior to deposition of the Chanute Shale.

The most characteristic feature of the Drum is the abundant white crinoid segments scattered throughout the limestone.

Post-Drum pre-Chanute erosion removed the Drum and, locally, much of the Cherryvale Shale from parts of northern and much of southern Allen County (fig. 5). Only one good outcrop of Drum was measured in the southern part of the county.

Section from Chanute Shale down into Winterset Limestone Member of Dennis Limestone in a creekbed and up a hill from the SE¼ SE¼ NW¼ sec. 25 to the SE¼ NE¼ NE¼ sec. 26, T. 26 S., R. 19 E.

	Thickness, feet
CHANUTE SHALE	
Shale, arenaceous, dusky-yellow, mostly covered	11.2
	11.2
DRUM LIMESTONE	
Limestone, medium-grained, light-olive-gray, massive, dense; contains crinoids and brachiopod fragments	2.6
	2.6
CHERRYVALE SHALE	
QUIVIRA SHALE MEMBER	
Shale, clayey, olive-gray and dusky-yellow, some limonite stains, sandier at top	2.3
WESTERVILLE LIMESTONE MEMBER	
Limestone, fine- to coarse-grained, light-olive-gray to brownish-gray, blobs of dark silty fillings in fossils, very fossiliferous	1.2
WEA SHALE MEMBER	
Shale, mostly covered	4.6
BLOCK LIMESTONE MEMBER	
Limestone, medium-grained, yellowish-tan, algal, dense; contains some fractured calcite crystals	1.8
FONTANA SHALE MEMBER	
Shale, mostly covered	8.8
	18.7
DENNIS LIMESTONE	
WINTERSET LIMESTONE MEMBER	
Limestone, poorly exposed, fine- to medium-grained, light-olive-gray to yellowish-gray, medium-bedded, algal with large brachiopods and bryozoans; contains white chert at 11 feet from base. Lower part covered	20.4±
	20.4±

CHANUTE SHALE

The Chanute Shale (Haworth and Bennett, 1908) varies greatly in thickness and lithology in Allen County. A definite range in thickness for the Chanute is difficult to determine owing to the channeling and filling previously mentioned. The thinnest section of Chanute Shale observed was at the SE¼ SE¼ sec. 33, T. 26 S.,

R. 18 E., where it is about 20 feet thick. The thickest section of Chanute Shale studied was along the east side of the NE¼ sec. 2, T. 24 S., R. 20 E., where about 69 feet of olive- to bluish-gray sandy shale and dusky-yellow thin-bedded siltstone is exposed.

Where the underlying Drum Limestone is absent, the lower part of the Chanute is marked by a thick sequence of dusky-yellow thin- to medium-bedded fine-grained sandstone, which is locally crossbedded.

Plant remains and carbonaceous smudges are the most characteristic organic remains found in the Chanute Shale.

Section from Muncie Creek Shale Member of Iola Limestone down into Drum Limestone measured by N. D. Newell in a road cut in the SE¼ SE¼ SE¼ sec. 33, T. 26 S., R. 18 E.

	Thickness, feet
IOLA LIMESTONE	
MUNCIE CREEK SHALE MEMBER	
Shale, phosphatic concretions at base	0.3
PAOLA LIMESTONE MEMBER	
Limestone, gray, blocky; contains cryptozoans and a few "worm borings"	1.5
	1.8
CHANUTE SHALE	
Sandstone, brown, thick-bedded, ripple marks	7.0
Coal (Thayer coal)	0.5
Underclay	1.0
Shale, greenish-gray	10.0
Limestone, yellow, nodular, in limy shale	2.0
	20.5
DRUM LIMESTONE	
Limestone, coquinoid, molluscan	2.0
Limestone, fine-grained, gray and buff, nodular	5.0±
	7.0±

IOLA LIMESTONE

The Iola comprises two limestone members and one intercalated shale member. They are, in ascending order, the Paola Limestone, Muncie Creek Shale, and Raytown Limestone Members. The Iola has an extensive outcrop area and is the best-exposed unit in the county. It has an average thickness of about 40 feet. The unit apparently thins to the south and to the northeast from the vicinity of Iola in the west-central part of the county. About 110 square miles of Allen County is directly underlain by Iola Limestone.

The type section of the Iola Limestone (Haworth and Kirk, 1894) is at the south edge of Iola in the Lehigh Portland Cement Co. quarry.

At several places along the outcrop of the Iola Limestone are inliers or "windows" through which Chanute Shale is exposed, as in secs. 9 and 16, T. 26 S., R. 18 E. (pl. 1). The Iola Limestone thins rather abruptly along the margins of these Chanute inliers. This type of inlier is rather common along the outcrop of the Iola and has been described by several geologists in other counties in eastern Kansas (Wagner, 1961; Jungmann, 1966). The Iola Limestone probably was deposited around topographic highs on the upper surface of the Chanute Shale (fig. 6).

Section from Plattsburg Limestone down into Paola Limestone Member of Iola Limestone measured by R. C. Moore at a quarry in the SW¼ SE¼ SE¼ sec. 35, T. 24 S., R. 18 E. Type section of the Iola Limestone.

	Thickness, feet
LANSING GROUP	
PLATTSBURG LIMESTONE	
Limestone, weathers buff, in beds 0.1 to 1.0 foot thick separated by black shale, weathers shaly at top; contains poorly preserved bryozoans, brachiopods, and crinoid stems	7.0
	7.0
KANSAS CITY GROUP	
LANE AND BONNER SPRINGS SHALES	
Shale, bluish-gray, uniform color, evenly bedded, silty, sandy in lower half; contains two or three 1-foot beds of hard, shaly micaceous sandstone	49.0
	49.0
IOLA LIMESTONE	
RAYTOWN LIMESTONE MEMBER	
Limestone, light-bluish-gray to nearly white, with top thin yellow crust and thick $CaCO_3$ coating rock and fossils, thin- and evenly bedded, dense, beds 0.1 to 1.0 foot thick with parting of fossiliferous black shale, abundant crinoid stems and calyces	6.0
Limestone, light-gray, massive, fine- to medium-crystalline with very light buff cast, part appears irregular and brecciated with fine-grained fragments, in dark ground-mass, locally porous with fine calcite crystals lining the cavities. Some limestone is white and dense. Well-preserved brachiopods, bryozoans, but mostly unfossiliferous. Quarry floor is 3± feet above base of formation (this 3 feet includes Muncie Creek Shale Member and Paola Limestone Member)	39.0±
	45.0±

Paola Limestone Member.—The Paola Limestone Member (Newell, 1935) is usually seen as a single massive bed of medium-gray to brownish-gray dense fine- to coarse-grained limestone. The top of the Paola has a wavy or hummocky surface and usually has "worm borings" extending from the top downward a few inches into the unit. The Paola has an average thickness of about 2.5 feet.

The Paola is usually algal and locally, as in the NE¼ NE¼ NE¼ sec. 11, T. 25 S., R. 19 E., is very fossiliferous.

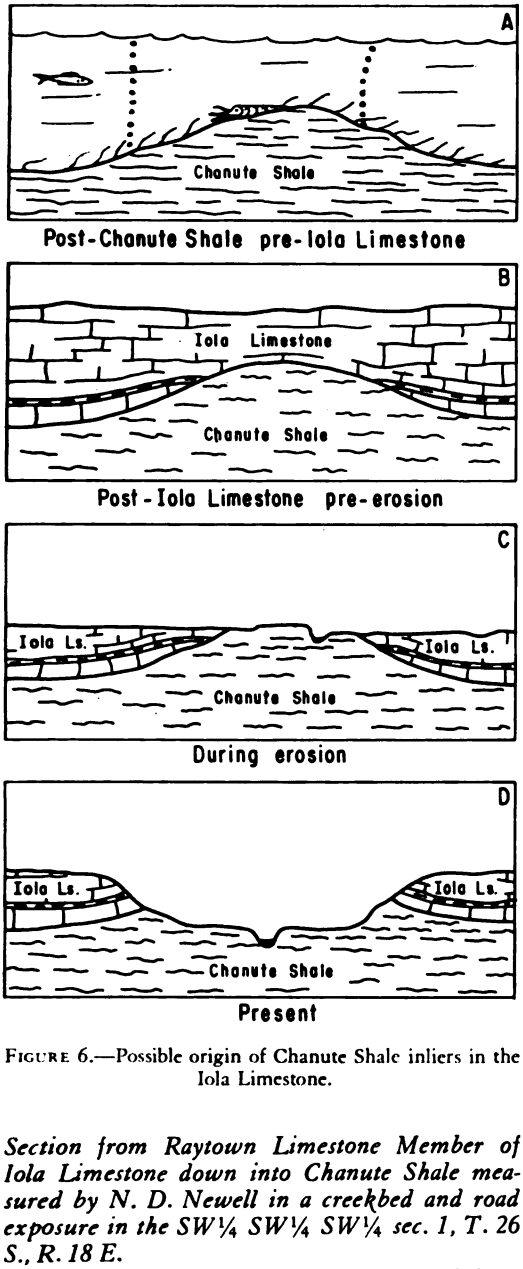


FIGURE 6.—Possible origin of Chanute Shale inliers in the Iola Limestone.

Section from Raytown Limestone Member of Iola Limestone down into Chanute Shale measured by N. D. Newell in a creekbed and road exposure in the SW¼ SW¼ SW¼ sec. 1, T. 26 S., R. 18 E.

	Thickness, feet
IOLA LIMESTONE	
RAYTOWN LIMESTONE MEMBER	
Limestone, whitish-gray, crystalline	20.0±
MUNCIE CREEK SHALE MEMBER	
Shale, gray to yellowish-gray; phosphatic concretions at base	0.3
PAOLA LIMESTONE MEMBER	
Limestone, fine-grained, bluish-gray, blocky; contains cryptozoans and a few "worm borings" at top	2.0
	22.3±

	Thickness, feet
CHANUTE SHALE	
Shale, silty, gray, soft	3.0
Sandstone, platy	15.0
Coal (Thayer coal)	0.3
Underclay; lower part hard, limy	2.0
	20.3

Muncie Creek Shale Member.—The Muncie Creek Shale Member (Newell, 1935) is a distinctive marker bed, which permits identification of the Iola Limestone even in badly weathered or partial exposures. It is an olive-gray to dusky-yellow clayey shale that contains spherical or ellipsoidal phosphatic nodules ¼ to 1 inch in diameter wherever exposed. The surface of these nodules weathers white or light gray, and the interior remains black or dark gray. Most of the nodules have small fossil fragments at their centers. Locally, small (½ to 2 inches) doubly terminated gypsum crystals are found in the Muncie Creek. The gypsum could be the result of oxidation of pyrite or some other sulfide with subsequent release of sulfite. The sulfite combines with ground water to form sulfuric acid, which reacts with calcium from the shale or the adjacent limestone bed or with apatite [$Ca_5(PO_4)_3F$] or collophane in the phosphatic nodules to form gypsum. Another explanation for the presence of the gypsum is that it could be primary; that is, formed at the time the shale was being deposited.

The Muncie Creek has an average thickness of about 0.5 foot.

Raytown Limestone Member.—The Raytown Limestone Member (Hinds and Greene, 1915) is a light-gray to olive-gray medium-bedded fine- to coarse-grained limestone that weathers white to buff. Limonite is found locally as filling in vugs, and coarsely crystalline calcite is abundant. In a quarry exposure at the SE¼ SW¼ sec. 25, T. 24 S., R. 20 E., styolites are found in the upper 3 feet of the main ledge of the member. At several localities three thin limestone beds and two thin intercalated shale beds are 3 to 7 feet above the main ledge of the member. These thin limestone beds and intercalated shales have a thickness of about 3.6 feet, are separated from the lower main ledge by gray shale, and are a persistent part of the Raytown in much of eastern Kansas. The beds are identified in several well logs.

The main ledge of the Raytown Limestone Member contains a fossil assemblage that is characterized by rather large brachiopods *(Linoproductus, Echinaria,* and *Neospirifer)* and bryozoans. The upper limestone beds and intercalated shale beds are very fossiliferous and include crinoid columnals, plates, and calyces; small brachiopods; bryozoans; gastropods; horn corals; and trilobites. The bedding planes of the individual limestone beds are encrusted, and individual fossils are coated with a type of algae that gives the surface a sharp, hackly appearance.

The Raytown (including the upper limestones and shales) has an average thickness of about 37 feet.

Kansas City Group—Zarah Subgroup

LANE AND BONNER SPRINGS SHALES

The Wyandotte Limestone, which usually separates the Lane Shale (Haworth and Kirk, 1895) from the Bonner Springs Shale (Newell, 1935) in areas north of Allen County, is present only along the northern county line in T. 23 S., R. 20 E. In this area, the Wyandotte is represented by a zone of thin-bedded flaggy micaceous and calcareous sandstones containing abundant marine fossils. The unit is not seen south of sec. 18, T. 24 S., R. 20 E., where an isolated outlier of calcareous sandstone about 1 foot thick may be seen.

The undifferentiated Lane and Bonner Springs Shales have an average thickness of about 59 feet. The unit is thicker in the northern part of the county, and thicknesses of 90 to 100 feet are not uncommon. The unit thins to the southwest, and at Humboldt it is about 30 feet thick. Where the unit attains its greatest thickness, it contains much dusky-yellow thin-bedded micaceous siltstone. The rest is characteristically light-olive-gray arenaceous to clayey shale. The siltstones in the unit contain plant impressions and carbonaceous smudges, and the shales are relatively unfossiliferous.

Section from Spring Hill Limestone Member of Plattsburg Limestone down into undifferentiated Lane and Bonner Springs Shales in the NW¼ NW¼ sec. 2, T. 25 S., R. 18 E.

	Thickness, feet
Lansing Group	
PLATTSBURG LIMESTONE	
Spring Hill Limestone Member	
Limestone, fine- to medium-grained, light-gray; contains shale parting, sponges, and brachiopods	5.6
Hickory Creek Shale Member	
Shale, brownish-gray, calcareous; contains dark-gray shale at base	0.7
Merriam Limestone Member	
Limestone, medium-grained, blocky-bedded, dense; contains small sponges, brachiopods, and *Heterocoelia*	1.5
	7.8
Kansas City Group	
LANE AND BONNER SPRINGS SHALES	
Shale, arenaceous, bluish-gray, paper-thin bedding	11.1
Limestone, olive-gray, dense, nodular; contains some *Myalina*	0.3
Shale, arenaceous, bluish-gray	38.0
	49.4

Lansing Group

PLATTSBURG LIMESTONE

The Plattsburg Limestone (Broadhead, 1865) is the lowermost formation in the Lansing Group. It comprises two limestone members and one intercalated shale member. They are, in ascending order, the Merriam Limestone, Hickory Creek Shale, and Spring Hill Limestone Members. The Plattsburg ranges in thickness from about 15 feet in the western and southwestern parts to about 80 feet in the northern part of the county. It is usually a scarp-forming unit and has an extensive area of outcrop. Outliers or isolated patches of Plattsburg cap hills in many areas (pl. 1).

Composite section from Stanton Limestone down into undifferentiated Lane and Bonner Springs Shales in the SW¼ NW¼ NW¼ sec. 20, T. 24 S., R. 18 E.

	Thickness, feet
Lansing Group	
STANTON LIMESTONE	
Limestone, fine- to coarse-grained, yellowish-tan to olive-tan, much crystalline calcite, badly weathered	5.0±
	5.0±
VILAS SHALE	
Shale, olive-gray with reddish-gray zone about 30 feet from base, thin limestone stringers near base with abundant fossils; mostly covered	52.8
	52.8
PLATTSBURG LIMESTONE	
Spring Hill Limestone Member	
Limestone, fine-grained, olive-gray; small pockets of shale, hematite concretions; algal with abundant fossil fragments	2.8
Shale, dark-reddish-brown, blocky; carbonaceous pebbles and limonite grains, almost conglomeratic	0.2
Limestone, fine-grained, olive-gray, weathers yellowish-tan; algal, streaks of carbonaceous material, small clay blebs	6.0
Limestone, shaly, soft, discontinuous	0.2
Limestone, fine-grained, medium-gray, dense; contains sparse brachiopods	1.8
Limestone, fine-grained, medium-gray, weathers light-gray mottled with dark-gray calcite stringers; contains crinoid stems in lower 0.9 foot	6.7
Hickory Creek Shale Member	
Shale, nodular, yellow, mostly covered	2.5
Merriam Limestone Member	
Limestone, bluish-gray, granular, blocky-	

	Thickness, feet
bedded; poorly exposed	2.2
	22.4
KANSAS CITY GROUP	
LANE AND BONNER SPRINGS SHALES	
Shale, clayey, bluish-gray; mostly covered	27.0±
	27.0±

Merriam Limestone Member.—The Merriam Limestone Member (Newell, 1935) is easily recognizable owing to its lithology and stratigraphic position. It is usually seen on the outcrop as a single massive bed and is a gray to bluish-gray fine- to medium-grained limestone. Locally, the Merriam contains *Heterocoelia* and other small sponges in its fossil assemblage. Many of the fossil fragments are coated with *Osagia*. The unit has an average thickness of about 2 feet.

Hickory Creek Shale Member.—The Hickory Creek Shale Member (Newell, 1935) is a yellowish-gray to brownish-gray calcareous shale that locally is dark gray in the lower part. Locally, as in the NW¼ sec. 20, T. 24 S., R. 18 E., the Hickory Creek is dusky yellow and nodular. The Hickory Creek has an average thickness of about 0.5 foot. The unit is fossiliferous with crinoid stems and scattered spirifers being most abundant.

Spring Hill Limestone Member.—The Spring Hill Limestone Member (Newell, 1935) is a light-olive-gray to medium-gray thin- to medium-bedded fine- to coarse-grained limestone. Calcite-filled veinlets and limonite blebs are common, and carbonaceous material is present in the upper part of the member in some outcrops. Dusky-yellow shale partings are common throughout the unit. The Spring Hill has an average thickness of about 20 feet.

The Spring Hill is fossiliferous, with the upper part containing a more varied fauna than the lower part. *Enteletes, Triticites,* and algae are the most abundant forms.

VILAS SHALE

The Vilas Shale (Adams, 1898) is a yellowish-gray to light-gray clayey shale. In the NW¼ sec. 20, T. 24 S., R. 18 E., the Vilas has a thin (1.0 foot) zone of maroon blocky clayey shale near the center. The unit thickens and becomes more arenaceous to the southwest. Large limestone concretions are found in the lower part of the unit in the southwestern part of the county. The Vilas has an average thickness of about 35 feet.

The Vilas Shale is relatively unfossiliferous. Crinoid stems and small brachiopods are found locally.

Section from Stanton Limestone down into Plattsburg Limestone measured by N. D. Newell in a quarry in the NW¼ SE¼ SE¼ sec. 27, T. 23 S., R. 18 E.

	Thickness, feet
STANTON LIMESTONE	2
VILAS SHALE	
Shale, argillaceous; lower half maroon and purple; upper half buff; some large limestone concretions in lower part	30
PLATTSBURG LIMESTONE	2
	34

STANTON LIMESTONE

The Stanton Limestone (Haworth and Bennett, 1908) is the uppermost formation in the Lansing Group. It includes three limestone members and two intercalated shale members. They are, in ascending order, the Captain Creek Limestone, Eudora Shale, Stoner Limestone, Rock Lake Shale, and South Bend Limestone Members. Exposures of the upper two members were poor in Allen County but were excellent just across the county line in Woodson County. Descriptions of these upper two units are based on measured sections in Woodson County. The Stanton Limestone has an average thickness of about 47 feet.

Section of Stanton Limestone in a quarry in the NE¼ NE¼ NE¼ sec. 27, T. 23 S., R. 18 E.

	Thickness, feet
STANTON LIMESTONE	
STONER LIMESTONE MEMBER	
Limestone, fine-grained, light-olive-gray, thin- to medium-bedded, wavy	9.0
Limestone, coarse-grained, very pale brown, blocky, thick-bedded, sub-oolitic with algal encrustations	7.8
Limestone, coarse-grained, light-gray; contains abundant faunal remains; dark carbonaceous layers at bedding planes, filled with fossils, worm trails	5.2
Limestone, fine-grained, very light olive gray, blocky-bedded	0.8
Shale, light-gray	0.3
Limestone, dark-gray, fossiliferous; *Enteletes* and crinoid remains common	0.2
	23.3
EUDORA SHALE MEMBER	
Shale, dark-olive-gray, very hard	1.4
Limestone, yellowish-gray, impure; contains numerous kinds of fossil fragments	0.3
Shale, dark-olive-gray, hard, blocky	1.0
	2.7
CAPTAIN CREEK LIMESTONE MEMBER	
Limestone, fine-grained, light-brownish-gray with darker stringers of calcite, thin-bedded, dense, wavy; contains *Neospirifer* and *Enteletes*	1.5
Limestone, fine-grained, light-olive-gray, weathers white and powdery, massive, soft; contains small *Hustedia* and crinoid	

	Thickness, feet
stems. Zone of medium-gray chert about 8 feet above quarry floor	10.0
	11.5

Captain Creek Limestone Member.—The Captain Creek Limestone Member (Newell, 1935) is the best-exposed member of the Stanton Limestone. It is an olive-gray dense medium-bedded fine- to coarse-grained limestone. Locally, as in the NE¼ sec. 27, T. 23 S., R. 18 E., most of the unit is seen as a single massive bed. The unit usually weathers to a buff color and locally weathers to a soft, powdery white outer rind. Chert and dark-gray calcite stringers are common in the upper part. The Captain Creek has an average thickness of about 11 feet in Allen County.

