Geology and Ground-Water Resources of Linn County, Kansas

By William J. Seevers

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WILLIAM J. SEEVERS *State Geological Survey of Kansas*

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ABSTRACT

Linn County is located along the Kansas-Missouri boundary in east-central Kansas and is a nearly square area of about 605 square miles. The relief in this area is moderate, and the topography is characterized by northeast-trending cuestas that face southeast. The county is located mostly within the Marais des Cygnes River drainage basin and contains a segment of this river in its northeastern part.

Pennsylvanian rocks, Desmoinesian and Missourian Stages, are exposed in the county and have an aggregate thickness of 660 feet. The dominant lithology is shale followed by limestone, sandstone, and minor amounts of coal. Rocks in this part of Kansas are gently tilted to the northwest at about 20 feet per mile.

All but the smallest tributary stream valleys are filled to some depth with locally derived and unconsolidated materials. These materials are mainly clay and silt with several feet of medium to coarse gravel near the base. Thickness of these valley-fill deposits ranges from several feet in smaller stream valleys to 50 feet in the principal valleys.

Approximately 780 feet of Arbuckle Group (Cambrian and Ordovician), 20 feet of Devonian, 320 feet of Mississippian, and 400 feet of Pennsylvanian (Desmoinesian) rock underlie the oldest outcropping Pennsylvanian rocks in Linn County.

Small domal structures of modest relief and a number of small-scale structures related to compaction and collapse are noted at the surface. Two apparent collapse-related structures in southeastern Linn County are associated with lead and zinc mineralization.

Only very small quantities of ground water are obtained from Pennsylvanian rocks in Linn County. Yields rarely exceed 1 gallon per minute and are normally barely sufficient for domestic purposes. Limestones are the most productive aquifers, and limestones of the lower part of the Kansas City Group are the best of the bedrock aquifers.

Ground water below a depth of about 100 feet in this area is normally too highly mineralized for use. However, in areas in Missouri close to the southeast corner of Linn County, water is obtained from the Cherokee Group at depths of 400 to 600 feet. At still greater depths in this area, large quantities (150 gallons per minute) of highly mineralized water are obtained from Ordovician rocks and moderate quantities (10 gallons per minute) from Mississippian rocks.

Large quantities (30 to 100 gallons per minute) of good quality water are obtained from properly constructed and developed wells in Illinoisan and Wisconsinan valley-fill deposits, mainly from thin gravel deposits near the base.

INTRODUCTION

Purpose of Investigation

This study of the geology and ground water in Linn County is one in a series of county investigations conducted in Kansas to evaluate the quality and quantity of ground water and the geologic parameters which control the occurrence of ground water.

Cooperators in this project are the State Geological Survey of Kansas, the U.S. Geological Survey, the Environmental Health Services of the Kansas State Department of Health, and the Division of Water Resources of the Kansas State Board of Agriculture.

Location and Extent of Area

Linn County, located in east-central Kansas in the first tier of counties west of the Kansas-Missouri boundary, is bounded on the north by Miami County, on the south by Bourbon County, and on the west by Anderson County (fig. 1). Total area of the county is about 605 square miles.

Physiography

Linn County is located in the Osage Plains section of the Central Lowlands physiographic province (Fenneman, 1931). Schoewe (1949) includes this area in the Osage Cuestas of the Osage Plains.

In areas of Linn County directly underlain by bedrock of Pennsylvanian age, topographic form is a function of differential erosion of the various limestone, sandstone, and shale rock units. Four physiographic divisions, which correspond to the outcrop areas of the Marmaton Group; the Pleasanton Group; the Bronson, Linn, and Zahara Subgroups of the Kansas City Group; and the Lansing Group, are recognized and are shown on plate 1.

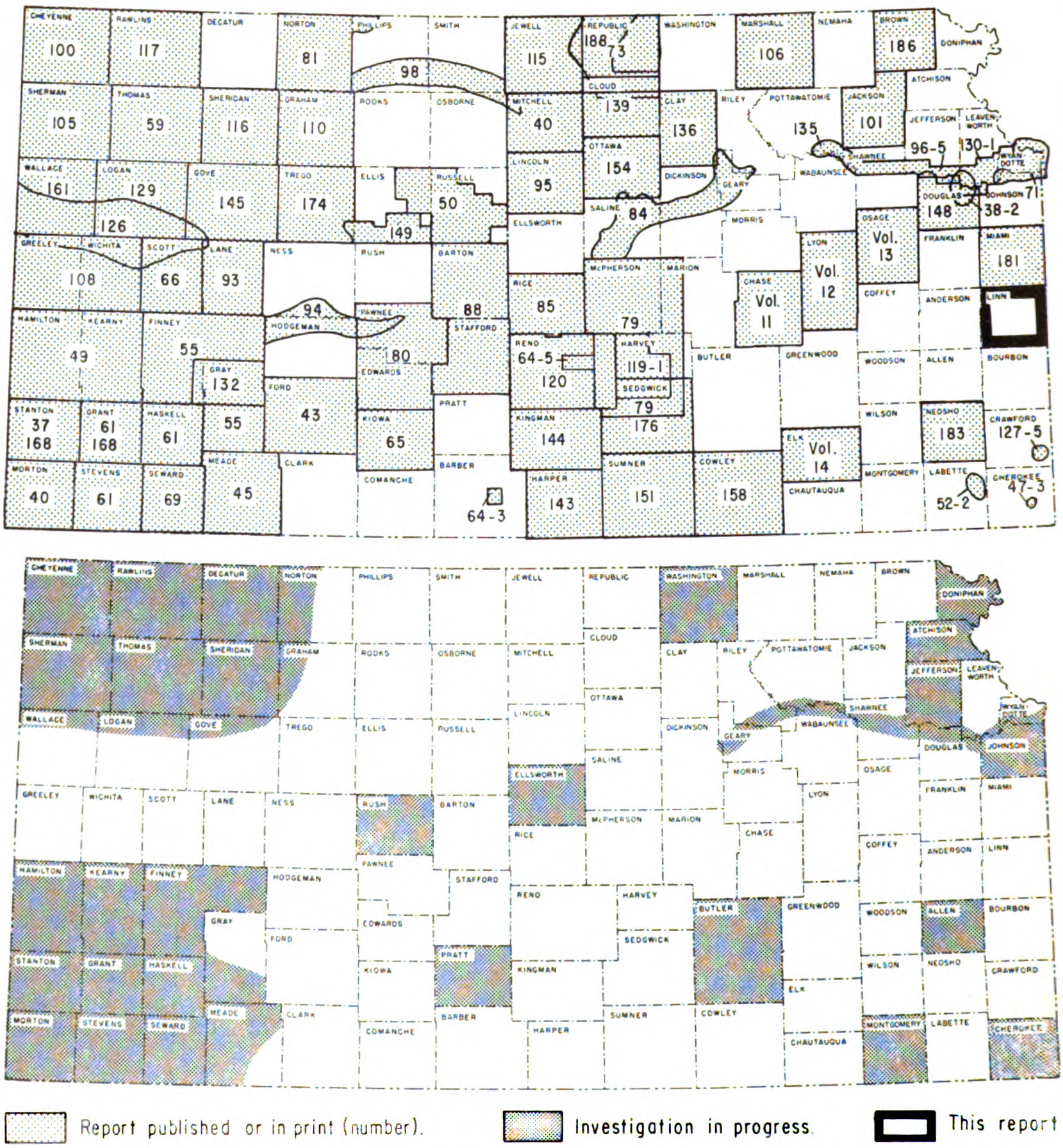


FIGURE 1.—Index maps of Kansas showing area discussed in this report, and other areas for which ground-water reports have been published by the State Geological Survey or are in preparation.

Drainage

The alluvial-filled valleys of the Marais des Cygnes River and its larger tributaries range from less than a mile to several miles in width in Linn County. The surface developed on these deposits is broad and featureless and is broken only locally by the erosional remnants of older alluvial deposits and by the scars of former meanders.

All but the southernmost tier of townships in the county are drained by the Marais des Cygnes River and its tributaries; the remaining area is drained by tributaries of the Little Osage River. The width of the Marais des Cygnes flood plain ranges from 1 to 6 miles and averages about 4 miles in Linn County. The width of the river channel averages about 200 feet. The gradient of the Marais des Cygnes River in Linn County is about 1.1 feet per mile.

Climate

The climate of Linn County is of the humid continental type and is favorable to the production of most of the crops grown in the State. The length of the growing season ranges from a minimum of 151 days to a maximum of 185 days; the average length is 181 days. The latest recorded date of a killing frost in the county was May 9th, and the earliest recorded date for a killing frost was September 9th.

Average temperatures at Mound City range from 31.7°F in January to 78.6°F in July, with an annual average of 56.3°F (based on the period 1931-60 from the U.S. Weather Bureau records).

Annual precipitation in Linn County averages about 39 inches (fig. 2, table 1) and increases very slightly from northwest to southeast. About 70 percent of the yearly precipitation occurs during the growing season (Furness, 1959, p. 41), and 95 percent occurs as rain.

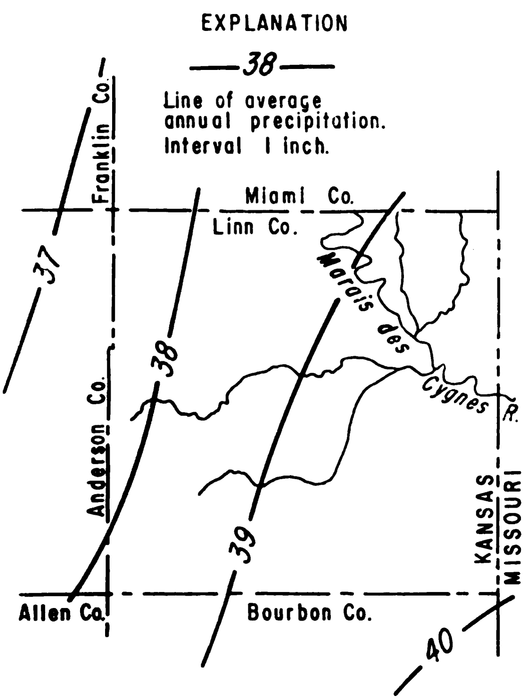


FIGURE 2.—Variation of annual precipitation in Linn County and adjoining areas.

TABLE 1.—Monthly normal precipitation at La Cygne, based on the period 1931-60 (from published records of the U.S. Weather Bureau).

Month	Mean precipitation, inches	Month	Mean precipitation, inches
January	1.52	July	4.73
February	1.43	August	3.55
March	2.59	September	4.40
April	3.76	October	3.04
May	5.28	November	2.12
June	5.46	December	1.52
		Annual	39.40

Previous Investigations

Geological investigations in Linn County and adjacent areas in which the stratigraphy, structural geology, and economic geology have been discussed include reports by numerous geologists and scientists listed in the References in this report.

Methods of Investigation

Data on which this report is based were collected in the summer and fall of 1960 and 1961. A number of stratigraphic sections were studied and described, and the significant formational contacts were located in the field and traced on aerial photographs. Two hundred twenty-two water wells were inventoried (table 4), and water samples for chemical analysis were collected from 25 selected wells in the county (table 2).

Test holes were drilled with a power auger across the Marais des Cygnes and several larger tributary valleys and with a hydraulic rotary drill in the upland bedrock areas. Samples were collected from all test holes and filed in the well-sample library at Lawrence.

Geology and other data were mapped on aerial photographs obtained from the Production and Marketing Administration of the U.S. Department of Agriculture and on base maps obtained from the State Highway Commission of Kansas.

Well-Numbering System

In this report wells and test holes are located according to the General Land Office coordinating system. According to this system (fig. 3), the first three sets of numbers of the well number designate the township, range, and section, in that order. The letters which follow indicate the quarter section, the quarter-quarter section, and the quarter-quarter-quarter section. The quarter sections are lettered *a*, *b*, *c*, and *d* in counterclockwise order starting in the northeast quadrant. When two or more wells or test holes are located within the same division, they are numbered serially in the order in which they were inventoried.

Acknowledgments

The author is deeply indebted to Dr. J. M. Jewett, Senior Geologist of the State Geological

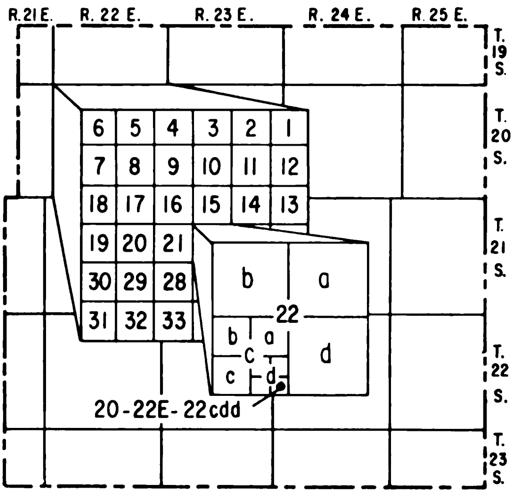


FIGURE 3.—Well-numbering system used in this report.

Survey of Kansas, who gave so freely of his time and understanding of the Paleozoic rocks of Kansas. Appreciation is also expressed to the many residents of Linn County who supplied much of the basic data and to the well drillers in the area—especially Claude Crowder of Fort Scott, Roy Cook and Clarence Haynes of Pleasanton, and Mr. T. Nelson of La Cygne, who provided many logs from this area; Virgil Burgat and Frank Wilson of the State Highway Commission of Kansas, who provided geologic profiles along highways in Linn County; and Richard Gentile of the Missouri Geological Survey and Water Resources, who provided geologic information from adjacent areas in Missouri.

GEOLOGIC UNITS[1]

The rocks which underlie and crop out in Linn County range in age from Precambrian to Recent and include sedimentary rocks of Cambrian, Ordovician, Devonian, Mississippian, Pennsylvanian, and Quaternary Systems. Thickness of the Paleozoic sequence in Linn County is about 2,200 feet. Paleozoic rocks which crop out in Linn County are Pennsylvanian in age and belong to the upper part of the Desmoinesian and lower part of the Missourian Stages; average thickness of these rocks is 660 feet.

Deposits of Quaternary and Recent age are mostly stream deposited and are found mainly in the stream valleys. Thickness of these deposits ranges from several feet to about 50 feet.

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

Cambrian and Ordovician Systems

The thick sequence of limestone and dolomite between the upper surface of the Precambrian and the base of the Chattanooga Shale is classed as Upper Cambrian and Ordovician and is, except for the lowermost Cambrian rocks, included in the Arbuckle Group. In Linn County eight wells which penetrate the top of this sequence have been reported. In one well, the Holeman and Edwards No. 9 Pollman in the SE¼ sec. 35, T. 19 S., R. 24 E., 690 feet of Arbuckle Group rocks and 90 feet of Upper Cambrian pre-Arbuckle rocks were penetrated. Sandstone of possible Simpson age is noted in the Evan *et al.* No. 1 Cook well in sec. 4, T. 22 S., R. 24 E., directly above Arbuckle limestone which according to Merriam and Atkinson (1956, p. 71) represents a sand-filled sink hole developed on the Arbuckle surface.

Rocks of the Cambrian System penetrated by the Pollman well are correlated with the Bonneterre and Eminence Dolomites. The basal Cambrian formation, the Lamotte Sandstone, was not penetrated by this well. In nearby areas thickness of this unit is about 40 feet. The entire thickness of Cambrian rocks in Linn County is approximately 300 feet.

The thickness of Ordovician rocks in the Pollman well is about 450 feet. Ordovician rocks recognized by Keroher and Kirby (1948) in the Pollman well include, in ascending order, the Gasconade Dolomite, Roubidoux Formation, and undifferentiated Cotter and Jefferson City Dolomites.

The altitude of the upper surface of the Arbuckle Group ranges from 130 feet above mean sea level in the southeastern part of the county to 365 feet below mean sea level in the northwestern part.

Generalized stratigraphic description of subsurface Cambrian and Ordovician rocks in Linn County.

	Thickness, feet
ORDOVICIAN SYSTEM	
LOWER ORDOVICIAN SERIES	
ARBUCKLE GROUP	
Cotter and Jefferson City Dolomites, undifferentiated	
Dolostone, dense to crystalline, white chert, and dolostone characterized by zones composed of dense concentrations of large brown oölites. Scattered zones of frosted quartz sand are common	168
Roubidoux Formation	
Dolomite, gray and pink, locally containing some chert. Three thin zones composed of quartz sand and a num-	

	Thickness, feet
ber of zones containing some scattered quartz sand are noted. Clear quartzose chert locally abundant. Lesser quantities of chert and the presence of large quantities of quartz sand characterize this formation	145
Gasconade Dolomite	
Dolomite, crystalline, light-gray to cream colored. Chert is white and opaque and is more abundant than in the Roubidoux Formation. A thin sandy zone at the base of this unit may be equivalent to the Gunter Sandstone Member of the Gasconade Dolomite	135
CAMBRIAN SYSTEM	
Upper Cambrian Series	
ARBUCKLE GROUP	
Eminence Dolomite	
Dolostone, fine- to coarse-grained, light-gray. Interval contains a 30-foot zone near the top which is reported to be chert free. Chert not as abundant as in Ordovician rocks	150
This unit marks base of Arbuckle Group	
BONNETERRE DOLOMITE	
This unit penetrated only to a depth of 90 feet in the Pollman well. Dark-gray coarsely crystalline dolomite which is much lighter in color than the overlying Eminence Dolomite. Some scattered grains of quartz sand associated with this unit. Average thickness of this unit in adjacent areas is about 125 feet	125
LAMOTTE SANDSTONE	
In nearby areas this unit is composed of subangular quartz sand which is commonly rather loosely cemented by calcareous material. This unit is normally found directly above the upper surface of the Precambrian	40

Devonian System

The shale separating the Arbuckle Group from the overlying Mississippian limestone in Linn County is correlated with the Devonian or Mississippian Chattanooga Shale. Gray and black shale, and locally a green shale, characterized both by plant spores and by finely disseminated pyrite, comprise this unit in Linn County. Black fissile shale, commonly associated with this formation elsewhere, has not been reported in Linn County. Medium to coarse well-rounded frosted quartz sand grains noted in the samples from the base of this unit are correlated with the Misener Sandstone of subsurface usage (Lee, 1940).

The Chattanooga Shale is present almost everywhere beneath the Mississippian limestone in Linn County and ranges in thickness from 10 to 25 feet.

Mississippian System

Rocks above the Chattanooga Shale and below the basal Pennsylvanian unconformity are included in the Mississippian System. In Linn County thickness of these rocks ranges from 290 to 350 feet, and limestone and dolomite predominate. The altitude of the upper surface of this system ranges from 400 feet above sea level near the southeast corner of the county to 50 feet below sea level in the northwest corner.

Subdivision of the Mississippian System in Linn County is based principally on the work done by Lee (1940) and on the study of drill cuttings from wells penetrating the Mississippian System in Linn County and adjoining areas by the Missouri Geological Survey and Water Resources and by the author. In Linn County Lee (1940) recognizes three stages of the Mississippian which, in ascending order, are correlated with the Kinderhookian, Osagian, and Meramecian Stages, and as many as five formations.

KINDERHOOKIAN STAGE

Two formations, the Chouteau Limestone and the Sedalia Dolomite, comprise the Kinderhookian Stage in Linn County. In the Heidenreich No. 5 Leasure well in sec. 24, T. 20 S., R. 23 E., Lee (Jewett, 1940b) correlated the 96 feet of dolomite and dolomitic limestone at the base of the Mississippian System with the Chouteau Limestone. A 5-foot zone of slightly cherty buff-gray dolomite found directly above this dolomite is considered by Lee as a partial equivalent of the Sedalia Dolomite. In a well near the southeastern corner of Linn County a thin bed of grayish-green shale in the Chouteau Limestone is correlated with the Northview Shale by the Missouri Geological Survey.

OSAGIAN STAGE

In Linn County the undifferentiated Burlington and Keokuk Limestones together comprise the Osagian Stage. The granular-textured dolomite and cherty gray limestone which range from 125 to 250 feet in thickness are the dominant lithologies.

MERAMECIAN STAGE

Rocks of the Meramecian Stage in Linn County range from 55 to 155 feet in thickness and are comprised mostly of the Warsaw Limestone. Beds which resemble the Salem (Spergen of former usage) and St. Louis Limestones may occur locally near the top of this stage.

Meramecian rocks in this area are characterized by the dominance of limestone, the ocurrence of a number of shale and silicious zones, the presence of sponge spicules and crinoid columnals, and by traces of glauconite and pyrite in nearly all samples.

A limestone, lithologically similar to the Warsaw Limestone but containing less chert, was identified by Lee (Jewett, 1940b) in the Leasure well as the Salem Limestone. Gray semigranular and fine-textured limestone found at the top of the Mississippian System in this well may possibly be equivalent to the St. Louis Limestone.

Pennsylvanian System

The Pennsylvanian System in Linn County is represented by parts of the Desmoinesian and Missourian Stages and is subdivided into the Cherokee, Marmaton, Pleasanton, Kansas City, and Lansing Groups. Shale, limestone, sandstone, and minor quantities of coal and underclay, in this order, are the most common rock types. The aggregate thickness of Pennsylvanian rocks in Linn County is 1,055 feet.

CHEROKEE GROUP

Pennsylvanian rocks between the unconformity at the top of the Mississippian System and the base of the Marmaton Group in eastern Kansas are classed as Desmoinesian and included in the Cherokee Group. According to the more than 200 logs of wells which penetrate this group in this area, the thickness ranges from 280 to 400 feet and averages about 350 feet. Thickness changes in this area are locally quite erratic and probably reflect the irregular configuration of the upper surface of the Mississippian rocks. Thickening of these rocks to the west in Linn County is a part of the regional thickening in the Forest City basin. Light and dark shale, black platy shale, sandy siltstone, medium to fine quartz sandstone, and ironstone are the common lithologic components of this group in Linn County. Several prominent coals, a few zones of coal smut, and a thin gray limestone are also noted in this interval. Zones containing medium to coarse pink siderite nodules are noted in many parts of this group.

Along its outcrop in southeastern Kansas, the Cherokee Group is divided into two formations of approximately equal thickness, named in their order of deposition, the Krebs and the Cabaniss Formations. In the subsurface in Linn County, this division can be made only locally.

Two sandstone beds are recognized in the lower half of the Cherokee Group, or the part which approximately corresponds to the Krebs Formation, one occurring near the base of the formation and the other near the top. The basal sandstone, referred to locally as the Burgess or Tucker sand, is probably equivalent to the Warner Sandstone Member of the Krebs at the outcrop. According to Jewett (1940b), thickness of this unit ranges from a few inches to more than 40 feet. The unit is absent in many wells in Linn County. The occurrence of this sandstone in direct contact with the Mississippian limestone is noted locally, but more commonly several feet of black pyritic shale separate these units. In Linn County the Warner Sandstone Member is a fine to medium micaceous sandstone composed of angular to subrounded quartz grains. The interval between the Warner and the upper sandstone contains a variety of lithologies. Black and gray shale predominate, and a few thin coal smut zones and a locally prominent coal bed are noted. Thickness of this shale ranges from several feet to about 80 feet. The sandstone occurring above this shale, widely referred to in the midcontinent as the Bartlesville sand, is found from 150 to about 300 feet below the top of the Cherokee Group in Linn County and ranges from 30 to 40 feet in thickness. Along the outcrop of the Cherokee Group in southeastern Kansas this unit is named the Bluejacket Sandstone Member of the Krebs Formation. The Bluejacket is composed mainly of fine white angular sand and some mica. Ironstone fragments and siderite nodules are noted locally.

In the upper half of the Cherokee Group in this area, a thin limestone bed and an overlying sandstone body of variable thickness, separated by gray shale and coal beds, occur between the top of the Bartlesville sand and the top of the Cherokee Group. The limestone noted in this interval is correlated with the Verdigris Limestone Member of the Cabaniss Formation of the outcrop, and the sandstone found above it is correlated with what is known locally as the Squirrel sand. The thickness of the interval between the top of the Bartlesville sand and the top of the Cherokee Group ranges from about 75 to 150 feet. Black platy shale and light- and dark-gray shale are the dominant lithologies in this interval. Coarse siderite nodules, one prominent coal bed, and as many as seven coal smut zones have been logged in this interval. Sandy siltstone, sandstone, gray shale, and some calcareous shale occur between the top of the Verdigris Limestone Member and the top of the Cherokee Group.

MARMATON GROUP

The rock units contained between the base of the Fort Scott Limestone and the disconformity at the base of the Missourian Stage are defined as the Marmaton Group (Jewett, 1941). Thickness of these rocks in Kansas averages about 200 feet, and the group is divided into eight formations: Fort Scott Limestone, Labette Shale, Pawnee Limestone, Bandera Shale, Altamont Limestone, Nowata Shale, Lenapah Limestone, and Holdenville Shale.

Fort Scott Limestone

The Fort Scott Limestone does not crop out in Linn County, and descriptions of this unit are based on outcrops found several miles to the south in Bourbon County and on a number of logs of wells which penetrate this unit in Linn County.

In Linn County a uniform thickness of about 20 feet of Fort Scott Limestone is reported in most wells which penetrate this unit. Two limestones of about equal thickness separated by several feet of shale comprise this formation. Several feet below the base of the Fort Scott Limestone a thin limestone bed, possibly equivalent to the Breezy Hill Limestone Member of the Cabaniss Formation of the Cherokee Group (Pierce and Courtier, 1938), has been logged in several wells.

The lower limestone member of the Fort Scott Limestone, named the Blackjack Creek Limestone Member (Cline, 1941), is described by Jewett (1941) as a massive bluish-gray and somewhat earthy limestone in Bourbon County averaging about 5 feet in thickness. The black platy and fissile shale found directly below this member serves as an excellent subsurface marker of the base of the Fort Scott Limestone.

The Little Osage Shale Member (Jewett, 1941), the middle member, is described as a dark-gray to black shale, ranging from 5 to 11 feet in thickness, which locally contains a thin bed of coal near the base.

The name Higginsville Limestone Member is applied to the upper member of the Fort Scott Limestone (Cline, 1941). The thickness of this unit in Linn County is about 15 feet. Along the outcrop in Bourbon County Jewett (1941) describes this unit as a massive light-gray brown-weathering limestone. Fusulinids and the massive cabbage-like coral *Chaetetes* are associated with this member.

Labette Shale

The Labette Shale (Haworth, 1898) is exposed only in southernmost Linn County in areas where south-flowing tributaries to the Little Osage River cut into and expose the upper part of this unit. Along the outcrop in Bourbon County and in wells which penetrate this unit in Linn County, the average thickness is about 35 feet, and the unit is contained between the black shale at the base of the Pawnee Limestone and the top of the Fort Scott Limestone. Near the southeastern corner of Linn County, a test hole drilled by the State Geological Survey in the NW¼ NW¼ NW¼ sec. 9, T. 23 S., R. 25 E., penetrated 46 feet of gray sandy shale and black shale between the base of the Pawnee Limestone and the top of the Fort Scott Limestone.

Pawnee Limestone

The Pawnee Limestone (Swallow, 1866) is the lowermost limestone unit cropping out in Linn County. Thickness of this unit averages 25 feet, and four separate members are recognized. In ascending order these are: Anna Shale, Myrick Station Limestone, Mine Creek Shale, and Laberdie Limestone Members.

ANNA SHALE MEMBER

The Anna Shale Member (Jewett, 1941) is a black fissile shale averaging about 2 feet in thickness. The unit is composed mostly of black fissile shale but grades downward into a gray calcareous shale. Flattened phosphatic concretions are found along the bedding planes and are commonly noted in the weathered debris below the outcrop. According to Jewett, this shale is present at nearly all exposures of the Pawnee Limestone in Kansas and is identified far into Missouri and Oklahoma.