The lower part of the unit contains a biota in which *Hustedia* and crinoid stems are the most common forms. The upper part contains *Neospirifer* and *Enteletes*. Algae are common in the extreme upper part of the unit.

Eudora Shale Member.—The Eudora Shale Member (Condra, 1930) is characteristically represented by a single bed of dark-olive-gray clay shale with isolated pockets or lenses of black fissile shale at the base. In a quarry at the NE cor. sec. 27, T. 23 S., R. 18 E., the Eudora is calcareous, indurated, and brittle and has a thin impure yellowish-gray limestone bed near the middle. The unit ranges from about 0.3 to 3 feet in thickness.

Scattered crinoid remains and the brachiopod *Composita* are the most abundant fossils found in the Eudora.

Stoner Limestone Member.—The Stoner Limestone Member (Condra, 1927) is a light-gray to olive-gray thin-bedded fine-grained limestone that has numerous light-gray silty shale partings in the lower third. The middle third is very pale brown to light-olive-gray wavy- and thick-bedded coarse-grained limestone. The Stoner has an average thickness of about 25 feet.

The lower part of the member contains black carbonaceous clayey material rich in fossil remains on the bedding planes. "Worm trails" are also locally abundant on the bedding planes. The middle part contains *Osagia*-like algal encrustations. *Enteletes, Composita,* and *Neospirifer* are common throughout the member.

Rock Lake Shale Member.—The Rock Lake Shale Member (Condra, 1927) is seen in only a few places in western Allen County. It consists of yellowish-orange and light-brown thin- to massive-bedded unfossiliferous fine-grained sandstone. The unit has a thickness of about 25 feet.

A few miles to the west in Woodson County, the Rock Lake is a light-gray clay shale with a thickness of about 6 feet.

South Bend Limestone Member.—The South Bend Limestone Member (Condra and Bengston, 1915) is poorly exposed in Allen County. In adjacent counties, however, the South Bend is composed of bluish-gray blocky thin-bedded coarse-grained crinoidal limestone with an average thickness of about 6 feet.

PENNSYLVANIAN SYSTEM—VIRGILIAN STAGE

Douglas Group

STRANGER FORMATION

The Stranger Formation (Newell, 1935) is comprised of five members. They are, in ascending order, the Weston Shale, Iatan Limestone, Tonganoxie Sandstone, Westphalia Limestone, and Vinland Shale Members. The Weston is the only member of the Stranger Formation in Allen County.

Weston Shale Member.—The Weston Shale Member (Keyes, 1899) underlies the upland surface in the northwestern part of the county but is poorly exposed. It is composed of light-olive-gray to bluish-gray clayey to sandy shale. The maximum thickness of the Weston in Allen County is probably about 30 feet.

TERTIARY(?) AND QUATERNARY SYSTEMS

Pre-Kansan and Kansan Deposits

Deposits of Pliocene(?) and Pleistocene age are found at altitudes 40 to 120 feet above the present flood plain of the Neosho River, scattered across upland surfaces and draped across valley walls. The gravels found at the highest levels are probably Pliocene in age, and the gravels found at the lower levels correspond in position to the Kansan age terrace described by O'Connor (1951) in the Cottonwood and Neosho River valleys. These lower deposits have a maximum thickness of about 8 feet. They are leached and oxidized, and consist mainly of chert pebbles in a dusky-yellow to reddish-yellow sandy clay matrix.

QUATERNARY SYSTEM—PLEISTOCENE SERIES

Illinoisan Stage

Deposits of gravel, sand, silt, and clay underlie a terrace 10 to 70 feet above the flood plain of the Neosho River (fig. 7). The Illinoisan terrace, owing to dissection, is not continuous. It slopes gently toward the river and merges with younger deposits, thus usually showing no definite topographic expression. Locally, as on the eastern side of geologic section D-D′ and the western side of section E-E′, noticeable bedrock "terraces" occur on the floor of the valley. These terraces are supported by resistant beds in the Raytown Limestone Member of the Iola Limestone and were formed by erosion.

Pleistocene terrace deposits southwest of Iola and northwest of Humboldt on the west side of the Neosho River, which are believed to be of Illinoisan age, are higher in relation to the flood plain surface than elsewhere along the valley (fig. 7, E-E′). One possible explanation for this apparent anomaly may be that the upper 10 to 15 feet of the deposits is colluvial deposits of Recent age or that the terrace deposits may actually be older than Illinoisan. The Illinoisan deposits and colluvium have been mapped together on plate 1.

The Illinoisan deposits are composed of reddish-tan and yellowish-tan clayey silt in the upper part and brown chert pebbles in a yellowish-tan sandy clay matrix in the lower few feet.

The contacts between the Illinoisan deposits and the Wisconsinan and Recent deposits on figure 7 were placed principally by color changes in the deposits. The younger deposits are usually dark grays and browns, whereas the older (Illinoisan) deposits are lighter in color.

The maximum thickness of the Illinoisan deposits in Allen County is about 32 feet.

Wisconsinan and Recent Stages

Deposits of Wisconsinan and Recent age occur in the stream valleys of Allen County (pl. 1). In the Neosho River valley, Wisconsinan age deposits underlie one low terrace. The terrace is about 5 feet above the present flood plain. The surface of the Wisconsinan and Recent deposits is usually flat and undissected. Owing to the presence of manmade levies in most of the county, the occurrence of natural levies in these deposits is difficult to determine.

The deposits underlying the flood plain and the low terrace have similar lithology and are discussed and mapped as one unit in this report. They are composed of grayish-brown to dark-reddish-brown clayey silt, but are chiefly brown chert gravel and sand in the lower few feet. The average thickness of these deposits in Allen County is about 25 feet. The sand and gravel ranges in thickness from 0 to 12 feet and averages about 4 feet. Locally, as in the SW¼ sec. 6, T. 24 S., R. 18 E., and the SE¼ NE¼ sec. 18, T. 25 S., R. 18 E., the deposits are predominantly sand and gravel or gravel.

Logs of selected test holes augered in the Neosho River valley are listed at the end of this report.

Structural Geology

A detailed discussion of the structural geology of Allen County is beyond the scope of this report. Regional and local structures have produced certain features, however, that are readily apparent in the exposed rocks. Some of these smaller structures, no doubt, have influenced the migration and accumulation of oil, and they are assumed also to have influenced ground-water movement and storage. Figure 4 is a structure contour map, based on drillers' logs, showing the configuration of the base of the Kansas City Group.

REGIONAL STRUCTURE

The Chautauqua arch is a major pre-Mississippian structure that trends northwest across southeastern Kansas, and in Allen County the Chattanooga Shale and Mississippian limestones directly overlie the eroded upper surface of the Arbuckle Group (Jewett, 1951). The Chautauqua arch did not directly affect the attitude of the Mississippian and Pennsylvanian rocks, but it did result in a topographically high area trending across the county upon which younger rocks were deposited.

A low post-Mississippian structure known as the Bourbon arch trends westward across northern Allen County. This structure separates the Forest City basin to the north and the Cherokee basin to the south. The thickness of the Mississippian rocks increases away from the Bourbon arch, indicating erosion and thinning of Mississippian rocks on the arch before Pennsylvanian rocks were deposited (Jewett, 1951).

The Cherokee basin (Pryor basin) extends into southwestern Allen County and is an extension of the McAlester basin of Oklahoma (Jewett, 1951).

Another structural feature of eastern Kansas is the Prairie Plains monocline (Prosser and Beede, 1904). This post-Permian structure has produced a generally northwestward regional dip of the rocks in Allen County of about 12 to 15 feet per mile (Moore and Elledge, 1920). Merriam (1963) states that the northeastward-trending Longton ridge extends into southwestern Allen County and affects surface rocks, as does an unnamed structure (see fig. 4) trending

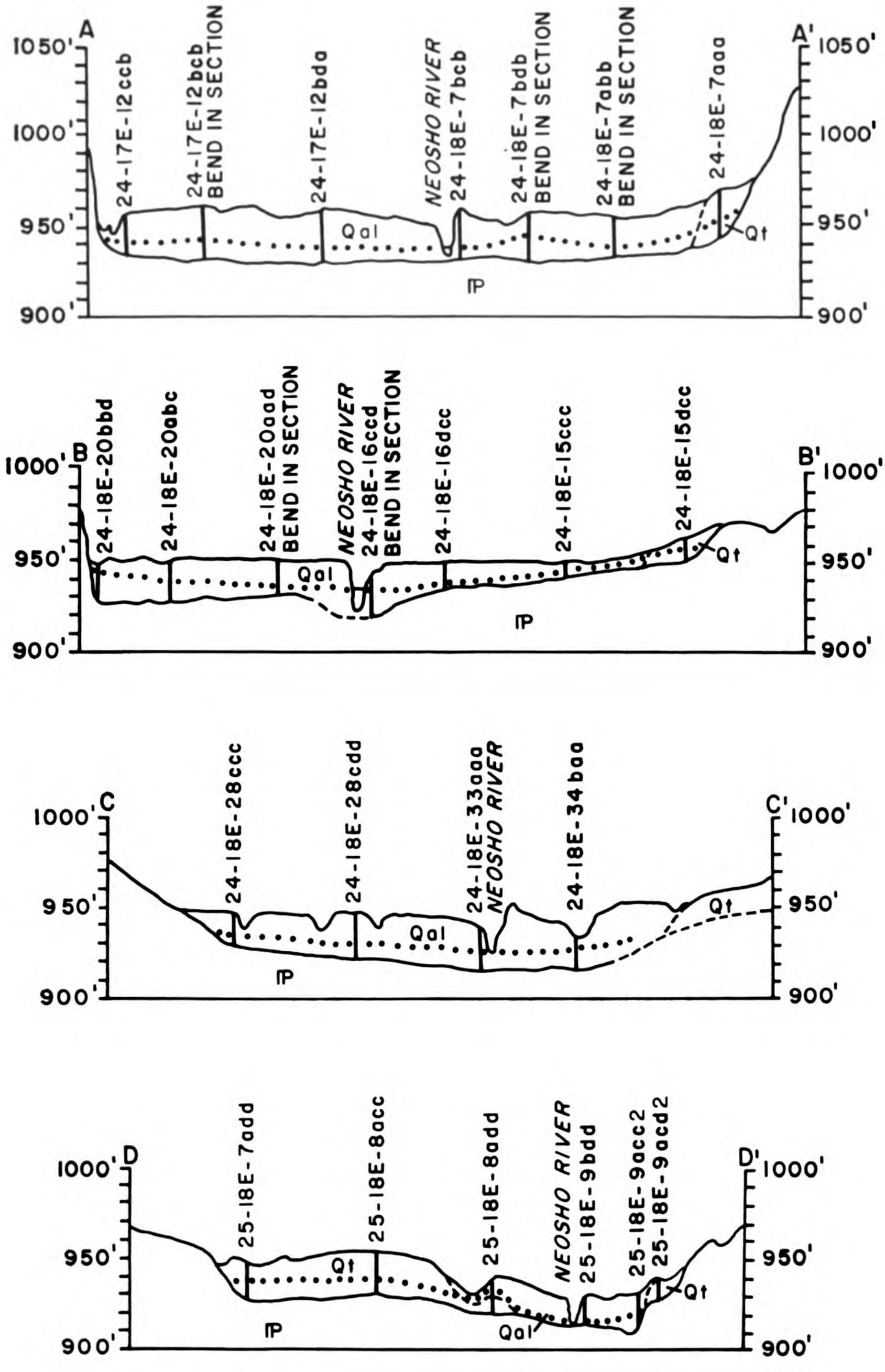
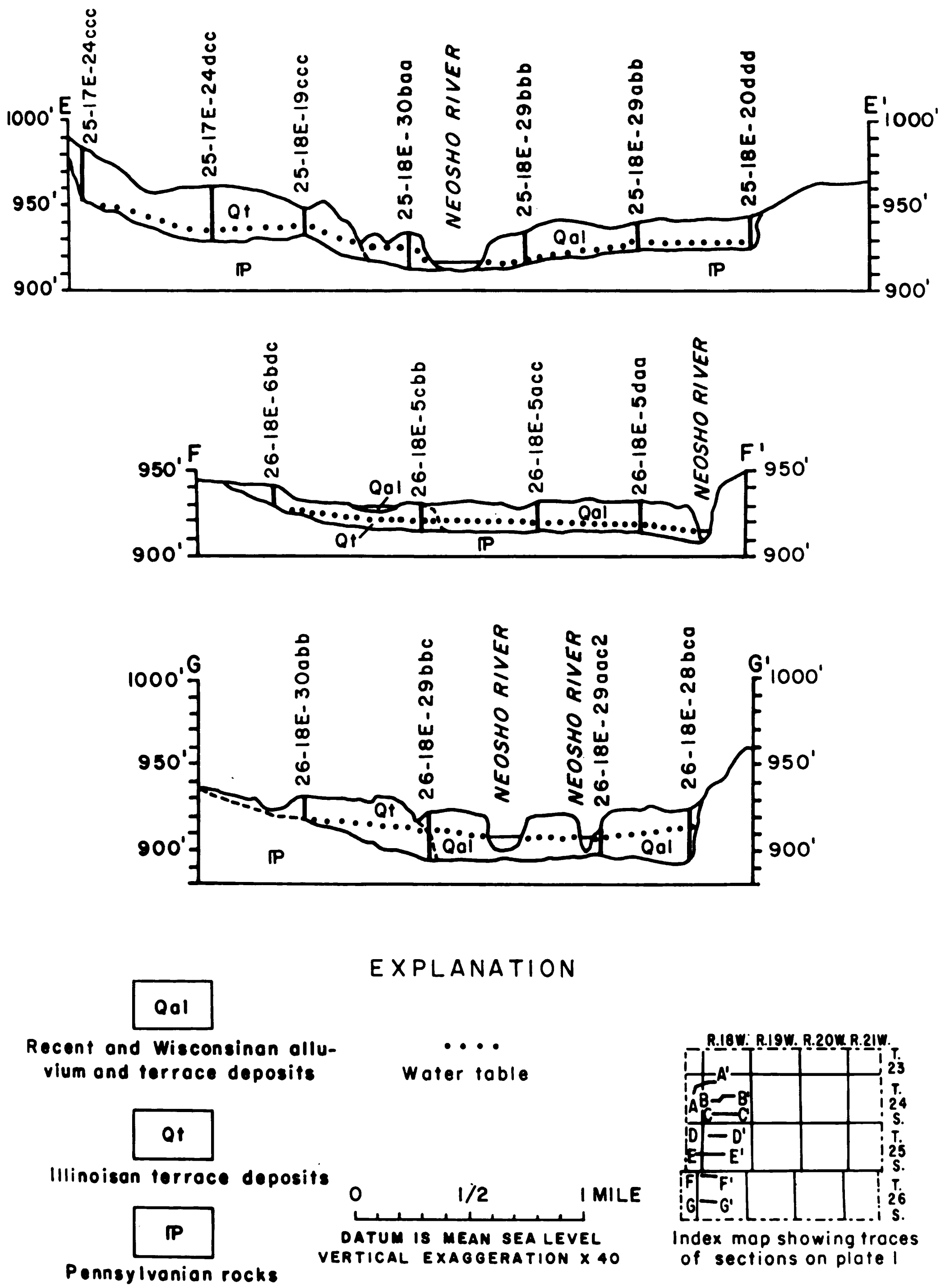


FIGURE 7.—Geologic sections across the Neosho River valley.


E
E'
1000'
950'
900'
25-17E-24ccc
25-17E-24dcc
25-18E-19ccc
25-18E-30baa
NEOSHO RIVER
25-18E-29bbb
25-18E-29abb
25-18E-20ddd
Qt
Qal
IP
F
F'
950'
900'
26-18E-6bdc
26-18E-5cbb
26-18E-5acc
26-18E-5daa
NEOSHO RIVER
Qal
Qt
IP
G
G'
1000'
950'
900'
26-18E-30abb
26-18E-29bbc
NEOSHO RIVER
NEOSHO RIVER
26-18E-29aac2
26-18E-28bca
Qt
Qal
IP
EXPLANATION
Qal
Recent and Wisconsinan alluvium and terrace deposits
Water table
Qt
Illinoisan terrace deposits
0 1/2 1 MILE
IP
Pennsylvanian rocks
DATUM IS MEAN SEA LEVEL
VERTICAL EXAGGERATION X 40
R.18W. R.19W. R.20W. R.21W.
T. 23
T. 24 S.
T. 25 S.
T. 26 S.
A A'
B B'
C C'
D D'
E E'
F F'
G G'
Index map showing traces of sections on plate 1

northwestward across central Allen County into Coffey County.

LOCAL STRUCTURES

In northern Allen County and in southern Anderson County just northeast of the town of Mildred is a small uplift called the Mildred dome (Charles, 1927). This structure has a surface closure of about 30 feet, and its axis is oriented about N. 65° W.

A northwestward-trending fault, which affects rocks from the Plattsburg Limestone through the Captain Creek Limestone Member of the Stanton Limestone, is located in the NE cor. sec. 19 and the SW¼ NW¼ sec. 20, T. 23 S., R. 19 E. (pl. 1).

Reversals of regional dip are shown in the outliers of Plattsburg Limestone scattered across north-central and west-central Allen County.

Many of the local structures probably are the result of regional factors. The area under discussion has been raised and depressed many times during geologic time, and the amount of movement probably has not been uniform over the county.

Some of the structural anomolies in Allen County may be reflections of the Precambrian surface. Differential compaction of sediments around Precambrian highs could produce minor structures that would be reflected in surface rocks. Many of the structures may have resulted from uneven distribution of the sediments at the time of deposition and before consolidation.

MINERAL RESOURCES

The total value of mineral resources produced in Allen County during 1963 was $11,789,000 (R. G. Hardy, oral commun., 1965).

Oil and Gas

The first discovery of gas in Allen County was at Iola in 1873 (Moore and Elledge, 1920). Active prospecting in 1894 near Humboldt led to the discovery of a considerable amount of gas and some oil. Development of other fields in the county closely followed these initial discoveries. In 1964, oil production from 1,815 wells in 11 fields was 845,099 barrels. Gas production totaled 617,320 million cubic feet of gas from 113 wells (Beene and Oros, 1965).

Some of the production reported in Allen County was from the "Squirrel sand" in the upper part of the Cherokee Group at a depth of about 800 to 950 feet. A major part of the

FIGURE 8.—Shale pit in undifferentiated Lane and Bonner Springs Shales, Humboldt Brick Co., NW¼ sec. 34, T. 25 S., R. 18 E.

production in the county, however, was from the Bartlesville sand, an oil sand in the lower part of the Cherokee Group at depths ranging from 550 to 1,000 feet. A few wells in the extreme northwestern part of the county produce from Mississippian limestones at about 1,200 feet (Goebel and others, 1962).

In 1964, 196 intent-to-drill permits and 6 secondary recovery permits were issued to oil and gas producers by the State Corporation Commission. A large percentage of the oil produced in the county is recovered by secondary methods.

Limestone

Several limestones have been quarried in Allen County and used for cement, crushed rock for road metal, riprap, subgrade, and embankment material. Three limestones are currently (1965) being quarried and processed for cement and road metal. They are the Stoner Limestone Member of the Stanton Limestone, the Spring Hill Limestone Member of the Plattsburg Limestone, and the Raytown Limestone Member of the Iola Limestone. The Raytown is the limestone being used in the production of cement. These limestones are being quarried where they are relatively thick; have desirable physical properties such as low magnesium content, fairly high calcium content, adequate hardness, and durability; and are near principal areas of use. The Winterset Limestone Member of the Dennis Limestone and the Bethany Falls Limestone Member of the Swope Limestone have been quarried in past years.

Sand and Gravel

Sand and gravel produced in Allen County totaled 3,000 short tons in 1963 (R. G. Hardy, oral commun., 1965).

The sand and gravel deposits are restricted to the valleys of the major streams and to upland surfaces adjacent to these streams. The deposits are composed predominantly of chert sand and gravel, but include about 20 to 30 percent clay and silt.

Ceramic Materials

At the present time (1965), only one shale is being used for the manufacture of brick and other ceramics in Allen County. This shale, the undifferentiated Lane and Bonner Springs Shales, is being taken from a pit near the northeast corner of Humboldt (fig. 8). The ceramics produced from the Lane and Bonner Springs are red or reddish brown.

GROUND-WATER RESOURCES

Recharge of Ground Water

The principal source of recharge to aquifers in Allen County is precipitation on the county. Some ground water moves into and out of the county from adjacent areas. Some recharge is contributed by streams.

PRECIPITATION

Only a small part of the precipitation on Allen County reaches the ground-water reservoir. A large percentage of the precipitation is discharged as surface runoff or returns to the atmosphere from the soil by evaporation and transpiration. The rate of precipitation, type of soil, character of underlying rocks, type and amount of vegetation, and topography all affect the rate and quantity of recharge.

Probably the most favorable conditions for recharge in Allen County occur in the alluvium and Pleistocene terrace deposits in the Neosho River valley.

A relatively rapid rise in water level follows moderate to heavy rainfall in areas directly underlain by the Iola Limestone and in areas where the Iola is an aquifer. This is probably due to recharge through an extensive joint system in the limestone. Other areas in the county either are directly underlain by relatively impermeable rocks or do not have a large enough outcrop area to be favorable for recharge.

Some recharge may occur through the black fissile shales of the Dennis and Swope Limestones in the extreme northeast and southeast corners of the county.

ADJACENT AREAS

Subsurface movement of water from areas outside of Allen County is probably a relatively unimportant source of recharge to the ground-water reservoir. The black shales of the Dennis and Swope Limestones mentioned above direct some water into Allen County from Neosho and Bourbon Counties.

STREAMS

Some water may reach the ground-water reservoir from streams during periods of high stage. However, when the stage of the stream drops below the level of the water table in the aquifer, the direction of ground-water flow is reversed, and the water is discharged from the aquifer into the stream. Flow in the smaller streams a week or more after rains probably is maintained by discharge from the ground-water reservoir.

The drainage area of the Neosho River above Iola is 3,818 square miles. If an average rainfall of 36 inches is assumed, then about 7.33 million acre-feet of precipitation is received annually for this area. The mean annual direct runoff for this area is about 1.02 million acre-feet (Busby and Armentrout, 1965), or 14 percent of the annual precipitation.

Discharge of Ground Water

In Allen County, ground water is discharged by seepage into streams, by evaporation and transpiration, by springs and wells, and by subsurface movement to adjacent areas. Climate and the stage of the water table control the rate of natural discharge. More water is discharged in some parts of the county than in others owing to local differences in geology and topography. Only a small part of the ground-water discharge in Allen County is pumped from wells. In this report, mean annual base flow in the Neosho River is assumed to be at least 0.23 million acre-feet and is about equal to mean annual recharge to the alluvial deposits. In other words, base flow is considered to result from ground-water discharge into the streams.

EVAPORATION AND TRANSPIRATION

More ground water is discharged by evaporation and transpiration than by all other means combined. Where the water table is near the land surface, direct evaporation of ground water occurs. Ground water is also transpired by many plants. The zone of saturation or the capillary fringe above it is penetrated by the roots of many plants in the stream valleys. In upland areas, the water table is relatively deep and discontinuous, and the ground-water reservoir is tapped by only a few plants. A fairly representative figure for loss by evaporation and transpiration (6.08 million acre-feet per year or about 29.8 inches) can be obtained by subtracting from total precipitation the combined amounts for mean base flow and mean direct runoff.

SUBSURFACE MOVEMENT

Subsurface movement of ground water into or from adjacent areas is relatively unimportant. Some water leaves the county through the alluvium and terrace deposits in the Neosho River valley and moves into Neosho County. A small amount of water leaves through consolidated rock aquifers across the western and northern borders of the county owing to the effect of the regional dip of the sediments.

SEEPS AND SPRINGS

Ground water is discharged by seeps and springs along valley walls and in upland areas. Water that remains after evaporation and transpiration by plants during the growing season flows in streams and leaves the county as surface runoff.

WELLS

Three types of wells are used to obtain water supplies in Allen County: dug wells, driven wells, and drilled wells. The type of well constructed depends mainly on 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 must penetrate.

Dug wells are large-diameter wells that are excavated with either hand tools or power equipment. These wells are usually cased with rock, but tile and concrete casings also are used. In wells of this type, the aquifer is usually penetrated only a few feet below the water table. This type of well is generally used in upland areas that are underlain by stratified deposits of Pennsylvanian age. Large-diameter dug wells are often desirable as they provide a greater storage space within the well, which compensates to some extent for a slow rate of water movement into a well constructed in deposits of low permeability. In addition, the larger storage space within the well is useful during periods of drought. The large diameter of this type of well permits a greater surface area of the aquifer to be exposed; hence, more water is available than in drilled wells in the same aquifer.

Driven wells are small-diameter wells consisting of 1¼- to 2-inch pipe having a screen or sandpoint attached to the bottom. The use of this type of well is limited to areas underlain by unconsolidated deposits and a relatively shallow water table. The pipe with a screen attached to the lower end is driven into the aquifer so that the screen is below the water table. The permeable gravel generally is in the lower part of the valley fill and these wells must be driven to bedrock.

Drilled wells inventoried in Allen County (table 5) range in diameter from about 4 to 12 inches and have been drilled with either percussion (cable tool) or rotary drilling machines. Wells drilled in unconsolidated deposits must be cased for their full depth and screened in the saturated zones. Wells drilled into Pennsylvanian bedrock may be uncased, except in the interval of weathered surface rock. The surface casing prevents rock in the weathered zone from falling into the well and seals out water from the surface and the weathered zone. Most drilled domestic and stock wells in the county range in diameter from 4 to 10 inches; yields of these wells range from about 1 to 5 gpm (gallons per minute).

Availability of Ground Water

CONSOLIDATED ROCK AQUIFERS

Limestone and Shale Aquifers

Limestone and shale units at or near the land surface are widespread throughout Allen County. The unweathered limestones and shales generally are relatively impermeable and do not yield enough water to a well to provide an adequate domestic water supply. However, weathering processes at or near the land surface enlarge the open spaces within the rocks, so that they may yield 1 to 5 gpm of ground water to shallow wells. Yields of 5 to 20 gpm have been reported from wells in the limestone and shale aquifers.

Movement of water through these aquifers is slow and complex. Joint systems and fractures in the limestones at or near the land surface (fig. 9) provide channels through which recharge and movement of ground water occur (Lattman and Parizek, 1964). Figure 10 is a map showing the strike of joint patterns in outcropping limestones in Allen County. Water is assumed to move downward along these fractures and joints until it reaches the contact with the shale at the base of the limestone or a point where the fracture closes and restricts further downward movement. Unweathered shale, being relatively impermeable, acts as an aquiclude, and the water moves laterally along the shale and limestone contact. The permeability of the weathered limestones and shales differs greatly from area to area. Recharge to and discharge from limestone and shale aquifers are greatly influenced by such factors as type and thickness of soil, vegetation, slope, topographic position, as well as thickness and extent of the weathered zone.

All the limestone and shale units that crop out in Allen County probably locally yield water in variable amounts to wells. Differences in permeability, degree of weathering, distance from points of recharge, well diameter, and structural attitude of the rocks govern the amount of water, if any, that can be obtained from wells.

Black fissile carbonaceous shale occurs in the Swope and Dennis Limestones, and locally in the Cherryvale Shale. These black shales yield some water to wells and locally are the principal aquifers for small domestic supplies.

The mineral or chemical quality of water from the weathered limestone and shale aquifers is generally satisfactory for domestic use, except for excessive hardness and iron content.

Sandstone Aquifers

Several of the shale units in Allen County contain intraformational sandstones that locally yield 1 to 2 gpm of ground water to domestic wells. The sandstones are similar lithologically and hydrologically, and are very fine to fine-grained micaceous quartzose sandstone with angular to subangular phenoclasts. The permeability of these sandstones is low, commonly in the magnitude of 1 to 50 gpd (gallons per day) per square foot, and most of the ground-water movement is probably along bedding planes.

UNCONSOLIDATED ROCK AQUIFERS

Neosho River valley.—Wells yielding 10 to 100 gpm can be obtained from most of the area mapped on plate 1 as Recent and Wisconsinan alluvium and Illinoisan terrace deposits in the Neosho River valley. Logs of test holes indicate that these deposits have a maximum thickness of about 35 feet, but the deposits are commonly 25 to 30 feet thick. The saturated thickness ranges from 0 to about 20 feet.

An 8-inch test hole (24-18E-28cdd) was drilled during this investigation and developed as a well. The initial saturated thickness at the well was 8.4 feet, which included 2.5 feet of silty gravel overlain by 5.9 feet of clayey silt. The well was screened using slotted pipe from a depth of 22 to 24.5 feet and was test-pumped at a rate of 15 gpm for 13 hours. The test indicated that the aquifer was artesian in the early part of the test, but after about 5 hours, water-table conditions existed in the vicinity of the pumping well. Hydraulic properties of the aquifer determined from this test are based on water-table conditions.

The results of this aquifer test indicate that the well has a specific capacity of about 26 gpm per foot of drawdown after pumping at a rate of 15 gpm for 13 hours. The aquifer has a coefficient of permeability (P) of about 5,200 gpd per square foot and a coefficient of transmissibility (T) of about 44,000 gpd per foot. Because of the thinness of the saturated material and the fact that only the lower few feet of the deposits have characteristics that give such high values for (T) and (P), longer periods of pumping would result in a decrease in saturated

FIGURE 9.—Joint patterns developed in the Iola Limestone in the NW¼ sec. 22, T. 26 S., R. 18 E.

thickness and would appreciably decrease the average values determined for T (15,000 to 25,000 gpd per foot) and the specific capacity (7.5 to 12.5 gpm per foot of drawdown).

Test hole log 25-18E-30baa indicates that parts of the aquifer have greater thicknesses of gravel and greater saturated thicknesses than was penetrated by the pumped well. Other conditions being equal, wells yielding 50 to 100 gpm probably could be obtained in some parts of the aquifer.

During years of high water-level stages, the potential yield of wells in the aquifer would be larger than normal; conversely, during periods of low water-level stages, the potential yield of wells in the aquifer would be smaller.

In the development of industrial and municipal water supplies in this aquifer, the normal fluctuation of the water table and the additional drawdown or decline caused by pumping are important factors to be considered in determining the dependable well yield that can be

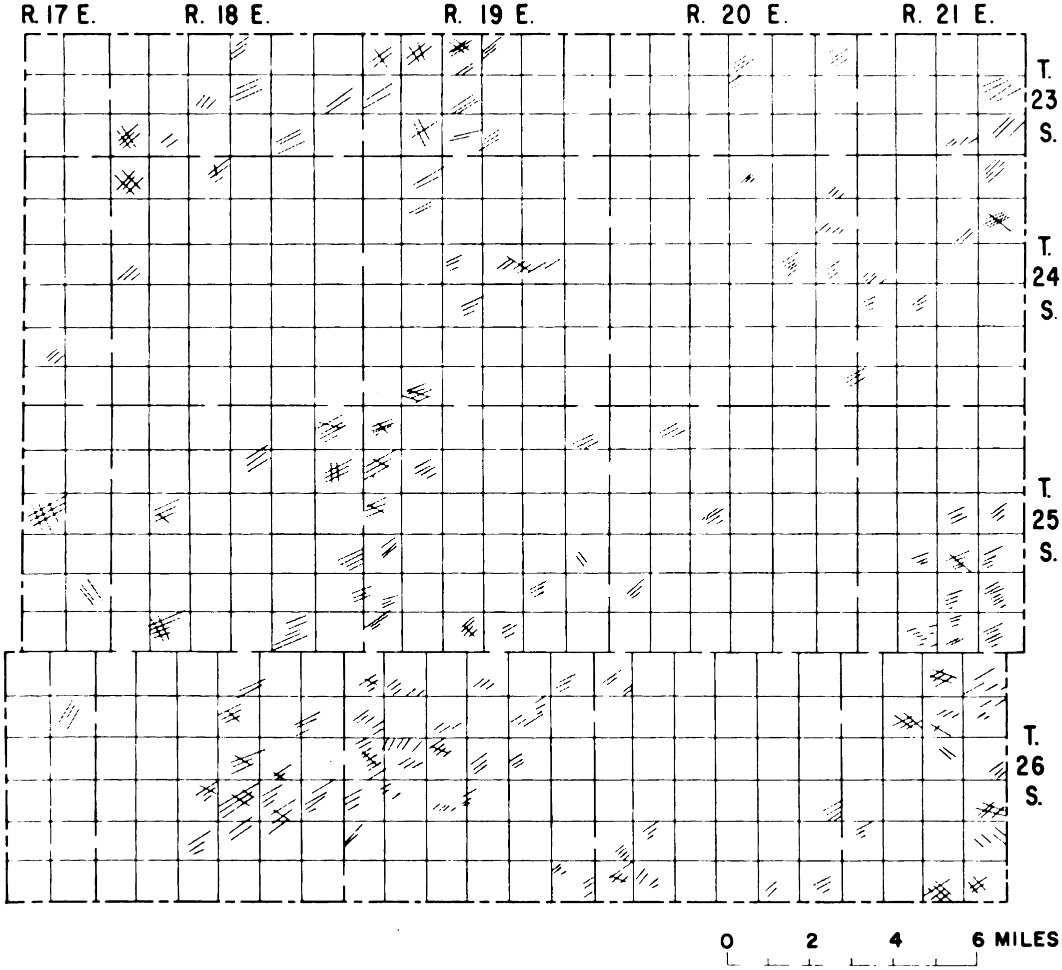


FIGURE 10.—Strike of joint patterns developed in outcropping limestones.

expected. Drawdown of the water table by increased pumping would provide additional storage space for recharge. In parts of the valley, natural discharge to the streams would be curtailed by a low water table, thereby conserving water that would otherwise be lost.

Southwest of Iola a hydraulic connection exists between the Illinoisan terrace deposits and the alluvium (fig. 7, E-E′). Ground water moves from the terrace deposits into the alluvium, which results in much higher water levels on the west side of the river than on the east.

Movement of ground water through the unconsolidated deposits is slow, as the hydraulic gradient is only about 10 to 20 feet per mile toward the river and 2 feet per mile in a downstream direction. The water table remains relatively constant in these deposits and does not fluctuate as rapidly as does the shallow water table in consolidated deposits.

Storage coefficients (ratio of the volume of water a rock will yield by gravity to its own volume) of the alluvial deposits are much higher than those in the consolidated rocks, and where sufficient saturated thickness occurs, dependable water supplies can be developed. Yields of 15 to 20 gpm from these deposits are not uncommon. Yields of 90 to 100 gpm can be obtained in parts of the aquifer.

The water obtained from the Wisconsinan and Recent alluvial aquifer is usually very hard calcium bicarbonate water with a high iron content. It would require treatment for some uses.

Other stream valleys.—Deposits of alluvium in other stream valleys in Allen County are thin and yield only small water supplies to wells. The alluvium in many of these tributary streams is so thin and discontinuous that it is not shown on plate 1.

Storage

SURFACE WATER

At the present time (1965), storage of surface water in Allen County is limited to farm ponds and two overflow dams in the channel of the Neosho River. In 1965, Allen County had about 2,459 farm ponds with an approximate storage capacity of 1,850 acre-feet of water (C. E. Crews, written commun., 1966).

GROUND WATER

Williams (1944) estimated in an earlier study of alluvium in the Neosho River valley near Parsons, Kans., that about 680 million gallons (2,100 acre-feet) of ground water was in storage per square mile of alluvium. This amount was determined by using an average thickness of water-bearing material in the alluvium of 17 feet and a storage coefficient of 20 percent. In Allen County in 1964, the average thickness of saturated alluvial deposits was about 8 feet. Using a storage coefficient of 20 percent and a saturated thickness of 8 feet, about 320 million gallons (980 acre-feet) of water per square mile of alluvium is in storage in the Neosho River valley in Allen County. Wisconsinan and Recent alluvial deposits in the Neosho River valley in Allen County underlie an area of about 54 square miles and contain about 17,300 million gallons (53,000 acre-feet) of water in storage.

If at least 5 percent of the mean annual precipitation (36.93 inches) in the valley recharges the aquifer, then about 35 million gallons (110 acre-feet) per square mile is added annually to the aquifer (Williams, 1944). Much of this, however, is probably transpired by plants or discharged into the Neosho River.

Chemical Character of Ground Water

GENERAL DISCUSSION

Water quality-controlling factors.—Water falling on the earth's surface absorbs gases from the atmosphere and from the soil. Absorption of these gases enables the water percolating to the aquifer to dissolve minerals from the rocks it contacts. The amount and type of minerals dissolved are determined by such factors as mineralogical composition of the rocks, solubility of the minerals contained, and rate of ground-water movement through the aquifer. These factors control the chemical quality of the water that characterizes an aquifer. Because these factors are variable, the chemical quality of ground water generally differs from place to place.

Properties of water determined by chemical analysis.—The kind and amount of dissolved minerals in ground water that determines corrosiveness, encrusting tendency, palatability, and other objectionable or desirable properties can be determined from the results of quantitative chemical analyses.

The analyses of 57 samples of water from wells and streams in Allen County are given in table 2. The concentrations of dissolved chemical constituents are expressed in parts per million (ppm). One part per million is 1 unit weight of constituent in 1 million unit weights of water. Generally, when describing the chemical composition of water and the relations of ions in solution, units of equivalents per million are more convenient to work with than units of parts per million. One equivalent per million is 1 unit chemical combining weight of a constituent in 1 million unit weights of water. Factors for the conversion of parts per million of mineral constituents to equivalents per million are given in table 3.

Methods used in this report.—A Piper (1944) diagram is a graphical method used to compare and interpret water-quality data. Figure 11 is a modified Piper diagram of percent equivalents per million of cations and anions for selected water samples in Allen County. The scale of the cations, calcium plus magnesium, ranges from 0 on the left side of the diagram to 100 percent on the right, whereas sodium plus potassium ranges from 0 on the right to 100 percent on the left. The scale of the anions, chloride plus sulfate plus nitrate, ranges from 0 at the bottom to 100 percent at the top, whereas bicarbonate plus carbonate ranges from 0 at the top to 100 percent at the bottom.