MYRICK STATION LIMESTONE MEMBER

Along the outcrop of the Pawnee Limestone in Linn County and neighboring areas, the Myrick Station Limestone Member (Cline, 1941) is exposed as a 4-foot ledge of massive light-yellow weathering limestone. The limestone is medium gray to bluish gray on fresh surfaces and displays a pseudoconchoidal fracture. Close to the outcrop of this member, large slump blocks are commonly noted.

At several exposures in Linn County wavy beds, several inches thick, weather into relief on vertical faces of this seemingly massive limestone. Fusulinids, crinoid columnals, and brachiopods occur in this member, but not in abundance.

MINE CREEK SHALE MEMBER

The thickest exposure of the Mine Creek Shale Member in Kansas is noted at the type locality along Mine Creek (Jewett, 1941) near the middle of the south side of sec. 23, T. 21 S., R. 25 E., in Linn County where its thickness is 16 feet. In the southeastern corner of the county and along the outcrop to the south, the average thickness of the shale is about 6 feet. Within the area of outcrop, characteristics of the Mine Creek noted at the type locality are maintained. The shale is commonly gray, is carbonaceous, and contains a fairly persistent limestone near the top.

LABERDIE LIMESTONE MEMBER

Thickness of the Laberdie Limestone Member (Jewett, 1941) of the Pawnee Limestone averages 6 feet at exposures in Linn County. In this area the limestone is light gray and crystalline. It is thin bedded and commonly weathers into thin slabs. At the type locality of the Laberdie Limestone Member is an abandoned quarry in the SW cor. sec. 6, T. 23 S., R. 25 E., Linn County. Jewett (1941, p. 321) describes the Laberdie Limestone Member as ". . . light gray, thin wavy irregular beds, weathers somewhat lighter in color than when fresh; more massive in lower part."

Chert is not normally associated with the limestone members of the Pawnee Limestone except locally in easternmost Linn County and in adjoining areas in Bates County, Mo. At one locality in the SE¼ sec. 2, T. 21 S., R. 25 E., a massive ledge of white-weathering chert, 1-foot thick, forms the topmost layer in the Laberdie Limestone.

Bandera Shale

Thick clastic deposits occurring between the top of the Pawnee Limestone and the base of the Altamont Limestone were named the Bandera Shale by Adams and others (1903). In Linn County thicknesses of the sandy siltstone and sandstone which comprise this unit average 45 feet. The widespread Mulberry coal, which occurs several feet above the base of the formation, averages about 1.5 feet in thickness. Exposures of the Bandera Shale are noted in the highwalls of most strip mines in eastern Linn County. Yellow-weathering light-gray sandy siltstone and fine sandstone are the dominant lithologies. Large and well-formed septarian concretions are found at nearly all exposures and are characteristic features of this unit in Linn County.

An excellent exposure of the upper part of the Bandera Shale is noted in a natural cutbank on the south side of the Marais des Cygnes River in the NW¼ NE¼ sec. 16, T. 21 S., R. 25 E., several miles northeast of Pleasanton. At this exposure, steeply dipping beds of the Bandera Shale are truncated by the overlying Altamont Limestone. Elsewhere in Linn County, particularly at exposures in the many Mulberry coal strip mines, local distortions of bedding and steeply dipping beds are common. Jewett (1941) reports a nearly black limestone several feet above the Mulberry coal along the outcrop in southern Bourbon County. In the vicinity of La Cygne, in northern Linn County, a similar bed is noted in the subsurface.

North of the Marais des Cygnes River in Linn County the Bandera Shale is thinner and its thickness is quite erratic. The average thickness in this area is about 20 feet, but locally in the area near Amsterdam in Bates County, Mo., it is only 5 feet. South of Pleasanton several localities have been observed where, in very localized circular "chimney-like" zones, the Bandera Shale and underlying beds have been highly disturbed and mineralized with lead and zinc sulfide minerals.

Sandstone beds near the top of this unit, referred to collectively as the Bandera Quarry Sandstone Member, produce some oil and gas in northern Linn County and in Miami County. Along the Bandera Shale outcrop in Linn County the thickness of this sandstone is approximately 10 feet.

Altamont Limestone

The prominent limestone directly overlying the Bandera Shale in Linn County is named the Altamont Limestone (Adams, 1896). In Kansas two limestone members and a middle shale member make up this unit, and the combined thickness is about 10 feet. The members of this formation are, in ascending order, the Amoret Limestone, Lake Neosho Shale, and Worland Limestone.

AMORET LIMESTONE MEMBER

Thickness of the Amoret Limestone Member (Jewett, 1941) rarely exceeds 1 foot at exposures in Linn County. At one exposure in the NW¼ NE¼ sec. 16, T. 21 S., R. 25 E., a 1.2-foot bed of yellow-weathering light-gray calcarinitic limestone composed of well-sorted algal-encrusted shell fragments comprises this member. A similar exposure of this same calcarinite facies is noted in a roadcut in the NW¼ NE¼ sec. 8, T. 22 S., R. 25 E. At other exposures in this area the Amoret Limestone also occurs as a 1-foot ledge of sandy light-gray limestone and as a zone of impure nodular limestone.

LAKE NEOSHO SHALE MEMBER

In Linn County the Lake Neosho Shale Member (Jewett, 1941) occurs as a light-gray shale, ranging from several inches to 5 feet in thickness, that is characterized by numerous small phosphatic concretions. Few exposures of this unit are noted in Linn County, and where the bed is present, it is either covered or obscured by slumping.

WORLAND LIMESTONE MEMBER

The Worland Limestone Member (Cline, 1941) is the principal limestone member of the Altamont Limestone and the most prominent Marmaton limestone member cropping out in Linn County. Across Linn County this member ranges in thickness from 3 to 5 feet, and it supports a very prominent escarpment.

Fresh surfaces of this limestone are light gray in color and the rock texture is sublithographic and homogeneous. On weathered surfaces the color of this rock is light gray. At a number of exposures in Linn County, a knobby, algal-like structure weathers into relief on the upper surface of this rock. *Phricodothyrus*, *Composita*, small horn corals, fusulinids, and crinoid columnals are commonly associated with this member and are distributed uniformly throughout it. *Phricodothyrus* is especially common and is noted at nearly all exposures.

Nowata Shale

Ohern (1910) named the shale, contained between the Altamont Limestone and the Lenapah Limestone, the Nowata Shale. In Linn County 12 exposures, both complete and incomplete, were noted and studied. The thickness of this shale ranges from 3 to 24 feet, and abrupt changes in thickness between closely spaced exposures are common. Yellow-weathering light-gray shale commonly occupies the entire Nowata Shale interval; however, sandstone beds have been noted locally both at the top and near the base. In the SE¼ NE¼ sec. 19, T. 21 S., R. 25 E., a thin bed of slabby fine-grained micaceous sandstone occurs 2 feet above the Altamont Limestone and occupies the position of the Walter Johnson Sandstone Member of the Nowata (Jewett, 1941).

In Linn County the thickest exposures of the Nowata Shale are observed east of Mound City on the flanks of the Mound City dome. In this area thicknesses in excess of 20 feet have been measured.

Lenapah Limestone

The limestone occurring between the Nowata Shale and the base of the Holdenville Shale was named Lenapah Limestone by Ohern (1910). In Kansas this formation is composed typically of the Norfleet Limestone, Perry Farm Shale, and Idenbro Limestone Members.

The outcrop of Lenapah Limestone is discontinuous across Linn County mainly due to post-Desmoinesian pre-Missourian erosion and locally because of nondeposition. Two members, the Norfleet and Perry Farm, are represented at most Lenapah Limestone exposures in Linn County, but the Idenbro is noted only locally.

NORFLEET LIMESTONE MEMBER

The lower member, named the Norfleet Limestone (Jewett, 1941, p. 338), is described as ". . . dense dove-gray to dark slabby limestone and limestone breccia. On weathering, the latter facies produces very hummocky outcrops. Where more massive, this limestone contains an abundance of the brachiopod *Dictyoclostus*; crinoid stems are abundant in the more slabby facies."

The Norfleet Limestone Member is widely recognized in both Linn County and Bates County, Mo., and is represented by a variety of limestone facies. The most common of these are highly fossiliferous brown-weathering limestone and an unfossiliferous sandy limestone. A massive light-gray crystalline limestone which displays the hummocky weathering surface described by Jewett is noted at several exposures in the vicinity of Mound City. The Norfleet is extremely fossiliferous and contains numerous dictyoclostids, *Echinaria*, *Composita*, *Mesolobus*, *Myalina*, horn corals, and crinoids. In Linn County the thickness of the Norfleet Limestone ranges from 0.5 to 4.5 feet.

PERRY FARM SHALE MEMBER

Jewett (1941) applied the name Perry Farm to the middle member of the Lenapah Limestone after exposures in Labette County, where 10 feet of gray calcareous and fossiliferous shale separates the two limestone members of this formation. Along the outcrop in Kansas, the Perry

Farm Shale Member nearly always contains small nodules of limestone, and in Linn County, where this shale is completely exposed at only a few locations, these nodules are nearly always found. Thickness of the Perry Farm Shale along this part of the outcrop ranges from about 1 to 10 feet.

IDENBRO LIMESTONE MEMBER

Jewett (1941) introduced the name Idenbro Limestone as the name for the upper member of the Lenapah Limestone and noted that the unit was characterized by its wavy beds of light-gray limestone. Along the northern part of the Kansas outcrop in Linn County and in adjoining areas in Missouri, only a few sections which include this member are exposed. A typical exposure of this limestone in Linn County occurs in a riffle in the Marais des Cygnes River at Trading Post. At this exposure, the limestone is about 2.5 feet thick and is a gray crystalline unfossiliferous limestone which locally appears to be cross stratified. Similar exposures of the Idenbro Limestone Member are noted at one locality several miles east of Pleasanton and at several localities in Bates County, Mo.

Holdenville Shale

The shale found between the pre-Missourian disconformity and the top of the Lenapah Limestone is called the Holdenville Shale (Taff, 1901). In Kansas, Jewett (1941) reports the thickness of this interval to range from 0 to more than 40 feet. In Linn County, owing either to nondeposition or to post-depositional erosion, this unit is either absent or partly missing. The thickness of the Holdenville in Linn County ranges from a few inches to more than 30 feet. Yellow-weathering gray clay shale occupies this entire interval along much of the outcrop; however, locally coal, black fissile shale, and nodular limestone occur near the base.

An excellent exposure of the Holdenville Shale is noted on the north side of the Marais des Cygnes River west of the bridge at Trading Post. A thin coal and underclay occur at the base and are directly overlain by about 2 feet of black fissile shale and dark-gray nodular limestone. Orbiculoid brachiopods occur in this limestone. Ten feet of dark-gray concretionary shale overlies this black and sandy shale, grades upward into the Hepler Sandstone Member of the Seminole Formation (Jewett, 1940b; Singler, 1965), and occupies the upper part of this exposure. Two miles northeast of Amsterdam, Mo. (Bates County), a similar sequence of beds comprises the Holdenville Shale.

PLEASANTON GROUP

The sequence of rocks occurring between the basal Missourian disconformity and the base of the Kansas City Group is named Pleasanton Group (Zeller, 1968; Singler, 1965) and is divided along part of its outcrop in southern Kansas into three formations: Seminole Formation, Checkerboard Limestone, and Tacket Formation. Along the northern part of the outcrop in Kansas, the Checkerboard Limestone is not recognized and the Seminole and Tacket Formations (Emery, 1962) are not easily differentiated.

In Linn County the Pleasanton Group consists mainly of siltstone with a thin sandstone, the Hepler Sandstone Member of the Seminole Formation, at the base and discontinuous sandstone beds, locally called Knobtown sandstone, near the top. Thickness of the Pleasanton Group in Linn County ranges from 100 to 150 feet.

The basal Missourian sandstone named Hepler (Jewett, 1940a), now considered the basal member of the Seminole Formation (Zeller, 1968; Singler, 1965), is the only member of this formation recognized in Linn County. It ranges in thickness from several inches to more than 30 feet and averages about 10 feet. Prominent exposures occur along most of the outcrop in the county, but locally the outcrop is either absent or too thin to support a bench. Test holes near Pleasanton penetrated two sandstone beds separated by more than 10 feet of shale at the base of the Pleasanton Group, but elsewhere only one is recognized. Test holes drilled in the area between Mound City and Pleasanton suggest a thinning of the Hepler Sandstone Member westward. In the vicinity of Mound City, maroon shale occupies the approximate position of this member. In Linn County in the area west of Mound City, no sandstone has been logged in wells penetrating the Pleasanton Group.

Weathered exposures of the Hepler Sandstone are commonly dark brown and locally, due to leaching of cementing materials, the sandstone appears friable. According to Hatcher (1961) the grain size of the Hepler Sandstone in Linn County varies from 1/4 to 1/16 millimeter. Individual beds range from less than 1 inch to more than 1 foot in thickness and are separated by thin weathered yellow clay. Where freshly exposed, the Hepler Sandstone Member appears as a light yellowish-gray hard sandstone. In the vicinity of Pleasanton, the Hepler Sandstone is charged with asphalt and has been used for road metal and paving stones. In this same area steeply dipping beds of the Hepler, which are probably related to slumping or collapse, are cut through and exposed along Muddy Creek. In the area east of Pleasanton, the Hepler Sandstone has the aspect of a channel sandstone. More than 20 feet of cross-stratified sandstone is exposed in a roadcut and quarry in the NE¼ sec. 8, T. 22 S., R. 25 E. South of the Marais des Cygnes River in Linn County, the Hepler Sandstone is commonly in contact with Lenepah Limestone and is locally in contact with the Altamont Limestone, but north of the Marais des Cygnes River the Hepler Sandstone normally occurs several feet above the Lenepah Limestone.

The part of the Pleasanton Group above the Hepler Sandstone Member consists mainly of the Tacket Formation, but because the Checkerboard Limestone is absent, it cannot be separated from the underlying Seminole Formation. The Checkerboard Limestone, a thin but prominent limestone bed found close above the Hepler Sandstone in southern Kansas, has been traced northward into southern Neosho County. The Exline Limestone, a comparable bed, is recognized in Bates County, Mo., and elsewhere to the north along the Missouri outcrop (Howe and Koenig, 1961). In Bates County and in the vicinity of Trading Post in Linn County, a concretionary zone containing numerous *Trepospira* occurs in the position of the Exline Limestone. The part of the Pleasanton Group above the Hepler consists mostly of gray to buff thin-bedded and micaceous siltstone. Sandstone beds, locally called Knobtown sandstone, occur in the upper one-third of this formation in the area north of Mound City. South of Mound City, dense blue limestone flags occupy the upper part of this formation. In the basal part of this unit, large oblate siltstone concretions are common. Close to the upper contact limestone nodules, chonetid brachiopods, and crinoid fragments are noted, and in exposures in Bates County, Mo., a coal smut occurs near the top of this formation. Hatcher (1961) reports the Knobtown to vary from a fine to very fine sandstone. Color ranges from buff to light gray and bedding from thin to massive. In Linn County thickness of this unit ranges from 9 to 35 feet. Brachiopods have been noted locally and plant fossils occur abundantly in this unit.

In the area south of Pleasanton and into northern Bourbon County a sequence of flaggy limestone beds known as the "Bourbon flags" occurs in the upper parts of this unit. Thickness of this sequence of flags ranges from a few feet to about 35 feet in Linn County and to about 60 feet in Bourbon County. Limestone in this sequence is dark blue and sublithographic. A sparse molluscan fauna is associated with this limestone. The rock breaks with a choncoidal fracture and is locally completely replaced by silica.

KANSAS CITY GROUP

The Kansas City Group includes the succession of beds between the base of the Hertha Limestone and the base of the Plattsburg Limestone. The average thickness of this group in Linn County is about 300 feet. In Kansas this group has been subdivided into the Bronson, Linn, and Zahara Subgroups. Thick massive limestones and thin black fissile shales are the most characteristic lithologies associated with this group.

Hertha Limestone

The basal formation of the Bronson Subgroup, the Hertha Limestone (Adams and others, 1903), consists of the Critzer Limestone, Mound City Shale, and Sniabar Limestone Members. The average thickness of this formation is about 20 feet in Linn County.

CRITZER LIMESTONE MEMBER

At the type section (Jewett, 1932), near the abandoned town site of Critzer in sec. 8, T. 22 S., R. 23 E., the Critzer Limestone Member occurs as a brown-weathering clastic molluscan limestone, but elsewhere in the county at least two other distinct facies have been identified. In the northern part of the county in the vicinity of La Cygne, nodular rubbly silty limestone occurs in this position, and in the area south of Mound City, a highly fossiliferous algal limestone facies is noted. In Linn County thickness of the Critzer ranges from 1 foot to more than 10 feet and averages about 4 feet.

The brown-weathering molluscan facies noted throughout much of the county occurs as a massive ledge of pitted and hummocky clastic limestone. Texture of this rock is commonly clastic, but it is locally noted as a fine-grained limestone. On fresh surfaces color ranges from medium to light gray, and the upper part is locally a calcarinite of algal-encrusted shell debris. Large Bellerophontid gastropods and other molluscan forms weather into sharp relief on the surface of this unit. *Myalina*, large productids, crinoid columnals, and Bellerophontid gastropods are the most common.

The nodular facies of the Critzer Limestone Member noted in the vicinity of La Cygne is an unfossiliferous yellowish-brown silty limestone which generally forms either a poorly resistant bench or a nodular limestone zone. At several exposures in this area no limestone occurs in the position of the Critzer Limestone.

South of Mound City in Linn County and northern Bourbon County, a wavy-bedded cherty limestone containing numerous horn corals, *Composita* and other brachiopods, and a distinct algal-like structure resembling the algae *Marksia,* occurs locally in the position of the Hertha Limestone. This facies was formerly recognized as a separate member of the Hertha and was formerly called the Schubert Creek Limestone (Moore, 1936) after exposures in northern Bourbon County.

MOUND CITY SHALE MEMBER

The middle member of the Hertha Limestone, the Mound City Shale (Jewett, 1932), is a medium- to dark-gray shale, commonly containing a thin encrinal limestone bed in its middle part. The shale is calcareous and quite fossiliferous and commonly contains limestone nodules and a thin coal smut zone. The thickness of the Mound City Shale Member ranges from 3 to 20 feet and averages about 6 feet in Linn County. In the NW cor. sec. 25, T. 22 S., R. 24 E., more than 20 feet of shale, which includes the thin crinoidal limestone bed and a thick sandstone bed, occupies the position of the Mound City. Similar thick deposits of Mound City are noted elsewhere in this area and in northern Bourbon County.

The Mound City Shale Member is quite fossiliferous along its outcrop in Linn County and both chonetid brachiopods and *Derbyia* are common. The thin crinoidal limestone occurring in the middle part of this unit is quite distinctive and serves as an excellent marker bed in central and southern Linn County. Thickness of this bed is about half a foot.

SNIABAR LIMESTONE MEMBER

The Sniabar Limestone (Newell, 1932, 1935), the upper member of the Hertha Limestone, is a persistent bed of uniform character along its outcrop in Linn County where it is recognized as a rust-brown-weathering massive-bedded limestone ranging from 2 to 6 feet in thickness. This limestone is fine grained and the color on unweathered surfaces is normally medium gray. Penetration of the rust-brown-weathering color deep into this unit is common, and at a number of exposures the entire thickness of the bed is this color. At several exposures a thin bed of bioclastic limestone composed of algal-encrusted shell fragments occupies the upper part of this member. Dictyoclostids, *Echinaria,* and other large productid brachiopods and the coral *Syringopora* dominate the fauna of this member.

LADORE SHALE

The Ladore Shale (Adams and others, 1904) occurs above the Sniabar Limestone Member and below the Middle Creek Limestone Member. In Linn County this brown-weathering calcareous shale ranges from 5 to 13 feet in thickness. Locally near the middle of this unit a bed of brown-weathering argillaceous limestone is noted that ranges from several inches to about 2 feet in thickness. This bed is most prominent in the vicinity of Farlinville, near the center of Linn County, and is noted elsewhere in the county as an obscure zone of pea-size limy nodules. The Ladore Shale is quite fossiliferous, especially near the upper contact, and brachiopods, especially *Derbyia* and *Chonetes,* are quite common.

SWOPE LIMESTONE

The Swope Limestone, named by Moore (1932), contains two limestones and a middle shale. The lower member, the Middle Creek Limestone, is a thin dense sublithographic limestone; the middle member, the Hushpuckney Shale, is composed in part of black fissile shale; and the principal member, the Bethany Falls Limestone, is a thick limestone composed of thin-bedded cherty limestone and a bed of massive oölitic limestone.

MIDDLE CREEK LIMESTONE MEMBER

Newell (1932) applied the name Middle Creek to the dark-blue sublithographic limestone found several feet below the Bethany Falls Limestone Member after exposures located 3 miles east of La Cygne. In this area and along much of its outcrop in Kansas, this unit maintains an almost constant thickness of 2 feet. The Middle Creek Limestone commonly breaks with a conchoidal fracture and is characterized by closely spaced vertical joints. Color of this rock varies from medium gray to bluish gray, and weathered surfaces are normally light yellowish gray. Fossils do not weather into relief on the weathered surface but are noted on fresh surfaces. Small brachiopods, ramose bryozoans, horn corals, and high-spired gastropods are the most common forms.

HUSHPUCKNEY SHALE MEMBER

The black fissile shale and brown clay shale found above the Middle Creek Limestone Member were named Hushpuckney by Newell (1932) after a creek exposure south of Fontana in Miami County, Kans. The lower half of this member normally consists of black fissile shale, and the upper half consists of brown clay shale. In Linn County thickness of this shale averages 5 feet. Megafossils are not noted in either part of this member in Linn County or elsewhere in Kansas.

BETHANY FALLS LIMESTONE MEMBER

The Bethany Falls Limestone, the principal member of the Swope Limestone, was named by Broadhead (1866) from exposures along Big Creek near Bethany, Mo. Along its outcrop in Linn County, thickness of this member ranges from 11 to 21 feet and consists mainly of massive- to thin-bedded cherty limestone with a thin bed of oölitic limestone at the top. The beds comprising the lower part of this member range from thick bedded to thin bedded. Thickness of individual beds, locally separated by thin shale partings, is erratic. Weathering color of this member varies from light gray to a distinctive light yellow. The rock is medium crystalline and contains numerous calcite-filled vugs, veins, and stylolites. A thin bed of limestone separated from the main part of this unit by several inches of shale marks the base of the Bethany Falls Limestone Member. The gray oölitic limestone found at the top of this member forms a massive ledge of very distinctive limestone which is easily traceable in the field. This limestone is light gray and is about 3 feet thick in Linn County. It is composed mainly of oölites and appears quite porous on weathered surfaces.

Galesburg Shale

Adams and others (1903) named the shale separating the Swope and Dennis Limestones the Galesburg Shale after exposures near the town of Galesburg in Neosho County. In Linn County the thickness of the Galesburg Shale is quite uniform, averaging about 2 feet. Gray unfossiliferous shale occupies the entire interval at most locations; however, locally nodular fossiliferous shale is found near the top, and a thin micaceous sandstone is found near the base. Both pelecypods and brachiopods have been noted in the upper nodular zone, but no fossils are noted below it. Near the SW cor. sec. 27, T. 21 S., R. 24 E., a 1.4-foot bed of fine micaceous sandstone occurs at the base of the Galesburg Shale.

Dennis Limestone

The Dennis Limestone, the uppermost formation in the Bronson Subgroup, was named and described by Adams and others (1903) from exposures near the town of Dennis in Labette County, Kans. This formation, which lies between the Galesburg Shale and the base of the Cherryvale Shale, is divisible into three distinct members: Canville Limestone, Stark Shale, and Winterset Limestone. The thickness of this unit along its outcrop in Kansas ranges from 2 to 70 feet, and in Linn County the average thickness estimated from composite measured sections and from well logs is about 35 feet.

The sequence of beds comprising this unit is lithologically similar to the sequence of units which make up the Swope Limestone. The two formations differ only in the greater thickness of the Winterset Limestone Member and in the shaly nature of the Canville Limestone Member over part of the outcrop in Linn County.

CANVILLE LIMESTONE MEMBER

The Canville Limestone (Jewett, 1932), the basal member of the Dennis Limestone, is a dense blue massive limestone characterized by closely spaced vertical joints and by a pseudoconchoidal fracture. In Linn County the thickness of this member ranges from 0 to about 2 feet. Along its outcrop dark calcareous shale and nodular limestone locally occupy the position of this member. From the vicinity of La Cygne northward into south-central Iowa, Lamerson (1956) reports a continuous bed of shaly and nodular limestone. South of Linn County the Canville Limestone Member thickens and is a continuous limestone bed. Crinoid columnals, brachiopods, and small gastropods are common in the limestone facies, and crinoid columnals are common in the shaly facies.

STARK SHALE MEMBER

In Linn County the Stark Shale Member (Jewett, 1932) consists of two parts, a lower platy black shale and an overlying soft gray blocky shale. Thickness of the lower bed averages 1.5 feet and the upper bed averages 2.5 feet. Characteristics of these beds are uniform over most of Linn County and the member appears to be continuous in the vicinity of the outcrop. Along the bedding planes in the black shale, phosphatic concretions are locally noted.

WINTERSET LIMESTONE MEMBER

The most conspicuous member of the Dennis Limestone, the Winterset Limestone (Tilton and Bain, 1897), is traceable from Oklahoma, where it is called the Hogshooter Limestone, northward into south-central Iowa (Moore, 1949). Thickness throughout this area ranges from a few feet to more than 70 feet.

In Linn County the thickness of this member ranges from 30 to 40 feet. Thin and thick wavy beds of fragmental and cherty limestone, separated locally by thin shale partings, are characteristic of this member. Weathering color varies from a chalky white to an earthy yellowish brown. On freshly broken surfaces the rock is light gray and is characterized by calcite-filled veins and numerous recrystalized fossils. Chert is especially common in the beds near the top, and thin beds of oölitic limestone are noted locally in other parts of this member. Productids and crinoids are among the more common fossils associated with this member, and fusulinids and ramose bryozoans are noted locally.

CHERRYVALE SHALE

The Cherryvale Shale (Haworth and Bennett, 1908) includes the beds that occur between the Dennis Limestone and the base of the Drum Limestone. In Linn County the thickness of this unit is variable, ranging from 40 to about 70 feet, and three members are locally recognized. Along the outcrop in Miami County and in areas to the north, the Cherryvale Shale is divisible into five members which are, in ascending order: Fontana Shale, Block Limestone, Wea Shale, Westerville Limestone, and Quivira Shale. However, south of the Linn-Miami County boundary, the Westerville Limestone Member has not been recognized, so the Wea and Quivira Shale Members are not divisible.

FONTANA SHALE MEMBER

The shale separating the Dennis and Block Limestones was named Fontana by Newell (1932) after exposures near Fontana in southern Miami County. In Linn County this unit ranges in thickness from 5 to 7 feet and is a gray clay shale.

BLOCK LIMESTONE MEMBER

Newell (1932) applied the name Block to the 3-foot bed of dense-blue massive-bedded limestone found close above the Winterset Limestone Member near the village of Block in Miami County. In Linn County the Block Limestone Member ranges from 1 to 7 feet in thickness and is a bluish-gray fine-grained limestone characterized by closely spaced vertical joints. On weathering the rock breaks into distinctive wedge-shaped blocks. Crinoids and brachiopods are common in this member and are noted at most outcrops. However, to the south the Block Limestone is either discontinuous or too thin to support a bench and is rarely noted.

WEA-QUIVIRA SHALE MEMBER

Both the Quivira and Wea Shale Members are recognized in the vicinity of their respective type exposures in Miami County, where they are separated by the Westerville Limestone Member. However, south of this area, the Westerville is recognized at only two localities in northern Linn County, and the two shale members are not normally separated. The combined shale members are termed Wea-Quivira. In Linn County this unit is a gray to olive-green clay shale which is about 40 feet thick.