Generally, waters are classified as to chemical type based on the abundance of specific cations and anions in solution. A calcium bicarbonate water is one in which the calcium exceeds 50 percent of the cations and bicarbonate exceeds 50 percent of the anions, based on equivalents per million. For water in which no cation or anion is predominant, the classification is based on the order of abundance of the specific ions, such as calcium magnesium bicarbonate. The percentage equivalents per million of a constituent (cation or anion) is the ratio of

TABLE 2.—Chemical analyses of water from selected wells and streams.
[Dissolved constituents and hardness in parts per million]

Well number[1]	Sample number (figs. 11-13)	Depth, feet	Geologic source[2]	Date of collection	Temperature (°F)	Dissolved solids (evaporated at 180°C)	Silica (SiO_2)	Total iron (Fe)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate[3] (NO_3)	Hardness as $CaCO_3$ Total	Hardness as $CaCO_3$ Noncarbonate	Specific conductance (micromhos at 25°C)	pH
23-18E-31ccc	1	19	Illinoisan St	3- 5-65	47	324	12	2.0	0.05	91	11	15	0.8	307	35	6.0	0.1	1.8	272	20	530	....
23-19E-26cad	2	Stream		5-13-64	56	265	16	....	....	70	7.2	14	5.4	251	23	5.0	.4	.9	204	0	430	....
29bba	3	Stream		5-13-64	62	261	8.0	....	....	75	7.0	11	3.3	232	24	18	.3	.5	216	26	440	....
23-20E-33aad	4	190	Chanute Sh	3- 5-65	49	1,961	12	.41	.15	176	171	208	12	395	1,016	169	2.0	.2	1,142	818	2,670	....
23-21E-32aba	5	148	Cherryvale Sh	3- 5-65	51	3,812	7.5	.24	.00	27	19	1,440	11	466	37	2,030	5.5	5.3	146	0	7,020	....
24-17E- 1bbb1	6	Stream		5-13-64	64	257	13	....	....	54	9.1	22	4.4	173	52	16	.4	1.0	172	30	410	....
12bad	7	Stream		5-13-64	66	234	11	....	....	54	11	10	4.7	166	44	13	.4	4.4	180	44	380	....
24-18E- 5ccb	8	30	Ilinoisan St	3- 5-65	55	403	14	.00	.00	118	11	14	.8	342	32	21	.1	24	340	60	700	....
10dcc	9	Stream		5-13-64	62	260	7.5	....	....	75	6.1	10	4.2	229	29	15	.4	.4	212	24	440	....
17aad	10	17	Quaternary Sys	3- 5-65	54	347	11	.00	.00	102	6.2	17	.8	303	36	7.0	.1	18	280	32	580	....
21bdb	11	Stream		5-13-64	67	230	10	....	....	53	6.8	14	4.7	168	43	12	.4	3.1	160	22	370	....
28ccc	12	19	Wisconsinan St	7-29-64	....	507	15	1.8	.28	142	21	....	....	454	77	15	.1	.0	441	69	760	....
32ddd	13	44	Iola Ls	3-26-65	....	1,982	18	2.2	.00	218	77	322	2.3	566	692	161	.4	212	860	396	2,500	....
36aaa	14	Stream		5-13-64	62	197	15	....	....	39	7.9	13	5.4	149	31	7.0	.5	4.4	130	8	310	....
24-19E- 9ccc	....	220	Dennis Ls	7-20-64	60	....	....	....	....	....	....	....	....	....	....	3,900	....	....	....	....	....	....
14daa	15	Stream		5-13-64	63	262	9.0	....	....	62	13	10	9.0	232	29	10	.5	5.3	208	18	430	....
24-20E- 1dda	16	110	Cherryvale Sh	3- 5-65	48	1,254	9.8	.00	.04	93	38	314	3.2	364	220	391	3.2	2.4	388	90	2,200	....
22ddc	17	55	Iola Ls	3- 5-65	46	793	8.2	5.7	.12	120	34	109	1.3	415	259	43	.2	14	439	99	1,200	....
31ccd	18	200	Dennis Ls	3- 5-65	47	378	7.8	3.5	.02	50	12	....	....	78	116	53	.9	44	174	110	610	....
34*	....	......	Mississippian Sys	......	....	[4]7,400	8.0	.00	....	138	59	[6]2,688	....	588	4	4,218	....	....	....	....	....	....
36*	....	160	Swope Ls	......	....	[4]2,410	8.0	.00	.00	48	37	[6]846	....	564	78	1,113	....	....	....	....	....	....
24-21E-15dcd	19	56	Cherryvale Sh	3- 5-65	59	379	12	.19	.00	86	27	18	.5	383	21	9.0	2.2	15	326	12	650	....
34*	....	1,035	Arbuckle Gp	......	....	[4]4,090	22	17	....	76	34	[6]1,480	....	515	21	2,199	....	....	....	....	....	....
25-17E-35ddd	20	235	Chanute Sh	3-26-65	....	4,280	8.2	1.8	.00	70	33	1,560	12	630	107	2,175	4.4	.3	310	0	6,700	....

TABLE 2.—Chemical analyses of water from selected wells and streams *(Concluded)*.

Well number[1]	Sample number (figs. 11-13)	Depth, feet	Geologic source[2]	Date of collection	Temperature (°F)	Dissolved solids (evaporated at 180°C)	Silica (SiO_2)	Total iron (Fe)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate[3] (NO_3)	Hardness as $CaCO_3$ Total	Hardness as $CaCO_3$ Noncarbonate	Specific conductance (micromhos at 25°C)	pH
25-18E- 8aaa	21	90	Iola Ls	3-26-65	50	978	20	.03	.00	178	26	109	1.3	429	314	38	.2	80	551	199	1,230	....
9acc1	22	Stream		5-13-64	69	228	11	....	....	54	9.6	10	4.7	163	44	12	.4	2.3	174	40	380	....
14ccb	23	220	Dennis Ls	3-26-65	....	1,139	5.7	.01	.00	248	26	51	3.8	264	186	76	.2	412	726	510	1,470	....
25-19E- 6ccb1	24	Stream		5-13-64	68	214	11	....	....	56	5.0	9.2	4.4	159	39	9.0	.4	1.6	160	30	340	....
6ccb2	25	65	Iola Ls	3- 5-65	53	1,152	16	.01	.00	136	42	192	1.8	437	317	112	.2	120	512	154	1,740	....
7cdc	....	195	Iola Ls, Chanute Sh	3- 5-65	52	2,848	7.2	.36	.00	18	15	1,092	8.0	805	86	1,170	11	.8	106	0	5,080	....
14aab	26	150	Cherryvale Sh	3-26-65	44	1,377	6.0	2.0	.00	13	1.8	544	3.8	605	16	435	16	.7	40	0	2,210	....
24cdc	27	225	do	6-29-65	....	272	16	5.7	.70	51	10	20	20	239	11	22	.6	3.6	168	0	450	7.3
25-20E-10ccb	....	120	Chanute Sh	3- 5-65	54	635	6.8	.00	.00	10	5.6	233	2.0	551	39	33	3.5	31	48	0	1,060	....
25baa	28	38	Cherryvale Sh	3-26-65	45	1,914	6.8	.13	.46	266	102	174	21	285	824	149	.6	230	1,082	848	2,390	....
27bbc	....	165	do	3-26-65	50	1,081	7.8	.00	.00	11	6.9	398	3.3	473	136	276	9.0	.2	56	0	1,760	....
30ddc	29	200	Cherryvale Sh, Dennis Ls	3-26-65	50	4,072	7.8	.20	.00	48	28	1,515	11	517	53	2,145	9.0	.2	235	0	6,700	....
25-21E-21*	....	100	Dennis Ls	......	....	....	8.0	3.0	....	17	18	[5]210	....	342	22	177	....	....	....	....	....	....
32aab	30	70	do	6-30-65	62	434	7.0	2.7	.00	77	45	22	1.0	373	73	22	2.2	1.6	377	71	730	7.8
26-18E- 2dab	31	Stream		5-13-64	67	224	10	....	....	61	4.4	9.5	3.8	188	33	7.0	.3	2.4	170	16	370	....
12*	....	......	Arbuckle Gp	......	....	....	8.0	9.	....	302	156	[5]11,998	....	616	3	19,148	....	....	....	....	....	....
13cbc	32	120	Iola Ls	6-28-65	65	911	9.8	.87	.27	203	21	38	52	368	88	132	.1	186	593	291	1,440	7.5
20*	....	1,054	Mississippian Sys	......	....	....	20	8.	....	107	70	[5]4,853	....	578	8	7,229	....	....	....	....	....	....
22*	....	1,385	Arbuckle Gp	......	....	....	18	....	....	118	55	[5]2,746	....	610	6	4,245	....	....	....	....	....	....
22aa*	....	......	do	......	....	....	14	....	....	46	48	[5]2,517	....	714	3	3,688	....	....	....	....	....	....
29aac1	33	Stream		5-13-64	68	235	11	....	....	54	11	10	4.7	168	43	14	.4	3.6	180	42	390	....
32ccc	34	22	Chanute Sh	3-26-65	50	2,386	13	1.1	.00	576	42	106	3.0	351	1,376	88	.6	8.0	1,610	1,322	2,500	....
34*	....	1,000	Arbuckle Gp	......	....	....	10	3.	....	452	369	[5]8,745	....	631	5	15,071	....	....	....	....	....	....

26-19E-7aaa	35	200	Dennis Ls, Cherryvale Sh	6-28-65	68	988	6.8	53	.48	138	30	121	31	300	156	105	.3	252	468	222	1,480	7.7
27bbc	36	130	Cherryvale Sh	3-26-65	50	824	9.8	.20	.00	46	15	238	4.0	422	207	91	3.2	2.4	176	0	1,220	....
36cdd	37	Stream		5-13-64	65	210	9.5	....	....	56	6.9	7.5	3.5	159	37	7.0	.4	3.2	168	38	340	....
26-20E-1bab	38	120	Dennis Ls	6-29-65	72	950	14	.21	.11	154	59	81	19	454	218	117	2.0	62	626	254	1,520	7.8
13bba	39	160	do	6-30-65	64	2,896	13	1.4	.0	352	105	395	2.4	298	1,306	213	.5	363	1,310	1,066	3,690	7.4
17aaa	40	160	Cherryvale Sh	6-30-65	62	697	14	3.1	.12	104	29	103	1.6	432	156	53	.3	24	378	24	1,100	7.6
15*	....	......	Mississippian Sys	......	....	[4]3,440	28	8.	....	88	48	[5]1,199	....	581	35	1,808	....	....	....	....	....	....
26-21E-15aba	41	91	Dennis Ls	6-30-65	64	1,318	9.8	.96	.0	189	39	172	1.4	354	304	105	1.0	323	632	342	1,880	8.0
28aaa	42	105	do	6-30-65	63	514	13	.07	.0	53	51	64	2.0	420	35	43	2.4	44	342	0	860	7.8
29*	....	1,640	Arbuckle Gp	......	....	[4]5,860	12	....	....	192	83	[5]1,971	....	383	41	3,369	....	....	....	....	....	....

[1] Analyses with asterisk after well number are by Oilfield Research Laboratory, Chanute, Kans. All other analyses are by Kansas State Department of Health.
[2] *Gp*, Group; *Ls*, Limestone; *Sh*, Shale; *St*, Stage; *Sys*, System.
[3] In areas where the nitrate content of water is known to exceed 45 ppm, the public should be warned of the potential dangers of using the water for infant feeding (U.S. Public Health Service, 1962, p. 7).
[4] Dissolved solids are calculated.
[5] Sodium (Na) and potassium (K) are calculated and reported as sodium.

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

Mineral constituents	Chemical symbol	Conversion factor
Cations		
Calcium	Ca^{++}	0.04990
Magnesium	Mg^{++}	.08220
Sodium	Na^{+}	.04350
Potassium	K^{+}	.02558
Anions		
Carbonate	CO_3^{--}	.03333
Bicarbonate	HCO_3^{-}	.01639
Sulfate	SO_4^{--}	.02082
Chloride	Cl^{-}	.02820
Fluoride	F^{-}	.05263
Nitrate	NO_3^{-}	.01613

the equivalents per million of the constituent to the total equivalents per million of cations or anions.

Large circled numbers on figure 11 indicate areas of a specific chemical type of water. For example, the principal cations and anions for a water that plots in quadrant 1 are calcium plus magnesium and bicarbonate plus carbonate, respectively. The percentage of calcium plus magnesium exceeds that of sodium plus potassium in most of the samples. Bicarbonate and carbonate comprise more than 50 percent of the anions in water from streams and Quaternary deposits. Chloride, sulfate, and nitrate are the principal anions in water from the bedrock aquifers (fig. 11).

Figures 12 and 13 are trilinear diagrams of percent equivalents per million of cations and anions for selected water samples in Allen County. Most of the data for water samples from limestone aquifers plot in the "no dominant type" area on the cation and anion plots. The data for water samples from shale aquifers show a varied pattern when plotted, but many fall into the sodium, chloride, and sulfate areas on figures 12 and 13. Magnesium is never the predominant cation, although in samples 4 and 42 it is the principal cation.

CHEMICAL QUALITY OF WATER IN RELATION TO SOURCE

FORMATIONS OF PRE-KANSAS CITY AGE

Potable ground water is generally not found in Allen County below the base of the Kansas City Group, and in many places the boundary between fresh and saline water is much higher in the stratigraphic section.

Samples from wells drilled into Lower Pennsylvanian, Mississippian, and Ordovician rocks

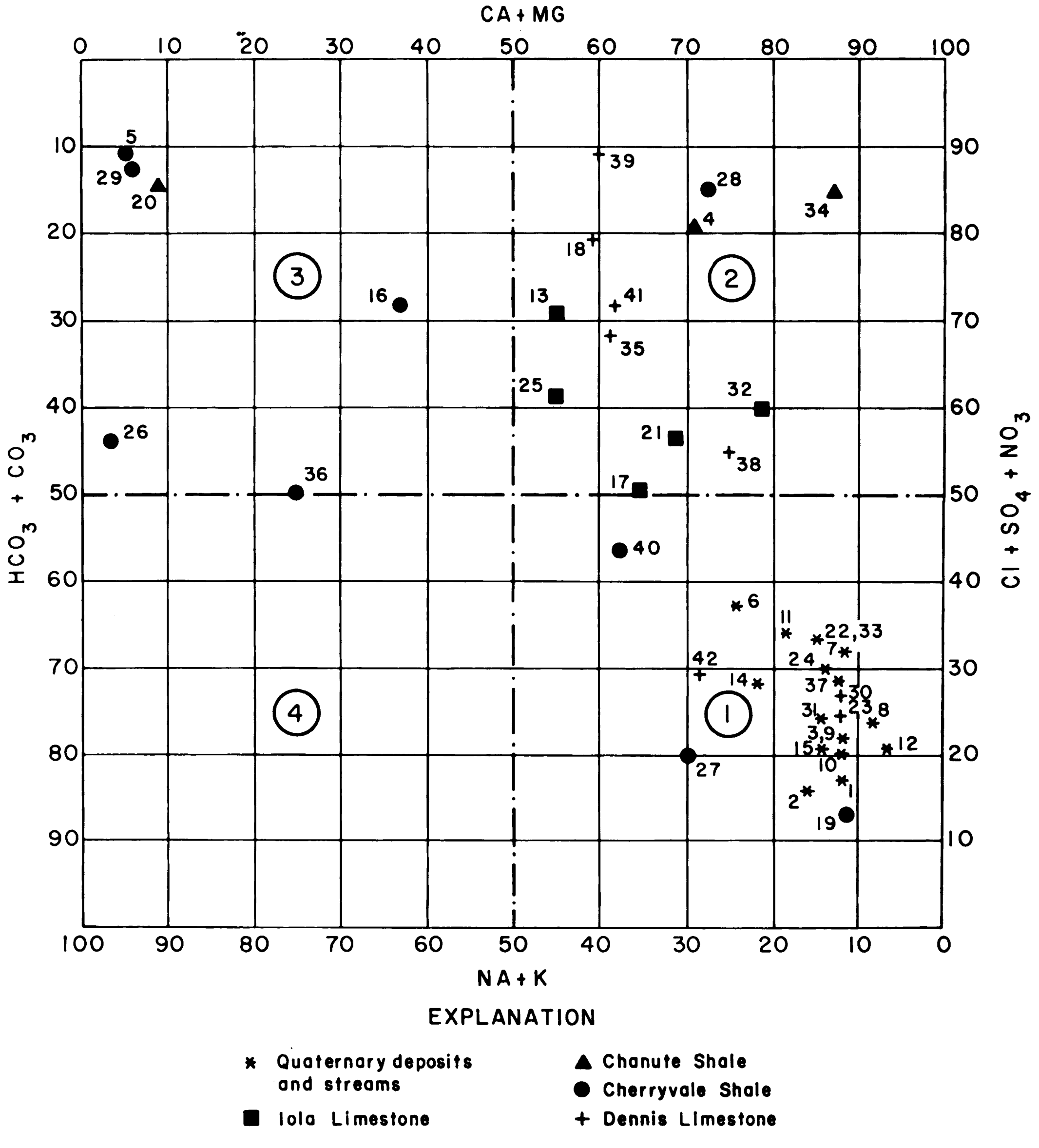


FIGURE 11.—Modified Piper diagram of percent equivalents per million of cations and anions for selected water samples. Small numbers by symbols are sample-identification numbers from table 2. Large circled numbers indicate areas of a specific chemical type of water.

have one common characteristic: all are high in sodium and chloride content. Table 2 includes water analyses from representative wells in Mississippian limestones and Arbuckle rocks.

The high chloride content of waters in rocks below the base of the Kansas City Group is probably due either to saline connate water or to concentration of chloride by some physical or chemical mechanism.

Very little is known about the artesian pressures of ground water in formations of pre-Kansas City age in Allen County. However, several reports indicate that water under artesian pressure from Mississippian and Ordovician rocks rises to within 20 feet of the land surface. One well in Bourbon County with a static water level 188 feet below land surface encountered the Jefferson City Dolomite at 1,461 feet.

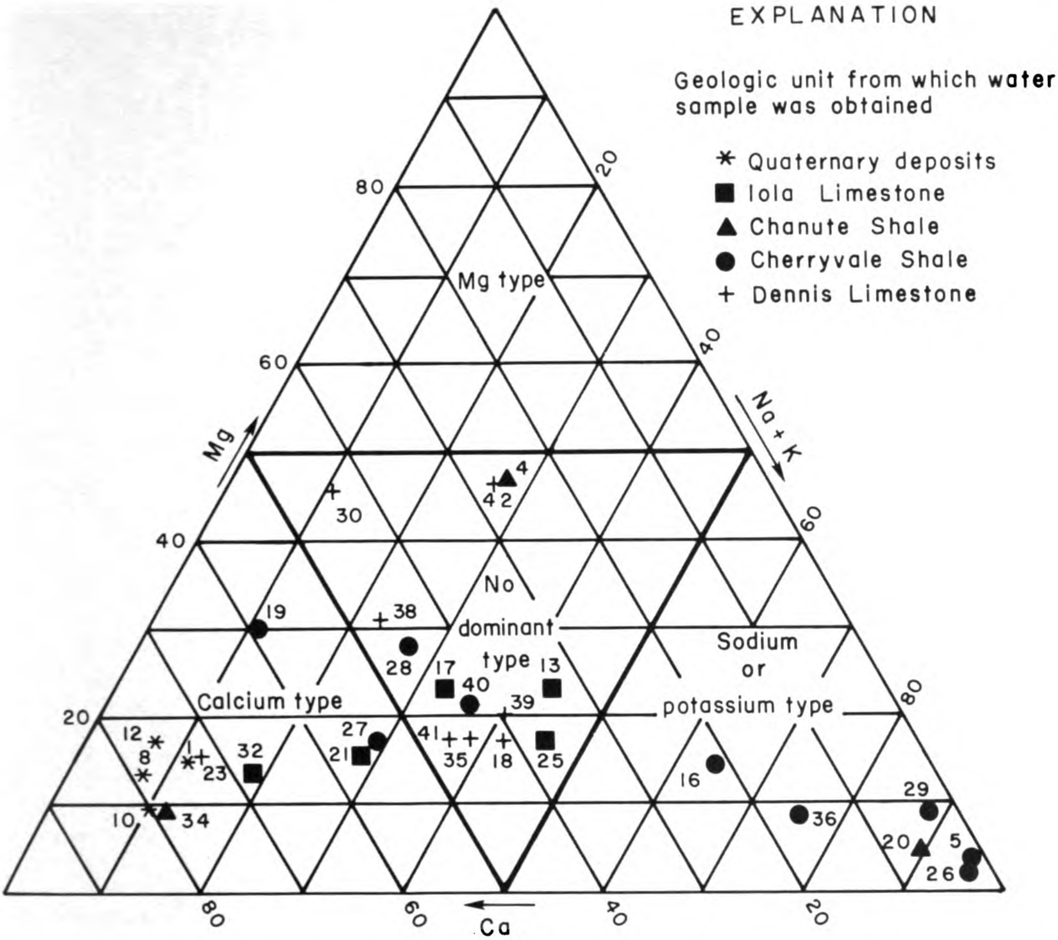


FIGURE 12.—Trilinear diagram of percent equivalents per million of cations for selected water samples. Numbers by symbols are sample-identification numbers from table 2.

CONSOLIDATED ROCKS

Certain problems arise in interpreting the chemical geohydrology of the consolidated aquifers in Allen County. The depth at which water is entering a well is usually difficult to determine; all the rocks penetrated by a well could conceivably yield some water to that well. Owing to vast differences in permeabilities of the units penetrated, some geologic units might yield water at such a slow rate that the water is undetected at the time the well is drilled. The chemical quality of water pumped from a well could vary seasonally because of a variation in the percentage of water from each aquifer in a multiaquifer well. Also, water from different horizons within the same aquifer could have different chemical characteristics.

Little is known concerning hydraulic heads in the consolidated rocks in Allen County. Head differentials in these rocks control to a great extent the flow pattern and, hence, the quality of the water. Certain inferences, however, can be made from the available data, which may explain to some extent certain aspects of the geochemistry of the water in these units.

Certain areas in the county have water of poor quality, an insufficient quantity of water, or both. The northwestern part of the county is underlain by consolidated deposits that are relatively impermeable and yield very little water to wells. Locally, however, wells yielding sufficient quantities of water for domestic use are drilled in this area. The shallow ground water in this area is locally high in chloride content, and the probability of getting an adequate supply of potable water is poor. In the extreme south-

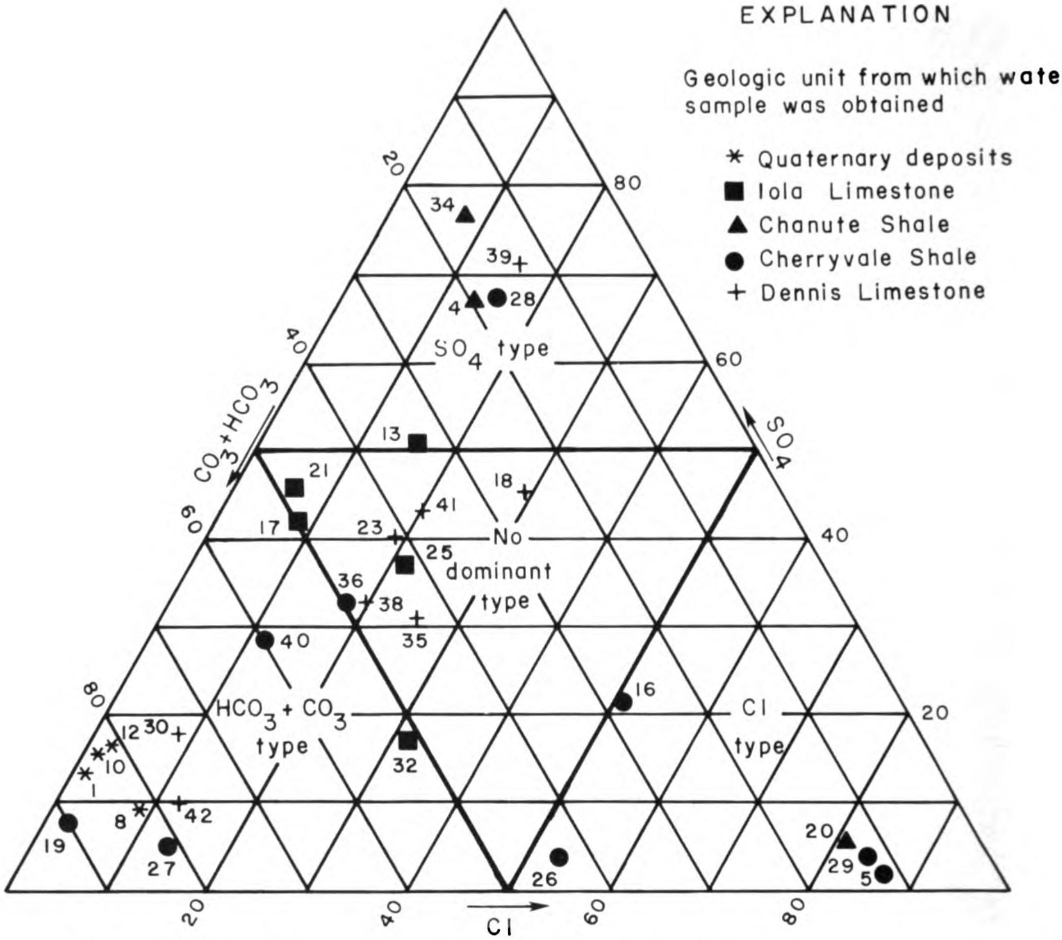


FIGURE 13.—Trilinear diagram of percent equivalents per million of anions for selected water samples. Numbers by symbols are sample-identification numbers from table 2.

western part of the county, in T. 26 S., R. 17 E., residents in the upland areas have difficulty in obtaining potable water; many of the people use cisterns and surface-water sources. Ground water in this area is characterized by a high chloride concentration. Ground water in an area in the central part of T. 25 S., R. 19 E., the western half of T. 25 S., R. 20 E., the extreme northeastern part of T. 26 S., R. 19 E., and the northwestern part of T. 26 S., R. 20 E., also contains high chloride concentrations at shallow geologic horizons.

Past exploration for and exploitation of gas and oil in the area may have contributed to the high concentrations of chloride in waters found in the rocks above the base of the Kansas City Group in Allen County.

LIMESTONE AQUIFERS

Most of the limestones in the county yield water in varying amounts. Only a few limestones, however, have a sufficiently wide outcrop band or sufficient permeability to be considered as important bedrock aquifers. The units in Allen County that have not been considered here are limited in their reliability as aquifers by such factors as insufficient thickness, low permeability, and limited outcrop area. The quality of the water from these limestones is poor except in local areas. A fairly good correlation seems to exist between quantity and quality of water in these limestones. Generally, the quality improves with increasing availability of water in the aquifer.

Dennis Limestone.—Water from the Dennis

Limestone is generally of the calcium bicarbonate sulfate type. However, some of the analyses of samples from wells in Allen County indicate that a high percentage composition of magnesium, sodium, and chloride occurs locally. Total ionic concentration varied widely; dissolved solids concentrations ranged from 378 to 2,896 ppm.

In the outcrop area, the Dennis Limestone contains some dolomite with a Ca/Mg ratio of 1. The ratios of water sampled from the Dennis in this area range from 0.6 to 1.5. As the water moves downdip to the north and to the west, some base exchange apparently occurs and, locally, sodium is exchanged for calcium.

High concentrations of sulfate are characteristic of the water from some wells in the Dennis in Allen County. These wells penetrate thin beds of black fissile shale in the upper part of the Winterset Limestone Member of the Dennis Limestone. Many of the wells also penetrate the Stark Shale Member of the Dennis, which is also black and fissile. Phosphatic nodules [$Ca_5(PO_4)_3F$] are scattered throughout these shales. The presence of high fluoride and phosphate content, as well as high sulfate content, in the water sampled indicates that the water probably is derived from the black shales.

In the outcrop area, wells drilled into the Dennis obtain water of excellent quality.

Water from depths greater than 100 feet generally contain lower concentrations of dissolved solids if the water is from the Dennis than if it is from other limestone aquifers, but water from a well drilled into the Dennis in the SW¼ SW¼ SW¼ sec. 9, T. 24 S., R. 19 E., had a chloride content of 3,900 ppm at a depth of 220 feet.

Nitrate in concentrations in excess of 250 ppm was found in four water samples from wells obtaining water from the Dennis in Allen County (table 2). Polluted water from a shallower horizon probably is entering these wells.

Iola Limestone.—Figure 11 shows that all the water samples from the Iola plot in area 2 of the Piper diagram, as do most of the waters sampled from limestone aquifers in Allen County. The principal cations are calcium and magnesium; the principal anions are sulfate and chloride. As mentioned previously, the extensive joint system in the Iola Limestone seems to give that unit fairly good horizontal and vertical permeability. This, and the fact that a large area of the county is directly underlain by the Iola Limestone, makes it one of the more important bedrock aquifers in Allen County. The fact that most of these joints are open for water movement indicates that the water is unsaturated with respect to calcium and bicarbonate. Water saturated with respect to calcium and bicarbonate would leave deposits in the open joints and decrease the permeability.

Water from shallow wells in the Iola in the outcrop area locally is relatively high in sulfate content. The exact mechanism for the formation of sulfate water at this horizon is not known. No insoluble residue data are available for the Iola Limestone in Allen County, but in counties to the north finely disseminated pyrite (FeS_2) does exist in the Iola (Miller, 1966). If finely disseminated pyrite were oxidized to form a soluble sulfate, the slightly acidic water would tend to keep deposits of calcium carbonate ($CaCO_3$) from forming in the joints. Gypsum in the form of selenite crystals occurs locally in the Muncie Creek Shale Member of the Iola. Solution of the gypsum by water moving through the Iola could increase the sulfate content of the ground water.

Locally, wells drilled into the Iola will yield 5 to 20 gpm of saline water. The magnitude of these well yields could result from the fact that saline water will cause more limestone solution, and hence more permeability, than fresh water (Back and Hanshaw, 1965).

Near the outcrop and along the strike of the Iola Limestone, water from that unit is of good chemical quality. The concentration of dissolved solids in the Iola increases with depth and distance from the area of recharge.

All but one of the analyses in table 2 containing concentrations of nitrate greater than 45 ppm are for water from limestone aquifers. Four of these analyses are for water samples from wells in the Iola Limestone and contain as much as 212 ppm nitrate. Polluted water possibly reaches the water table through the joint system in the limestones, but such high nitrate concentrations as those found in local areas in eastern Kansas are difficult to explain.

Other limestone aquifers.—A few wells in Allen County obtain water from the Swope Limestone. The chemical analysis (table 2) of only one water sample from the Swope Limestone is insufficient to determine the quality of water in the aquifer.

SHALE AND SANDSTONE AQUIFERS

Water in shale and sandstone aquifers in Allen County is usually of poorer quality than water from the limestone aquifers at comparable depths. In part, this is due to the much lower permeabilities of the shales and sandstones. Water in these aquifers moves so slowly that chemical processes in the aquifer have time to completely change the chemical character of the water.

Some water in these aquifers may be connate; that is, water trapped in the sediments during deposition. Because of extremely low permeabilities of the aquifer, this water moves very slowly out of the area. As a result, the shales act as large reservoirs of saline water from which chloride in high concentrations may be slowly diffused to adjoining aquifers.

Bredehoeft and others (1963) in a study of the Illinois basin, an area similar to the Cherokee basin, suggested that a process called clay-membrane concentration was responsible for large amounts of dissolved ions in water from some formations. This process is based on the premise that certain types of clay differentially restrict the passage of ions. The clay particles are negatively charged and repel the anions but are permeable to the cations. Water molecules that do not ionize to the same extent as salt molecules will respond to the differences in hydrostatic head and move upward through the shales if lower hydrostatic heads exist in the overlying beds. If the efficiency of the clay membrane is high, the trapped anions will attract cations and prevent their passage, and over a long period of time large concentrations of these ions will be trapped.

Lane and Bonner Springs and Vilas Shales.—Very little water is available from these two units in Allen County. Locally, saturated sandy zones in the shales have enough permeability to yield a few hundred gallons of water per day to wells. The chemical quality of water available from these shales is highly varied.

The Lane and Bonner Springs Shales are essentially an aquiclude, except for a persistent sandy zone near the middle of the unit that yields water to several wells in the north-central part of the county. Several wells in this sandy zone are reported to yield water of fairly good quality.

The Vilas is the better aquifer of the two. Wells in the Vilas obtain small quantities of fairly good-quality water from shallow, large-diameter dug wells, but the shallow wells may become dry during prolonged dry periods.

Cherryvale and Chanute Shales.—The Cherryvale and Chanute Shales commonly yield water of the sodium sulfate chloride type. As is characteristic of shale aquifers in Allen County, water from the Cherryvale and Chanute has no definite water-quality pattern on the Piper diagram (fig. 11) or on the trilinear diagrams (figs. 12, 13). Owing to differences in permeability in these shales, very slow mixing of water in a lateral direction within the individual formations is possibly occurring.

Waters from the sandstones in the Cherryvale and Chanute sequence have a rather characteristic chemical quality. They are generally hard and high in concentration of chloride and fluoride; the maximum concentrations reported are 2,175 ppm and 16 ppm, respectively. Shallow wells in the outcrop area of the Cherryvale and Chanute Shales usually obtain water of fairly good quality that becomes progressively poorer downdip.

Unconsolidated Deposits

DEPOSITS IN TERRACE POSITION

The chemical quality of water from unconsolidated terrace deposits is highly unpredictable owing to wide ranges in the permeability, topographic position, and varied nature of the rocks directly underlying the deposits. Water from the terrace deposits generally is of good quality, and is similar to that of the alluvial deposits. The water is of the calcium bicarbonate type.

ALLUVIUM IN THE NEOSHO VALLEY

The chemical quality of water in the alluvium in the Neosho River valley is uniformly good, except for local areas where pollution may exist. The data from water samples from wells in these deposits plot in area 1 of figure 11, which indicates a large percentage of calcium plus magnesium relative to sodium plus potassium. The chemical quality of these samples is characteristic of water from these deposits in other counties through which the Neosho River flows. The water from these deposits generally has a hardness of 250 to 450 ppm and may have a high iron content.

Any pollution that becomes apparent in water from wells in the alluvium is probably from a local source. Because of the high permeability of the alluvium and the large quantity of water moving through the aquifer, dilution of any polluting waters may occur a short distance from the point of pollution. Locally in the valley, well water with a high nitrate content has been reported; the aquifer supplying most of these wells is probably being polluted from such sources as sewage effluent and crop fertilizer.

Proper well covering should be provided for wells to prevent surface pollution. The water should be analyzed frequently for nitrate content and for the presence of bacteria. This service can be provided through the County Health Officer at little or no expense to the well owner.

The quality of water from the alluvium in the Neosho Valley is quite similar to the quality of water from the Neosho River, which is expected inasmuch as a good hydraulic connection between the river and the alluvial deposits exists along the entire valley.

In the areas of the county where the alluvium is underlain by the Iola Limestone, water slightly higher in sulfate content has been reported from wells in the alluvium. Water from the Iola Limestone in the west-central part of the county generally has a high sulfate content. Some mixing of waters probably occurs due to an extensive and well-developed joint system where alluvium directly overlies the Iola.

CHEMICAL QUALITY OF WATER IN RELATION TO USE

Water-quality criteria differ according to use. Water for domestic purposes should be clear; colorless; free from objectionable odor, taste, and disease-causing micro-organisms; and of reasonable temperature. The significance of certain chemical constituents in ground water and the maximum concentrations recommended for drinking water are given in table 4.

Rigid criteria are not available for evaluating the usefulness of a water as a supply for watering stock. However, most animals seem to be able to use water considerably poorer in quality than would be considered satisfactory for human beings (Hem, 1959).

Use of ground water for agricultural or industrial purposes is very limited in Allen County. However, water-quality requirements for these purposes must be considered. Guidelines for relating the chemical quality to its suitability for irrigation have been proposed (U.S. Salinity Laboratory Staff, 1954). The two main criteria for determining the suitability of water for irrigation are the dissolved-solids content and the sodium concentration relative to the calcium and magnesium concentrations.

Water-quality requirements for industrial use vary depending upon the specific use to be made of the water. Generally, water of a low dissolved-solids content and of a fairly uniform quality will meet the requirements of most industries.

SANITARY CONSIDERATION

Well water may have an objectionable taste due to dissolved mineral matter, but it may be free from harmful bacteria and, consequently, safe for drinking. Other well water, good tasting and seemingly pure, may contain harmful bacteria. Pollution may be indicated by excessive amounts of certain dissolved minerals, such as chloride or nitrate.

Recommendations may be obtained from the State Department of Health concerning sanitary construction, locations, and pump installations for different types of wells.

Utilization of Ground Water

PAST AND PRESENT USE

In Allen County, ground water is used chiefly for domestic and stock purposes. At the present time (1965), no municipal systems use water from ground-water sources. Almost all industry in Allen County uses water from municipal supplies, with the exception of the oil industry, which uses ground water for repressuring in the recovery of oil.

Nearly all domestic and stock water supplies in rural areas are obtained from privately owned wells. In upland areas, ground-water supplies are obtained from dug or drilled wells. Ground water is difficult to obtain in some of the upland areas, and cisterns are used as a source of domestic water on many farms. In valley areas, most supplies are obtained from driven, drilled, or dug wells. Ponds that provide domestic and stock water supplies have been constructed in many places in the county. In June 1965, 147 families were being served by rural water districts that purchased water from the city of Iola, which obtains its water from the Neosho River (Mrs. Elba Bowman, oral commun., 1965). The towns of Gas City and LaHarpe are also served by municipal supplies purchased from Iola (fig. 14).

POTENTIAL USE

The largest ground-water potential in the county lies in the Neosho River valley. With proper well location, construction, spacing, and pumping rates, 50 to 100 gpm of water could be pumped from wells in the valley deposits for domestic, stock, irrigation, industrial, or municipal supplies.

The potential of upland limestone, shale, and sandstone aquifers is not as good as that of the unconsolidated aquifers. Large quantities of potable ground water are not available from the consolidated aquifers, and in the foreseeable future these aquifers probably will not be important to the economic development of the county.

TABLE 4.—Quality of water in relation to use.

Constituent	Principal characteristics	Acceptable maximum concentration, in parts per million[1]	Range in concentration in ground water in Allen County, in parts per million[2]
Dissolved solids	Water high in dissolved-solids content 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 — generally satisfactory 1,000—may have noticeable taste or be unsuitable in some other respect	272-7,400
Hardness[3]	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.	——	40-1,610
Total iron (Fe)	Iron stains cooking utensils, plumbing fixtures, and laundry. Water may have disagreeable taste.	0.3	0-53
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	0.1-16
Nitrate (NO_3)	Nitrate concentration of 90 ppm may cause cyanosis in infants (Metzler and Stoltenberg, 1950). Comly (1945) states that concentrations of 45 ppm may be harmful to infants. Adverse effects from drinking high-nitrate water are also possible in older children and adults.	45	0-412 (8 samples>90 ppm 10 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 persons not accustomed to drinking such water.	250	3-1,376
Chloride (Cl)	Chloride in ground water may be derived from connate marine water in sediments, from sewage, or from solution of minerals containing chloride.	250	6.0-19,148

[1] Concentrations as recommended by the U.S. Public Health Service (1962).
[2] Based an analyses of 44 ground-water samples (table 2).
[3] The hardness of water is classified as follows: 60 ppm or less, soft; 61-120 ppm, moderately hard; 121-180 ppm, hard; and 181 ppm or more, very hard.

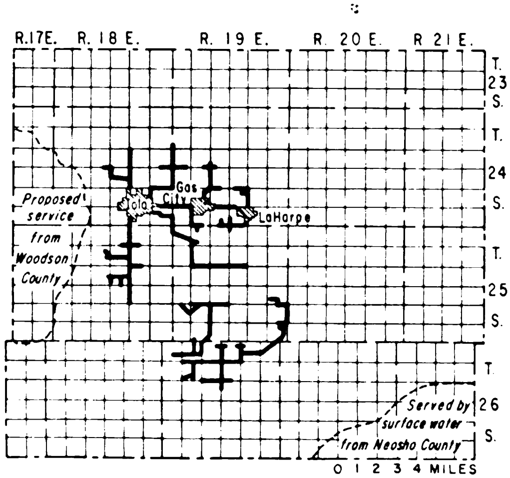


FIGURE 14.—Areas served by rural water districts (1965).

RECORDS OF WELLS AND TEST HOLES

Information pertaining to 176 water wells and test holes in Allen County is given in table 5. Measured depths to water level are given to the nearest 0.1 foot. Measured depths of wells are given to the nearest 0.1 foot, whereas reported depths are given only to the nearest foot.

TABLE 5.—Records of wells and test holes.