DRUM LIMESTONE

Two limestone beds, locally separated by several inches of shale, comprise the Drum Limestone in Linn County. In Kansas this unit separates the Cherryvale Shale, below, from the Chanute Shale. The basal member, called the Dewey Limestone, is the prominent brown encrinal limestone noted at the majority of exposures in Linn County. The upper member, which is recognized only locally in the county, is a cross-stratified oölitic limestone.

The name Drum Limestone was applied by Adams and others (1903) after exposures along Drum Creek in Montgomery County, Kans. According to Moore (1936), the thickness of the Drum Limestone in Kansas ranges from 2 to 60 feet, and the bed is not everywhere recognized. Thickness of the Drum Limestone in Linn County ranges from several inches to 9 feet.

DEWEY LIMESTONE MEMBER

The Dewey Limestone (Hinds and Greene, 1915) is the most prominent of the two members of the Drum Limestone in Linn County. Thickness of this member ranges from several inches to 3 feet and averages about 1.5 feet. Where typically exposed, this member is a deep-brown-weathering massive-bedded limestone characterized by a dense concentration of fossil debris. Crinoid columnals, *Marginifera,* fenestellid bryozoans, and lath-like shell fragments are commonly noted. The texture of the Dewey Limestone is coarse crystalline, and the color on fresh surfaces is bluish gray. In the northern part of the outcrop the limestone is massive and is noted at most Drum Limestone exposures, but in southern Linn County this member is either missing or discontinuous.

CORBIN CITY LIMESTONE MEMBER

Moore (1932) applied the name Corbin City to the upper member of the Drum Limestone from exposures near Corbin City in Montgomery County, Kans. Over much of its outcrop in Kansas the member is a coarse-textured coquina of marine fossil debris. In northern Linn County the Corbin City, where present, is a cross-stratified oölitic molluscan limestone which ranges in thickness from 0.2 to about 6 feet and weathers reddish brown. In southern Linn County the Corbin City Limestone is noted only locally and occurs as an impure nodular limestone.

Chanute Shale

Haworth and Bennett (1908) defined the Chanute Shale to include all beds between the top of the Drum Limestone and the base of the Iola Limestone. Exposures in the vicinity of Chanute in northern Neosho County were selected as type exposures (Moore, 1936).

In Linn County thickness of the Chanute ranges from 30 to 40 feet. A prominent sandstone ranging from 8 to 30 feet thick occupies the upper part of this formation, and olive-green clay shale makes up the remaining part. Coal, ranging from a thin smut zone to about 1 foot in thickness, separates these two units.

The part of the Chanute Shale lying below the coal ranges from 2 to 15 feet in thickness, consists mostly of olive-gray clay shale, and contains sandy shale and limy zones locally. Near the town of Parker in SE¼ sec. 8, T. 20 S., R. 22 E., 2 feet of maroon shale directly above the Drum Limestone was recognized in the core trench of the Parker Municipal Lake. Elsewhere in the county this shale was not recognized, but in northeastern Kansas and adjoining areas in Missouri a similar shale has been noted (Moore, 1936).

Haworth and Kirk (1894) first noted the thin coal in the middle part of the Chanute and named it Thayer coal. In Linn County the coal is widespread and occurs at most exposures. In the vicinity of Blue Mound, it is of significant thickness and quality and has been mined for local use.

The part of the Chanute Shale above the Thayer coal and below the Iola Limestone ranges from 16 to 30 feet in thickness in Linn County and is composed mainly of the Cottage Grove Sandstone Member (Newell, 1935). The sandstone which comprises the Cottage Grove ranges from fine to very fine and appears on the outcrop much like the Hepler Sandstone Member. Beds range in thickness from very thin to thick and are locally ripple marked. In sec. 11, T. 22 S., R. 21 E., an exposure of Cottage Grove Sandstone, which is topographically higher than Iola Limestone, occurs probably as a result of limestone deposition around a mass of thickened sandstone. Wagner (1961) reports a similar condition along the Cottage Grove outcrop in Wilson County, as does Jungmann (1966) in Neosho County.

Iola Limestone

The Iola Limestone, after limestone directly underlying Iola, Kans. (Haworth and Kirk, 1894), is defined as the formation underlain by the Chanute Shale and overlain by the Lane Shale. In Kansas two limestone members, separated by a thin but distinct shale member, are recognized, which in ascending order are: Paola Limestone, Muncie Creek Shale, and Raytown Limestone. Thickness of the formation in Kansas ranges from 0 to more than 30 feet. In Linn County the total thickness of the Iola Limestone ranges from 11 to 16 feet.

PAOLA LIMESTONE MEMBER

Newell (1932) applied the name Paola to the dense-blue massive limestone found at the base of the Iola Limestone at exposures near Paola, Kans. At this exposure and along much of the outcrop in Kansas, the Paola Limestone Member ranges from 2 to 3 feet thick and commonly appears as a dense and dark-blue limestone. Closely spaced vertical joints and subconchoidal fractures characterize this member. In Linn County exposures of the Paola Limestone are obscure and it appears that the member is not continuous across the county.

MUNCIE CREEK SHALE MEMBER

The gray clay shale containing numerous phosphatic concretions and the black platy shale separating the two limestone members of the Iola Limestone were named Muncie Creek by Newell (1932). In Kansas the thickness of this member ranges from several inches to about 3 feet. Thickness of this shale in Linn County is rarely more than a few inches, and the bed is generally obscured by slumping. Occurrence of this member at most Iola Limestone exposures is suggested only by the presence of phosphatic concretions.

RAYTOWN LIMESTONE MEMBER

The main member of the Iola Limestone was named Raytown (Hinds and Greene, 1915) after exposures in the vicinity of Raytown, Mo. In Kansas thickness of this member ranges from about 5 feet near the type locality to about 28 feet in the vicinity of Iola. In Linn County thickness ranges from 9 to 13 feet. Weathering color varies from yellowish brown to almost white, and on fresh surfaces the color is light gray and the texture is medium to fine grained. Limonite-stained zones noted along the bedding planes are quite distinctive and are a unique feature of this limestone at its outcrop. The thin to medium wavy beds which comprise this member weather into relief on the outcrop surface and are in sharp contrast with the more massive lower limestone member. The Raytown Limestone Member in Linn County is not abundantly fossiliferous, as it is elsewhere along the outcrop, and commonly contains only some shell debris, crinoid columnals, and a few brachiopods.

Lane Shale

Shale occurring between the top of the Iola Limestone and the base of the Wyandotte Limestone was named the Lane Shale (Haworth and Kirk, 1894) after exposures near Lane in southern Franklin County. The shale, according to Moore (1936), is recognized northward from Lane into Nebraska and Iowa; south of Lane, the Wyandotte Limestone is reported to pinch out and the Lane and Bonner Springs Shales coalesce.

In Linn County the Wyandotte Limestone appears continuous across the northwest corner of the county, so the Lane Shale is considered a discrete unit. Thickness of the Lane Shale in this area ranges from about 40 to 100 feet. Slopes underlain by the Lane Shale are mostly covered. Where seen, the shale appears as a uniform bluish-gray noncalcareous clay shale locally containing thin beds of buff silty and sandy shale.

Wyandotte Limestone

The limestone formation above the Lane Shale and below the Bonner Springs Shale was named the Wyandotte Limestone (Newell, 1932) after quarry exposures near Bonner Springs in Wyandotte County, Kans. Five members comprising this formation are: Frisbie Limestone, Quindaro Shale, Argentine Limestone, Island Creek Shale, and Farley Limestone. The combined thickness of this formation in the vicinity of the type section is about 40 feet, but to the south in Miami and Franklin Counties, the Wyandotte Limestone thins to about 25 feet. In Kansas the Wyandotte Limestone can be traced from the vicinity of the type section southward to Lane in southern Franklin County. South of Lane the Wyandotte is recognized locally but is represented by a number of discontinuous facies.

In the vicinity of Parker in northwestern Linn County, exposures of the Wyandotte Limestone, which resemble the Argentine Limestone Member, are recognized and can be traced northward into Miami County. South of Parker a thin dark-blue bed of limestone occupies the position of the Wyandotte.

In a roadcut northwest of Parker in the NE¼ sec. 2, T. 20 S., R. 21 E., the Wyandotte consists of a massive ledge of fine-grained limestone overlain by 8 feet of wavy-bedded limestone. The individual beds comprising the upper part at this exposure range from thick to medium bedded and weather light yellowish brown. Calcite-filled veins and calcite-replaced fossils weather into sharp relief on the surface of this rock.

Thirty feet of limestone correlated with the Wyandotte Limestone is exposed in the quarry walls at the Giles Quarry in the SW¼ sec. 23, T. 19 S., R. 21 E. At this locality a fine-grained light-gray wavy-bedded limestone characterized by a varied brachiopod fauna occurs. Well-preserved specimens of ***Enteletes*** dominate this fauna and are associated with horn corals, crinoids, and fenestellid bryozoans.

Bonner Springs Shale

Newell (1932) applied the name Bonner Springs to the thick shale sequence separating the Wyandotte Limestone from the Plattsburg Limestone. The Bonner Springs Shale typically consists of gray to buff shale and commonly contains a thin sandstone bed near the base. The thickness of this shale along its outcrop in Kansas ranges from about 6 to 60 feet; thickness of this unit in Linn County is about 50 feet. The interval containing the Bonner Springs Shale is mostly covered in Linn County, and where exposed it appears mostly as gray silty shale. In the SE¼ sec. 2, T. 20 S., R. 21 E., several feet of thin-bedded brown micaceous sandstone occur near the base of the unit.

LANSING GROUP

The Lansing Group occurs next above the Kansas City Group and is represented in Linn County only by its basal formation, the Plattsburg Limestone.

Plattsburg Limestone

The Plattsburg Limestone (Broadhead, 1866) is found in extreme northwestern Linn County and is represented by erosional remnants of the lower part of this formation.

Erosional remnants of the Plattsburg Limestone are rarely more than 10 feet thick in Linn County and are composed mainly of fine- to medium-crystalline fossiliferous limestone. Numerous brachiopods, crinoids, bryozoans, sponges, and much recrystalized calcite are associated with this limestone. Considerable quantities of chert weather free and mantle the upper surface of this limestone.

Quaternary System

PLEISTOCENE SERIES

Bordering the Marais des Cygnes River valley in Linn County, erosional remnants of alluvial deposits of Illinoisan and Kansan age and several deposits of chert gravel older than Kansan occur in step-like succession above the flood plain. Deposits occurring between the bedrock floor of the present valley and the flood-plain surface fill a valley which was probably cut and filled during Wisconsinan time. The narrow belt contained within the limits of the meander belt represents the surface cut during Recent time, and the uppermost part of the valley-fill deposits and much of the material filling the smaller tributary valleys are of Recent age.

Dating of the several Quaternary terrace deposits in eastern Kansas is based principally on their topographic position as related to the prominent Kansan Emporia terrace (O'Connor and others, 1955, p. 7), which occurs 40 feet above the Neosho-Cottonwood River flood plain at Emporia, and to the modern flood-plain surface.

Pre-Kansan Deposits

At one locality (NW¼ SW¼ sec. 30, T. 19 S., R. 24 E.) in Linn County a deposit of chert gravel, which rests on a bedrock surface 100 feet above the Marais des Cygnes flood plain, is noted. The gravel deposit is less than a foot thick and covers only a few acres. The deposit is classed as pre-Kansan on the basis of its topographic position. Pre-Kansan deposits are not mapped on the geologic map (pl. 1).

Kansan Deposits

In easternmost Linn County, immediately south of the Marais des Cygnes River, chert gravel deposits, which are comparable in lithology and topographic position to the Kansan Emporia terrace deposits, rest on bedrock surfaces 40 to 50 feet above the modern flood plain. Coarse to medium chert gravel deposits ranging from 1 to 4 feet in thickness comprise these deposits. Adjacent to the river these deposits are thick and well exposed, but a short distance to the south they are thin and overlain by several feet of clay. No other deposits of Kansan material are noted in Linn County. These deposits are not mapped on the geologic map (pl. 1).

Illinoisan Deposits

The prominant terrace that borders the flood plain of the Marais des Cygnes River is dated as Illinoisan on the basis of its position with respect to the flood plain and to deposits dated as Kansan. The deposits which underlie this terrace surface range in thickness from 20 to 35 feet and are lithologically quite similar to Wisconsinan and Recent deposits. However, the color of these older deposits is lighter due to leaching and oxidation. The upper surface of these terrace deposits normally occurs from 10 to 30 feet above the flood plain, and the deposits rest on a bedrock surface that is 20 to 30 feet above the floor of the modern valley. They underlie about 34 square miles of the county.

In 1961 an excellent exposure of Illinoisan terrace material was exposed in a newly opened coal pit. This section was measured and is described below.

Measured section in the Endicott Coal Co. coal pit in NE¼ SE¼ sec. 10, T. 21 S., R. 25 E., Linn County.

	Thickness, feet
Soil	1.6
QUATERNARY SYSTEM	
Pleistocene Series	
Illinoisan terrace deposits	
Clay, slightly sandy, yellow, red stain	1.0
Clay, slightly sandy, variegated, red and yellow	3.0
Clay, contains small pockets of sand, yellow and red	2.0

	Thickness, feet
Clay, slightly sandy, yellowish-gray	3.0
Clay, yellowish-gray	0.3
Sandstone lense, limonitic; contacts sharp	0.3
Clay, yellowish-gray	0.4
Clay, silty to sandy, yellow; contacts very sharp	11.4
Sand, very coarse, and chert gravel	0.4
Chert gravel, medium to coarse, well-sorted	1.4
Chert and medium limestone gravel, and chert cobbles; large pieces of shale noted locally	2.0
Clay, very bright yellow	0.4
PENNSYLVANIAN SYSTEM	
DESMOINESIAN STAGE	
Shale, gray	2.0
Coal (top of unit)	

WISCONSINAN AND RECENT DEPOSITS

The fluvial deposits that fill valleys of the Marais des Cygnes River and its tributaries range from 40 to 50 feet in thickness and are composed mainly of dark-gray and grayish-brown silt and clay-size material. Coarse and medium subrounded chert and limestone gravel deposits 2 to 10 feet in thickness occur near the base of these deposits. These deposits underlie about 75 square miles.

Structure

REGIONAL

The sequence of Paleozoic rocks in Linn County has, on a number of occasions since its

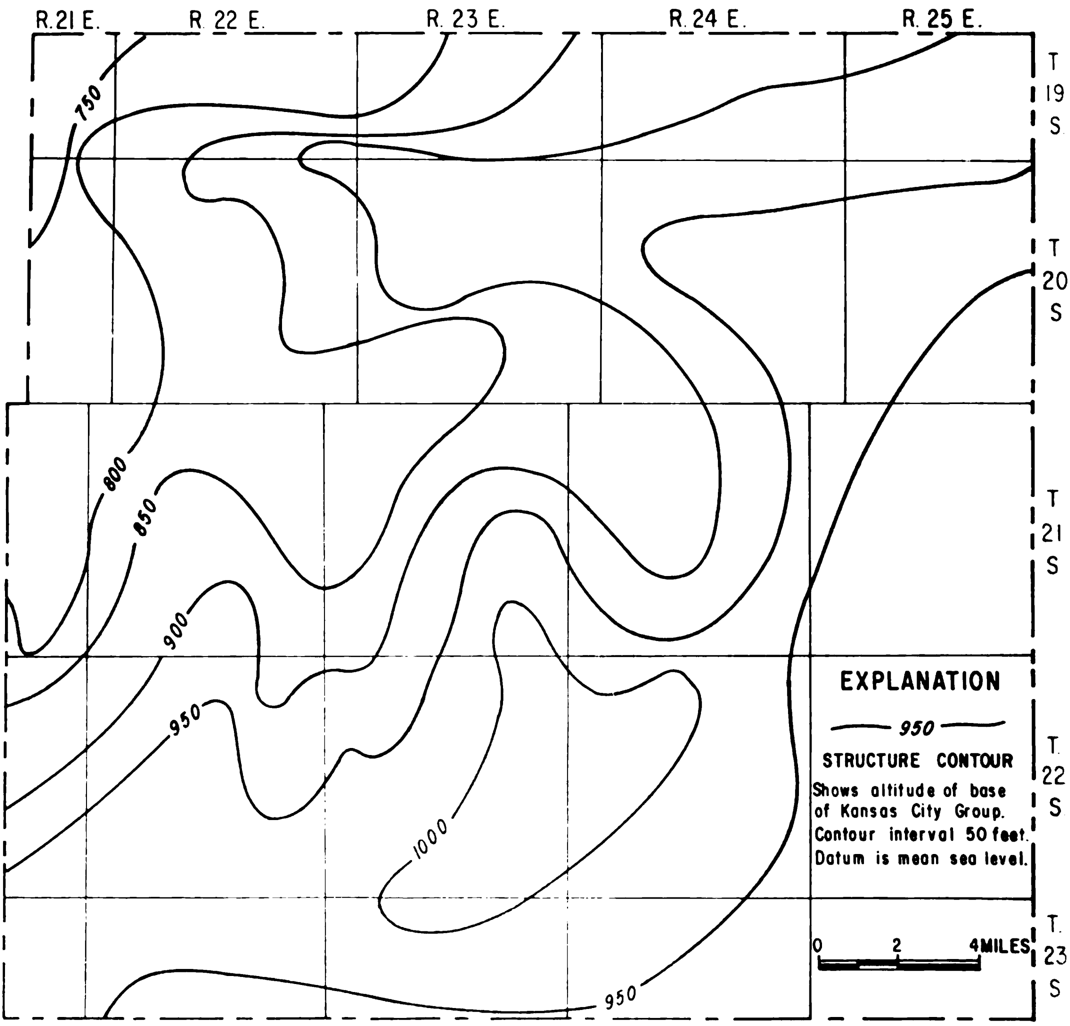


FIGURE 4.—Configuration of base of Kansas City Group (interpolated from logs of oil and gas test wells).

deposition, been deformed by tectonic events of regional and local magnitude. One of the earliest events, the pre-Mississippian uplift of the Ozark dome, established the northwest dip of the pre-Mississippian rocks in eastern Kansas and resulted in erosion of Middle Ordovician rocks in Linn County. Post-Mississippian subsidence in eastern Kansas and adjoining areas during the earliest period of Pennsylvanian deposition formed the Forest City basin, a basin marked by thickening of the Cherokee Group to the northwest in Linn County. The southern boundary of this basin, a positive structural element known as the Bourbon arch, underlies southernmost Linn County. The principal tectonic event in eastern Kansas, the post-Permian tilting of rocks to the northwest, known as the Prairie Plains monocline (homocline), established the present northwest dip in eastern Kansas. The structural configuration resulting from these events is shown in figures 4 and 5.

LOCAL

Several prominent domal structures and a number of local deformations related to compaction and possibly to collapse are observed in Linn County, and several have been mapped and described in detail. One domal structure, probably the largest, the Mound City dome (Jewett, 1949), was shown by Padgam (1957) to be a slightly elongated dome 1.5 miles in

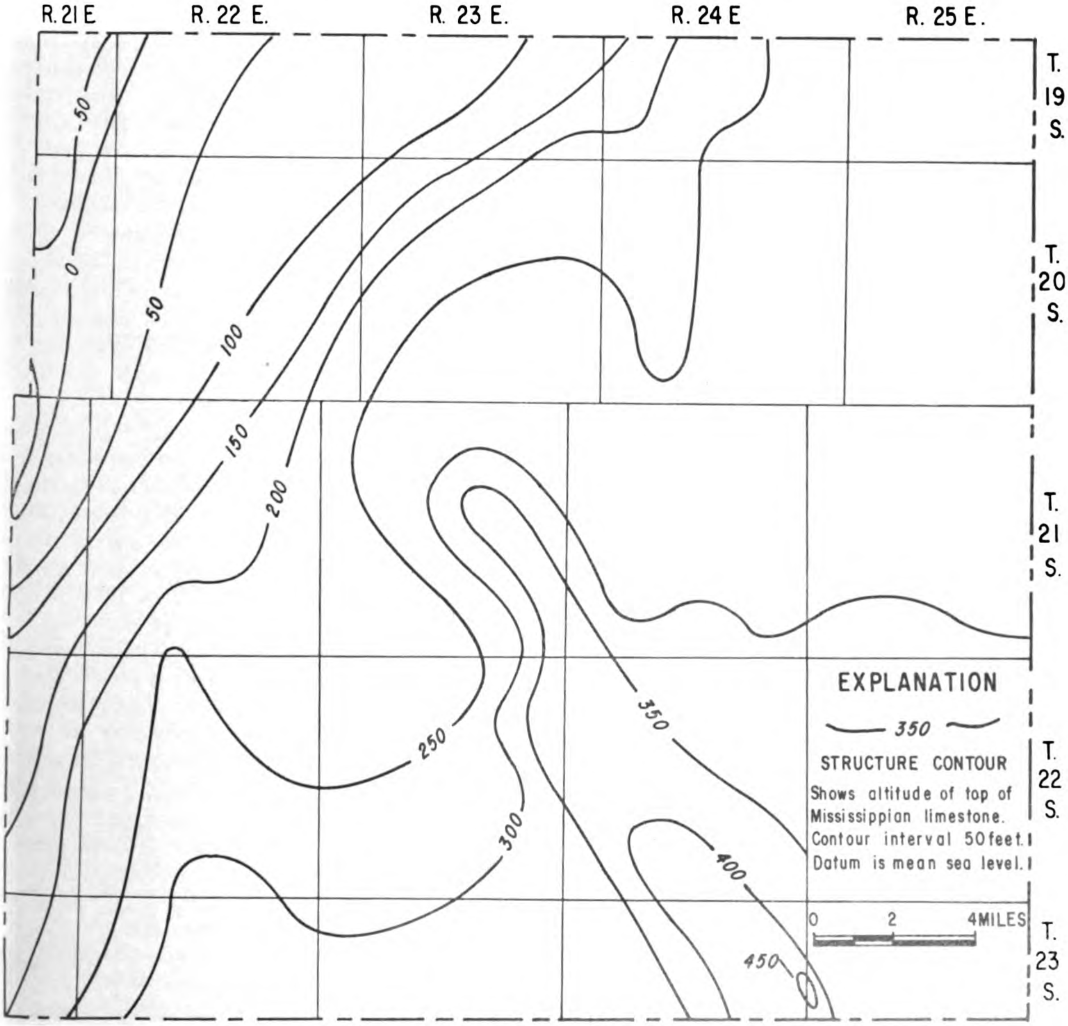


FIGURE 5.—Configuration of upper surface of Mississippian limestone (interpolated from logs of oil and gas test wells).

diameter located 1 mile northeast of Mound City. A number of smaller domes were noted by Padgam in this area and along the Kansas-Missouri boundary east of Pleasanton. Similar structures have also been noted in the vicinity of Trading Post and Prescott.

Anomalous dips and distortions in bedding noted in exposures of the Bandera Shale are normally directly underlain by flat-lying beds and are probably the result of compaction. Other peculiar structures include small-diameter chimney-like zones of brecciated Desmoinesian rock in the Pleasanton-Prescott area that are associated with lead and zinc mineralization (Schoewe, 1959), closed depressions or sink holes on the upper surface of the Mississippian System near Pleasanton, and very steeply dipping beds of the Hepler Sandstone Member of the Seminole Formation noted just north of Pleasanton (Padgam, 1957). Because these structures are local and abrupt and occur above possible Mississippian solution features, it is suggested that they are related to these solution features.

GROUND WATER

Source

The source of ground water in Linn County is the precipitation on the county and adjacent areas with streams that drain into Linn County. Most of the moisture that falls on the county is removed as surface runoff or is returned directly to the atmosphere by evaporation or transpiration. The part not directly removed percolates downward into the soil and into voids in the underlying bedrock. At some depth below land surface all voids are completely filled and the rock is saturated. The water in the saturated rock is ground water.

Recharge and Discharge

The quantity of water that reaches the zone of saturation is recharge to the aquifer. Recharge is greatest when evapotranspiration and other losses are lowest and rainfall is highest; in Linn County this occurs during the spring months.

The rates of recharge vary widely and depend mainly on topography and rock and soil textures. The areas receiving greatest recharge in Linn County are the broad, flat, and poorly drained surfaces developed on the valley fill and terrace surfaces, and on the gentle dip slopes of several of the thicker limestone units. Areas where recharge is slight include: most steep, well-drained slopes; surfaces underlain by impermeable shale; and surfaces underlain by soils with well-developed clay pans.

Recharge to the alluvium is greater than to any of the other formations in the county because the soil zone is the most permeable, and runoff and discharge from the valley sides must cross the alluvium or percolate through it before being discharged into the streams. Occasional flood water from the streams at high stage is also a source of recharge. Much of the water available for recharge is presently being discharged as streamflow.

Infiltration is the passage of water through the soil surface and into the soil, and infiltration capacity (Horton, 1933) is the maximum rate of this movement. According to soil-moisture data compiled by the local Soil Conservation Service, the infiltration capacities of all Linn County soils are extremely low: 0.3 inch per hour through soils developed on Pennsylvanian rocks younger than the Pleasanton Group, 0.1 inch per hour through soils developed on Pleasanton and Marmaton Groups, and 0.5 inch per hour through soils of alluvial origin.

The discharge of ground water in Linn County is mainly through springs and seeps and by evaporation from the surface of the aquifer at its outcrop. Some ground water is discharged by wells, and some is discharged by transpiration where root systems are close to the water table.

An estimate of the runoff from Linn County, which includes both surface water and ground water, may be made using the long-term streamflow record from Big Sugar Creek at Farlinville. According to this record, mean annual runoff from this drainage area for the period from 1930 to 1931 and from 1950 to 1956 was 130 cfs (cubic feet per second) or 8.94 inches (Furness, 1959, table 3). The largest part of this runoff is storm runoff that occurs during a relatively short period of time. The remainder, or the discharge that maintains flow between storms, is ground-water discharge or base flow.

According to an accumulated frequency or flow-duration curve based on the entire record from the Farlinville gage, more than 90 percent of the total discharge occurs in about 10 percent of the time (Furness, 1959, fig. 77). Similarly, about 85 percent of the precipitation was received in about 50 percent of the time. On the basis of these estimates, it was assumed that the discharge that occurs at the Farlinville gage between 50 percent and 90 percent of the time is derived mainly from ground water. Ground-water recharge in the area is approximately equal to this discharge, derived from ground water. Accordingly, from the flow-duration curves (Furness, 1959, fig. 77), ground-water discharge into Big Sugar Creek ranges from 1.1 inches (Q_{50}) to 0.2 inch (Q_{90}) annually.

This range of discharge appears to be in the right order of magnitude as shown by more recent data. According to Busby and Armentrout (1965, p. 89) the average base flow of Big Sugar Creek for the period 1923-62 was 19.9 cfs or 1.4 inches annually, and the mean base flow varied from 41.3 cfs or 2.8 inches in 1962 to zero for several other years.

Despite normal seasonal fluctuations, the average altitude of the water table in Linn County is reasonably constant from year to year (fig. 6). It can be assumed, therefore, that the total quantity of water added to these aquifers as recharge is approximately equal to the total quantity discharged. Based on approximations of ground-water discharge from streamflow hydrographs, total annual recharge probably varies from 2.8 inches to nearly zero. If considerable water is lost by evapotranspiration along the outcrop of the consolidated rocks, as appears probable from examination of figure 7, the recharge to the alluvium may be more than the average of 1.4 inches and possibly more than 2.0 inches, the average for the nongrowing season.

Movement

In Linn County the movement of ground water is in the direction of the hydraulic gradient at a rate that is proportional to this gradient and to the permeability of the aquifer. Movement of ground water in unconsolidated valley-fill deposits of the Marais des Cygnes River and its larger tributaries occurs mainly in basal sands and gravels and is in a direction which is both downstream and toward streams.

The rate of movement of water through these sands and gravels may be estimated by application of the relationship

$$V = \frac{PI}{39{,}500p} \text{ (after Wenzel, 1942, p. 71),}$$

where:

V is the average velocity, in feet per day;

P is the coefficient of permeability, in gallons per day per square foot;

I is the hydraulic gradient, in feet per mile; and

p is the porosity.

Based on an approximation of permeability of 2,000 gallons per day per square foot from reported aquifer-test data, a hydraulic gradient of 1 foot per mile, and an estimated 15 percent porosity, the rate of water movement is 0.34 foot per day. These are minimum estimates and indicate that a considerable quantity of water moves downgradient through the deposits.

The hydraulic gradient of water in the upland bedrock aquifers is northwestward, in the direction of regional dip, except in small areas of anomalous structure. Most ground water, moving in accordance with these gradients, moves toward a point of discharge where wells, land surface, or streams intersect the water table. Based on an estimated value for P of 100 gallons per day per square foot, a regional hydraulic gradient of 1 foot per mile, and a porosity of 10 percent, the rate of movement

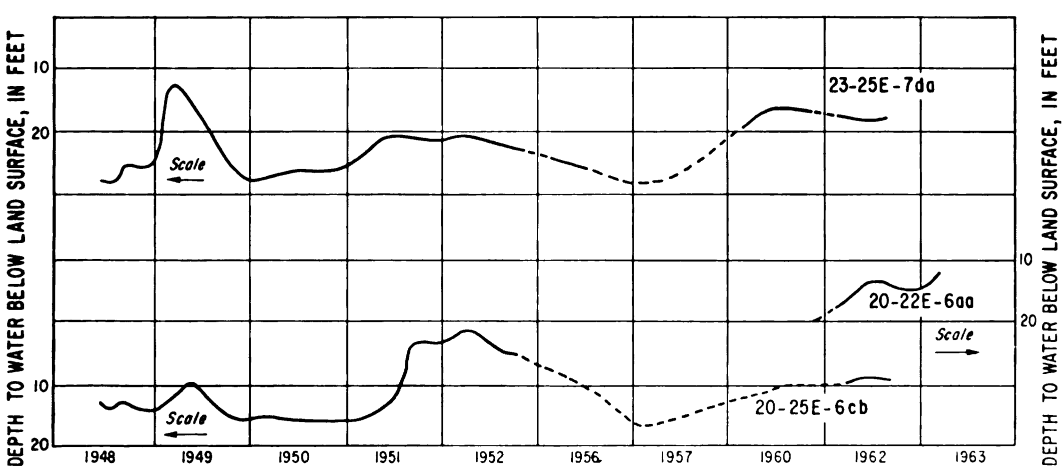


FIGURE 6.—Hydrographs of three selected wells.

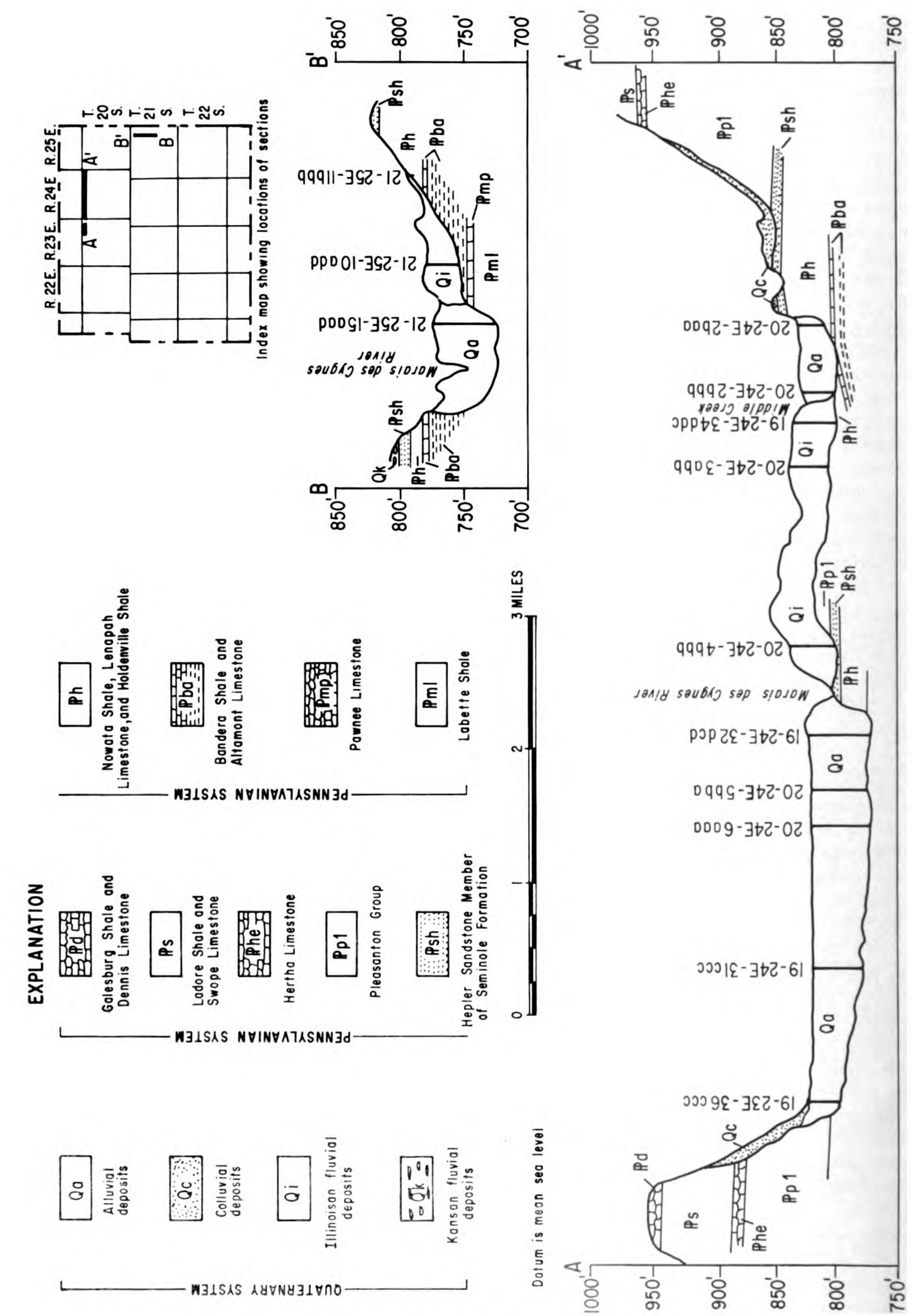


Figure 7.—Geologic sections.

through these aquifers may be as low as 0.03 foot per day.

Chemical Character

Ground water in Linn County contains dissolved minerals and other matter obtained from the rocks and soil with which it has come in contact and from sources of manmade contamination. The degree of mineralization of the waters is dependent on such factors as the mineralogical composition of the rocks or soil and the length of time the water is in contact with soluble products. Two general sources of contamination resulting from the activities of man are petroleum production and waste disposal.

The chemical quality of 25 representative ground-water samples collected in Linn County is shown in table 2.

Various graphical and computer techniques were used during the course of this study in an attempt to gain some understanding of the general chemical characteristics of ground water in the county. Figure 8 shows total dissolved solids in each water sample in parts per million (ppm), depth of well, and lithology of the aquifer from which the water sample was obtained. The highly mineralized water sample from Mississippian age rocks (well number 20-22E-15c) is not shown. Total dissolved solids as used here represents the sum of dissolved mineral constituents in the water. The range in values illustrates the diversity of water quality in the county.

Wells 20-24E-3ba (depth 21 feet) and 21-22E-17ac (depth 62 feet) in alluvium and Dennis and Swope Limestones, respectively, have water with high total dissolved solids content when compared with water from similar aquifers and comparable depths. The analyses of water from these wells show that the high dissolved solids can be attributed to sodium and chloride. The precise source of the mineralization is not known, but by using Na/Cl ratios obtained from the analyses, some inferences can be made. In situations where natural chemical conditions prevail, a Na/Cl ratio of 0.8000 or greater can be expected (Walter E. Hill, Jr., Chemist, State Geological Survey of Kansas, written commun., 1961). Lower ratios indicate that high sodium-chloride water is being introduced into the aquifer. The Na/Cl ratio at well 20-24E-3ba is 0.3219. This ratio is low enough to indicate possible pollution from brines or wastes being introduced into the aquifer and not from natural pollution. The Na/Cl ratio at well 21-22E-17ac is 0.6842. This ratio is marginal and does not definitely indicate an unnatural chemical situation in the aquifer. The chloride content (2,800 ppm) is, however, unusually high for the reasonably shallow depth (62 feet) of the well.

Well 22-24E-14dc in the Fort Scott Limestone yields water that is also high in dissolved solids and has a chloride concentration of 1,960 ppm. The Na/Cl ratio is 0.8265, which indicates that natural conditions probably are responsible for the increased salinity. The depth of the well (228 feet) places it in a zone sufficiently deep that higher total solids and higher salinity should be expected.

A log-log plot of total dissolved solids versus chloride concentration (fig. 9A) shows the relationship of these two constituents in Linn County.

A log-log plot of total dissolved solids versus total hardness (fig. 9B) illustrates the normal relationship of these two constituents in ground waters in Linn County. It is probable that points well off the normal trend show base exchange of sodium for calcium (natural softening). These samples also have relatively high fluoride content which indicates the presence of a natural zeolite or collophane [$Ca_5F(PO_4)_3$] in the aquifer.

Figure 9C shows the relationship of sulfate concentration to total dissolved solids. It may be noted that the three wells previously discussed, which are high in chloride and dissolved solids, plot far off the normal trend. Most of the brines from deeper formations have a very low sulfate content. If pollution is occurring in the shallow aquifers, then the sulfate concentration should probably stay relatively low with an increase in total dissolved solids and salinity.

The significance of each of the several constituents is discussed in the following paragraphs, excluding well 20-22E-15c, and is described in table 3. For a more detailed treatment of this subject, the reader is referred to Hem (1959).

Dissolved solids.—Dissolved solids is the total quantity of dissolved mineral matter remaining after evaporation of the water sample. The taste and overall quality of water containing less than 500 ppm dissolved solids are not affected except where iron and hardness are excessive. Water containing more than 1,000 ppm total solids is generally objectionable. Water samples collected in Linn County had dissolved solids ranging from 222 to 5,163 ppm.

TABLE 2.—Analyses of water from selected wells (in parts per million except as otherwise indicated[1]).
(Samples analyzed by H. A. Stoltenberg, Kansas State Department of Health.)

Well number	Sample number	Depth, feet	Geologic source	Date of collection	Temperature (°F)	Dissolved solids (evaporated at 180°C)	Silica (SiO_2)	Iron (Fe)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na+K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate[2] (NO_3)	Hardness as $CaCO_3$: Total	Hardness as $CaCO_3$: Carbonate	Hardness as $CaCO_3$: Noncarbonate	Specific conductance (micromhos at 25°C)	pH
19-21E-23cb	1	120	Chanute Shale	3-27-63	....	639	6.0	0.59	.00	6.4	0.5	250	454	91	28	2.8	0.4	18	18	0	1,060	....
19-23E-30dd	2	18	Cherryvale Shale	9-21-61	62	1,396	15	.25	.38	286	63	85	442	608	106	.6	15	972	362	610	2,070	....
19-24E-31dd	3	31	Pleasanton Group	9-21-61	....	222	12	.18	.00	43	13	12	127	62	5.0	.3	12	161	104	57	380	....
20-22E- 9bb	4	85	Drum and Iola Limestones	3-27-63	....	524	18	.42	.17	70	33	74	398	114	18	.4	1.0	310	310	0	850	....
20-22E-15c	5	1,290	Mississippian System	3- 1-64	....	12,150	.0	1.1	.00	328	176	4,162	56	3.7	7,450	1.0	.4	1,542	46	1,496	20,050	6.8
20-22E-32cdd	6	18	Cherryvale Shale	3-27-63	....	1,004	15	.09	.00	234	38	61	371	181	212	.1	80	740	304	436	1,700	....
20-22E-33dd	7	20	Alluvium	3-27-63	....	370	12	.05	.00	114	9.6	10	337	41	11	.1	5.8	324	276	48	630	....
20-23E-36cb	8	18	Alluvium	9-19-61	....	331	17	.05	.00	99	5.1	9.7	254	52	14	.1	8.9	268	208	60	580	....
20-24E- 3ba	9	21	Alluvium	9-19-61	....	1,968	17	.04	.00	315	69	330	405	4.1	1,025	.1	8.0	1,070	332	738	4,050	....
20-24E-19ca	10	20	Dennis and Swope Limestones	9-19-61	59	370	7.5	.24	.00	114	5.7	9.9	310	30	6.0	.1	44	308	254	54	650	....
20-25E-31da	11	68	Marmaton Group	9-19-61	....	632	12	2.3	....	28	13	209	566	41	49	.8	.4	124	124	0	1,110	....
21-22E-17ac	12	62	Dennis and Swope Limestones	3-27-63	....	5,163	10	.82	.00	53	33	1,916	610	40	2,800	4.6	6.2	268	268	0	9,370	....

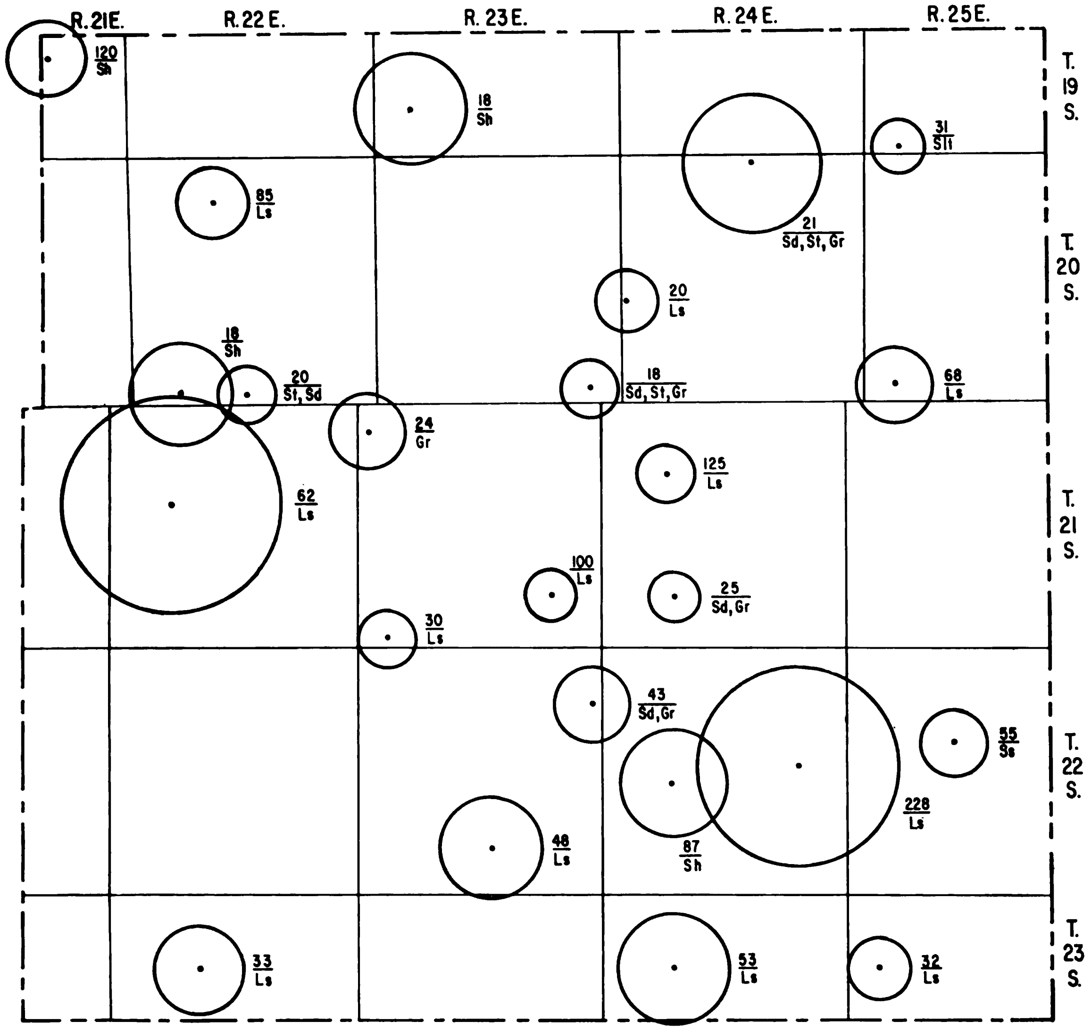
21-23E- 6ca	13	24	Colluvium and alluvium	9-20-61	....	522	12	.01	.00	160	13	12	451	70	16	.1	17	452	370	82	900	....
21-23E-26da	14	100	Dennis and Swope Limestones	9-21-61	....	296	9.5	.30	.00	48	17	35	222	62	12	.4	2.2	190	182	8	530	....
21-23E-31dc	15	30	Dennis Limestone	9-20-61	....	351	7.5	.37	.00	88	14	22	302	51	13	.3	6.2	277	248	29	630	....
21-24E- 8cd	16	125	Dennis Limestone	9-19-61	....	374	9.0	2.9	.00	108	7.4	16	293	81	7.0	.2	.4	300	240	60	640	....
21-24E-29da	17	25	Alluvium	9-20-61	....	264	12	.15	.00	65	15	9.4	239	30	8.0	.4	6.2	224	196	28	480	....
22-23E-12aa	18	43	Terrace deposits	9-20-61	62	728	11	1.1	.00	138	37	88	500	44	163	.1	.4	496	410	86	1,350	....
22-23E-27cd	19	48	Dennis Limestone	9-20-61	....	1,032	20	1.6	.47	144	58	158	695	74	169	1.0	66	598	570	28	1,830	....
22-24E-14dc	20	228	Fort Scott Limestone	9-20-61	....	4,296	9.5	.96	.00	53	30	1,620	1,193	34	1,960	.6	.4	256	256	0	7,960	....
22-24E-20ad	21	87	Holdenville Shale	9-20-61	....	1,102	7.0	.08	.00	38	10	389	595	52	305	1.6	6.2	136	136	0	2,030	....
22-25E-16ab	22	55	Hepler Sandstone Member of Seminole Formation	9-19-61	....	436	6.5	.07	.00	62	29	56	298	80	36	.2	19	274	244	30	780	....
23-22E- 9cc	23	33	Dennis Limestone	3-27-63	....	820	13	5.2	.00	102	31	132	305	324	53	.9	14	382	250	132	1,290	....

TABLE 2.—Analyses of water from selected wells *(Concluded)*.

Well number	Sample number	Depth, feet	Geologic source	Date of collection	Temperature (°F)	Dissolved solids (evaporated at 180°C)	Silica (SiO_2)	Iron (Fe)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na+K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate[2] (NO_3)	Hardness as $CaCO_3$ Total	Carbonate	Noncarbonate	Specific conductance (micromhos at 25°C)	pH
23-24E- 8dd	24	53	Pawnee(?) Limestone	9-20-61	....	1,376	11	3.6	.00	318	39	46	266	316	152	.1	363	954	218	736	2,150	....
23-25E- 7dd	25	32	Pawnee Limestone	9-18-61	....	382	7.0	.12	.00	40	13	74	168	74	42	.3	49	154	138	16	660	....

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

[2] In areas in which 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).



EXPLANATION

Location of well. Radius of circle indicates total dissolved solids, in parts per million.

100 500 1,000 5,000 10,000

Scale of radii

0 3 6 MILES

120 / Ls

Number indicates depth of well, in feet. Letters identify predominant lithology of aquifer:

Gr, gravel
Ls, limestone
Sd, sand
Sh, shale
Slt, siltstone
Ss, sandstone
St, silt

FIGURE 8.—Location and depth of sampled wells, lithology of aquifers, and total dissolved solids of water.

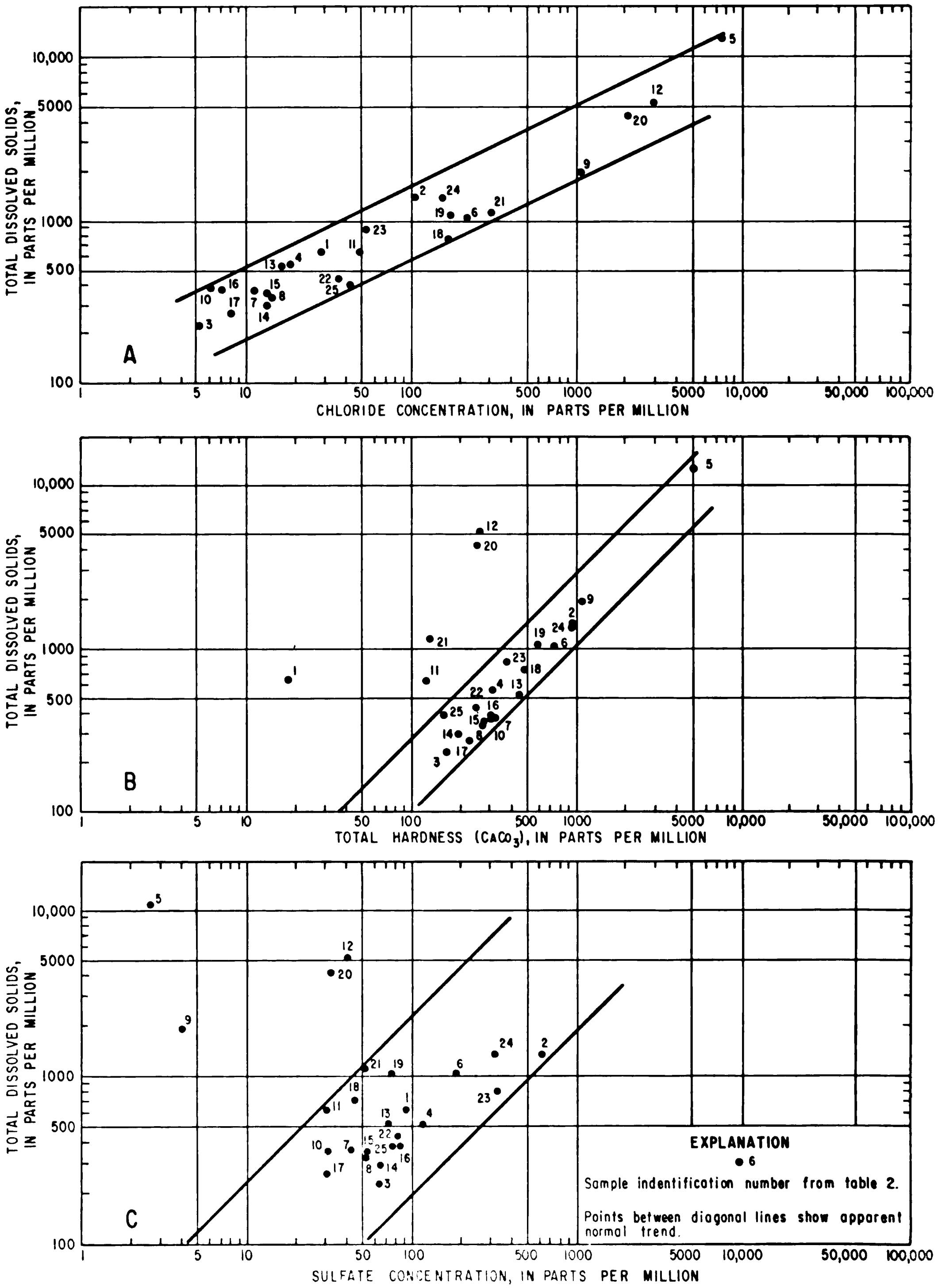


FIGURE 9.—Relationship between total dissolved solids and (A) chloride concentration, (B) total hardness, and (C) sulfate concentration.

TABLE 3.—Significance of certain chemical constituents in ground water.

Constituent	Recommended limit[1], ppm	Range in Linn County[2], ppm	Undesirable effects
Total dissolved solids	500	222-5,163	Taste affected when quantity exceeds 500 ppm.
Manganese	0.05	0.00-0.47	Impairs taste of water and produces brown stain.
Iron	0.3	0.01-5.2	Iron may be easily tasted in drinking water containing more than 1.8 ppm and may cause staining of laundry and plumbing fixtures when the amount exceeds 0.3 ppm.
Fluoride	0.8-1.5 (for annual average maximum air temperatures from 53.8°F to 58.3°F) Optimum level for this temperature range 1.1	0.1-4.6	Excessive fluoride in drinking water produces objectionable dental fluorosis. Other expected effects from excessively high concentrations include bone changes when water containing 8-20 ppm is consumed over a long period of time, crippling fluorosis when 20 ppm or more is consumed per day for 20 or more years, and death when 2,250-4,500 ppm fluoride is consumed in a single dose.
Nitrate	45	0.4-363	Water containing nitrate in excess of 45 ppm may cause nitrate poisoning of infants (cyanosis).
Sulfate	250	4.1-608	Water containing sulfate in excess of 750 ppm has a laxative effect (500 ppm when water is also high in magnesium). Can be tasted when concentration exceeds 250 ppm.
Chloride	250	5.0-2,800	Can be tasted when concentration exceeds 250 ppm.

[1] U.S. Public Health Service, 1962.

[2] Sample No. 5, table 2, not considered.

Hardness.—Hardness of water is generally recognized by the increased quantity of soap required to produce lather. Hardness is a function of the calcium carbonate equivalent to the calcium and magnesium and all other cations individually determined. Calcium and magnesium are responsible for almost all hardness.

Salts of calcium and magnesium carbonate may be removed from water by ordinary softening processes. However, compounds of magnesium and calcium formed with the sulfate or chloride anion cannot be removed in this way, and water containing these anions is considered permanently hard.

Water with a total hardness from 0 to 60 ppm is considered soft; 61 to 120 ppm, moderately hard; 121 to 180 ppm, hard; and in excess of 180 ppm, very hard. Water samples collected in Linn County had a range in total hardness from 18 to 1,070 ppm.

Iron.—The occurrence of iron in excess of a few tenths of a part per million is objectionable. Water containing more than 0.3 ppm iron has an objectionable taste and will stain laundry and plumbing fixtures. Iron concentrations in water samples from Linn County ranged from 0.01 to 5.2 ppm.

Fluoride.—According to many dental authorities, the occurrence of fluorides in drinking water in concentrations of about 1 ppm will prevent or lessen tooth decay in children. However, concentrations in excess of this amount will cause a dental defect known as mottled teeth in children up to 12 years of age (Dean, 1936, 1938). Fluoride concentrations in water samples from Linn County ranged from 0.1 to 4.6 ppm.

Nitrate.—Water containing concentrations of 45 ppm or more of nitrate is considered by the U.S. Public Health Service to be the cause of cyanosis (blue babies) when used in the preparation of formulas. Boiling will not render water high in nitrate safe; in fact, it may increase the concentration. Nitrate in water is considered a final oxidation product of nitrogenous material and may indicate organic contamination. Nitrate concentrations in water samples from Linn County ranged from 0.4 to 363 ppm.

Sulfate.—Sulfate is one of the most common ions present in natural waters and is commonly derived from solution of iron sulfide and calcium sulfate. Sulfate combined with magnesium (epsom salts) and sodium (glaubers salt) in concentrations exceeding 500 ppm may have a laxative effect on some persons.

In Linn County high concentrations of sulfate are noted in water associated with black shale, coal, and other rock units containing large amounts of iron sulfide. Concentrations are reported to increase during dry periods when water remains in contact with the sulfides for longer periods of time. Sulfate concentrations in water samples from Linn County ranged from 4.1 to 608 ppm.