Well number[1]	Owner or user	Depth of well, in feet[2]	Diameter of well, in inches	Type of casing[3]	Principal water-bearing unit: Character of material[4]	Principal water-bearing unit: Geologic source[5]	Method of lift,[6] type of power[7]	Use[8]	Depth to water level below land surface, in feet	Date of measurement	Altitude of land surface above mean sea level, in feet	Yield, in gallons per minute[2]
23-17E-14ccc	Glenn Haag	103 R	10	S	Ls	Plattsburg Ls	Cy, H	D, S	29.2	6-64		
25aab	State Geol. Survey	30.0	4	N	Gr, St, Cl	Illinoisan St	N	T	10.0	6-65		
25dbb	John Harrington	24.6	48	R	Ls	Stanton Ls	J, E	D	22.6	6-64		
35ccb	William Mentzer	30.1	10	S	Ls	do	J, E	D	12.2	6-64		
23-18E-22bbc	Mack C. Colt, Inc.	120 R	8	S	Ls	Stanton Ls, Plattsburg Ls	N	N	36.1	......		
24dac	Artie Clark	120 R	10	S	Ss, Ls	Vilas Sh, Plattsburg Ls	Cy, H, E	N	52.0	6-64		
27dad	Avery Wilmoth	20.0	48	R	Ls	Stanton Ls	J, E	D	10.0	6-64		
29aaa	Clarence Turner	70.0	6	S	Ls	do	J, E	D, S	51.6	6-64		
31ccc•	Allen County	18.6	72	R	Sd, Gr	Illinoisan St	Cy, H	PS	7.4	6-64		
23-19E-19ada	State Geol. Survey	258.0	4	N	Ls, Sh	Plattsburg Ls, Iola Ls	N	T	20.0	8-64		
19dad	Roy Howard	18.1	48	R	Ls	Stanton Ls	N	N	11.9	6-64		
20cad	Rawlin Strickler	32.0	48	R	Ls	Plattsburg Ls	J, E	D, S	9.0	6-64		
20dad	State Geol. Survey	168.0	4	N	Ls, Sh	do	N	T	9.8	8-64		
23ddd	James Hay	28.6	48	R	Ls	do	J, E	D	8.9	6-64		
29bbb	Charles Martin	15.6	48	R	Ls	do	Cy, H	D	9.0	6-64		
30aaa	Forest Runer	13.0	72	R	Ls	Stanton Ls	N	N	6.8	6-64		
31dcc	Harold E. White	16.9	36	R	Ls	do	Cy, H	N	12.0	6-64		
33adb	George E. Mabie	18.5	36	R	Ss	Lane and Bonner Springs Sh	Cy, H	D	8.5	6-64		
36bcb	Martin Nilges	15.6	36	R	Sandy Sh	do	Cy, H	N	2.6	6-64		
23-20E-25bbb	Curtice Call	39.3	192	R	Ls	Iola Ls	Cy, H	S	8.1	7-64		
33aad•	W. W. McElvain	190 R	10	S	Ss, Cl	Chanute Sh	J, E	D, S	26.7	7-64		
35ccc	Harold Shelton	22.0	48	R	Ls	Iola Ls	J, E	D, S	6.4	7-64		
23-21E-22bdc	E. M. Hosley	36.0	10	T	Ls, Sh	Dennis Ls	N	N	10.0	7-64		
32aba•	Hugh Murrow	148 R	10	S	Black Sh	Cherryvale Sh	Sub, E	D, S	76.6	7-64		
24-17E- 1abb	State Geol. Survey	19.0	4	N	Gr, St, Cl	Wisconsinan St, Recent St	N	T	14.2	5-65	965	
1bbb2	do	13.0	4	N	Gr, St, Cl	do	N	T	Dry	5-65	962	
14aaa	C. M. Heath	100.0	8	S	Ss	Vilas Sh	N	O	22.5	6-64		
25aab	Ray Townsen	100.0	8	S	Ls, Sh	Plattsburg Ls	J, E	D	27.0	6-64		2 R
26ddd	D. H. Shumaker	167 R	8	S	Ls, Sh	do	C, E	D, S	5.6	6-64		2 R
35dcc	Don McDonald	27.7	36	R	Ls, Sh	Stanton Ls	J, E	D, S	7.8	6-64		5 R
24-18E- 1cbb	State Geol. Survey	12.0	4	N	Gr, St, Cl	Wisconsinan St, Recent St	N	T	......	5-65	965	
2add	J. E. Powell	29.0	48	R	Ls	Plattsburg Ls	Cy, H	D	11.0	......		
2ddd	State Geol. Survey	8.0	4	N	St, Cl	Wisconsinan St, Recent St	N	T	4.2	5-65	958	
4baa	Fred Sinclair	165 R	10	S	Ls, Sh	Iola Ls	N	N	68.5	6-64		
5ccb•	Kenneth Heinz	30.1	8	S	Sd, Gr, St	Illinoisan St	J, E	D, S	4.1	6-64		
6baa	State Geol. Survey	23.0	4	N	Gr, St, Cl	Wisconsinan St, Recent St	N	T	12.3	5-65	961	
6bbb	do	20.0	4	N	Gr, St, Cl	do	N	T	6.8	5-65	965	
6bcb	do	18.0	4	N	Gr, St, Cl	do	N	T	8.6	5-65	961	
6cbc	do	18.0	4	N	Gr, St, Cl	do	N	T	......	5-65	961	
9aaa	do	231.0	4	N	Ls, Sh	Plattsburg Ls, Iola Ls	N	T	13.6	6-65		
10ccc	do	16.0	4	N	Gr, St, Cl	Illinoisan St	N	T	12.2	5-65	964	
10ccd	Mrs. G. McCoin	30.2	8	S	Ls	Iola Ls	N	N	13.3	6-64		

TABLE 5.—Records of wells and test holes (*Continued*).

Well number[1]	Owner or user	Depth of well, in feet[2]	Diameter of well, in inches	Type of casing[3]	Principal water-bearing unit: Character of material[4]	Principal water-bearing unit: Geologic source[5]	Method of lift,[6] type of power[7]	Use[8]	Depth to water level below land surface, in feet	Date of measurement	Altitude of land surface above mean sea level, in feet	Yield, in gallons per minute[2]
10cdd	State Geol. Survey	18.0	4	N	Gr, St, Cl	Wisconsinan St, Recent St	N	T	14.0	5-65		
13ddc	Carl C. Conger	24.0	48	R	Sandy Sh	Lane and Bonner Springs Sh	J, E	S	15.1	6-64		
15dbb	State Geol. Survey	13.0	4	N	Gr, St, Cl	Wisconsinan St, Recent St	N	T	......	5-65	954	
17aad*	V. R. Estep	16.6	1	G	Sd, Gr	Quaternary Sys	C, E	D, S	6.2	6-64		6 R
17ccc	Henry Spurgen	200 R	8	S	Ls, Sh	Plattsburg Ls, Iola Ls	N	O	17.6	6-64		
20ccb	State Geol. Survey	15.0	4	N	Gr, St	Recent to Illinoisan St	N	T	......	5-65	985	
22dcc	Frieda Bohm	22.8	48	R	Ls, Sh	Iola Ls	N	O	17.7	6-64		
28ccc*	State Geol. Survey	19.0	4	N	Gr, St	Wisconsinan St, Recent St	N	T	12.9	7-64	948	
28cdd	do	24.5	8	S	Gr, St	Recent St, Wisconsinan St	N	O	16.1	7-64	948	20
29aaa	do	23.0	4	N	Gr, St, Cl	Wisconsinan St, Recent St	N	T	9.8	5-65	947	
29add	do	18.0	4	N	Gr, St, Cl	do	N	T	7.2	5-65	945	
29bcc	do	4.0	4	N	Gr, St	Recent to Illinoisan St	N	T	......	5-65	971	
29ccc	Miss Ann Deis	31.4	36	R	Ls	Plattsburg Ls	N	N	18.0	6-64		
32ddd*	Mrs. E. C. Arnold	44.0	8	S	Ls, Sh	Iola Ls, Chanute Sh	Cy, H	N	18.4	6-64		
33bcc	State Geol. Survey	196.0	1	G	Ls, Sh	Iola Ls, Drum Ls	N	O	30.5	7-64		
33ccc	do	19.0	8	N	Gr, St	Recent St, Wisconsinan St	N	T	12.9	7-64	948	
24-19E- 2ddd	J. R. Hicks	130 R	10	S	Ls, Sh	Iola Ls, Dennis Ls	J, E	D, S	12.7	6-64		2 R
7cbb	Harry Schaffer	15.0	48	R	Sandy Sh	Lane and Bonner Springs Sh	N	N	8.4	6-64		
9ccc*	State Geol. Survey	220.0	1	G	Ls, Sh	Dennis Ls	N	O	45.2	7-64		
15bbc	F. B. Leavell	25.5	36	R	Ls	Iola Ls	N	N	11.7	6-64		
21bcb	Fred Duffy	11.8	48	R	Ls	do	Cy, H	S	5.2	6-64		
25cdd	A. W. Seifker	18.3	36	R	Ls	do	Cy, H	S	5.5	7-64		
27ccc	Paul Cramm	18.1	36	R	Sandy Sh	Lane and Bonner Springs Sh	Cy, H	S	9.1	6-64		
30dab	Country club	21.3	36	R	Ls, Sh	Iola Ls	Cy, H	PS	6.0	6-64		2 R
36ccd	Mrs. Bertha Cordell	178 R	10	S	Ls	Dennis Ls	Sub, E	D, S	39.0	7-64		3 R
24-20E- 1dda*	Tom Vanatta	110 R	8	S	Black Sh	Cherryvale Sh	J, E	D, S	58.8	7-64		
5dda	A. B. Hopkins	39.1	10	S	Ls	Iola Ls	Cy, H	D	18.8	7-64		
10daa	Harold Blue	70.0	8	S	Ls	do	J, E	D, S	7.1	7-64		
19bbc	Wilburn Ludlum, Jr.	6.0	96	R	Ls	do	J, E	S	.9	6-64		20 R
20ddc	Ralph L. Ensminger	35.3	36	R	Ls	do	C, NG	N	8.5	7-64		
22ddc*	Harold E. Lewis	54.9	10	T	Ls	do	Cy, H	D	36.0	7-64		
24aba	Wayne Bradford	120 R	10	S	Ss, Ls, Sh	Chanute Sh, Cherryvale Sh	Cy, E	D, S	51.6	7-64		
31ccd*	V. L. Terrill	200 R	10	S	Black Sh	Dennis Ls	J, E	S	12.1	7-64		
35cdd	Margaret Krieger	30.0	10	S	Ls	Iola Ls	J, E	D, S	5.8	7-64		
24-21E- 8aad	Edward Bradford	107 R	10	S	Ls, Sh	Dennis Ls	N	N	33.1	7-64		
15dcd*	Glenn E. Smith	56.2	8	S	Ss, Ls, Sh	Cherryvale Sh	J, E	D, S	24.4	7-64		
29aaa	Kenneth Bacon	85.4	8	S	Ss, Sh	do	N	N	5.6	7-64		
31dcc	Robert W. Wood	24.0	10	G	Ss, Ls, Sh	Chanute Sh	J, E	D	9.9	7-64		
35bcb	John F. Camac	20.2	48	R	Ss	Cherryvale Sh	Cy, H	S	6.2	7-64		
25-17E- 1ada	Jack Stotler	30.0	48	R	Ls, Sh	Stanton Ls	Cy, E	D	7.1	6-64		
14aad	E. D. Potts	16.7	36	R	Ss	Vilas Sh	Cy, H	D	10.7	6-64		
23cdd	W. W. Works	17.0	8	S	Ls, Sh	Stanton Ls	N	N	2.4	6-64		

	24abb	State Geol. Survey	15.0	4	N	Gr, St, Cl	Illinoisan St	N	T	Dry	5-65	966	
	25cdd	do	32.0	4	N	Gr, St, Cl	do	Cy, G	T	27.9	5-65	960	
	35ddd•	Mrs. Hazel Fredricks	235.0	8	S	Ls, Sh	Iola Ls, Chanute Sh	J, E	D, S	17.4	6-64		3 R
	36aaa	State Geol. Survey	12.0	4	N	Gr, St, Cl	Illinoisan St	N	T	Dry	5-65	945	
	36bbb	do	......	4	N	Gr, St, Cl	do	N	T	Dry	5-65	968	
	36ddd	do	13.0	4	N	St, Cl	do	N	T	Dry	5-65	961	
25-18E-	4aca	Willard Hammer	25.6	36	R	Ls, Sh	Lane Sh, Iola Ls	C, E	D, S	19.2	6-64		2 R
	4baa	State Geol. Survey	13.0	4	N	Gr, St, Cl	Illinoisan St	N	T	......	5-65	957	
	4bcc	do	20.0	4	N	Gr, St, Cl	do	N	T	......	5-65	955	
	4bdd	do	14.0	4	N	Gr, St, Cl	do	N	T	12.9	5-65	953	
	8aaa•	Ralph Diggs	90.0	8	S	Ls, Gr	Illinoisan St, Iola Ls	J, E	D	18.1	6-64		2 R
	9acd1	Hill Packing Co.	200 R	8	S	Black Sh	Dennis Ls, Swope Ls	N	O	14.1	6-64		
	12bbb	Roy Hays	21.4	48	R	Ls	Plattsburg Ls	Cy, H	D	10.7	6-64		
	14ccb•	Loyd Holly	220 R	10	S	Black Sh	Dennis Ls	C, E	D, S	33.5	6-64		
	17add	State Geol. Survey	13.0	4	N	Gr, St, Cl	Wisconsinan St, Recent St	N	T	......	5-65	943	
	17bdd	do	23.0	4	N	St, Cl	do	N	T	18.8	5-65	938	
	18add	do	25.0	4	N	Gr, St, Cl	do	N	T	......	5-65	943	
	18ccc	do	20.0	4	N	Gr, St, Cl	do	N	T	8.0	5-65	944	
	18ccd	Mrs. Milo Miller	22.0	36	R	Sandy Sh	Upper Pennsylvanian Ser	J, E	D	19.3	6-64		2 R
	18dcc	State Geol. Survey	26.0	4	N	Gr, St, Cl	Wisconsinan St, Recent St	N	T	16.0	5-65	944	
	20bbb	do	19.0	4	N	Gr, St, Cl	do	N	T	13.1	5-65	938	
	21ccc	Clint Baker	24.0	48	R	Gr	Illinoisan St	J, E	D, S	19.4	6-64		2 R
	26bcd	Joseph Potts	25.5	36	R	Ls	Iola Ls	C, E	S	15.1	6-64		
	30cac	J. R. Townsen	17.0	36	R	Sd, Gr, St	Terrace Dep	Cy, H, W	S	11.0	6-64		
	32ccc	State Geol. Survey	18.0	4	N	Gr, St, Cl	Wisconsinan St, Recent St	N	T	13.5	5-65	932	
	33bad	Russell Lytle	37.8	8	S	Ls	Iola Ls	N	O	11.0	6-64		
25-19E-	6ccb2•	Ralph Sherrill	65.0	10	S	Ls	do	J, E	D, S	11.8	7-64		
	7cdc•	J. L. Hampton	195 R	10	S	Ss, Ls	Iola Ls, Chanute Sh	J, E	D, S	54.1	7-64		
	8aaa	Edwin Laver	26.9	48	R	Ls	Iola Ls	J, E	D	11.4	7-64		
	10daa	State Geol. Survey	170.0	4	N	Black Sh	Dennis Ls	N	T	44.3	6-65		
	14aab•	Elmer McEndree	150 R	10	S	Ss	Cherryvale Sh	C, E	S	72.1	7-64		
	16aad	D. E. Anderson	177 R	10	S	Ss, Sh	Cherryvale Sh, Dennis Ls	Cy, H	O	65.1	7-64		
	20ddc	I. C. Coltrane	22.0	36	R	Ls	Iola Ls	N	N	11.0	7-64		
	23ccb	A. W. Wade	28.0	36	R	Ls	do	N	N	11.8	7-64		
	24cdc•	W. A. Jones	225 R	10	S	Ss, Ls, Sh	Cherryvale Sh	Cy, E	S	75.4	7-64		
	36ddd	State Geol. Survey	206.0	4	N	Black Sh	Dennis Ls	N	T	42.8	6-65		
25-20E-	1bbb	do	130.0	4	N	Coal	Chanute Sh	N	T	10.1	7-65		
	6bbb	D. W. Swearingen	18.3	96	R	Ls	Iola Ls	C, E	D, S	12.7	7-64		3 R
	7bba	Harry Laver	80.3	10	S	Ss	Chanute Sh, Cherryvale Sh	Cy, E	S	36.3	7-64		
	10ccb•	Carl Stanley	120 R	10	S	Sh	Chanute Sh	Sub, E	D, S	9.3	7-64		
	12ddd	Olan Hobelman	18.3	60	R	Ls	Iola Ls	Cy, E	S	12.2	7-64		
	25baa•	Charles Larue	37.8	10	S	Black Sh	Cherryvale Sh	J, E	S	23.5	7-64		
	27bbc•	Arthur West	165 R	10	S	Sh	do	Sub, E	D	45.3	7-64		
	30ddc•	Curtis Stanley	200 R	10	S	Ls, Sh	Cherryvale Sh, Dennis Ls	Sub, E	D, S	47.4	7-64		
25-21E-	16ccc	Lloyd Franklin	35.4	36	R	Ls	Cherryvale Sh	J, E	D, S	27.6	7-64		
	32aab•	Carl Anderson	70.2	10	S	Black Sh	Dennis Ls	Cy, H	D	10.2	7-64		
26-17E-	1dba	State Geol. Survey	22.0	4	N	Gr, St, Cl	Wisconsinan St, Recent St	N	T	13.7	5-65	921	
	11aba	do	192.0	4	N	Ls, Sh	Plattsburg Ls	N	T	11.8	8-64		
	12abb	do	17.0	4	N	Gr, St, Cl	Wisconsinan St, Recent St	N	T	15.2	5-65	931	

TABLE 5.—Records of wells and test holes *(Concluded)*.

Well number[1]	Owner or user	Depth of well, in feet[2]	Diameter of well, in inches	Type of casing[3]	Principal water-bearing unit: Character of material[4]	Principal water-bearing unit: Geologic source[5]	Method of lift,[6] type of power[7]	Use[8]	Depth to water level below land surface, in feet	Date of measurement	Altitude of land surface above mean sea level, in feet	Yield, in gallons per minute[2]
12bcc	Francis Temming	120 R	8	S	Ls, Sh	Plattsburg Ls	N	N	21.0	6-64		
26-18E- 2daa	Gerald Brinkman	22.3	60	R	Ls, Sh	Iola Ls, Chanute Sh	Cy, E	D	20.1	6-64		
6aaa	State Geol. Survey	13.0	4	N	Gr, St, Cl	Illinoisan St	N	T	Dry	5-65	937	
7aad	do	18.0	4	N	Gr, St, Cl	Wisconsinan St, Recent St	N	T	16.5	5-65	932	
8ada	do	23.0	4	N	Gr, St, Cl	do	N	T	13.1	5-65	931	
8cbb	do	18.0	4	N	Gr, St, Cl	do	N	T	8.5	5-65	927	
13cbc*	Harold E. Lasman	120 R	8	S	Ls, Sd	Iola Ls, Cherryvale Sh	Cy, E	S, O	47.5	......		
16acc	John Squire	29.1	36	R	Ls	Iola Ls	J, E	D, S	25.7	6-64		
17aaa	State Geol. Survey	26.0	4	N	Gr, St, Cl	Wisconsinan St, Recent St	N	T	12.4	5-65	920	
17cdd1	Herb Barnett	26.7	36	R	Gr	Quaternary Sys	J, E	D	22.4	6-64		
17cdd2	State Geol. Survey	18.0	4	N	St, Cl	Illinoisan St	N	T	14.7	5-65	933	
18aaa	do	18.0	4	N	Gr, St, Cl	Wisconsinan St, Recent St	N	T	8.0	5-65	925	
18abb	do	20.0	4	N	Gr, St, Cl	do	N	T	11.7	5-65	927	
18dcc	do	24.0	4	N	Gr, St, Cl	Illinoisan St	N	T	16.7	5-65	941	
19aaa	do	13.0	4	N	Gr, St, Cl	do	N	T	12.1	5-65	934	
19bbb	do	23.0	4	N	Gr, St, Cl	do	N	T	16.8	5-65	942	
19bcc	Myrl Ford	16.4	36	R	Sh, Cl	Lane and Bonner Springs Sh	J, E	S	10.0	6-64		2 E
19daa	State Geol. Survey	13.0	4	N	Gr, St, Cl	Illinoisan St	N	T	10.5	5-65	931	
28dcc	Joe Riedei	12.0	48	R	Ls	Iola Ls	J, E	D, S	2.6	6-64		
32ccc*	John Thurman	22.1	8	S	Sh	Chanute Sh	Cy, H	D	14.3	6-64		
36bbb	Henry Storck	165 R	8	S	Ss	Cherryvale Sh	N	N	50.3	6-64		
26-19E- 1baa	John Baptist	48.8	10	S	Ls	Iola Ls	Cy, H	N	7.5	7-64		2 R
3bba	Andrew Setter	22.4	60	R	Ls	do	N	N	5.1	7-64		
7aaa*	A. L. Churchill	200 R	10	S	Ss, Ls	Cherryvale Sh, Dennis Ls	C, E	D	64.1	7-64		
12bbb	J. R. Bowles	170 R	12	S	Ss	Cherryvale Sh	N	O	67.3	7-64		
16aab	Orville Croisant	21.3	36	R	Ls	Iola Ls	J, E	S	2.7	7-64		
17ccb	L. F. Bruenger	260 R	10	S	Ss, Sh	Cherryvale Sh	Cy, E	S	65.8	7-64		
27bbc*	Howard Russell	130 R	8	S	Ss, Sh	Quivira Sh Me of Cherryvale Sh, Dennis Ls	C, E	D	74.6	7-64		
32bbb	Mrs. Hessel Ray	260 R	10	S	Ss, Sh	Cherryvale Sh, Dennis Ls	N	N	88.5	7-64		
35daa	Herbert Mallock	180 R	10	S	Ss, Ls	do	Cy, E	S	73.5	7-64		
26-20E- 1bab*	James C. Goyette	120 R	10	S	Ls, Sh	Dennis Ls	J, E	S	16.5	7-64		
4abb	Lyle Wing	17.3	36	....	Sandy Sh	Cherryvale Sh	J, E	D	11.2	7-64		
13bba*	Sam E. Fisher	160 R	10	S	Black Sh	Dennis Ls	Cy, H	N	15.1	7-64		
17aaa*	Ardell Brooks	160 R	10	S	Ss, Ls, Sh	Cherryvale Sh	Cy, E	S	10.5	7-64		
22aad	A. D. Prell	178 R	10	T	Ls, Sh	Dennis Ls	J, E	S	17.8	7-64		
24aaa	State Geol. Survey	205.0	1	G	Black Sh	Dennis Ls, Swope Ls	N	O	15.5	8-64		
27ccc	Robert Larson, Sr.	120 R	10	S	Ls, Sh	do	Cy, E	S	20.2	7-64		
30aab	Bud Butts	76.8	8	S	Black Sh	Dennis Ls	N	N	13.8	7-64		
26-21E-15aba*	D. J. Daniels	90.6	10	S	Black Sh	do	C, E	D	66.3	7-64		
20bbb	Conrad Jackson	14.0	36	R	Sandy Sh	Cherryvale Sh	N	N	9.8	7-64		
28aaa*	H. A. Williams	105 R	8	S	Ls, Sh	Dennis Ls, Swope Ls	J, E	D, S	43.8	7-64		
31aab	City of Savonburg	52.7	10	S	Black Sh	Dennis Ls	N	O	25.5	7-64		
34ddd	State Geol. Survey	136.0	4	N	Black Sh	Dennis Ls, Swope Ls	N	T	8.4	7-65		

[1] Asterisk following well number indicates analysis of water is given in table 2.
[2] *R*, reported; *E*, estimated.
[3] *G*, galvanized; *N*, none; *R*, rock; *S*, steel; *T*, tile.
[4] *Cl*, clay; *Gr*, gravel; *Ls*, limestone; *Sd*, sand; *Sh*, shale; *Ss*, sandstone; *St*, silt.
[5] *Dep*, deposits; *Ls*, Limestone; *Me*, Member; *Ser*, Series; *Sh*, Shale; *St*, Stage; *Sys*, System.
[6] *C*, centrifugal; *Cy*, cylinder; *J*, jet; *N*, none; *Sub*, submersible.
[7] *E*, electric; *G*, gasoline; *H*, hand; *NG*, natural gas; *W*, wind.
[8] *D*, domestic; *N*, none; *O*, observation; *PS*, public supply; *S*, stock; *T*, test.