Chloride.—Chloride in combination with sodium forms table salt (NaCl), one of the more common chloride salts found in Linn County ground water. Concentrations of less than 250 ppm chloride normally do not affect the taste of water. However, concentrations in excess of this amount do affect the taste and are, according to most authorities, objectionable.

In Linn County ground water obtained at depths greater than 100 feet generally contains objectionable quantities of chloride and is not often used. Excessive concentrations of chloride at depth are considered natural because of their uniform distribution at uniform depth over the entire county. Chloride concentrations in water samples from Linn County ranged from 5.0 to 2,800 ppm.

Hydrogen sulfide.—Although no attempt was made to measure hydrogen sulfide in ground-water samples collected in Linn County, its pungent odor (like rotten eggs) was noted in a number of water samples. Even in very small quantities, hydrogen sulfide is noticeable and objectionable and, in combination with iron, will form a black precipitate (iron sulfite).

Utilization

The greatest use of ground water in Linn County is for domestic and stock purposes. One municipality, La Cygne, formerly used ground water, and several oil fields in the county are repressured with mineralized water pumped from Ordovician limestone.

Domestic and stock.—There are approximately 850 wells in rural Linn County which supply all or most of the domestic and stock supplies. In 1961 and 1962 the amount of water derived from wells and springs, with the exception of municipal and industrial sources, was estimated to be about 350,000 gallons per day.

Approximately 50 percent of the wells in Linn County are dug wells. These wells are several feet in diameter near the surface and increase in diameter with depth. Dug wells in this area commonly penetrate only the upper part of the aquifer and are likely to "go dry" during prolonged periods of drought. Yields from dug wells are normally small, and the wells are subject to contamination.

Drilled wells in Linn County are generally about 100 feet in depth and commonly penetrate one or more aquifers. Wells of this type are installed with percussion-type drills and generally range in diameter from 6 to 8 inches. Casings in these wells normally are set from ground surface down to the first resistant rock layer in order to prevent contamination.

Municipal.—The municipal water system at La Cygne, until 1964, depended solely on ground water. Two wells were used—a large-diameter dug well that penetrates water-bearing terrace gravels, and a gravel-packed well that obtains water from gravel and sand near the base of the Marais des Cygnes valley fill. The dug well served as the principal source through much of the year, and the gravel-packed well was used during periods of peak demand. Water was pumped from these wells into a 60,000-gallon elevated tank. In 1960 average daily consumption was reported to be 57,000 gallons per day.

Availability

In this report, "small" supplies of ground water refer to yields of less than 10 gpm (gallons per minute) and "moderate" supplies refer to yields greater than 10 gpm but less than 50 gpm. Except locally in alluvial deposits, yields greater than 50 gpm are not available in the county.

CAMBRIAN AND ORDOVICIAN SYSTEMS

No well in Linn County penetrates rocks older than the Arbuckle Group. Most wells in the county that penetrate the Arbuckle Group produce some highly mineralized water, particularly from the sandy and cherty zones in the undifferentiated Cotter and Jefferson City Dolomites and the Roubidoux Formation.

A well drilled into the Roubidoux Formation a number of years ago for the city of Butler, in Bates County, Mo., 16 miles east of Linn County, encountered highly mineralized water reported to contain 2,500 ppm chloride and 165 ppm sulfate. This well was pumped at a rate of 150 gpm.

DEVONIAN SYSTEM

In Linn County no well is known which obtains water from the Chattanooga Shale. According to Schoff (Reed and others, 1955), the hydrologic importance of this unit is that it serves as a barrier between water in the Arbuckle Group and water in the Mississippian limestone.

MISSISSIPPIAN SYSTEM

In Linn County most of the wells drilled into rocks of the Mississippian System encounter some very highly mineralized water (see analysis for 20-22E-15c, table 2) in one or more zones. Silicious zones composed principally of chert and normally less than 10 feet thick are the most common water-bearing zones in this sequence. Estimates based on bailer tests by drillers suggest that yields from these zones in excess of 10 gpm are rare.

PENNSYLVANIAN SYSTEM

Aquifers of Pennsylvanian age provide most of the ground water for domestic use in Linn County. Individual yields obtained from these aquifers are small and locally inadequate; however, most formations provide enough water for domestic purposes. Limestones, especially the thicker members of the Kansas City Group, are the most important aquifers, sandstones are next in importance, and shales and siltstones are least important.

Knowledge of the hydrologic properties of the several Pennsylvanian rock units is based largely on random sampling of typical water wells in the county and on reports by water-well drillers and well owners. Following is a discussion, by groups, of the Pennsylvanian rock units that yield water.

Cherokee Group

Large quantities of highly mineralized water are obtained from thin layers of residual chert along the Mississippian-Pennsylvanian contact zone, and from the Warner Sandstone and Bluejacket Sandstone Members of the Krebs Formation in Linn County. Many oil and gas wells in the county penetrate these water-bearing zones, and considerable quantities of mineralized water have been brought to the surface together with the oil and gas; some of this water has been a source of pollution. According to most drillers and oil and gas producers in the county, water from these zones is too highly mineralized to use. However, several miles east of the southeastern corner of Linn County, potable water is obtained from this group and is used by several municipalities.

At the town of Hume a single well drilled to the base of the Cherokee Group provides water for about 100 people. The well is reported to obtain water from the base of the Cherokee Group at a depth of 600 feet and from the Bartlesville sand at a depth of 400 feet. The well is normally pumped at about 35 gpm, and the reported specific capacity is about 3 gpm per foot of drawdown. These facts are mentioned for the reason that less mineralized water might move northwestward at some time in the future.

Marmaton Group

Due to the dominance of fine-grained lithologies and the thinness of the several carbonate rock units, very little ground water is obtained from the Marmaton Group in Linn County. Most successful wells drilled into the Marmaton Group obtain water from either the Pawnee Limestone or the Altamont Limestone. The Fort Scott Limestone in Linn County normally is below the zone of fresh water, and the Lenapah Limestone is too thin and nonpersistant to be of importance. Other water-bearing zones in the Marmaton Group include contact zones especially between rocks of contrasting lithologies, such as coal beds and black fissile shales, where some ground water may be recovered.

Pleasanton Group

With the exception of the relatively thin layers of sandstone at the base and near the top of the group, there are no significant zones within the Pleasanton Group which will transmit water. Consequently, very few of the wells observed in Linn County depend solely on the rocks of this group as a source of water.

Within the vicinity of their outcrops, sandstone members of this group are poorly situated topographically to receive recharge and too fine grained to transmit water. The small quantity of water that does move through these rocks is usually in vertical joints and permeable zones along bedding planes.

Kansas City Group

The most productive Pennsylvanian aquifers in Linn County are the thick limestone members of the Swope and Dennis Limestones. The combined thickness of these adjacent formations is great, and areally they directly underlie a considerable part of the county. The nearly flat and poorly drained surfaces directly underlain by these formations are well suited as recharge areas.

The permeability of the thicker limestones is relatively high as a result of solution widening of joints and other rock openings. Both limestones also are underlain by widespread black fissile shale, which tends to retard downward percolation of water and to conduct water along permeable horizontal planes.

Water wells that penetrate these lower rocks of the Kansas City Group are normally successful; however, the yield of a well is dependent on the number and size of rock openings intersected in the limestones and on the thickness and permeability of the black shale members. For this reason larger-diameter wells generally yield larger quantities of water.

The remaining part of the Kansas City

Group is composed mainly of fine clastic deposits which yield little water, and with the exception of the Wyandotte Limestone, no important aquifers are present within this interval. The thick limestone facies of the Wyandotte Limestone found locally near the northwestern corner of the county is similar lithologically to the thick limestone units at the base of this group and probably is hydrologically similar. Because of the limited area of exposure within the county, few wells that penetrate this limestone were inventoried.

Lansing Group

As only a few square miles in the northwestern corner of Linn County are underlain by the Lansing Group, a representative number of water wells was not examined. However, because of the lithologic similarity between the thick limestones of this group and the lower limestones of the Kansas City Group, it is assumed that their hydrologic properties are similar.

QUATERNARY SYSTEM

The largest supplies of ground water in Linn County are contained in the unconsolidated Illinoisan, Wisconsinan, and Recent alluvial deposits. These deposits underlie about 110 square miles in the county (pl. 1). Other Quaternary deposits, the Kansan and pre-Kansan gravel and colluvial deposits, are not water bearing.

Illinoisan Deposits

A number of domestic wells yield small supplies of water (about 10 gpm) from the basal gravel in the Illinoisan terrace deposits.

Former La Cygne city well No. 20-24E-5aaa, a dug well 20 feet in diameter and 38 feet deep, penetrates 3.5 feet of gravel near the base. Three short horizontal galleries extend into the gravel. This well was pumped at an average rate of about 30 gpm for a number of years. This well indicates that properly constructed and developed wells that penetrate this basal gravel may yield more than 30 gpm, but yields of 10 gpm from present small wells are more common.

Thickness of the saturated zone rarely exceeds 5 feet and decreases toward the topographic divide. Consequently, pumping rates, which result in moderate drawdown only, are possible. However, the specific capacity (gallons per minute per foot of drawdown) is comparatively large, and these deposits receive considerable recharge from both rainfall and abutting bedrock formations (fig. 7). The areal extent of the Illinoisan terrace deposits is about 34 square miles as mapped (pl. 1). This amount represents only a small part of the total area of Linn County, but is a potential source for several installations requiring moderate supplies of water. The construction and performance of the large-diameter city well at La Cygne illustrate the potential of these deposits for further development. The yield of this well also suggests that wells with more and longer collection galleries might support larger pumping rates.

Wisconsinan and Recent Deposits

In the sparsely settled flood plains of the Marais des Cygnes River and its tributaries several shallow dug wells, one municipal well No. 19-24E-33ccc, and a number of augered test holes penetrate and obtain water from gravel at the base of Wisconsinan deposits. About 75 square miles are underlain by these deposits in Linn County.

In December 1960 a number of test holes were augered in the Marais des Cygnes Valley from La Cygne west to the bedrock valley wall. Figure 7, a geologic section drawn on the basis of data obtained from these holes, shows that the thickness of these deposits ranges from about 30 feet near the edge of the valley to 50 feet near the middle of the valley. The saturated thickness varies in the same direction from 23 to about 40 feet. In December 1960 the average static water level in this area was about 12 feet below land surface.

Wells that penetrate only the upper few feet of the zone of saturation, as many domestic wells do, may obtain only a few gallons of water per minute, but wells which penetrate the gravel at the base of these deposits may obtain more than 100 gpm. The specific capacity of a gravel-packed municipal well at La Cygne, which obtains water from Wisconsinan deposits, was 6.3 gpm per foot of drawdown in 1935 when the well was drilled and 5.4 gpm per foot in 1953. Similar hydrologic properties are reported by Williams (1944) from a well drilled through comparable deposits in the Neosho River valley fill in northeastern Labette County. In this area a test well penetrating 30 feet of silt, clay, and about 5 feet of coarse gravel was pumped for 98 hours at an average rate of 90 gpm. According to Williams, the specific capacity of this well was 3.9 gpm per foot of drawdown and the permeability of the aquifer was 420 gallons of water per day per square foot.

A hydrologic study in the Neosho River valley during the summer of 1964 supports Williams' data for these similar deposits. Forty test holes were drilled within the valley between Iola and the Kansas-Oklahoma border and nine 6¼-inch observation wells with slotted-pipe well screens were installed and developed. These wells were pumped at an average rate of 20 gpm for periods of no longer than 1 hour. Specific capacities measured during these preliminary tests varied from 3.6 gpm per foot of drawdown to 87 gpm per foot, and averaged about 7 gpm per foot.

The saturated thickness, areal extent, and pumping data available indicate that a large quantity of ground water is in storage and is available for pumping in these deposits in Linn County. Yields of 100 gpm or more probably could be developed from properly constructed wells. The chemical quality of this available water is fair. It is hard at some locations, containing mostly carbonate hardness (see table 2), and might require treatment for some uses. Runoff and discharge from the valley sides provide most of the recharge to the alluvium. Occasional flood water from the streams at high stage is also a source of recharge. Much of this recharge is being rejected by the saturated aquifer and leaves the area as streamflow. Increased pumping from wells would intercept some discharge to the streams and provide space for increased storage from recharge. Therefore, a perennial supply to wells is indicated and considerable development appears possible.

RECORDS OF WELLS AND TEST HOLES

Descriptions of 242 wells, test holes, and springs in Linn County are given in table 4. All reported information was obtained from owners or tenants and is given in feet. Measured depths of wells and depths to water levels are given in feet and tenths of feet below land surface. The well-numbering system is explained on page 5. The locations of wells and test holes are shown on plate 1.

TABLE 4.—Records of wells, test holes, and springs.

Well number[1]	Owner or user	Type of well[2]	Depth of well, in feet[3]	Diameter of well, in inches	Type of casing[4]	Principal water-bearing unit: Character of material	Principal water-bearing unit: Geologic source	Method of lift, type of power[5]	Use of water[6]	Depth to water level below land surface, in feet[3]	Date of measurement	Height of land surface above mean sea level, in feet[7]	Remarks[8] (Yields given in gallons per minute)
19-21E-23cb*	Lee Giles	Dr	120	6	S	Shale	Chanute Shale	J, E	D	23.80	7-5-61	1,025 Alt.	Estimated yield 1.5.
24cd	James Morgan	Du	22.9	24	R	Limestone	Plattsburg Limestone	Cy, E	D	11.20	8-1-60	....	Reported to be good well.
19-22E-20aa	Robert White	Dr	54.6	6	GI	do	Dennis Limestone	N	N	27.13	7-5-61	1,009 Alt.	
23ad	Milton G. Kramer	Dr	20.5	6	T	Limestone(?)	Block Limestone Member of Cherryvale Shale, and Dennis(?) Limestone	N	N	4.47	7-5-61	909 Alt.	Reported oil and gas test well, plugged at 20.00 feet. Well served surrounding area during drought periods.
27da	F. M. Nolan	Du	36.0	36	R	Black shale	Muncie Creek Shale Member of Iola Limestone	Cy, H	D	9.39	8-8-61	....	Reported water enters well at 15 feet and 36 feet below land surface.
27dd	Dale Lawhead	Dr	74.9	10	S	Limestone(?)	Iola Limestone(?)	Cy, H	N	9.65	8-29-60	....	Reported to be wet weather well. Several unsuccessful attempts have been made to obtain ground water here.
19-23E-26bc	John Prine	Du	11.7	60+	R	Limestone	Dennis Limestone	N	N	4.33	6-13-60	880±	
26cb	do	Du	24.8	56	R	Gravel	Alluvium	N	N	5.70	6-13-60	820±	
26ccc	U.S.G.S.	Au	46.0	4	N	Sand and silt	do	N	N	12.00	12-7-60	811	
29aa	Haymie McCarty	Dr	100.0	....	....	Limestone	Dennis Limestone	Cy, W	D	49.14	8-8-61	....	Water reported high in sulfates.
29bb	C. F. Ferris	Du	23.9	36	R	do	Dennis(?) Limestone	J, E	D	19.27	8-8-61	....	
30dd*	Owen B. Hahnfeld	Du	18	168	R	Black fissile shale	Cherryvale Shale	J, E	S	12	8-8-61	....	Dug by KERC. Reported well served surrounding area during drought. Sulfates reported high during dry times.
36dc	H. A. Haupt	Du	21.6	60	R	Gravel	Alluvium	J, E	D	6.97	6-13-61	815±	Reported as excellent well.
19-24E-24ad	W. R. Shields	Du	36.5	48	R	Limestone	Dennis Limestone	Cy, H	N	10.40	6-16-60	945±	Water reported hard.
26ad	A. J. Maris	Du	32.5	....	....	Shale	Pleasanton Group	J, E	S	28.55	8-30-61	868±	Reported well goes dry in August.
26bb	C. C. Karr	Du	22.9	28	R	Gravel	Alluvium	J, E	D	13.30	8-30-61	816±	
29cb	F. Mann	Dr	150	6	S	Limestone	Swope Limestone	B	D	66.76	8-1-61	870±	Reported water level varies from 115 to 40 feet. Well used only to provide drinking water.

31ccc	U.S.G.S.	Au	48.5	4	N	Silt	Alluvium	N	N	18.00	12-7-60	805	
32dcd	do	Au	53.5	4	N	Gravel	do	N	N	12.50	12-8-60	804	
33ccc	City of La Cygne	Du	38.5	240	B	Sand and gravel	do	C, E	M	28.93	6-7-61	816.5±	Yield 90.
34ba	Ed Grahs	Dr	61.0	6	S	Gravel	do	Cy, E	D	32.17	6-30-61	836±	
35ac	W. A. Montee	Du	31.7	40	R	Sand and gravel	Colluvium and alluvium	Cy, H	D	9.81	8-30-61	814±	Reported water hauled from this well during drought.
36cd	F. M. De Hoff	Sp	....	....	....	Siltstone	Pleasanton Group	Cy, E	D	....	....	832±	
19-25E-19dc	R. Smythe	Du	25	120	R	Limestone	do	C, H	D	16.90	7-26-61	953±	Water enters well through open joints in limestone.
22aa	Eugene Brenckle	Dr	87	....	....	Limestone and shale	Dennis Limestone	J, E	D	40	7-16-61	....	
28ab	J. Praither	Du	22.6	48	R	Siltstone	Pleasanton Group	N	N	8.87	7-26-61	843±	
28abb	U.S.G.S.	Au	25.5	4	N	Silt and clay	Terrace deposits	N	N	6.85	8-28-61	830	
28ad	J. L. Jarred	Du	17.0	24	R	Siltstone	Holdenville Shale	Cy, H	D	10.86	7-26-61	840±	Reported water enters well through joints in shale.
28bbb	U.S.G.S.	Au	25.5	4	N	Silt and clay	Terrace deposits	N	N	10.27	8-28-61	830	
31dd•	School No. 96 B. A. Cline	Du	30.8	36	B	Siltstone(?)	Pleasanton Group	Cy, H	D	4.57	6-16-60	866±	Reported water hauled from this well during drought.
20-21E-12dd	A. Parks	Dr	61.0	8	T	Lime-stone(?)	Iola Limestone(?)	Cy, H	D	24.49	7-5-61	....	Cl, 300 ppm.
13dd	L. Troutman	Du	23.0	36	R	Limestone and shale	Iola Limestone and Lane Shale	N	N	8.11	7-5-61	....	
20-21E-34dc (Anderson Co.)	S. E. Povenmire	Dr	80.1	8	GI	do	do	N	N	13.60	8-7-61	....	
35cd	E. Holderman	Dr	69.9	8	T	do	do	N	S	9.90	8-7-61	....	
20-22E-3cc	C. H. Traul	Du	38.0	36	R	do	Lane Shale and Iola(?) Limestone	Cy, H	S	23.89	8-9-61	....	
6aa	C. F. Kerr	Du	....	....	R	Limestone	Wyandotte Lime-stone	Cy, H	D	13.58	7-29-61	1,044±	Water-level observation well.
9bb•	B. F. Nickell	Dr	85	8	S	do	Drum and Iola Limestones	J, E	D	12.13	8-1-60	....	Well reported drilled in 1900 and deepened in 1961. Most of water enters well along upper contact of Drum Limestone.
12cd	H. Stiles	Du	23.0	30	R	Limestone and shale	Drum Limestone and Chanute Shale	J, E	D	17.93	8-8-61	....	
14cc	J. Burnett	Dr	52.2	6	S	Limestone	Dennis Limestone	Cy, H	N	14.93	8-9-61	....	
15ab	L. W. Dunlop	Du	48.5	60	R	Limestone and shale	....	Cy, H	N	16.45	8-9-61	....	
15ba	do	Dr	41.6	6	S	Limestone	....	Cy, H	D	10.31	8-9-61	....	
20cc	R. Troutman	Du	12.4	....	....	do	Iola Limestone	J, E	D	5.50	8-15-60	....	Salty water.

TABLE 4.—Records of wells, test holes, and springs (*Continued*).

Well number[1]	Owner or user	Type of well[2]	Depth of well, in feet[3]	Diameter of well, in inches	Type of casing[4]	Principal water-bearing unit: Character of material	Principal water-bearing unit: Geologic source	Method of lift, type of power[5]	Use of water[6]	Depth to water level below land surface, in feet[3]	Date of measurement	Height of land surface above mean sea level, in feet[7]	Remarks[8] (Yields given in gallons per minute)
22cd1	J. W. Gross	Dr	160.5	8	S	do	......	N	N	48.20	8-9-61	......	
22cd2	do	Du	41.9	50	R	do	Iola Limestone	Cy, H	D	12.53	8-9-61	......	
27cd	Wm. L. Hime	Dr	110	8	S	Limestone and shale	Dennis(?) Limestone	N	N	51.62	8-9-61	......	
29aa	Owen Root	Du	16.7	36	R	Limestone	Dennis Limestone	Cy, H	D	10.00	8-15-60	898±	
29ab	Tom Boman	Du	17.8	96	R	do	Drum(?) Limestone	Cy, E	D	7.10	8-9-61	......	
32cdd*	D. B. Johnson	Du	18.3	84	R	Shale	Cherryvale Shale	J, E	D	13.25	8-15-60	......	
33dd*	J. Wheeler	Du	19.5	120	R	Silt and sand	Alluvium	Cy, H	D	10.40	9-14-60	......	Well dug by KERC.
20-23E-1bb	J. Teagarden	Du	18.3	30	R	do	do	Cy, H	D	11.81	8-1-61	820±	
2bb	W. Scott	Du	56	72	R	Limestone	Dennis Limestone	J, E & Cy, H	D	27.22	8-1-61	930±	Water enters well through fractures in Winterset Limestone Member.
6aa	Cadmus Coop.	Dr	19	6	S	do	Swope Limestone	Cy, H	D	14.08	8-26-60	......	
7aa	E. A. Pulhamus	Dr	57.4	6	S	do	Dennis Limestone	Cy, H	N	19.25	8-8-61	......	Well reported inadequate for domestic use.
14cd	R. Teagarden	Du	30.3	36	R	do	do	J, E	D	21.50	8-31-61	1,020±	
15dd	Prairie Home School	Du	14.7	30	R	do	do	Cy, H	N	4.90	5-24-60	994	Reported as excellent well.
16cd	Horace Stainbrook	Du	28	60	R	do	Dennis and Swope Limestones	C, E	D	5.40	5-24-60	940	
30ad	A. E. Crosswhite	Du	28	50	R	do	do	Cy, H	D, S	10.40	8-8-61	......	
31ba	Robert Robins	Du	22	40	R	do	Dennis Limestone	J, E	D	10	8-9-61	......	
34ac	E. A. Carpenter	Du	29.7	50	R	do	do	Cy, H	D	20.17	8-11-61	995±	Water enters well through vertical joints in Winterset Limestone Member.
36cb*	Frank Crothers	Du	18.0	48	R	Sand, silt, and gravel	Alluvium	Cy, E	D, S	5.08	8-11-61	810±	Reported water hauled from this well.
20-24E-3ba*	C. D. Vawter	Du	21.2	72	C	do	do	Cy, E	S	10.88	8-31-61	803	
4ab	"Toad" Nelson	Dr	62.9	6	S	do	do	Cy, E	D	20.26	8-30-61	820	
4bba	U.S.G.S.	Au	39.0	4	N	Sand	do	N	N	17.20	7-1-59	815	
5aa	City of La Cygne	Dr	49.4	12	S	Sand, silt, and gravel	do	C, E	M	12.25	1938	801.8	Gravel packed well.
5bba	U.S.G.S.	Au	43.0	4	N	Sand and gravel	do	N	N	10.70	7-1-59	805	Augered for U.S. Bureau of Reclamation.
6aaa	do	Au	45.0	4	N	do	do	N	N	12.10	12-7-60	805	
7aa	R. Burch	Du	28.9	....	....	Sand, silt, and gravel	do	Cy, H	D	14.30	8-11-61	800±	

7bd	Paul K. Creager	Dr	24.0	6	S	do	do	Cy, H	N	9.75	8-31-61	797	
12dd	R. D. Evans	Dr	46.4	6	GI	Limestone and shale	....	Cy, H	D	12.18	8-31-61	821	Water reported very hard.
14bd	C. W. Massey	Dr	36.8	6	S	Sand, silt, and gravel	Alluvium	J, E	S	20.05	8-30-60	800	
16ac	Coffin	Dr	34.6	6	S	do	do	Cy, H	S	6.57	6-17-60	795	
19ca*	C. C. Gross	Du	20	72	R	Limestone	Dennis and Swope Limestones	J, E	D	14	8-11-61	1,000	Asphaltic Bethany Falls Limestone Member of Swope Limestone penetrated.
20ac	Brooklyn School No. 32	Du	15.8	18-36	R	do	Dennis Limestone	Cy, H	D	2.54	5-24-60	987	Reported water hauled from this well.
20da	Edna Wade	Dr	80	8	S	do	Dennis and Swope Limestones	Cy, H	D, S	45.79	6-13-60	985	Reported yield 0.5.
24cd	Otis Andrews	Du	23.2	....	R	Gravel	Alluvium	J, E	D, S	13.90	8-30-61	792	
27bd	Mitch Baugh, Jr.	Dr	37.9	8	GI	Limestone	Swope and Hertha Limestones	J, E	D	16.37	6-14-60	935	Estimated yield 1.
32cb	Oak Grove School No. 77	Du	10.4	48	R	Siltstone and colluvium	Pleasanton Group	Cy, H	N	4.68	6-15-60	860	
35ab	Boicourt School	Du	17.2	48	R	Colluvium and silt-stone	do	Cy, H	D	10.47	6-15-60	815±	
35dc	Boicourt Hunting Assn.	Dr	100	6	S	Gravel and soapstone	Alluvium	N	N	1.11	6-15-60	785	Encountered salt water and gas.
20-25E-4ba	C. M. Brayton	Du	28.7	....	....	Sand and silt	do	Cy, H	D	4.89	6-17-60	812	
5bb	H. A. Peterson	Dr	45.7	6	S	Limestone and shale	....	Cy, H	D	8.10	6-8-60	855	Water reported hard and high in iron.
5cb	C. M. Brayton	Du	40	48	....	Siltstone	Pleasanton(?) Group	Cy, H	D	32	6-15-60	858	Water reported hard and inadequate for domestic use.
6dd	H. Hamilton	Dr	178	8	....	Limestone and shale	....	Cy, W	D	58	6-16-60	855	Water reported high in iron.
8ca	T. B. Leivy	Du	15.7	48	R	Shale(?)	Holdenville Shale(?)	Cy, H	D	9.67	6-15-61	830	
9bcc	U.S.G.S.	Au	21.5	4	N	Gravel	Alluvium	N	N	11.80	12-8-60	796	
10bc	Macedonia School No. 65	Du	16.7	40	R	Limestone and shale	Upper part of Marmaton Group	Cy, H	N	3.80	5-27-60	820	
20bc	Wm. A. Woodburn	Du	33.9	....	....	Shale	Lower part of Pleasanton Group	Cy, H	S	5.61	6-17-60	822	
28ad	E. D. Burton	Du	19.8	40	....	Shale and sand-stone(?)	Upper part of Marmaton Group	J, E	D	4.55	5-27-60	845	
30ad	Peter Upham	Dr	54	6	S	Colluvium and shale	do	J, E	D	4.47	6-17-60	804	Reported as excellent well.
30cdd	U.S.G.S.	Au	36.5	4	N	Gravel	Aluvium	N	N	16.00	12-8-60	791	
30dc	Lloyd L. Grosshart	Du	29	30	R	Silt and sand	do	Cy, H	D	22.86	6-3-60	800	Reported as excellent well.

TABLE 4.—Records of wells, test holes, and springs *(Continued)*.

Well number[1]	Owner or user	Type of well[2]	Depth of well, in feet[3]	Diameter of well, in inches	Type of casing[4]	Principal water-bearing unit: Character of material	Principal water-bearing unit: Geologic source	Method of lift, type of power[5]	Use of water[6]	Depth to water level below land surface, in feet[3]	Date of measurement	Height of land surface above mean sea level, in feet[7]	Remarks[8] (Yields given in gallons per minute)
31da*	Marais des Cygnes Waterfowl Refuge	Dr	68	6	S	Limestone and shale	Upper part of Marmaton Group	J, E	D	10	6-14-60	815	Estimated yield 1.
33ab	S. M. Steamson	Du	40.8	30	R	do	Lower part of Pleasanton Group and upper part of Marmaton Group	Cy, H	S	9.90	5-27-60	835	Water reported hard.
33cd	R. W. Stoughton	DD	26.6	48	R	Shale	....	J, E	D	8.48	6-14-60	795	
35cd	Wm. D. Hamilton	Du	45.2	....	....	Shale and limestone	....	Cy, H	D	5.15	6-14-60	....	
21-21E-14cc	G. Osborn	Du	35.1	120	R	Limestone	Drum(?) Limestone	J, E	D	11.00	8-7-61	....	Supplies water to three homes.
36cc	M. Ball	Du	27.9	50	....	Sandy shale and coal	Thayer(?) coal	J, E & Cy, H	D	15.93	8-10-61	....	Sulfates may be high; waters from adjacent wells high in sulfates.
21-22E-15cb	B. B. Logan	Du	22.2	48	R	Limestone	do	Cy, H	D	8.16	8-19-61	....	Cl, 210 ppm.
15dd	J. Voss	Dr	55.0	6	S	do	Dennis Limestone	Cy, H	D	7.65	8-7-61	....	
17ab	W. Frear	Dr	70	....	....	Limestone and shale	....	Cy, H	D	10	8-7-61	....	Chlorides reported high in 150-foot well which is 100 yards north of this well.
17ac*	A. H. Berry	Dr	62	8	T	Limestone	Dennis and Swope Limestones	J, E	D	23.60	8-16-60	....	
23ca	J. M. Knight	Du	23.0	120	R	Silt and sand	Alluvium	Cy, H	D	20.00	8-7-61	....	KERC well.
23db	C. D. Fausett	Dr	80	6	S	do	do	C, E	D	15.70	8-25-60	....	
30cc	Jack O'Hara	Dr	89.0	6	S	Limestone and black shale	Dennis and Swope Limestones	Cy, H	N	44.62	8-10-61	....	
34ba	D. Ungeheuer	Du	24.0	60	R	Limestone	Dennis Limestone	Cy, E	D, S	18.35	8-10-61	....	
35ba	School	Dr	84.5	6	S	do	do	Cy, H	N	12.31	6-29-61	....	Located in yard of abandoned school.
36cc	W. Jackson	Dr	34.5	6	S	do	do	Cy, H	D	11.00	8-2-61	....	
21-23E-1ad	F. Clearwater	Du	21.2	48	R	Siltstone	Pleasanton Group	Cy, H	D	13.10	8-31-61	815	
2ca	D. Morrison	DD	16.0	48	R	Gravel	Colluvium	Cy, H	D	8.35	8-31-61	815	
6ca*	R. Wilcox	Du	24.1	40	R	Gravel	Colluvium and alluvium	J, E	D	12.66	8-10-61	....	
11bd	B. West	Du	30.0	50	R	Shale and silt	Colluvium and Pleasanton Group	Cy, H	N	7.63	8-8-61	812	
11cd	Farlinville Community Hall	Du	28.9	24	R	Silt and sand	Alluvium	Cy, H	D	10.06	5-27-60	820	Located in Farlinville community building yard.
12aa	F. Querry	Du	25.0	60	R	do	do	Cy, E	D	14.39	8-15-60	800	

14db	Harold West	Dr	24.4	13	GI	Silt, sand, and silt-stone	Colluvium and Pleasanton Group	Cy, E	D	9.15	5-24-60	845	
17db	School No. 6 A. L. Richards	Dr	33	....	....	Limestone	Dennis and Swope Limestones	Cy, H	N	10.90	8-24-60	....	
26da*	R. J. Cooper	Dr	100	6	GI	do	do	J, E	D	68.45	6-29-61	1,030	
27ca	H. Switzer	Dr	68.6	8	T	do	do	N	N	6.27	6-29-61	1,035	
28db	Floyd Burkhead	Du	9	40	R	do	Dennis Limestone	N	N	3.00	6-29-61	1,025±	
30bd	L. Cox	Du	22.1	48	R	do	do	J, E	D	12.04	8-10-61	....	
31dc*	Wall St. Church and Grange	Dr	30.0	6	S	do	do	Cy, H	D	21.40	6-30-61	1,002 Alt.	
36ca	L. Stanbrough	Du	18.2	48	R	Silt and sand	Colluvium and alluvium	J, E	D	4.26	8-10-61	890	
21-24E-8ac	John Wolfinger	Du	65	56	....	Limestone	Swope Limestone	Cy, H	D	50.27	6-15-60	900	
8cd*	R. E. Copple	Dr	125	6	S	do	Dennis Limestone	J, E	D	7.75	6-15-60	930	Yield about 1. Reported as oil and gas test well, plugged at 125 feet.
12ca1	M. Baugh	Du	38.0	30	R	Siltstone	Pleasanton Group	N	N	8.37	6-2-60	850	Wet weather well.
12ca2	do	Du	12.8	60	R	do	do	Cy, H	S	5.96	6-2-60	850	
12ca3	do	Dr	110	6	GI	do	do	N	N	26.30	6-2-60	845	Water reported high in chlorides.
13bc1	John Loudin	Dr	125	6	....	Shale	Middle part of Marmaton Group	N	N	20	6-1-60	825	Reported water from black shale 90 feet below surface.
13bc2	do	Dr	500	....	S	....	....	Cy, G, H	D, S	19.50	6-1-60	827	Water reported high in chlorides. Water enters well at 170 feet. Well drilled as oil and gas test well.
13bd	Owen Baugh	Du	19.0	60	R	Silt and shale	Pleasanton Group and colluvium	Cy, H	S	6.12	6-1-60	833	
13da	Green Valley School No. 45	Du	22.4	32	B	Siltstone and sandstone	Hepler Sandstone Member of Semi-nole Formation	Cy, H	D	5.12	6-1-60	800	
16aac	U.S.G.S.	Au	34.5	4	N	Silt and clay	Terrace deposits	N	N	7.91	8-18-61	795	
19ca	C. Nation	Du	10.7	50	R	Silt, sand, and shale	Colluvium and Pleasanton Group	J, E	D	6.99	7-28-61	873	
25cb1	H. Walker	Du	16.9	46	R	Siltstone	Pleasanton Group	Cy, H	D	5.25	6-2-60	835	
25cb2	do	Du	20.0	24	R	do	do	Cy, H	D	7.49	6-2-60	850	
25da	R. Cook	Dr	35	....	....	Shale	Holdenville(?) Shale	S, E	D	9	6-1-60	850	
26ab	J. C. McCulley	Du	19.7	30	R	Siltstone	Pleasanton Group	Cy, H	D, S	1.45	6-1-60	885	KERC well.
26bb	T. C. Ashley	Du	13.2	44	R	Limestone	Dennis Limestone	Cy, E	D	8.04	6-1-60	1,025	
29ca	A. Long	Du	15.3	48	R	Shale	Upper part of Marmaton Group	N	N	7.35	8-7-61	834	Water reported high in chlorides. Flowing "salt water" spring reported south of house.

TABLE 4.—Records of wells, test holes, and springs (*Continued*).

Well number[1]	Owner or user	Type of well[2]	Depth of well, in feet[3]	Diameter of well, in inches	Type of casing[4]	Principal water-bearing unit: Character of material	Principal water-bearing unit: Geologic source	Method of lift, type of power[5]	Use of water[6]	Depth to water level below land surface, in feet[3]	Date of measurement	Height of land surface above mean sea level, in feet[7]	Remarks[8] (Yields given in gallons per minute)
29da*	C. A. Furse	Du	24.6	48	R	Sand and gravel	Alluvium	J, E	D	15.40	7-28-61	820	
29dad	U.S.G.S.	Au	31.0	4	N	Gravel	Terrace deposits	N	N	15.30	8-18-61	812	
35ab	Leola Jurgens	Du	35.2	60	B	Siltstone	Pleasanton Group	Cy, E	D	9.21	5-24-60	917	
21-25E-1bc	W. Hamilton	Dr	100	7	S	Shale and limestone	....	N	N	25.23	6-14-60	819	
2ab	do	Du	29.8	48	....	do	....	Cy, H	D	4.84	6-14-60	799	
2bc	J. W. Hughes	Du	12.7	48	....	Shale	Holdenville Shale	Cy, H	N	4.44	6-7-61	815	
2cb	do	Dr	62.5	6	S	Limestone and shale	Middle part of Marmaton Group	C, E	D	21.63	8-30-61	843	
5ac1	H. Queen	Dr	58	6	GI	do	do	J, E	D	31.44	6-3-60	790	
5ac2	do	Dr	55.4	6	GI	do	do	J, E	D	12.89	6-3-60	790	Water reported hard and high in iron.
5bd	Marais des Cygnes Waterfowl Refuge	Dr	102	6	....	do	do	J, E	D	30	6-14-60	820	Reported yield 1.
15aad	U.S.G.S.	Au	53.5	4	N	Gravel	Alluvium	N	N	15.72	8-24-61	784	
16ab	W. Fultz	Dr	90	6	S	Black shale	Pawnee Limestone	Cy, H	D	18.23	6-16-60	790	
19ab	G. Thomas	Du	14.6	40	R	Shale	Holdenville Shale	N	N	10.84	5-25-60	800	
21da	L. B. Spencer	Dr	100	8	S	Shale and limestone	....	Cy, H	D	11.76	6-15-60	838	Supplies Community Building.
26ab	R. Roland	Du	15.5	36	R	Silt and sand	Alluvium	Cy, H	D	0.60	6-8-60	778	
26bd1	M. Wortman	Du	21.5	36	R	Shale and limestone	Pawnee Limestone	Cy, H	D	13.73	6-14-60	805	
26bd2	do	Dr	49.4	6	S	Limestone	do	Cy, H	D	23.99	6-14-60	805	Water reported very hard.
28ba	Harvey Savage	Dr	198	6	T	Limestone and shale	....	N	N	6.06	6-15-60	827	Water reported salty.
29dd1	Don Fortman	Dr	137	....	....	do	....	S, E	D	40	6-3-60	850	Water reported salty; not used for drinking.
29dd2	do	Du	20.0	....	R	Sandstone	Hepler Sandstone Member of Seminole Formation	Cy, E	D	6.09	6-3-60	850	
30db	Robert Stevanus	Dr	80	6	S	Shale	Anna Shale Member of Pawnee Limestone	N	N	3.27	8-22-60	850	Reported as inadequate for domestic use. Cl, 240 ppm.
30dc	Harry Sisson	Dr	20	8	S	Sandstone(?)	Hepler Sandstone Member of Seminole Formation	N	N	7.33	6-3-60	848	Well may have caved in. Well reported as always poor.
31bc	City of Pleasanton	Du	27.8	36	R	Sandstone	do	Cy, E	D, S	2.16	6-2-60	860	Excellent well.
32dc	School No. 74	Du	25.6	36	R	Sandstone(?)	do	Cy, H	D	4.48	5-26-60	837	

	33aa	W. H. Jones	Dr	84	6	S	Limestone and shale	....	J, E	N	32.68	6-15-60	825	Water reported salty.
	33bc	C. G. Trout	Sp	....	....	....	Sandstone	Hepler Sandstone Member of Seminole Formation	Cy, E	D	....	....	833	Supplies three farm homes.
	34aa	E. L. Alterman	Dr	90	6	S	Limestone	Pawnee Limestone	J, E	D	14.86	6-3-60	800	Water reported high in sulfates. Reported that gas is produced from well.
	34ba	O. R. Blevins	Du	20.0	55	R	Silt and sand	Alluvium	Cy, H	D	7.34	6-3-60	793	Water reported hard.
22-21E-11bb		D. Miller	Dr	32.2	8	T	do	Iola Limestone	Cy, H	D	8.49	8-10-61	....	
	11cd	F. K. Ross	Du	16.6	72	R	Shale and limestone	Cherryvale(?) Shale	J, E	S	13.22	8-10-61	....	
	14cd	Glen Gregg	Dr	152	6	S	Coal(?)	Thayer coal(?)	Cy, E	D, S	83.52	6-30-61	1,030 Alt.	Water reported high in sulfates.
22-22E-11aa		Glenn E. McGee	Dr	47.0	6	S	Limestone	Dennis Limestone	Cy, H	S	9.54	6-30-61	971 Alt.	
	16ba	E. Thyer	Du	20.2	60	R	Shale and limestone	Block Limestone and Cherryvale Shale	Cy, W	D, S	3.35	6-30-61	997 Alt.	Estimated yield 1.
	20aa	T. A. Rodgers	Du	12.0	84	R	do	do	Cy, E	D, S	1.41	6-30-61	1,059 Alt.	Estimated yield 1.
	27dc	J. J. Baker	Dr	50	6	S	Limestone	Dennis Limestone	Cy, E	D	22	7-21-61	....	
	32aa	McVey Grocery Blue Mound, Kansas	Dr	65	6	....	do	Dennis, Swope, and Hertha Limestones	J, E	N	7.20	6-30-61	1,050	Water enters well 65 feet below land surface.
	32cc	R. Baker	Dr	75	6	....	do	Dennis and Swope Limestones	J, E	D, S	15	7-21-61	....	Water enters well at 35 and 55 feet below land surface.
	36ba	R. Benson	Dr	62.5	8	T	do	do	Cy, H	S	12.55	7-21-61	....	
22-23E-5ad		C. Kettler	Dr	64.6	8	T	do	Dennis Limestone	N	N	12.41	6-30-61	993 Alt.	
	8cc	L. J. Markum	Du	32	30	R	Black fissile shale	Holdenville Shale	J, E	D	15.70	7-26-61	....	Reported black fissile shale, 1.5 feet thick and 19 feet below land surface, serves as chief aquifer.
	8cca	U.S.G.S.	Au	19.5	4	N	Gravel	Terrace deposits	N	N	14.72	8-17-61	....	
	9ac	A. R. Dingus	Du	20.0	36	R	Silt and sand	Alluvium	J, E	D	6.68	7-26-61	....	
	11bbc	U.S.G.S.	Au	23.5	4	N	Gravel	Terrace deposits	N	N	11.90	8-17-61	....	
	12aa*	Kansas State Highway Comm.	Dr	43	6	S	do	do	J, E	D	21.75	5-24-60	850	
	14bb	C. H. Mantey	Du	29.8	48	R	Silt and shale	Lower part of Pleasanton Group and colluvium	J, E	D	11.87	7-26-61	893	
	18db	F. Sisson	Dr	25.9	8	T	Limestone	Swope Limestone	Cy, H	N	5.78	7-26-61	....	
	18dd	C. Sisson	Du	28.6	....	R	do	do	Cy, H	N	5.80	7-19-60	....	
	27cd*	G. Vaughn	Dr	47.6	6	S	do	Dennis Limestone	Cy, H	D	12.09	7-21-61	....	

TABLE 4.—Records of wells, test holes, and springs (*Continued*).

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29dc	R. McDonald	DD	45	36	....	Limestone and shale	Winterset Limestone and Stark Shale Members of Dennis Limestone	Cy, H	D	5.59	7-21-61	....	
31ab	S. F. Priest	Du	50.4	60	R	do	do	J, E	D	20.71	7-21-61	....	
22-24E-1db	Sam McKee	Dr	505	6	S	do	....	N	N	127.51	6-2-60	883	Reported this well serves as gas well for city of Pleasanton.
3bd	E. Treethan	Sp	....	....	....	do	Contact between Hertha Limestone and Pleasanton Group	....	D	....	....	990	Serves three homes; estimated yield 0.5.
4cb	E. H. Isenhour	Du	30	48	R	do	Bandera Shale	Cy, E	D	9.11	7-28-61	860	
5bc1	W. L. Murray	Du	31.0	72	R	Limestone and gravel	Alluvium and Pawnee Limestone	Cy, E	D	15.54	7-28-61	830	
5bc2	do	Du	18	50	....	do	do	J, E	S	13.73	7-28-61	830	
6dc	L. Brown	Dr	58.8	6	S	Limestone and shale	Pawnee(?) Limestone	J, E	D	20.54	7-28-61	833	Water reported salty.
7ca	Mound City	Dr	181	8	T	do	....	N	N	23.64	6-29-61	854	Water reported high in sulfates. Formerly used as source of mineral water.
9ca	L. Amery	Dr	84.3	6	GI	do	....	J, E	D	27.05	7-14-61	930	
12ad	D. Baldwin	Dr	41	8	S	Sandstone, limestone, and shale	....	J, E	D	8.94	6-29-61	855	
14cc	Community Building W. C. Gilmore	Du	17.2	36	R	Sandstone	Hepler(?) Sandstone Member of Seminole Formation	Cy, H	D	5.83	7-14-60	909	
14dc*	J. Blasco	Dr	228	6	S	Limestone	Fort Scott Limestone	J, E	S	25	7-6-61	872	Reported well sometimes yields natural gas. Reported yield 5.
20ad*	A. Greyhouse	Dr	86.9	6	GI	Shale	Holdenville Shale	J, E	D	37.83	7-14-61	955	
22ba	E. Johnson	Du	20.2	....	....	Silt and shale	Lower part of Pleasanton Group and colluvium	Cy, H	D	6.36	7-6-61	890	
26ad	J. Owen	Dr	200	6	....	Limestone	Base of Hertha Limestone	Cy, E	N	35	7-6-61	1,010	Estimated yield 1.
26dd	H. Avery	Dr	50	6	S	Clay and silt	Recent(?) deposits	Cy, H	S	2.53	7-6-61	905	

29aa	W. Smith	Du	19.7	84	R	Sand	Alluvium	J, E	D	11.50	7-14-61	935	Reported water-bearing sand resembles quicksand.
22-25E-3ad	Mack Holmes	Du	32.8	48	R	Sandstone and shale	Hepler Sandstone Member of Seminole Formation	Cy, E	D	20.10	5-31-60	912	
3db	Claude Parton	Du	17.7	72	R	do	do	Cy, H	D	5.02	5-23-60	887	
8aaa	U.S.G.S.	Au	13.5	4	N	Gravel	Alluvium	N	N	8.60	8-23-61	808	
8aab	do	Au	18.5	4	N	do	do	N	N	15.50	8-23-61	812	
11ac	C. A. Bell	Du	18.2	....	R	Limestone	Limestone flags in Pleasanton Group	Cy, H	N	5.95	5-31-60	980	
12ba	Glen Arnold	Dr	68.5	8	GI	Limestone and shale	....	N	N	17.78	5-31-60	950	
13ba	F. F. Lindelle	Du	23.1	60	R	Shale	Holdenville Shale	Cy, H	S	7.25	5-31-60	895	
16ab*	Carl Badgett	Dr	55	7	S	Shale and sandstone	Hepler Sandstone Member of Seminole Formation	J, E	D	11.68	5-23-60	875	
16ba	Ralph Hamilton	Du	25.3	48	R	Sandstone	do	J, E	D	6.37	5-23-60	895	
19dd	Fairmount Grange	Du	18.1	40	R	Shale	Pleasanton Group	Cy, H	D	5.09	5-26-60	925	
23-21E-13cb1	C. West	Dr	115	6	S	Limestone	Dennis Limestone	J, E	D	42.75	7-26-61	....	
13cb2	C. West	Dr	120	6	S	do	do	J, E	S	33.88	7-26-61	....	
23-22E-5ab	D. Murrow	Dr	52.4	12	T	do	do	Cy, H	D	20.58	7-20-60	....	
9cc*	A. J. Bradley	Dr	33.0	8	S	do	do	Cy, H	D	20.32	8-17-60	....	
23-23E-1dd	F. C. Casida	Dr	42.0	6	T	do	Limestone flags in Pleasanton Group	Cy, H	D	26.80	8-25-61	937	
16ad	F. Stoughton	Du	17.8	48	R	do	do	Cy, H	D	7.39	7-25-61	....	
17cc	J. Powell	Dr	27	4	T	do	do	Cy, H	D	17.79	9-1-60	....	
23-24E-1da	A. W. Ham	Du	29.7	18	R	Limestone	Pawnee Limestone	J, E	D	16.64	7-25-61	842	
3aa	J. Gabbert	Dr	65	6	S	Limestone and shale	....	N	N	12.53	7-25-61	880	Reported inadequate for domestic supply.
3cb	C. Holsinger	Dr	120	6	S	do	....	N	N	49.84	7-25-61	885	Cl, 171 ppm.
5aa	J. Higgins	Dr	38	6	....	Limestone	Upper part of Marmaton Group	J, E	D	20	7-14-61	885	Estimated yield 0.5.
5dc	R. Cox	Du	17.9	48	....	do	do	Cy, W	D, S	6.87	7-14-61	870	
6cb	M. E. Hawkins	Du	20.7	144	R	Silt and sand	Alluvium	Cy, H	D, S	10.23	7-25-61	875	KERC well.
7dd1	J. Nepote	Du	40	48	R	Limestone and shale	Upper part of Marmaton Group	Cy, H	N	7.08	7-7-61	885	
7dd2	School No. 99	Dr	49	8	T	do	do	Cy, H	D	7.46	7-7-61	885	
8dd*	Fred and Waldo Cox	Dr	53.1	10	T	Limestone	Pawnee(?) Limestone	Cy, H	N	21.86	7-7-61	880	Water very high in nitrates.
10cc	A. D. Shaw School No. 63	Du	35.3	48	R	Shale	Upper part of Marmaton Group	N	N	8.19	7-14-61	887	Reported water hauled from this well during drought.
13bc	L. N. McCabe	Du	25.0	48	R	do	Bandera Shale	Cy, H	N	15.00	7-6-61	840	
13dd1	Karl Seested	Dr	16	4	GI	Limestone	Pawnee Limestone	Cy, E	D	8.60	5-25-60	850	Water enters well through fracture system in Pawnee Limestone.

TABLE 4.—Records of wells, test holes, and springs (*Concluded*).

Well number[1]	Owner or user	Type of well[2]	Depth of well, in feet[3]	Diameter of well, in inches	Type of casing[4]	Principal water-bearing unit: Character of material	Principal water-bearing unit: Geologic source	Method of lift, type of power[5]	Use of water[6]	Depth to water level below land surface, in feet[3]	Date of measurement	Height of land surface above mean sea level, in feet[7]	Remarks[8] (Yields given in gallons per minute)
13dd2	do	Du	12	24	R	do	do	Cy, H	S	3.50	5-25-60	848	
17cb	B. L. Pinkerton	Dr	435	6	S			N	N	15	7-7-61	875	Reported well was drilled for gas.
23-25E-7aa	Prescott Grade School	Du	20.0	60	R	Limestone	Pawnee(?) Limestone	J, E	D	7.83	7-6-61	893	
7da1	Otie Grisby	Du	19.4	18	R	do	do	Cy, E	D	8.79	5-25-60	883	
7da2	do	Du	17.7	40	R	do	do	N	N	6.81	5-25-60	884	Water-level observation well.
7dd*	K. Black	Du	32	72	R	do	Pawnee Limestone	J, E	D, S	13.49	7-6-61	865	
8bb	Pete Holmes	Dr	49.7	6	S	Limestone and shale	do	J, E	D	15.77	7-6-61	890	
10aa	Wayne Miller	Du	14.5	48	R	Shale	Bandera Shale	Cy, H	S	5.90	7-6-61	839	
18cd	A. J. Lambertson	Du	37.5	20	R	Limestone	Pawnee Limestone	B	D	10.09	5-25-60	863	

[1] Asterisk following well number indicates analysis of water is given in table 2.

[2] Type of well: *Au*, augered; *Du*, dug; *Dr*, drilled; *DD*, dug and drilled; *Sp*, spring.

[3] Reported depths below land surface are given in feet; measured depths below land surface are given in feet and tenths.

[4] Type of casing: *B*, brick; *GI*, galvanized iron; *N*, none; *R*, rock; *S*, steel pipe; *T*, tile.

[5] Method of lift: *B*, bucket; *C*, centrifugal; *Cy*, cylinder; *J*, jet; *N*, none; *S*, submersible.
Type of power: *E*, electric; *H*, hand; *W*, wind.

[6] Use of water: *D*, domestic; *M*, municipal; *N*, none; *S*, stock.

[7] Height of land surface above mean sea level, in feet, estimated from 10-foot contour interval on modern 7½-minute topographic maps, accurate to ±5 feet. *Alt.*, altitude above mean sea level measured with aneroid barometer.

[8] *KERC*, Kansas Emergency Relief Commission well; *Cl*, chlorides measured in field.

LOGS OF WELLS AND TEST HOLES

Logs of 99 test holes in Linn County are listed on the following pages. Test holes lacking a measurement of depth to water are not shown on plate 1.

19-23E-26ccc.—Sample log of test hole in SW¼ SW¼ SW¼ sec. 26, T. 19 S., R. 23 E., in center of road intersection; augered December 7, 1960. Altitude of land surface, 811 feet; depth to water, 12.00 feet.

	Thickness, feet	Depth, feet
QUATERNARY SYSTEM		
Pleistocene Series		
Alluvium		
Soil and clay, brown	3.5	3.5
Clay with limonitic fragments, brown	5.0	8.5
Clay, brown	5.0	13.5
Clay, slightly sandy, reddish-brown	5.0	18.5
Clay, silty, sandy, light reddish-brown (moist)	10.0	28.5
Clay, gray (wet)	15.0	43.5
Siltstone, gray	2.5	46.0

19-23E-35add.—Sample log of test hole in SE¼ SE¼ NE¼ sec. 35, T. 19 S., R. 23 E., in north road shoulder 90 feet west of E¼ corner; augered December 7, 1960.

	Thickness, feet	Depth, feet
QUATERNARY SYSTEM		
Pleistocene Series		
Alluvium		
Soil and clay	3.5	3.5
Clay, brown	5.0	8.5
Clay with hard light-buff fragments	5.0	13.5
Clay, brown	5.0	18.5
Clay, silty, reddish-brown	5.0	23.5
Clay, silty, sandy, gray	5.0	28.5
Clay, silty, sandy, reddish-brown	5.0	33.5
Clay, silty, dark reddish-brown	15.0	48.5
Clay and chert gravel	2.5	51.0
Clay, gray	2.5	53.5
Siltstone, gray	2.5	56.0

19-23E-36ccc.—Sample log of test hole in SW¼ SW¼ SW¼ sec. 36, T. 19 S., R. 23 E., in east road shoulder 75 feet north of SW corner; augered December 7, 1960. Altitude of land surface, 811 feet.

	Thickness, feet	Depth, feet
QUATERNARY SYSTEM		
Pleistocene Series		
Colluvium and alluvium		
Soil, sandy, brown	3.5	3.5
Clay, sandy, limonite-stained, gray	20.0	23.5
Siltstone, gray	5.0	28.5

19-24E-31ccc.—Sample log of test hole in SW¼ SW¼ SW¼ sec. 31, T. 19 S., R. 24 E., 18 feet east and 40 feet north of SW corner; augered December 7, 1960. Altitude of land surface, 805 feet; depth to water, 18.00 feet.