LOGS OF SELECTED TEST HOLES IN THE NEOSHO RIVER VALLEY

The following logs of 39 test holes, selected because of their geographic location in the valley and position in regard to the present course of the Neosho River, were used in the compilation of the geologic sections. Logs of additional test holes may be consulted in the files of the U.S. and State Geological Survey offices, Lawrence, Kans.

All altitudes were interpolated from modern 7½-minute topographic maps.

24-17E-12bcb.—Sample log of test hole in the NW¼ SW¼ NW¼ sec. 12, T. 24 S., R. 17 E.; augered May 28, 1965. Altitude of land surface, 962 feet; depth to water, 17.7 feet.

	Thickness, feet	*Depth, feet*
Soil	3	3
QUATERNARY SYSTEM		
Pleistocene Series		
RECENT AND WISCONSINAN STAGES		
Alluvium and terrace deposits, undifferentiated		
Silt, brown	5	8
Silt, dark-yellowish-brown	10	18
Sand, fine to coarse, and very silty fine to coarse gravel	12	30
PENNSYLVANIAN SYSTEM		
Upper Pennsylvanian Series		
MISSOURIAN STAGE		
Lansing Group		
Vilas(?) Shale		
Shale	1	31

24-17E-12bda.—Sample log of test hole in the NE¼ SE¼ NW¼ sec. 12, T. 24 S., R. 17 E.; augered May 28, 1965. Altitude of land surface, 960 feet; depth to water, 21.1 feet.

	Thickness, feet	*Depth, feet*
QUATERNARY SYSTEM		
Pleistocene Series		
RECENT AND WISCONSINAN STAGES		
Alluvium and terrace deposits, undifferentiated		
Silt, brown	13	13
Silt, sandy, brown	7	20
Silt, sandy, grayish-tan	5	25
Gravel, fine to coarse	3	28
PENNSYLVANIAN SYSTEM		
Upper Pennsylvanian Series		
MISSOURIAN STAGE		
Lansing Group		
Vilas(?) Shale		
Shale	....	28

24-17E-12ccb.—Sample log of test hole in the NW¼ SW¼ SW¼ sec. 12, T. 24 S., R. 17 E.; augered May 28, 1965. Altitude of land surface, 957 feet; depth to water, 15.0 feet.

	Thickness, feet	*Depth, feet*
Road fill	5	5
QUATERNARY SYSTEM		
Pleistocene Series		
RECENT AND WISCONSINAN STAGES		
Alluvium and terrace deposits, undifferentiated		
Silt, brown	16	21
PENNSYLVANIAN SYSTEM		
Upper Pennsylvanian Series		
MISSOURIAN STAGE		
Lansing Group		
Vilas(?) Shale		
Shale	1	22

24-18E-7aaa.—Sample log of test hole in the NE¼ NE¼ NE¼ sec. 7, T. 24 S., R. 18 E.; augered May 19, 1965. Altitude of land surface, 972 feet; depth to water, 16.3 feet.

	Thickness, feet	*Depth, feet*
QUATERNARY SYSTEM		
Pleistocene Series		
ILLINOISAN STAGE		
Terrace deposits		
Silt, sandy, yellowish-tan	5	5
Sand, fine, yellowish-tan	8	13
Sand, fine, very silty, yellowish-tan	13	26
Gravel, fine to coarse, brown	2	28
PENNSYLVANIAN SYSTEM		
Upper Pennsylvanian Series		
MISSOURIAN STAGE		
Lansing Group		
Vilas(?) Shale		
Shale, grayish-tan	1	29

24-18E-7abb.—Sample log of test hole in the NW¼ NW¼ NE¼ sec. 7, T. 24 S., R. 18 E.; augered May 19, 1965. Altitude of land surface, 956 feet; depth to water, 17.8 feet.

	Thickness, feet	*Depth, feet*
Soil	3	3
QUATERNARY SYSTEM		
Pleistocene Series		
RECENT AND WISCONSINAN STAGES		
Alluvium and terrace deposits, undifferentiated		
Silt, clayey, grayish-brown	10	13
Silt, clayey, dark-bluish-gray	5	18
Silt, clayey, dark-bluish-gray, and fine to coarse gravel	5	23
PENNSYLVANIAN SYSTEM		
Upper Pennsylvanian Series		
MISSOURIAN STAGE		
Lansing Group		
Plattsburg Limestone		
Limestone	....	23

24-18E-7bcb.—Sample log of test hole in the NW¼ SW¼ NW¼ sec. 7, T. 24 S., R. 18 E.; augered May 19, 1965. Altitude of land surface, 960 feet; depth to water, 21.2 feet.

	Thickness, feet	*Depth, feet*
Soil	3	3
QUATERNARY SYSTEM		
Pleistocene Series		
RECENT AND WISCONSINAN STAGES		
Alluvium and terrace deposits, undifferentiated		
Silt, reddish-brown	15	18
Silt, clayey, brown	6	24

	Thickness, feet	Depth, feet
Gravel, chert, fine to coarse, silty, brown	1	25
PENNSYLVANIAN SYSTEM		
Upper Pennsylvanian Series		
MISSOURIAN STAGE		
Lansing Group		
Shale	1	26

24-18E-7bdb.—Sample log of test hole in the NW¼ SE¼ NW¼ sec. 7, T. 24 S., R. 18 E.; augered May 19, 1965. Altitude of land surface, 958 feet; depth to water, 12.5 feet.

	Thickness, feet	Depth, feet
Soil	3	3
QUATERNARY SYSTEM		
Pleistocene Series		
RECENT AND WISCONSINAN STAGES		
Alluvium and terrace deposits, undifferentiated		
Silt, clayey, brown	9	12
Silt, yellowish-brown; fine to coarse chert gravel in lower 3 feet	11	23
Gravel, fine to coarse, less silt than above	3	26
PENNSYLVANIAN SYSTEM		
Upper Pennsylvanian Series		
MISSOURIAN STAGE		
Lansing Group		
Plattsburg Limestone		
Limestone	....	26

24-18E-15ccc.—Sample log of test hole in the SW¼ SW¼ SW¼ sec. 15, T. 24 S., R. 18 E.; augered May 19, 1965. Altitude of land surface, 952 feet; depth to water, 4.7 feet.

	Thickness, feet	Depth, feet
Soil	3	3
QUATERNARY SYSTEM		
Pleistocene Series		
RECENT AND WISCONSINAN STAGES		
Alluvium and terrace deposits, undifferentiated		
Silt, yellowish-tan	3	6
Gravel, fine to medium, mixed with yellowish-tan silt	2	8
Gravel, fine to coarse	1	9
PENNSYLVANIAN SYSTEM		
Upper Pennsylvanian Series		
MISSOURIAN STAGE		
Kansas City Group		
Iola Limestone	....	9

24-18E-15dcc.—Sample log of test hole in the SW¼ SW¼ SE¼ sec. 15, T. 24 S., R. 18 E.; augered May 19, 1965. Altitude of land surface, 965 feet; depth to water, 6.1 feet.

	Thickness, feet	Depth, feet
Soil, clayey, yellowish-brown	2.5	2.5
QUATERNARY SYSTEM		
Pleistocene Series		
ILLINOISAN STAGE		
Terrace deposits		
Clay, silty, yellowish-tan; fine to medium gravel and mottled gray clay in lower 2 feet	11.5	14
PENNSYLVANIAN SYSTEM		
Upper Pennsylvanian Series		
MISSOURIAN STAGE		
Kansas City Group		
Iola Limestone	....	14

24-18E-16ccd.—Sample log of test hole in the SE¼ SW¼ SW¼ sec. 16, T. 24 S., R. 18 E.; augered May 19, 1965. Altitude of land surface, 945 feet; depth to water, 10.7 feet.

	Thickness, feet	Depth, feet
QUATERNARY SYSTEM		
Pleistocene Series		
RECENT AND WISCONSINAN STAGES		
Alluvium and terrace deposits, undifferentiated		
Silt, reddish-brown	8	8
Silt, clayey, light-brown; some fine to medium gravel at base	15	23
PENNSYLVANIAN SYSTEM		
Upper Pennsylvanian Series		
MISSOURIAN STAGE		
Kansas City Group		
Iola Limestone		
Shale, gray	1	24

24-18E-16dcc.—Sample log of test hole in the SW¼ SW¼ SE¼ sec. 16, T. 24 S., R. 18 E.; augered May 19, 1965. Altitude of land surface, 951 feet; depth to water, 11.7 feet.

	Thickness, feet	Depth, feet
Soil	3	3
QUATERNARY SYSTEM		
Pleistocene Series		
RECENT AND WISCONSINAN STAGES		
Alluvium and terrace deposits, undifferentiated		
Silt, yellowish-tan	4	7
Silt, reddish-brown, with fine to coarse brown chert gravel	7	14
PENNSYLVANIAN SYSTEM		
Upper Pennsylvanian Series		
MISSOURIAN STAGE		
Kansas City Group		
Iola Limestone	....	14

24-18E-20aad.—Sample log of test hole in the SE¼ NE¼ NE¼ sec. 20, T. 24 S., R. 18 E.; augered May 27, 1965. Altitude of land surface, 951 feet; depth to water, 14.1 feet.

	Thickness, feet	Depth, feet
Soil	3	3
QUATERNARY SYSTEM		
Pleistocene Series		
RECENT AND WISCONSINAN STAGES		
Alluvium and terrace deposits, undifferentiated		
Silt, brown, sandy in lower 5 feet	15	18
PENNSYLVANIAN SYSTEM		
Upper Pennsylvanian Series		
MISSOURIAN STAGE		
Kansas City Group		
Lane and Bonner Springs Shales		
Shale	1	19

24-18E-20abc.—Sample log of test hole in the SW¼ NW¼ NE¼ sec. 20, T. 24 S., R. 18 E.; augered May 27, 1965. Altitude of land surface, 951 feet; depth to water, 12.1 feet.

	Thickness, feet	Depth, feet
Road fill	3	3
QUATERNARY SYSTEM		
Pleistocene Series		
Recent and Wisconsinan stages		
Alluvium and terrace deposits, undifferentiated		
Silt, light-brown	5	8
Silt, brown	11	19
Gravel, fine to coarse, silty	4	23
PENNSYLVANIAN SYSTEM		
Upper Pennsylvanian Series		
Missourian stage		
Kansas City Group		
Lane and Bonner Springs Shales		
Shale	1	24

24-18E-20bbd.—Sample log of test hole in the SE¼ NW¼ NW¼ sec. 20, T. 24 S., R. 18 E.; augered May 27, 1965. Altitude of land surface, 948 feet; depth to water, 4.4 feet.

	Thickness, feet	Depth, feet
Soil	3	3
QUATERNARY SYSTEM		
Pleistocene Series		
Recent and Wisconsinan stages		
Alluvium and terrace deposits, undifferentiated		
Silt, brown; gravel from 18 to 22 feet	19	22
PENNSYLVANIAN SYSTEM		
Upper Pennsylvanian Series		
Missourian stage		
Kansas City Group		
Lane and Bonner Springs Shales		
Shale	0.5	22.5

24-18E-28ccc.—Driller's log of test hole in the SW¼ SW¼ SW¼ sec. 28, T. 24 S., R. 18 E.; drilled by Jungmann Bros. Drilling Co., July 29, 1964. Altitude of land surface, 948 feet; depth to water, 12.9 feet.

	Thickness, feet	Depth, feet
QUATERNARY SYSTEM		
Pleistocene Series		
Recent and Wisconsinan stages		
Alluvium and terrace deposits, undifferentiated		
Silt, light-brown	8	8
Silt, clayey, reddish-brown; some sand	9	17
Gravel, fine to coarse, silty	2	19
PENNSYLVANIAN SYSTEM		
Upper Pennsylvanian Series		
Missourian stage		
Kansas City Group		
Iola Limestone		
Limestone	....	19

24-18E-28cdd.—Driller's log of test hole in the SE¼ SE¼ SW¼ sec. 28, T. 24 S., R. 18 E.; drilled by Jungmann Bros. Drilling Co., July 29, 1964. Altitude of land surface, 948 feet; depth to water, 16.1 feet.

	Thickness, feet	Depth, feet
QUATERNARY SYSTEM		
Pleistocene Series		
Recent and Wisconsinan stages		
Alluvium and terrace deposits, undifferentiated		
Silt, brown	11	11
Silt, clayey, reddish-brown	10	21
Silt, clayey, dark-tan	1	22
Gravel, fine to coarse, silty	2.5	24.5
PENNSYLVANIAN SYSTEM		
Upper Pennsylvanian Series		
Missourian stage		
Kansas City Group		
Iola Limestone		
Limestone	....	24.5

24-18E-33aaa.—Driller's log of test hole in the NE¼ NE¼ NE¼ sec. 33, T. 24 S., R. 18 E.; drilled by Jungmann Bros. Drilling Co., July 29, 1964. Altitude of land surface, 938 feet; depth to water, 13.0 feet.

	Thickness, feet	Depth, feet
QUATERNARY SYSTEM		
Pleistocene Series		
Recent and Wisconsinan stages		
Alluvium and terrace deposits, undifferentiated		
Silt, reddish-brown	8	8
Silt, dark-brown	9	17
Silt, clayey, dark-brown	5	22
Gravel, fine to coarse, silty	1	23
PENNSYLVANIAN SYSTEM		
Upper Pennsylvanian Series		
Missourian stage		
Kansas City Group		
Iola Limestone		
Limestone	....	23

24-18E-34baa.—Driller's log of test hole in the NE¼ NE¼ NW¼ sec. 34, T. 24 S., R. 18 E.; drilled by Jungmann Bros. Drilling Co., July 29, 1964. Altitude of land surface, 935 feet; depth to water, 8.5 feet.

	Thickness, feet	Depth, feet
QUATERNARY SYSTEM		
Pleistocene Series		
Recent and Wisconsinan stages		
Alluvium and terrace deposits, undifferentiated		
Silt, dark-grayish-brown	12	12
Silt, clayey, reddish-brown	5	17
Gravel, fine to coarse, silty	1.5	18.5
PENNSYLVANIAN SYSTEM		
Upper Pennsylvanian Series		
Missourian stage		
Kansas City Group		
Iola Limestone		
Limestone	....	18.5

25-17E-24ccc.—Sample log of test hole in the SW¼ SW¼ SW¼ sec. 24, T. 25 S., R. 17 E.; augered May 25, 1965. Altitude of land surface, 983 feet; dry hole.

	Thickness, feet	Depth, feet
Soil	3	3
QUATERNARY SYSTEM		
Pleistocene Series		
Illinoisan(?) stage		
Terrace deposits		
Silt, clayey, yellowish-tan	10	13

	Thickness, feet	Depth, feet
Silt, light-tan; some limestone pebbles; gravel in lower 4 feet	19	32
PENNSYLVANIAN SYSTEM		
Upper Pennsylvanian Series		
Missourian Stage		
Lansing Group		
Vilas Shale		
Shale	1	33

25-17E-24dcc.—Sample log of test hole in the SW¼ SW¼ SE¼ sec. 24, T. 25 S., R. 17 E.; augered May 26, 1965. Altitude of land surface, 961 feet; depth to water, 25.4 feet.

	Thickness, feet	Depth, feet
Soil	3	3
QUATERNARY SYSTEM		
Pleistocene Series		
Illinoisan Stage		
Terrace deposits		
Silt, yellowish-tan and gray	10	13
Silt, clayey, reddish-tan; some sparsely scattered limestone gravel	10	23
Silt, clayey, reddish-tan; chert gravel at 25 feet	9	32
PENNSYLVANIAN SYSTEM		
Upper Pennsylvanian Series		
Missourian Stage		
Lansing Group		
Vilas Shale		
Shale	1	33

25-18E-7add.—Sample log of test hole in the SE¼ SE¼ NE¼ sec. 7, T. 25 S., R. 18 E.; augered May 27, 1965. Altitude of land surface, 947 feet; depth to water, 9.3 feet.

	Thickness, feet	Depth, feet
Soil	3	3
QUATERNARY SYSTEM		
Pleistocene Series		
Illinoisan Stage		
Terrace deposits		
Silt, sandy, tan	16	19
PENNSYLVANIAN SYSTEM		
Upper Pennsylvanian Series		
Missourian Stage		
Lansing Group		
Vilas Shale		
Shale	0.5	19.5

25-18E-8acc.—Sample log of test hole in the SW¼ SW¼ NE¼ sec. 8, T. 25 S., R. 18 E.; augered May 27, 1965. Altitude of land surface, 954 feet; depth to water, 14.0 feet.

	Thickness, feet	Depth, feet
Soil	3	3
QUATERNARY SYSTEM		
Pleistocene Series		
Illinoisan Stage		
Terrace deposits		
Silt, yellowish-brown	10	13
Silt, clayey, yellowish-brown	5	18
Silt, sandy, yellowish-brown; some gravel at 22 feet	5	23
PENNSYLVANIAN SYSTEM		
Upper Pennsylvanian Series		
Missourian Stage		
Kansas City Group		
Lane and Bonner Springs(?) Shales		
Shale		23

25-18E-8add.—Sample log of test hole in the SE¼ SE¼ NE¼ sec. 8, T. 25 S., R. 18 E.; augered May 27, 1965. Altitude of land surface, 940 feet; depth to water, 6.1 feet.

	Thickness, feet	Depth, feet
QUATERNARY SYSTEM		
Pleistocene Series		
Recent and Wisconsinan Stages		
Alluvium and terrace deposits, undifferentiated		
Silt, brown	8	8
Illinoisan Stage		
Terrace deposits		
Silt, yellowish-tan	6	14
Gravel, fine to coarse, and tan sandy silt	4	18
PENNSYLVANIAN SYSTEM		
Upper Pennsylvanian Series		
Missourian Stage		
Kansas City Group		
Iola Limestone		
Limestone		18

25-18E-9acc2.—Sample log of test hole in the SW¼ SW¼ NE¼ sec. 9, T. 25 S., R. 18 E.; augered May 20, 1965. Altitude of land surface, 933 feet; depth to water, 12.7 feet.

	Thickness, feet	Depth, feet
QUATERNARY SYSTEM		
Pleistocene Series		
Recent and Wisconsinan Stages		
Alluvium and terrace deposits, undifferentiated		
Silt, dark-yellowish-brown	8	8
Silt, clayey, yellowish-brown	15	23
PENNSYLVANIAN SYSTEM		
Upper Pennsylvanian Series		
Missourian Stage		
Kansas City Group		
Iola Limestone		
Limestone		23

25-18E-9acd2.—Sample log of test hole in the SE¼ SW¼ NE¼ sec. 9, T. 25 S., R. 18 E.; augered May 20, 1965. Altitude of land surface, 942 feet; dry hole.

	Thickness, feet	Depth, feet
QUATERNARY SYSTEM		
Pleistocene Series		
Illinoisan Stage		
Terrace deposits		
Silt, reddish-brown	8	8
Silt, reddish-brown, and fine to coarse chert gravel	5	13
PENNSYLVANIAN SYSTEM		
Upper Pennsylvanian Series		
Missourian Stage		
Kansas City Group		
Iola Limestone		
Limestone		13

25-18E-9bdd.—Sample log of test hole in the SE¼ SE¼ NW¼ sec. 9, T. 25 S., R. 18 E.; augered May 20, 1965. Altitude of land surface, 933 feet; dry hole.

	Thickness, feet	Depth, feet
Soil	3	3
QUATERNARY SYSTEM		
Pleistocene Series		
recent and wisconsinan stages		
Alluvium and terrace deposits, undifferentiated		
Silt, dark-grayish-brown	12	15
Gravel, fine to coarse, and dark-gray silt; some limestone gravel in lower part	4	19
PENNSYLVANIAN SYSTEM		
Upper Pennsylvanian Series		
missourian stage		
Kansas City Group		
Iola Limestone		
Limestone	....	19

25-18E-19ccc.—Sample log of test hole in the SW¼ SW¼ SW¼ sec. 19, T. 25 S., R. 18 E.; augered May 26, 1965. Altitude of land surface, 947 feet; depth to water, 8.0 feet.

	Thickness, feet	Depth, feet
Soil	3	3
QUATERNARY SYSTEM		
Pleistocene Series		
illinoisan stage		
Terrace deposits		
Silt, sandy, tan; some fine gravel	5	8
Silt, sandy, tan, and fine to coarse gravel	6	14
PENNSYLVANIAN SYSTEM		
Upper Pennsylvanian Series		
missourian stage		
Lansing Group		
Plattsburg Limestone		
Limestone	....	14

25-18E-20ddd.—Sample log of test hole in the SE¼ SE¼ SE¼ sec. 20, T. 25 S., R. 18 E.; augered May 21, 1965. Altitude of land surface, 944 feet; depth to water, 16.9 feet.

	Thickness, feet	Depth, feet
QUATERNARY SYSTEM		
Pleistocene Series		
recent and wisconsinan stages		
Alluvium and terrace deposits, undifferentiated		
Silt, bluish-gray	3	3
Silt, bluish-green	5	8
Silt, bluish-gray	2	10
Silt, olive-gray; sandy in lower 4 feet	7	17
Gravel, coarse, silty	2	19
PENNSYLVANIAN SYSTEM		
Upper Pennsylvanian Series		
missourian stage		
Kansas City Group		
Iola Limestone		
Limestone	....	19

25-18E-29abb.—Sample log of test hole in the NW¼ NW¼ NE¼ sec. 29, T. 25 S., R. 18 E.; augered May 21, 1965. Altitude of land surface, 938 feet; depth to water, 10.3 feet.

	Thickness, feet	Depth, feet
Soil	3	3
QUATERNARY SYSTEM		
Pleistocene Series		
recent and wisconsinan stages		
Alluvium and terrace deposits, undifferentiated		
Silt, sandy, reddish-brown to tan	5	8
Silt, sandy, tan	4	12
Gravel, fine to coarse, silty	2	14
PENNSYLVANIAN SYSTEM		
Upper Pennsylvanian Series		
missourian stage		
Kansas City Group		
Iola Limestone		
Limestone	....	14

25-18E-29bbb.—Sample log of test hole in the NW¼ NW¼ NW¼ sec. 29, T. 25 S., R. 18 E.; augered May 21, 1965. Altitude of land surface, 935 feet; dry hole.

	Thickness, feet	Depth, feet
QUATERNARY SYSTEM		
Pleistocene Series		
recent and wisconsinan stages		
Alluvium and terrace deposits, undifferentiated		
Silt, brown, hard	8	8
Silt, dark-yellowish-brown	8	16
Silt, clayey, bluish-gray	2	18
PENNSYLVANIAN SYSTEM		
Upper Pennsylvanian Series		
missourian stage		
Kansas City Group		
Chanute Shale		
Shale	1	19

25-18E-30baa.—Sample log of test hole in the NE¼ NE¼ NW¼ sec. 30, T. 25 S., R. 18 E.; augered May 27, 1965. Altitude of land surface, 935 feet; depth to water, 8.0 feet.

	Thickness, feet	Depth, feet
QUATERNARY SYSTEM		
Pleistocene Series		
recent and wisconsinan stages		
Alluvium and terrace deposits, undifferentiated		
Silt, dark-brown	8	8
Silt, yellowish-brown	7	15
Gravel, fine to coarse, sandy	7	22
PENNSYLVANIAN SYSTEM		
Upper Pennsylvanian Series		
missourian stage		
Lansing Group		
Plattsburg Limestone		
Limestone	....	22

26-18E-5acc.—Sample log of test hole in the SW¼ SW¼ NE¼ sec. 5, T. 26 S., R. 18 E.; augered May 24, 1965. Altitude of land surface, 933 feet; depth to water, 12.5 feet.

	Thickness, feet	Depth, feet
Soil	3	3

	Thickness, feet	*Depth, feet*
QUATERNARY SYSTEM		
Pleistocene Series		
RECENT AND WISCONSINAN STAGES		
Alluvium and terrace deposits, undifferentiated		
Sand, fine, silty, and fine gravel	5	8
Gravel, fine to coarse, with reddish-tan silt; much fine to coarse sand in lower 5 feet	10	18
PENNSYLVANIAN SYSTEM		
Upper Pennsylvanian Series		
MISSOURIAN STAGE		
Kansas City Group		
Iola Limestone		
Limestone	....	18

26-18E-5cbb.—Sample log of test hole in the NW¼ NW¼ SW¼ sec. 5, T. 26 S., R. 18 E.; augered May 24, 1965. Altitude of land surface, 932 feet; depth to water, 11.3 feet.

	Thickness, feet	*Depth, feet*
Soil	5	5
QUATERNARY SYSTEM		
Pleistocene Series		
ILLINOISAN STAGE		
Terrace deposits		
Silt, yellowish-tan; some reddish-tan silt from 8 to 18 feet; fine to medium chert gravel from 14 to 18 feet	13	18
PENNSYLVANIAN SYSTEM		
Upper Pennsylvanian Series		
MISSOURIAN STAGE		
Kansas City Group		
Iola Limestone		
Shale	1	19

26-18E-5daa.—Sample log of test hole in the NE¼ NE¼ SE¼ sec. 5, T. 26 S., R. 18 E.; augered May 24, 1965. Altitude of land surface, 933 feet; depth to water, 13.7 feet.

	Thickness, feet	*Depth, feet*
Soil	5	5
QUATERNARY SYSTEM		
Pleistocene Series		
RECENT AND WISCONSINAN STAGES		
Alluvium and terrace deposits, undifferentiated		
Silt, reddish-brown	7	12
Silt, sandy, reddish-brown; some fine to medium gravel	1	13
Gravel, fine to coarse, silty	6	19
PENNSYLVANIAN SYSTEM		
Upper Pennsylvanian Series		
MISSOURIAN STAGE		
Kansas City Group		
Iola Limestone		
Limestone	....	19

26-18E-6bdc.—Sample log of test hole in the SW¼ SE¼ NW¼ sec. 6, T. 26 S., R. 18 E.; augered May 25, 1965. Altitude of land surface, 941 feet; dry hole.

	Thickness, feet	*Depth, feet*
QUATERNARY SYSTEM		
Pleistocene Series		
ILLINOISAN STAGE		
Terarce deposits		
Silt, light-brown	8	8
Silt, yellowish-brown; some gravel	4	12
PENNSYLVANIAN SYSTEM		
Upper Pennsylvanian Series		
MISSOURIAN STAGE		
Kansas City Group		
Iola Limestone		
Limestone	....	12

26-18E-28bca.—Sample log of test hole in the NE¼ SW¼ NW¼ sec. 28, T. 26 S., R. 18 E.; augered May 21, 1965. Altitude of land surface, 924 feet; depth to water, 10.3 feet.

	Thickness, feet	*Depth, feet*
Soil	3	3
QUATERNARY SYSTEM		
Pleistocene Series		
RECENT AND WISCONSINAN STAGES		
Alluvium and terrace deposits, undifferentiated		
Silt, brown	20	23
Gravel, fine to coarse, silty	7	30
PENNSYLVANIAN SYSTEM		
Upper Pennsylvanian Series		
MISSOURIAN STAGE		
Kansas City Group		
Chanute Shale		
Shale	1	31

26-18-29aac2.—Sample log of test hole in the SW¼ NE¼ NE¼ sec. 29, T. 26 S., R. 18 E.; augered May 21, 1965. Altitude of land surface, 920 feet; depth to water, 10.3 feet.

	Thickness, feet	*Depth, feet*
Soil	3	3
QUATERNARY SYSTEM		
Pleistocene Series		
RECENT AND WISCONSINAN STAGES		
Alluvium and terrace deposits, undifferentiated		
Silt, dark-brown	5	8
Silt, sandy, brown	7	15
Gravel, fine to coarse, silty	8	23
PENNSYLVANIAN SYSTEM		
Upper Pennsylvanian Series		
MISSOURIAN STAGE		
Kansas City Group		
Chanute Shale		
Shale	1	24

26-18E-29bbc.—Sample log of test hole in the SW¼ NW¼ NW¼ sec. 29, T. 26 S., R. 18 E.; augered May 21, 1965. Altitude of land surface, 924 feet; depth to water, 9.6 feet.

	Thickness, feet	*Depth, feet*
Soil	3	3
QUATERNARY SYSTEM		
Pleistocene Series		
RECENT AND WISCONSINAN STAGES		
Alluvium and terrace deposits, undifferentiated		
Silt, brown	10	13

	Thickness, feet	Depth, feet
ILLINOISAN STAGE		
Terrace deposits		
Silt, light-brown	5	18
Silt, clayey, yellowish-tan and gray	5	23
Silt, sandy, olive-gray	5	28
PENNSYLVANIAN SYSTEM		
Upper Pennsylvanian Series		
MISSOURIAN STAGE		
Kansas City Group		
Chanute Shale		
Shale	1	29

26-18E-30abb.—Sample log of test hole in the NW¼ NW¼ NE¼ sec. 30, T. 26 S., R. 18 E.; augered May 21, 1965. Altitude of land surface, 932 feet; dry hole.

	Thickness, feet	Depth, feet
Soil	3	3
QUATERNARY SYSTEM		
Pleistocene Series		
ILLINOISAN STAGE		
Terrace deposits		
Silt, light-brown	5	8
Silt, yellowish-brown	4	12
Gravel, fine to coarse, silty	1	13
PENNSYLVANIAN SYSTEM		
Upper Pennsylvanian Series		
MISSOURIAN STAGE		
Kansas City Group		
Chanute Shale		
Shale	....	13

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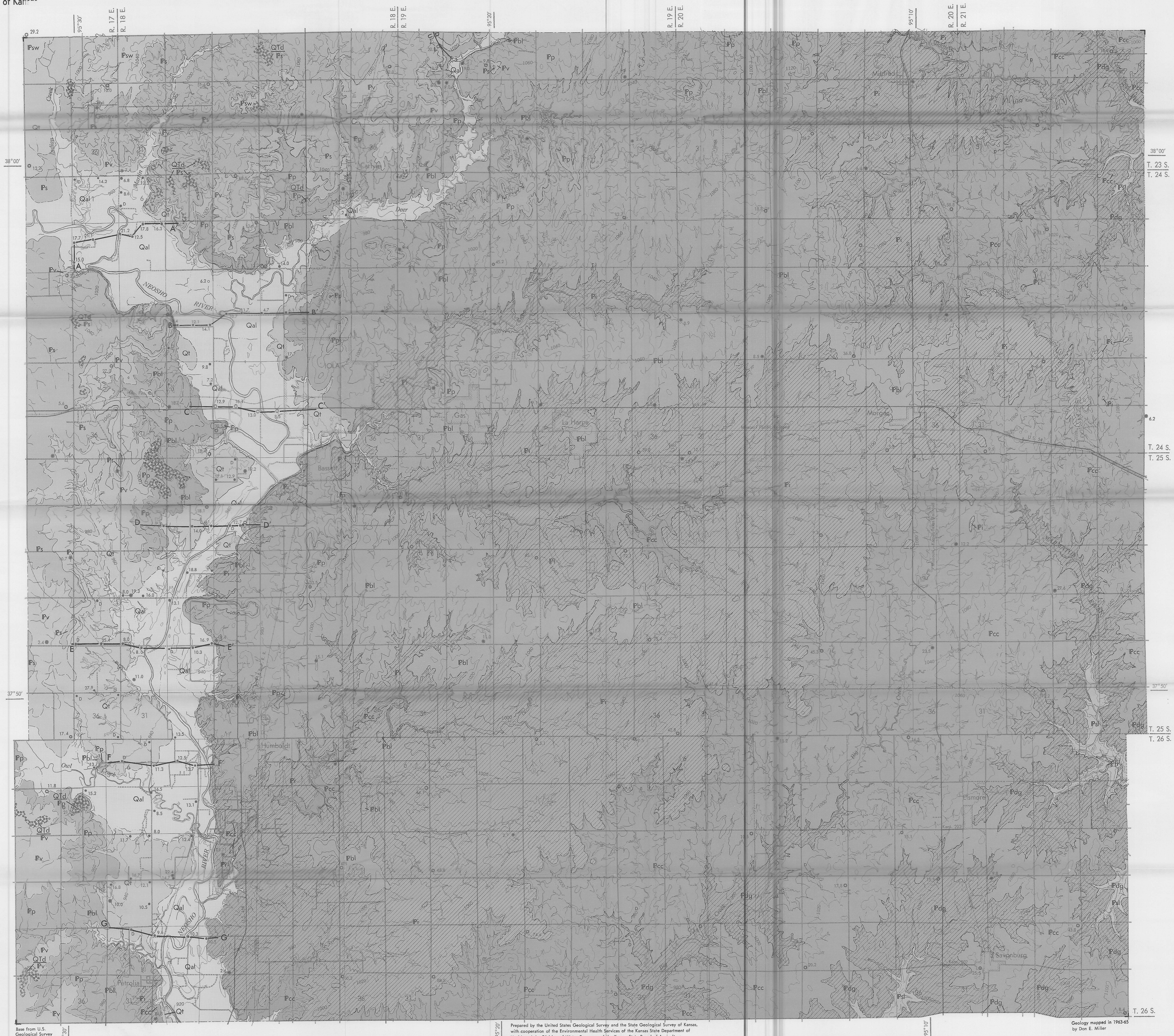
GEOLOGIC MAP OF ALLEN COUNTY, KANSAS



EXPLANATION

Qal	Recent and Wisconsinan alluvium and terrace deposits	Pleistocene	QUATERNARY
Qt	Illinoisan terrace deposits	Pleistocene	QUATERNARY
QTd	Kansan and pre-Kansan deposits	Pliocene (?) and Pleistocene	TERTIARY (?) AND QUATERNARY
IPsw	Weston Shale Member of the Stranger Formation	Upper Pennsylvanian — DOUGLAS GROUP	PENNSYLVANIAN
IPs	Stanton Limestone	Upper Pennsylvanian — LANSING GROUP	PENNSYLVANIAN
IPv	Vilas Shale	Upper Pennsylvanian — LANSING GROUP	PENNSYLVANIAN
IPp	Plattsburg Limestone	Upper Pennsylvanian — LANSING GROUP	PENNSYLVANIAN
IPbl	Bonner Springs and Lane Shales	Upper Pennsylvanian — KANSAS CITY GROUP	PENNSYLVANIAN
IPi	Iola Limestone	Upper Pennsylvanian — KANSAS CITY GROUP	PENNSYLVANIAN
IPcc (D)	Chanute and Cherryvale Shales; D, Drum Limestone	Upper Pennsylvanian — KANSAS CITY GROUP	PENNSYLVANIAN
IPdg	Dennis Limestone and Galesburg Shale	Upper Pennsylvanian — KANSAS CITY GROUP	PENNSYLVANIAN
IPsl	Swope Limestone and Ladore Shale	Upper Pennsylvanian — KANSAS CITY GROUP	PENNSYLVANIAN
IPh	Hertha Limestone	Upper Pennsylvanian — KANSAS CITY GROUP	PENNSYLVANIAN

Contact
Dashed where approximate or inferred

U D ?
Fault
Dashed where approximately located; queried where uncertain. U, upthrown side; D, downthrown side

76.6
Number indicates depth to water level, in feet below land surface

A —— A'
Geologic section shown on figure 7

Drive core well

Drilled well

Dug hole

Driven well

Augered test hole

D indicates dry well

Modern 7 1/2-minute topographic maps not available for western edge of county

True North / Magnetic North 8°

APPROXIMATE MEAN DECLINATION, 1965

Scale 1:63 360

1 0 1 2 MILES

CONTOUR INTERVAL 20 FEET
DATUM IS MEAN SEA LEVEL

Base from U.S. Geological Survey

Prepared by the United States Geological Survey and the State Geological Survey of Kansas, with cooperation of the Environmental Health Services of the Kansas State Department of Health and the Division of Water Resources of the Kansas State Board of Agriculture

Geology mapped in 1963-65 by Don E. Miller

State Geological Survey
of Kansas

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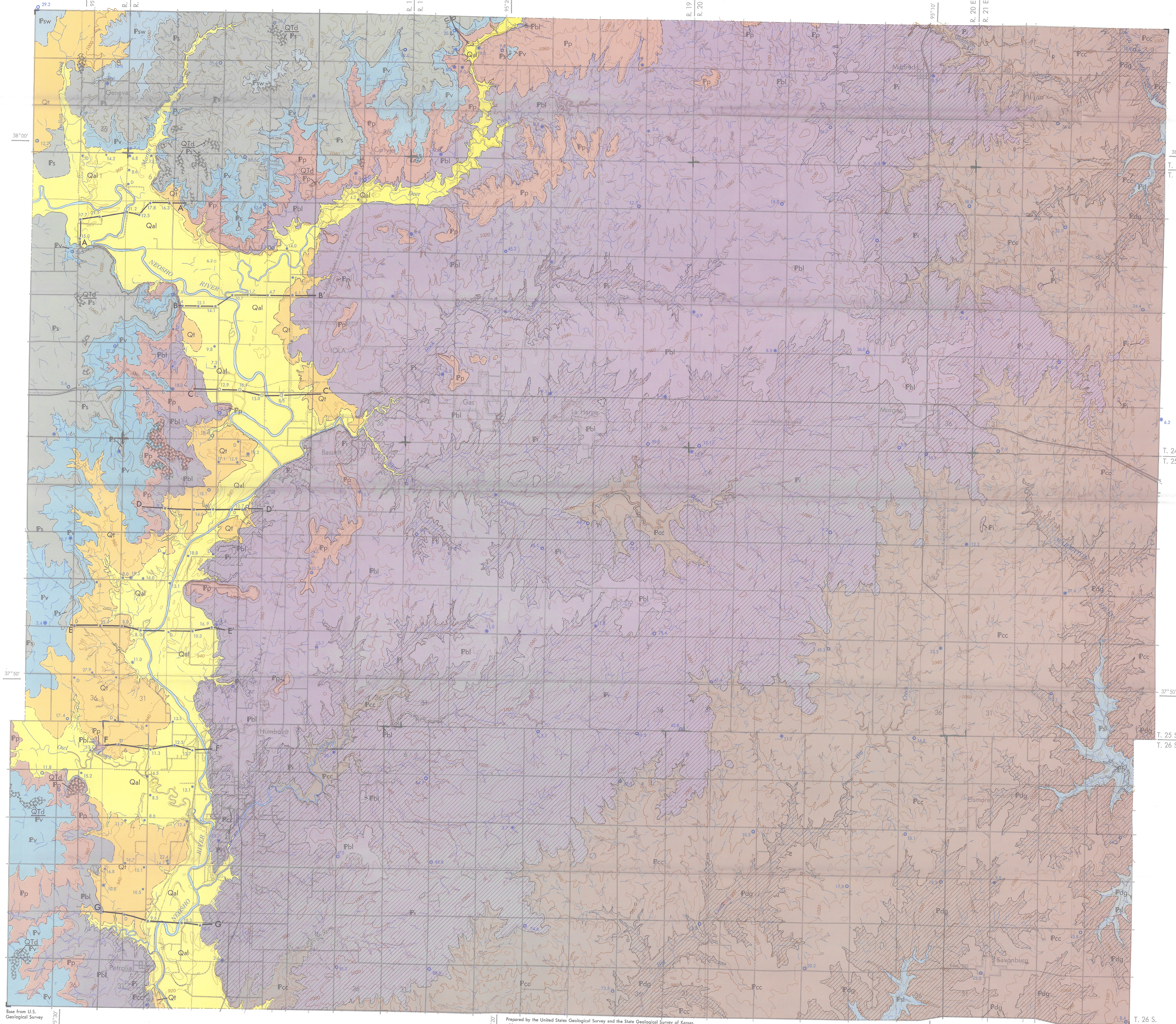
Bulletin 195
Plate 1



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Pleistocene; Pliocene (?) and Pleistocene; TERTIARY (?) AND QUATERNARY; QUATERNARY; DOUGLAS GROUP; LANSING GROUP; KANSAS CITY GROUP; Upper Pennsylvanian; PENNSYLVANIAN

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