	Thickness, feet	Depth, feet
QUATERNARY SYSTEM		
Pleistocene Series		
Alluvium		
Soil, slightly sandy, brown	3.5	3.5
Clay, slightly sandy, reddish-brown	10.0	13.5
Clay, silty, slightly sandy, light-brown (moist)	5.0	18.5
Clay, brown (moist)	20.0	38.5
Clay, gray (moist)	5.0	43.5
PENNSYLVANIAN SYSTEM		
Middle Pennsylvanian Series		
Desmoinesian stage		
Siltstone and clay, gray (moist)	5.0	48.5

19-24E-32dcd.—Sample log of test hole in SE¼ SW¼ SE¼ sec. 32, T. 19 S., R. 24 E., in road ditch north of Highway 135, 0.5 mile west of La Cygne; augered December 7, 1960. Altitude of land surface, 804 feet; depth to water, 12.50 feet.

	Thickness, feet	Depth, feet
QUATERNARY SYSTEM		
Pleistocene Series		
Alluvium		
Soil and clay, gray	3.5	3.5
Soil and clay, brown	5.0	8.5
Clay, gray-streaked, brown	5.0	13.5
Clay, limonite-stained, brown	5.0	18.5
Clay, light grayish-brown	5.0	23.5
Clay, gray-banded, brown	5.0	28.5
Clay, gray	5.0	33.5
Clay, slightly sandy, gray	10.0	43.5
Clay, sandy, reddish-gray	5.0	48.5
Clay and chert gravel	2.0	50.5
PENNSYLVANIAN SYSTEM		
Middle Pennsylvanian Series		
Desmoinesian stage		
Shale	3.0	53.5

19-24E-34ddc.—Sample log of test hole drilled in SW¼ SE¼ SE¼ sec. 34, T. 19 S., R. 24 E. Altitude of land surface, 810 ± feet.

	Thickness, feet	Depth, feet
QUATERNARY SYSTEM		
Pleistocene Series		
Silt and clay	11.0	11.0
Sand and silt	17.0	28.0
Sand and gravel	6.0	34.0
PENNSYLVANIAN SYSTEM		
Middle Pennsylvanian Series		
Desmoinesian stage		
Altamont Limestone		
Limestone	5.2	39.2

19-24E-35aaa.—Sample log of test hole in NE¼ NE¼ NE¼ sec. 35, T. 19 S., R. 24 E., in south shoulder at road intersection; augered August 28, 1961. Altitude of land surface, 970 ± feet.

	Thickness, feet	Depth, feet
QUATERNARY SYSTEM		
Pleistocene Series		
Illinoisan stage (terrace deposits)		
Clay, silty, yellowish-tan	3.5	3.5
Clay, yellow	5.0	8.5
Clay, dry, yellow	5.0	13.5
PENNSYLVANIAN SYSTEM		
Middle Pennsylvanian Series		
Desmoinesian stage		
Siltstone, yellow	3.0	16.5

19-24E-35abb.—Sample log of test hole in NW¼ NW¼ NE¼ sec. 35, T. 19 S., R. 24 E.; augered August 28, 1961. Altitude of land surface, 820 feet.

	Thickness, feet	Depth, feet
QUATERNARY SYSTEM		
Pleistocene Series		
Illinoisan stage (terrace deposits)		
Soil and clay, dark reddish-brown	3.5	3.5
Clay, dark-brown	10.0	13.5
Clay, yellowish-brown	5.0	18.5
PENNSYLVANIAN SYSTEM		
Middle Pennsylvanian Series		
Desmoinesian stage		
Siltstone, bluish-gray	3.0	21.5

19-25E-28abb.—Sample log of test hole in NW¼ NW¼ NE¼ sec. 28, T. 19 S., R. 25 E., in south shoulder of road adjacent to driveway; augered August 28, 1961. Altitude of land surface, 830 feet; depth to water, 6.85 feet.

	Thickness, feet	Depth, feet
QUATERNARY SYSTEM		
Pleistocene Series		
Terrace deposits		
Clay, dark-brown	3.5	3.5
Clay, yellowish-tan	10.0	13.5
Clay, yellowish-tan (wet)	5.0	18.5
Clay, tan (free water)	5.0	23.5
PENNSYLVANIAN SYSTEM		
Upper Pennsylvanian Series		
Missourian stage		
Siltstone, gray	2.0	25.5

19-25E-28bbb.—Sample log of test hole in NW¼ NW¼ NW¼ sec. 28, T. 19 S., R. 25 E., in south road shoulder; augered August 28, 1961. Altitude of land surface, 830 feet; depth to water, 10.27 feet.

	Thickness, feet	Depth, feet
QUATERNARY SYSTEM		
Pleistocene Series		
Terrace deposits		
Soil and clay, reddish-brown	3.5	3.5
Clay, silty, reddish-brown	5.0	8.5
Clay, red	5.0	13.5
Clay, yellowish-tan (moist)	5.0	18.5
Clay (no sample)	5.0	23.5
Siltstone, gray	2.0	25.5

20-22E-1bbb.—Sample log of test hole in NW¼ NW¼ NW¼ sec. 1, T. 20 S., R. 22 E.; augered August 14, 1961.

	Thickness, feet	Depth, feet
QUATERNARY SYSTEM		
Pleistocene Series		
Colluvium		
Clay, silty, yellowish-brown	7.5	7.5
Clay, silty, brownish-yellow	1.0	8.5
Clay, yellowish-gray	3.0	11.5
Clay, yellowish-gray (moist)	1.0	12.5
Clay, silty, grayish-black	6.0	18.5
PENNSYLVANIAN SYSTEM		
Upper Pennsylvanian Series		
Missourian stage		
Cherryvale Shale		
Shale	1.0	19.5

20-22E-32dcc.—Sample log of test hole in SW¼ SW¼ SE¼ sec. 32, T. 20 S., R. 22 E., in north road shoulder 100 yards west of Finley Market; augered August 15, 1961.

	Thickness, feet	Depth, feet
QUATERNARY SYSTEM		
Pleistocene Series		
Colluvium		
Clay, yellowish-brown	3.5	3.5
Clay, brown	15.0	18.5
PENNSYLVANIAN SYSTEM		
Upper Pennsylvanian Series		
Missourian stage		
Limestone	....	18.5

20-24E-2aaa.—Sample log of test hole in NE¼ NE¼ NE¼ sec. 2, T. 20 S., R. 24 E., 15 feet west of NE corner; drilled July 5, 1961. Altitude of land surface, 835 ± feet.

	Thickness, feet	Depth, feet
QUATERNARY SYSTEM		
Pleistocene Series		
Colluvium and alluvium, undifferentiated	11.6	11.6
PENNSYLVANIAN SYSTEM		
Upper Pennsylvanian Series		
Missourian stage		
Hepler Sandstone Member of Seminole Formation	1.2	12.8
Middle Pennsylvanian Series		
Desmoinesian stage		
Holdenville and Nowata Shales		
Shale, brown	5.1	17.9
Shale, gray	16.4	34.3
Shale, limy, gray	23.6	57.9
Altamont Limestone		
Limestone, light-gray	4.8	62.7

20-24E-2aab.—Sample log of test hole in NW¼ NE¼ NE¼ sec. 2, T. 20 S., R. 24 E., 0.24 mile west of NE corner; drilled July 5, 1961. Altitude of land surface, 820 ± feet.

	Thickness, feet	Depth, feet
QUATERNARY SYSTEM		
Pleistocene Series		
Soil and clay	16.6	16.6
PENNSYLVANIAN SYSTEM		
Middle Pennsylvanian Series		
Desmoinesian stage		
Holdenville and Nowata Shales		
Shale, gray	28.2	44.8
Altamont Limestone		
Limestone	3.2	48.0

20-24E-2baa.—Sample log of test hole in the NE¼ NE¼ NW¼ sec. 2, T. 20 S., R. 24 E., 20 feet west of road intersection; drilled July 6, 1961. Altitude of land surface, 805 ± feet.

	Thickness, feet	Depth, feet
QUATERNARY SYSTEM		
Pleistocene Series		
Silt and clay	20.0	20.0
PENNSYLVANIAN SYSTEM		
Middle Pennsylvanian Series		
Desmoinesian stage		
Nowata Shale		
Shale, light-gray	8.0	28.0

	Thickness, feet	*Depth, feet*
Altamont Limestone		
Limestone	5.0	33.0

20-24E-2bbb.—Sample log of test hole drilled in the NW¼ NW¼ NW¼ sec. 2, T. 20 S., R. 24 E. Altitude of land surface, 804 ± feet.

	Thickness, feet	*Depth, feet*
QUATERNARY SYSTEM		
PLEISTOCENE SERIES		
Silt and clay	23.0	23.0
Gravel	7.0	30.0
PENNSYLVANIAN SYSTEM		
MIDDLE PENNSYLVANIAN SERIES		
DESMOINESIAN STAGE		
Nowata Shale		
Shale, gray	3.6	33.6
Altamont Limestone		
Limestone	4.3	37.9

20-24E-3abb.—Sample log of test hole in NW¼ NW¼ NE¼ sec. 3, T. 20 S., R. 24 E., in east road shoulder 25 feet south of center line of Highway 135; augered December 8, 1960. Altitude of land surface, 814 feet.

	Thickness, feet	*Depth, feet*
Soil and road fill	3.5	3.5
QUATERNARY SYSTEM		
PLEISTOCENE SERIES		
Clay, light-yellow	10.0	13.5
Clay, sandy, gray, streaked yellow	10.0	23.5
Clay, very sandy, gray-streaked, yellow	5.0	28.5
Clay, sandy, yellow	5.0	33.5
PENNSYLVANIAN SYSTEM		
UPPER PENNSYLVANIAN SERIES		
MISSOURIAN STAGE		
Hepler Sandstone Member of Seminole Formation		
Sandstone(?)	1.5	35.0

20-24E-4bba.—Sample log of test hole in NE¼ NW¼ NW¼ sec. 4, T. 20 S., R. 24 E., 1,000 feet east of river bridge 10 feet below bridge floor; augered July 1, 1959. Altitude of land surface, 815 feet; depth to water, 17.20 feet.

	Thickness, feet	*Depth, feet*
QUATERNARY SYSTEM		
PLEISTOCENE SERIES		
Clay loam, grayish-brown (damp)	12.0	12.0
Sandy loam and fine sand, light grayish-brown (damp)	10.5	22.5
Sand, very fine, silty, very dirty, very light grayish-brown (saturated)	3.5	26.0
Sand, very fine, silty, very dirty, light-gray to gray (saturated)	9.0	35.0
PENNSYLVANIAN SYSTEM		
MIDDLE PENNSYLVANIAN SERIES		
DESMOINESIAN STAGE		
Siltstone or shale, gray to grayish-blue, trace of coal	4.0	39.0

20-24E-5abb.—Sample log of test hole in NW¼ NW¼ NE¼ sec. 5, T. 20 S., R. 24 E., 25 feet east of La Cygne municipal well about 2,000 feet west of Marais des Cygnes River; augered July 28, 1961. Altitude of land surface, 808 feet.

	Thickness, feet	*Depth, feet*
QUATERNARY SYSTEM		
PLEISTOCENE SERIES		
Clay, dark-brown	33.0	33.0
Clay, dark-brown (wet)	5.0	38.0
Clay, sandy, brown (wet)	18.0	56.0
Clay and gravel (wet)	4.0	60.0
PENNSYLVANIAN SYSTEM		
MIDDLE PENNSYLVANIAN SERIES		
DESMOINESIAN STAGE		
Shale, sandy, gray (wet)	....	60.0

20-24E-5bba.—Sample log of test hole in NE¼ NW¼ NW¼ sec. 5, T. 20 S., R. 24 E., near borrow pit 4 to 5 feet below road surface; augered July 1, 1959. Altitude of land surface, 805 feet; depth to water, 10.70 feet.

	Thickness, feet	*Depth, feet*
QUATERNARY SYSTEM		
PLEISTOCENE SERIES		
Clay loam, very dark grayish-brown (damp)	2.0	2.0
Clay, very dark grayish-brown (damp), plastic	3.0	5.0
Clay, silty, dark-gray (damp), plastic	2.5	7.5
Clay loam, silty, dark grayish-brown (damp)	7.5	15.0
Clay loam, silty, light grayish-brown (damp)	6.5	21.5
Clay loam, sandy, and fine sand, light reddish-brown (damp to moist)	4.5	26.0
Clay loam, sandy, and very fine sand, light reddish-brown (moist)	6.0	32.0
Sand, very fine, silty, very dirty, very light grayish-brown (saturated)	10.0	42.0
Clay, bluish-gray (saturated), some coarse chert gravel	1.0	43.0

20-24E-6aaa.—Sample log of test hole in NE¼ NE¼ NE¼ sec. 6, T. 20 S., R. 24 E., in west road shoulder 28 feet south of center line of Highway 135; augered December 7, 1960. Altitude of land surface, 805 feet; depth to water, 12.10 feet.

	Thickness, feet	*Depth, feet*
QUATERNARY SYSTEM		
PLEISTOCENE SERIES		
Soil and road fill	3.5	3.5
Clay, grayish-green	10.0	13.5
Clay, sandy, reddish-brown	5.0	18.5
Clay, sandy, yellowish-brown (moist)	10.0	28.5
Clay, sandy, brown (wet)	5.0	33.5
Clay, fine, sandy, yellow (very wet)	5.0	38.5
Clay and chert gravel, sandy, yellow	5.0	43.5
PENNSYLVANIAN SYSTEM		
MIDDLE PENNSYLVANIAN SERIES		
DESMOINESIAN STAGE		
Shale, gray	1.5	45.0

20-24E-13add.—Sample log of test hole in SE¼ SE¼ NE¼ sec. 13, T. 20 S., R. 24 E., in center of road intersection; augered August 25, 1961. Altitude of land surface, 827 feet.

	Thickness, feet	Depth, feet
Soil, dark-brown	2.0	2.0
QUATERNARY SYSTEM		
Pleistocene Series		
Clay, dark-yellow	1.5	3.5
Clay, yellow	15.0	18.5
PENNSYLVANIAN SYSTEM		
Middle Pennsylvanian Series		
desmoinesian stage		
Bedrock	....	18.5

20-24E-13bcc.—Sample log of test hole in SW¼ SW¼ NW¼ sec. 13, T. 20 S., R. 24 E., in south road shoulder opposite farm yard; augered August 24, 1961. Altitude of land surface, 807 feet.

	Thickness, feet	Depth, feet
Clay soil, brown	3.5	3.5
QUATERNARY SYSTEM		
Pleistocene Series		
Clay, yellow	10.0	13.5
PENNSYLVANIAN SYSTEM		
Middle Pennsylvanian Series		
desmoinesian(?) stage		
Siltstone	1.0	14.5

20-24E-24bcd.—Sample log of test hole in SE¼ SW¼ NW¼ sec. 24, T. 20 S., R. 24 E., in west road shoulder 75 yards north of half-mile hedge row and 15 yards west of road center line; drilled July 11, 1961. Altitude of land surface, 810 feet.

	Thickness, feet	Depth, feet
QUATERNARY SYSTEM		
Pleistocene Series		
Clay, light-yellow	25.0	25.0
Chert gravel, with some sandstone fragments	3.5	28.5
Gravel, sandstone fragments	1.0	29.5
PENNSYLVANIAN SYSTEM		
Middle Pennsylvanian Series		
desmoinesian stage		
Limestone	....	29.5

20-24E-24cbd.—Sample log of test hole in SE¼ NW¼ SW¼ sec. 24, T. 20 S., R. 24 E., in west road shoulder; augered August 24, 1961. Altitude of land surface, 800 feet.

	Thickness, feet	Depth, feet
QUATERNARY SYSTEM		
Pleistocene Series		
Clay, dark-brown	3.5	3.5
Clay, yellow	10.0	13.5
Chert gravel	2.0	15.5
PENNSYLVANIAN SYSTEM		
Middle Pennsylvanian Series		
desmoinesian stage		
Limestone	....	15.5

20-25E-3bbb.—Sample log of test hole in NW¼ NW¼ NW¼ sec. 3, T. 20 S., R. 25 E.; augered August 24, 1961. Altitude of land surface, 837 feet.

	Thickness, feet	Depth, feet
QUATERNARY SYSTEM		
Pleistocene Series		
Clay, yellowish-tan	5.5	5.5
Clay, loose chert, red	2.0	7.5
Clay, yellowish-gray	1.0	8.5
PENNSYLVANIAN SYSTEM		
Middle Pennsylvanian Series		
desmoinesian stage		
Limestone	....	8.5

20-25E-4baa.—Sample log of test hole in NE¼ NE¼ NW¼ sec. 4, T. 20 S., R. 25 E., in south road shoulder adjacent to farm house; augered August 28, 1961. Altitude of land surface, 812 ± feet.

	Thickness, feet	Depth, feet
QUATERNARY SYSTEM		
Pleistocene Series		
Clay, dark-brown	3.5	3.5
Clay, yellowish-tan	10.0	13.5
Clay, red	1.0	14.5
Clay, tannish-gray, wet (auger feeds poorly)	9.0	23.5
PENNSYLVANIAN SYSTEM		
Middle Pennsylvanian Series		
desmoinesian stage		
Siltstone, gray	2.0	25.5

20-25E-5aab.—Sample log of test hole in NW¼ NE¼ NE¼ sec. 5, T. 20 S., R. 25 E., in south road shoulder; augered August 28, 1961. Altitude of land surface, 830 ± feet.

	Thickness, feet	Depth, feet
QUATERNARY SYSTEM		
Pleistocene Series		
Clay, dark-brown	2.5	2.5
Clay, yellowish-tan	1.0	3.5
Clay, yellowish-tan, grades to yellow	5.0	8.5
Clay, yellowish-red	10.0	18.5
Clay, reddish-yellow	1.5	20.0
Clay and chert gravel, reddish-yellow (dry)	3.5	23.5
Clay, yellow, contains sparse chert gravel	2.0	25.5
PENNSYLVANIAN SYSTEM		
Middle Pennsylvanian Series		
desmoinesian(?) stage		
Siltstone, gray	....	25.5

20-25E-8bcc.—Sample log of test hole in SW¼ SW¼ NW¼ sec. 8, T. 20 S., R. 25 E., in south road shoulder 75 feet east of W¼ cor. sec. 8; augered August 25, 1961. Altitude of land surface, 837 feet.

	Thickness, feet	Depth, feet
QUATERNARY SYSTEM		
Pleistocene Series		
Clay, yellowish-tan	3.5	3.5
Clay, silty, yellow	5.0	8.5
Clay, yellowish-tan	5.0	13.5
Clay, slightly sandy, yellow	5.0	18.5
Clay, slightly sandy, yellow (moist)	15.0	33.5
PENNSYLVANIAN SYSTEM		
Siltstone, gray	2.0	35.5

20-25E-8bdd.—Sample log of test hole in SE¼ SE¼ NW¼ sec. 8, T. 20 S., R. 25 E., in north road shoulder; augered August 24, 1961. Altitude of land surface, 840 feet.

	Thickness, feet	Depth, feet
QUATERNARY SYSTEM		
Pleistocene Series		
Clay, brown	3.5	3.5
Clay, yellowish-gray	12.0	15.5
Clay, compact, sandy	3.0	18.5
PENNSYLVANIAN SYSTEM		
Middle Pennsylvanian Series		
Desmoinesian Stage		
Limestone (resembles Lenapah Limestone)	....	18.5

20-25E-8dad.—Sample log of test hole in SE¼ NE¼ SE¼ sec. 8, T. 20 S., R. 25 E., on south side of field access road 10 feet west of road center line and 60 feet south of bridge; augered December 8, 1960. Altitude of land surface, 800 feet.

	Thickness, feet	Depth, feet
QUATERNARY SYSTEM		
Pleistocene Series		
Clay, red	3.5	3.5
Clay, slightly sandy, reddish-brown	15.0	18.5
PENNSYLVANIAN SYSTEM		
Middle Pennsylvanian Series		
Desmoinesian Stage		
Siltstone	1.0	19.5

20-25E-9bcc.—Sample log of test hole in SW¼ SW¼ NW¼ sec. 9, T. 20 S., R. 25 E., in center of driveway about 50 feet east of bridge; augered December 8, 1960. Altitude of land surface, 796 feet; depth to water, 11.80 feet.

	Thickness, feet	Depth, feet
QUATERNARY SYSTEM		
Pleistocene Series		
Clay, brown	3.5	3.5
Silt and clay, brown	5.0	8.5
Clay, yellowish-brown	5.0	13.5
Clay and chert gravel	2.5	16.0
Clay, dark yellowish-brown	2.5	18.5
PENNSYLVANIAN SYSTEM		
Middle Pennsylvanian Series		
Desmoinesian Stage		
Shale, yellowish-red	3.0	21.5

20-25E-18aaa.—Sample log of test hole in NE¼ NE¼ NE¼ sec. 18, T. 20 S., R. 25 E., in south road shoulder 100 yards west of NE corner; augered August 25, 1961. Altitude of land surface, 812 feet.

	Thickness, feet	Depth, feet
QUATERNARY SYSTEM		
Pleistocene Series		
Silt and clay, brown	3.0	3.0
Clay, yellow	0.5	3.5
Clay, dark-yellow (moist)	5.0	8.5
Clay, reddish-yellow (dry, resembles bedrock debris)	2.0	10.5
Clay, sandy, reddish-yellow	3.0	13.5
Clay, grayish-yellow	5.0	18.5
Clay, sandy, reddish-yellow	5.0	23.5
Clay, sandy, light-yellow	5.0	28.5
PENNSYLVANIAN SYSTEM		
Bedrock, sandstone(?)	....	28.5

20-25E-19ada.—Sample log of test hole in NE¼ SE¼ NE¼ sec. 19, T. 20 S., R. 25 E., in center of driveway of abandoned service station 0.25 mile south of bridge and 15 feet west of center line of Highway 69; augered December 8, 1960. Altitude of land surface, 793 feet.

	Thickness, feet	Depth, feet
QUATERNARY SYSTEM		
Pleistocene Series		
Silt and clay, reddish-yellow	3.5	3.5
Clay, sandy, yellowish-brown	10.0	13.5
PENNSYLVANIAN SYSTEM		
Middle Pennsylvanian Series		
Desmoinesian Stage		
Limestone	2.5	16.0

20-25E-29cdc.—Sample log of test hole in SW¼ SE¼ SW¼ sec. 29, T. 20 S., R. 25 E.; augered August 24, 1961. Altitude of land surface, 821 feet.

	Thickness, feet	Depth, feet
QUATERNARY SYSTEM		
Pleistocene Series		
Clay, some loose chert gravel, yellow	3.5	3.5
Clay, yellow	3.0	6.5
Clay, some loose chert gravel, yellowish-red	2.0	8.5
PENNSYLVANIAN SYSTEM		
Upper Pennsylvanian Series		
Missourian Stage		
Siltstone, sandy	....	8.5

20-25E-29ddd.—Sample log of test hole in SE¼ SE¼ SE¼ sec. 29, T. 20 S., R. 25 E., in north road shoulder 100 yards west of SE corner; augered August 24, 1961. Altitude of land surface, 840 feet.

	Thickness, feet	Depth, feet
QUATERNARY SYSTEM		
Pleistocene Series		
Clay, silty, tan	1.0	1.0
Soil and clay, tan	1.5	2.5
Clay, tan	1.0	3.5
Clay, yellow	10.0	13.5
Clay and shale	3.0	16.5
PENNSYLVANIAN SYSTEM		
Upper Pennsylvanian Series		
Missourian Stage		
Sandstone(?), weathered, reddish-brown	....	16.5

20-25E-30cdd.—Sample log of test hole in SE¼ SE¼ SW¼ sec. 30, T. 20 S., R. 25 E., in north road shoulder at east boundary of Marais des Cygnes Game Refuge 0.25 mile west of the Lloyd Grosshart farm; augered December 8, 1960. Altitude of land surface, 791 feet; depth to water, 16.00 feet.

	Thickness, feet	Depth, feet
QUATERNARY SYSTEM		
Pleistocene Series		
Clay, brown	3.5	3.5
Clay, slightly sandy, yellowish-brown	10.0	13.5
Clay, sandy, yellowish-brown	5.0	18.5
Clay, very sandy, yellowish-brown (wet)	15.0	33.5
Clay and chert gravel (wet)	3.0	36.5
PENNSYLVANIAN SYSTEM		
Middle Pennsylvanian Series		
Desmoinesian Stage		
Bedrock	....	36.5

20-25E-30dcd.—Sample log of test hole in SE¼ SW¼ SE¼ sec. 30, T. 20 S., R. 25 E., in north road shoulder opposite the Lloyd Grosshart farm home; augered August 24, 1961. Altitude of land surface, 803 feet.

	Thickness, feet	Depth, feet
QUATERNARY SYSTEM		
Pleistocene Series		
Clay, dark yellowish-red	2.5	2.5
Clay, yellow	1.0	3.5
Clay, slightly sandy, yellow	10.0	13.5
Clay, sandy, yellowish-red	5.0	18.5

20-25E-34ccc.—Sample log of test hole in SW¼ SW¼ SW¼ sec. 34, T. 20 S., R. 25 E., in east road shoulder 650 feet north of SW corner; drilled July 11, 1961. Altitude of land surface, 820 feet.

	Thickness, feet	Depth, feet
Soil, silty, brown	2.0	2.0
Clay, yellowish-gray	14.0	16.0
PENNSYLVANIAN SYSTEM		
Upper Pennsylvanian Series		
Missourian(?) Stage		
Pleasanton(?) Group		
Shale, calcareous, gray	4.0	20.0
Shale, thin-bedded, interbedded with limonitic nodules, bluish-gray	10.0	30.0
Shale, thin-bedded, bluish-gray	1.0	31.0
Middle Pennsylvanian Series		
Desmoinesian(?) Stage		
Marmaton(?) Group		
Shale, fissile, hard, black	1.0	32.0
Shale, bluish-gray	7.0	39.0
Shale, fissile, hard, black	1.0	40.0
Shale, blue	5.0	45.0
Limestone, soft, impure, bluish-gray	5.0	50.0
Shale, interbedded thin sandy limestone, gray	10.0	60.0
Shale, bluish-gray	6.0	66.0
Shale, fissile, black, interbedded with gray shale	1.0	67.0
Shale, bluish-gray	3.0	70.0
Shale, fissile, black	1.0	71.0
Shale, bluish-gray	16.0	87.0
Shale, limy, bluish-gray	2.0	89.0
Shale, bluish-gray	1.0	90.0
Shale, hard, bluish-gray	10.0	100.0
Shale, bluish-gray	10.0	110.0
Coal	0.5	110.5
Shale, bluish-gray	8.5	119.0
Shale, sandy, bluish-gray	1.0	120.0
Shale, silty, gray	5.0	125.0
Shale, gray	3.0	128.0
Limestone, moderately hard	2.0	130.0
Coal and silty gray shale (Mulberry? coal)	5.0	135.0
Limestone, hard, gray (Pawnee? Limestone)	2.0	137.0

21-22E-9bbb.—Sample log of test hole in NW¼ NW¼ NW¼ sec. 9, T. 21 S., R. 22 E., in southeast corner of road intersection; augered August 15, 1961.

	Thickness, feet	Depth, feet
QUATERNARY SYSTEM		
Pleistocene Series, undifferentiated		
Colluvium and soil, reddish-brown	3.5	3.5
Colluvium and clay, red	5.0	8.5
Colluvium and clay, tan	5.0	13.5
PENNSYLVANIAN SYSTEM		
Upper Pennsylvanian Series		
Missourian Stage		
Shale, gray	5.0	18.5

21-22E-23cad.—Sample log of test hole in SE¼ NE¼ SW¼ sec. 23, T. 21 S., R. 22 E., in northeast road shoulder 200 yards northwest of low water bridge; augered August 15, 1961.

	Thickness, feet	Depth, feet
QUATERNARY SYSTEM		
Pleistocene Series		
Silt and clay, brown	3.5	3.5
Clay, reddish-brown	21.5	25.0
Clay and chert gravel	1.5	26.5
PENNSYLVANIAN SYSTEM		
Upper Pennsylvanian Series		
Missourian Stage		
Siltstone, bluish-gray	1.0	27.5

21-23E-25acd.—Sample log of test hole in SE¼ SW¼ NE¼ sec. 25, T. 21 S., R. 23 E., in north road shoulder 0.3 mile west of E¼ corner; drilled July 13, 1961. Altitude of land surface, 910 feet.

	Thickness, feet	Depth, feet
Clay and road metal, yellow	10.0	10.0
Clay, yellowish-brown	16.0	26.0
PENNSYLVANIAN SYSTEM		
Upper Pennsylvanian Series		
Missourian Stage		
Pleasanton Group		
Shale, bluish-gray	38.0	64.0
Shale, limy, interbedded with coal	0.1	64.1
Shale, limy, light-gray	5.9	70.0
Shale, light-gray	9.0	79.0
Shale, maroon	5.0	84.0
Middle Pennsylvanian Series		
Desmoinesian Stage		
Marmaton Group		
Shale, fissile, black	2.0	86.0
Shale, dark-gray	8.0	94.0
Limestone	....	94.0

21-24E-9ccd.—Sample log of test hole in SE¼ SW¼ SW¼ sec. 9, T. 21 S., R. 24 E., in driveway at intersection with road; augered August 18, 1961. Altitude of land surface, 800 feet.

	Thickness, feet	Depth, feet
QUATERNARY SYSTEM		
Pleistocene Series		
Clay, silty, light yellowish-brown	3.5	3.5
Clay, silty, light-yellow	5.0	8.5
Silt, yellowish-red (dry)	5.0	13.5
Clay, gray, silty	5.0	18.5
Clay, silty, trace loose chert gravel, reddish-yellow	5.0	23.5
PENNSYLVANIAN SYSTEM		
Middle Pennsylvanian Series		
Desmoinesian Stage		
Siltstone, blue	....	23.5

21-24E-13bdd.—Sample log of test hole in SE¼ SE¼ NW¼ sec. 13, T. 21 S., R. 24 E., in south road shoulder 200 yards west of intersection in center sec. 13; drilled July 19, 1961. Altitude of land surface, 828 feet.

	Thickness, feet	*Depth, feet*
Soil and clay, yellowish-gray	18.0	18.0
PENNSYLVANIAN SYSTEM		
Upper Pennsylvanian Series		
MISSOURIAN STAGE		
Hepler Sandstone Member of Seminole Formation		
Sandstone, limy (drill would not penetrate)	2.0	20.0

21-24E-16aac.—Sample log of test hole in SW¼ NE¼ NE¼ sec. 16, T. 21 S., R. 24 E.; augered August 18, 1961. Altitude of land surface, 795 feet; depth to water, 7.91 feet.

	Thickness, feet	*Depth, feet*
QUATERNARY SYSTEM		
Pleistocene Series		
Clay, dark-brown	3.5	3.5
Clay, silty, yellowish-tan	10.0	13.5
Clay, yellow (wet)	5.0	18.5
Clay, yellow (free water)	10.0	28.5
Clay, dark reddish-brown	5.0	33.5
PENNSYLVANIAN SYSTEM		
Upper Pennsylvanian Series		
MISSOURIAN STAGE		
Shale, maroon	1.0	34.5

21-24E-25bdd.—Sample log of test hole in SE¼ SE¼ NW¼ sec. 25, T. 21 S., R. 24 E.; augered August 23, 1961. Altitude of land surface, 855 feet.

	Thickness, feet	*Depth, feet*
QUATERNARY SYSTEM		
Pleistocene Series, undifferentiated		
Colluvial clay and loose chert gravel, dark-yellow	3.5	3.5
Colluvial clay, sandy, reddish-gray	4.0	7.5
PENNSYLVANIAN SYSTEM		
Upper Pennsylvanian Series		
MISSOURIAN STAGE		
Siltstone, gray	1.0	8.5

21-24E-25dab.—Sample log of test hole in NW¼ NE¼ SE¼ sec. 25, T. 21 S., R. 24 E., south of shed located in abandoned quarry across road from the Frank Woods farm home; drilled July 12, 1961. Altitude of land surface, 812 feet.

	Thickness, feet	*Depth, feet*
Clay and rock fill	3.0	3.0
PENNSYLVANIAN SYSTEM		
Upper Pennsylvanian Series		
MISSOURIAN STAGE		
Hepler Sandstone Member of Seminole Formation		
Sandstone, asphaltic, bluish-black	4.0	7.0
Shale, sandy, calcareous, bluish-gray	3.0	10.0
Shale, calcareous, light bluish-gray	9.0	19.0
Sandstone, asphaltic, bluish-gray	1.0	20.0
Sandstone, calcareous, light-gray	4.0	24.0
Sandstone, asphaltic, bluish-gray	3.0	27.0
Sandstone, asphaltic, locally quite soft, bluish-gray	2.0	29.0
Middle Pennsylvanian Series		
DESMOINESIAN STAGE		
Lenapah Limestone		
Limestone, sandy, light-gray	1.0	30.0
Limestone, very fine, dove-gray	1.0	31.0

21-24E-29bdd.—Sample log of test hole in SE¼ SE¼ NW¼ sec. 29, T. 21 S., R. 24 E., in road opposite driveway; augered August 18, 1961. Altitude of land surface, 813 feet.

	Thickness, feet	*Depth, feet*
QUATERNARY SYSTEM		
Pleistocene Series		
Soil and clay, reddish-brown	3.5	3.5
Clay, dark-brown	5.0	8.5
Clay, silty, yellowish-tan	3.5	12.0
Clay and loose chert gravel	1.5	13.5
Clay	3.0	16.5
PENNSYLVANIAN SYSTEM		
Middle Pennsylvanian Series		
DESMOINESIAN STAGE		
Siltstone, weathered, yellow	....	16.5

21-24E-29dad.—Sample log of test hole in SE¼ NE¼ SE¼ sec. 29, T. 21 S., R. 24 E., in north road shoulder 100 feet east of driveway; augered August 18, 1961. Altitude of land surface, 812 feet; depth to water, 15.30 feet.

	Thickness, feet	*Depth, feet*
QUATERNARY SYSTEM		
Pleistocene Series		
Clay, silty, yellowish-red	3.5	3.5
Clay, light reddish-yellow	20.0	23.5
Clay, trace loose chert gravel, light reddish-yellow	0.5	24.0
Clay, light reddish-yellow	4.5	28.5
Clay, silty, sandy, yellow	1.5	30.0
Clay and loose chert gravel (wet)	1.0	31.0
PENNSYLVANIAN SYSTEM		
Middle Pennsylvanian Series		
DESMOINESIAN STAGE		
Shale	....	31.0

21-24E-33bba.—Sample log of test hole in NE¼ NW¼ NW¼ sec. 33, T. 21 S., R. 24 E., drilled on center line of abandoned road 100 feet south of center line of east-west road; drilled July 12, 1961. Altitude of land surface, 877 feet.

	Thickness, feet	*Depth, feet*
Road fill and clay	10.0	10.0
Subsoil clay, yellow, some chert fragments	10.0	20.0
Subsoil clay, yellow	7.0	27.0
PENNSYLVANIAN SYSTEM		
Upper Pennsylvanian Series		
MISSOURIAN STAGE		
Shale, gray, with trace of maroon shale	3.0	30.0
Shale, interbedded gray and maroon	5.0	35.0

	Thickness, feet	Depth, feet
MIDDLE PENNSYLVANIAN SERIES		
DESMOINESIAN STAGE		
Limestone, sandy, bluish-gray (bluish-green when wet)	5.0	40.0

21-25E-2ccc.—Sample log of test hole in SW¼ SW¼ SW¼ sec. 2, T. 21 S., R. 25 E.; augered August 24, 1961. Altitude of land surface, 808 feet.

	Thickness, feet	Depth, feet
QUATERNARY SYSTEM		
PLEISTOCENE SERIES		
Clay, yellowish-tan	3.5	3.5
Clay, trace black nodular material, yellowish-gray	5.0	8.5
Clay, sandy, grayish-yellow	5.0	13.5
Clay, sandy, yellow	2.0	15.5
PENNSYLVANIAN SYSTEM		
MIDDLE PENNSYLVANIAN SERIES		
DESMOINESIAN STAGE		
Limestone	....	15.5

21-25E-4adc.—Sample log of test hole in SW¼ SE¼ NE¼ sec. 4, T. 21 S., R. 25 E., in north road shoulder 1 mile east of Trading Post; augered August 24, 1961. Altitude of land surface, 804 feet.

	Thickness, feet	Depth, feet
QUATERNARY SYSTEM		
PLEISTOCENE SERIES		
Clay, silty, dark yellowish-tan	3.5	3.5
Clay, yellowish-gray	5.0	8.5
Clay, yellowish-gray (moist)	10.0	18.5
Clay, slightly sandy, yellow (moist)	5.0	23.5
Clay, sandy, reddish-yellow	4.0	27.5
Clay, grayish-yellow	1.0	28.5
Clay, very sandy, loose chert gravel, yellowish-gray (wet)	5.0	33.5
PENNSYLVANIAN SYSTEM		
UPPER PENNSYLVANIAN SERIES		
MISSOURIAN STAGE		
Siltstone, bluish-gray	....	33.5

21-25E-5add.—Sample log of test hole in SE¼ SE¼ NE¼ sec. 5, T. 21 S., R. 25 E., in north road shoulder about 50 feet east of right-angle bend in road; augered August 24, 1961. Altitude of land surface, 805 feet.

	Thickness, feet	Depth, feet
QUATERNARY SYSTEM		
PLEISTOCENE SERIES		
Clay, sandy, yellow	3.5	3.5
Clay, slightly sandy, yellow	7.0	10.5
Clay, gray	2.0	12.5
PENNSYLVANIAN SYSTEM		
UPPER PENNSYLVANIAN SERIES		
MISSOURIAN STAGE		
Bedrock (some sandstone fragments)	....	12.5

21-25E-10add.—Sample log of test hole in SE¼ SE¼ NE¼ sec. 10, T. 21 S., R. 25 E., in west road shoulder opposite driveway; augered August 24, 1961. Altitude of land surface, 788 feet.

	Thickness, feet	Depth, feet
QUATERNARY SYSTEM		
PLEISTOCENE SERIES		
Clay and soil	3.5	3.5
Clay, reddish-yellow	5.0	8.5
Clay, trace loose chert gravel, dark-yellow	5.0	13.5
Chert gravel and clay, reddish-brown	0.5	14.0
Clay and loose chert gravel, reddish-brown	1.5	15.5
Clay, sandy, light-yellow	2.0	17.5
Clay, sandy, and loose chert gravel, light-yellow	1.0	18.5
Clay and chert gravel	6.0	24.5
PENNSYLVANIAN SYSTEM		
MIDDLE PENNSYLVANIAN SERIES		
DESMOINESIAN STAGE		
Bedrock	....	24.5

21-25E-11bbb.—Sample log of test hole drilled in NW¼ NW¼ NW¼ sec. 11, T. 21 S., R. 25 E., 600 feet east and 20 feet south of NW corner. Altitude of land surface, 810 feet.

	Thickness, feet	Depth, feet
Road fill and soil	5.0	5.0
PENNSYLVANIAN SYSTEM		
MIDDLE PENNSYLVANIAN SERIES		
DESMOINESIAN STAGE		
Marmaton Group		
Shale	6.3	11.3
Sandstone	10.0	21.3
Limestone	3.6	24.9
Shale	4.9	29.8
Sandstone bands	8.9	38.7
Shale, dark	2.6	41.3
Slate, sandy	1.8	43.1
Slate, dark	5.4	48.5
Coal (Mulberry)	1.8	50.3
Limestone	....	50.3

21-25E-15aad.—Sample log of test hole in SE¼ NE¼ NE¼ sec. 15, T. 21 S., R. 25 E., in center of road 25 feet east of right-angle bend; augered August 24, 1961. Altitude of land surface, 784 feet; depth to water, 15.72 feet.

	Thickness, feet	Depth, feet
QUATERNARY SYSTEM		
PLEISTOCENE SERIES		
Soil and clay, dark-brown	7.5	7.5
Clay, dark-brown (moist)	1.0	8.5
Clay, silty, grayish-brown (moist)	15.0	23.5
Clay, brownish-gray (dry)	5.0	28.5
Clay, sandy, gray (wet)	10.0	38.5
Clay and gravel, sandy, gray (wet)	15.0	53.5
PENNSYLVANIAN SYSTEM		
MIDDLE PENNSYLVANIAN SERIES		
DESMOINESIAN STAGE		
Siltstone	....	53.5

21-25E-16cdd.—Sample log of test hole in SE¼ SE¼ SW¼ sec. 16, T. 21 S., R. 25 E., in west road shoulder opposite driveway; augered August 21, 1961. Altitude of land surface, 840 feet.

	Thickness, feet	Depth, feet
QUATERNARY SYSTEM		
PLEISTOCENE SERIES		
Soil, silty, sandy, with loose chert gravel, tan	3.0	3.0

Chert gravel, compact	0.5	3.5
Clay, yellow	2.0	5.5
PENNSYLVANIAN SYSTEM		
Upper Pennsylvanian Series		
missourian stage		
Sandstone, weathered	3.0	8.5

21-25E-18dbb.—Sample log of test hole in NW¼ NW¼ SE¼ sec. 18, T. 21 S., R. 25 E.; augered August 18, 1961. Altitude of land surface, 797 feet.

	Thickness, feet	*Depth, feet*
QUATERNARY SYSTEM		
Pleistocene Series		
Clay and soil, dark-brown	3.5	3.5
Clay, silty, yellowish-gray	10.0	13.5
Clay, yellow	20.0	33.5
Clay, gray	5.0	38.5
PENNSYLVANIAN SYSTEM		
Middle Pennsylvanian Series		
desmoinesian stage		
Bedrock	....	38.5

21-25E-19acc.—Sample log of test hole in SW¼ SW¼ NE¼ sec. 19, T. 21 S., R. 25 E., on west side of Highway 69, 1.5 miles north of Pleasanton; augered August 21, 1961. Altitude of land surface, 803 feet.

	Thickness, feet	*Depth, feet*
QUATERNARY SYSTEM		
Pleistocene Series		
Soil and clay, light-tan	3.5	3.5
Clay, sandy, yellow	4.5	8.0
Chert gravey (wet)	0.5	8.5
PENNSYLVANIAN SYSTEM		
Upper Pennsylvanian Series		
missourian(?) stage		
Sandstone(?)	....	8.5

21-25E-22dcd.—Sample log of test hole in SE¼ SW¼ SE¼ sec. 22, T. 21 S., R. 25 E.; augered August 22, 1961. Altitude of land surface, 800 feet.

	Thickness, feet	*Depth, feet*
Soil, dark-brown, and red clay	3.5	3.5
Subsoil clay, yellow	5.0	8.5
Subsoil clay, light-yellow	9.0	17.5
PENNSYLVANIAN SYSTEM		
Middle Pennsylvanian Series		
desmoinesian stage		
Bedrock	....	17.5

22-21E-1aaa.—Sample log of test hole in NE¼ NE¼ NE¼ sec. 1, T. 22 S., R. 21 E.; augered August 15, 1961.

	Thickness, feet	*Depth, feet*
Soil and clay, dark-brown	3.5	3.5
PENNSYLVANIAN SYSTEM		
Upper Pennsylvanian Series		
missourian stage		
Cherryvale Shale		
Shale, light-yellow	3.5	7.0
Dennis Limestone		
Limestone	....	7.0

22-21E-35bbb.—Sample log of test hole in NW¼ NW¼ NW¼ sec. 35, T. 22 S., R. 21 E., in east road shoulder 0.1 mile south of NW corner; drilled July 18, 1961. Altitude of land surface, 1,091 feet.

	Thickness, feet	*Depth, feet*
PENNSYLVANIAN SYSTEM		
Upper Pennsylvanian Series		
missourian stage		
Chanute and Cherryvale Shales		
Clay, with fragments of limonitic sandstone	4.0	4.0
Siltstone, very sandy, hard, yellow	3.0	7.0
Sandstone, limonitic, very hard, yellowish-red	4.0	11.0
Limestone, sandy, gray	3.0	14.0
Shale, gray	2.0	16.0
Coal (Thayer)	0.1	16.1
Shale, bluish-gray	1.9	18.0
Shale, with thin interbedded limestone lenses	2.0	20.0
Shale, calcareous, light-gray	4.0	24.0
Limestone	0.5	24.5
Shale, medium-gray	23.5	48.0
Shale, moderately hard, light-gray	2.0	50.0
Shale, calcareous, hard, light-gray	10.0	60.0
Shale, fissile, black	0.1	60.1
Shale, light-gray	20.9	81.0
Shale, moderately hard, interbedded with thin limestone lenses, light-gray	0.5	81.5
Dennis Limestone		
Limestone, medium-gray	1.5	83.0

22-22E-17dcc.—Sample log of test hole in SW¼ SW¼ SE¼ sec. 17, T. 22 S., R. 22 E., in south road shoulder opposite the Rodgers farm home; augered August 16, 1961.

	Thickness, feet	*Depth, feet*
Soil and clay, silty, yellow	3.5	3.5
Subsoil and clay, yellowish-gray	5.0	8.5
PENNSYLVANIAN SYSTEM		
Upper Pennsylvanian Series		
missourian stage		
Cherryvale Shale		
Clay and weathered shale, yellowish-gray	5.0	13.5
Dennis Limestone		
Limestone	1.0	14.5

22-22E-30aad.—Sample log of test hole in SE¼ NE¼ NE¼ sec. 30, T. 22 S., R. 22 E., in west road shoulder and on crest of hill of dead-end north access road to the Blue Mound city lake; augered July 18, 1961. Altitude of land surface, 1,074 feet.

	Thickness, feet	*Depth, feet*
QUATERNARY SYSTEM		
Pleistocene Series, undifferentiated		
Colluvial clay, dark yellowish-gray	10.0	10.0
PENNSYLVANIAN SYSTEM		
Upper Pennsylvanian Series		
missourian stage		
Chanute and Cherryvale Shales		
Limestone	0.5	10.5
Shale, maroon	7.5	18.0
Shale, gray	2.0	20.0
Shale, bluish-gray	7.0	27.0
Shale, hard, bluish-gray	0.5	27.5
Shale, bluish-gray	7.5	35.0
Shale, hard, bluish-gray	0.1	35.1

	Thickness, feet	Depth, feet
Shale, bluish-gray	4.9	40.0
Shale, coaly, black	0.1	40.1
Shale, bluish-gray	8.9	49.0
Shale, platy, black	1.0	50.0
Shale, gray	5.0	55.0
Shale, interbedded with thin resistant beds	5.0	60.0
Shale, gray	5.0	65.0
Shale, resistant, gray	0.1	65.1
Shale, gray	4.9	70.0
Dennis Limestone		
Limestone	3.0	73.0

22-22E-30adc.—Sample log of test hole in SW¼ SE¼ NE¼ sec. 30, T. 22 S., R. 22 E., in center of parking area at the end of south access road leading to the Blue Mound city lake; drilled July 18, 1961. Altitude of land surface, 1,068 feet.

	Thickness, feet	Depth, feet
QUATERNARY SYSTEM		
Pleistocene Series, undifferentiated		
Colluvial clay, yellow and yellowish-gray	6.0	6.0
Colluvial clay, with fragments of limonitic sandstone	4.0	10.0
PENNSYLVANIAN SYSTEM		
Upper Pennsylvanian Series		
Missourian Stage		
Chanute and Cherryvale Shales		
Shale, interbedded with limonitic sandstone	4.0	14.0
Limestone	0.2	14.2
Shale, gray	5.8	20.0
Shale, interbedded with hard shaly material, gray	19.0	39.0
Shale, fissile, black	1.0	40.0
Shale, gray	7.0	47.0
Shale, fissile, black	0.1	47.1
Shale, gray	12.9	60.0
Dennis Limestone		
Limestone, fine-grained, dark-gray	3.0	63.0

22-22E-32aaa.—Sample log of test hole in NE¼ NE¼ NE¼ sec. 32, T. 22 S., R. 22 E., in south road shoulder 0.5 mile south of Blue Mound; augered August 16, 1961.

	Thickness, feet	Depth, feet
Soil and clay, dark-brown	3.5	3.5
Subsoil clay, yellowish-red	4.0	7.5
PENNSYLVANIAN SYSTEM		
Upper Pennsylvanian Series		
Missourian Stage		
Cherryvale Shale		
Shale	0.1	7.6
Dennis Limestone		
Limestone	....	7.6

22-23E-3cbb.—Sample log of test hole in NW¼ NW¼ SW¼ sec. 3, T. 22 S., R. 23 E., in west shoulder of driveway 150 yards south of right-angle bend in driveway.

	Thickness, feet	Depth, feet
Soil, dark-brown	1.0	1.0
QUATERNARY SYSTEM		
Pleistocene Series		
Clay, yellowish-tan	2.5	3.5
Clay, reddish-yellow	5.0	8.5
Clay and loose chert gravel	5.0	13.5
PENNSYLVANIAN SYSTEM		
Middle Pennsylvanian Series		
Desmoinesian Stage		
Siltstone, weathered	....	13.5

22-23E-3ccb.—Sample log of test hole in NW¼ SW¼ SW¼ sec. 3, T. 22 S., R. 23 E., in west shoulder of driveway about 100 yards north of low-water bridge; augered August 17, 1961.

	Thickness, feet	Depth, feet
Soil, dark-brown	1.0	1.0
QUATERNARY SYSTEM		
Pleistocene Series		
Clay, tan	2.5	3.5
Clay, reddish-tan	5.0	8.5
Clay, yellow	1.5	10.0
Clay and loose chert gravel	2.5	12.5
PENNSYLVANIAN SYSTEM		
Middle Pennsylvanian Series		
Desmoinesian Stage		
Shale, yellow	....	12.5

22-23E-7dab.—Sample log of test hole in NW¼ NE¼ SE¼ sec. 7, T. 22 S., R. 23 E., in south road shoulder 25 feet east of bridge; augered August 17, 1961.

	Thickness, feet	Depth, feet
Clay, silty, reddish-brown	3.5	3.5
QUATERNARY SYSTEM		
Pleistocene Series		
Clay, reddish-brown	15.0	18.5
Clay, with some loose chert gravel, gray	3.0	21.5
PENNSYLVANIAN SYSTEM		
Middle Pennsylvanian Series		
Desmoinesian Stage		
Shale, gray	....	21.5

22-23E-8cca.—Sample log of test hole in NE¼ SW¼ SW¼ sec. 8, T. 22 S., R. 23 E., in west road shoulder 50 feet north of intersection of abandoned railroad grade and road at Critzer, Kans.; augered August 17, 1961. Depth to water, 14.72 feet.

	Thickness, feet	Depth, feet
Soil and clay, dark-brown	3.5	3.5
QUATERNARY SYSTEM		
Pleistocene Series		
Clay, dark reddish-brown	10.0	13.5
Clay, with some loose chert gravel, reddish-brown	5.0	18.5
PENNSYLVANIAN SYSTEM		
Upper Pennsylvanian Series		
Missourian Stage		
Bedrock	1.0	19.5

22-23E-9abb.—Sample log of test hole in NW¼ NW¼ NE¼ sec. 9, T. 22 S., R. 23 E.; augered August 17, 1961. Altitude of land surface, 904 feet.

	Thickness, feet	Depth, feet
Clay, silty, reddish-brown	3.5	3.5
QUATERNARY SYSTEM		
Pleistocene Series		
Clay, limonite-stained, gray	3.0	6.5

	Thickness, feet	Depth, feet
Clay, yellow	2.0	8.5
Clay, yellowish-tan	5.0	13.5
Clay, compact with sandstone fragments, yellow	5.0	18.5
Clay, yellow	2.0	20.5
PENNSYLVANIAN SYSTEM		
Bedrock	....	20.5

22-23E-9acc.—Sample log of test hole in SW¼ SW¼ NE¼ sec. 9, T. 22 S., R. 23 E., in east road shoulder opposite the Dingus farm home; augered August 17, 1961.

	Thickness, feet	Depth, feet
Soil and road fill, dark-brown	3.5	3.5
QUATERNARY SYSTEM		
Pleistocene Series		
Clay, yellow and gray	5.0	8.5
Clay, yellow and red	5.0	13.5
Clay, yellowish-red	3.0	16.5
PENNSYLVANIAN SYSTEM		
Shale	....	16.5

22-23E-9dcc.—Sample log of test hole in SW¼ SW¼ SE¼ sec. 9, T. 22 S., R. 23 E., in east road shoulder opposite the Dingus driveway 100 yards south of bridge; augered August 17, 1961.

	Thickness, feet	Depth, feet
Soil and clay, silty, tan	3.5	3.5
QUATERNARY SYSTEM		
Pleistocene Series		
Clay, dark-tan	5.0	8.5
Clay, silty, brown	10.0	18.5
Clay and loose chert gravel (moist)	4.0	22.5
PENNSYLVANIAN SYSTEM		
Siltstone, blue	1.0	23.5

22-23E-11bbc.—Sample log of test hole in SW¼ NW¼ NW¼ sec. 11, T. 22 S., R. 23 E.; augered August 17, 1961. Depth to water, 11.90 feet.

	Thickness, feet	Depth, feet
Soil and clay, dark-brown	3.5	3.5
QUATERNARY SYSTEM		
Pleistocene Series		
Clay, grayish-brown	10.0	13.5
Clay, gray	5.0	18.5
Clay, grayish-tan	5.0	23.5
PENNSYLVANIAN SYSTEM		
Middle Pennsylvanian Series		
Desmoinesian stage		
Limestone	....	23.5

22-23E-11cbb.—Sample log of test hole in NW¼ NW¼ SW¼ sec. 11, T. 22 S., R. 23 E., in east road shoulder 100 yards north of low-water bridge; augered August 17, 1961.

	Thickness, feet	Depth, feet
Soil, dark-brown	3.5	3.5
QUATERNARY SYSTEM		
Pleistocene Series		
Clay, reddish-brown	2.5	6.0
Clay and loose gravel, reddish-brown	2.5	8.5

	Thickness, feet	Depth, feet
PENNSYLVANIAN SYSTEM		
Middle Pennsylvanian Series		
Desmoinesian stage		
Limestone	....	8.5

22-24E-2acc.—Sample log of test hole in SW¼ SW¼ NE¼ sec. 2, T. 22 S., R. 24 E.; augered August 23, 1961. Altitude of land surface, 902 feet.

	Thickness, feet	Depth, feet
Soil, dark-brown	1.0	1.0
QUATERNARY SYSTEM		
Pleistocene Series, undifferentiated		
Colluvial clay, yellow	2.5	3.5
Colluvial clay, yellowish-gray	5.0	8.5
Colluvial clay, compact, yellow	5.0	13.5
Colluvial clay, yellow	8.0	21.5
PENNSYLVANIAN SYSTEM		
Siltstone	....	21.5

22-24E-2bab.—Sample log of test hole in NW¼ NE¼ NW¼ sec. 2, T. 22 S., R. 24 E.; drilled July 19, 1961. Altitude of land surface, 900 feet.

	Thickness, feet	Depth, feet
Clay, dark-gray	12.0	12.0
PENNSYLVANIAN SYSTEM		
Upper Pennsylvanian Series		
Missourian stage		
Hepler Sandstone Member of Seminole Formation		
Shale, fragments of asphaltic sandstone, gray	8.0	20.0
Middle Pennsylvanian Series		
Desmoinesian stage		
Marmaton Group		
Shale, sandy, light-gray	10.0	30.0
Shale, bluish-gray	7.0	37.0
Shale, fissile, black	0.5	37.5
Shale, gray, interbedded with light-gray clayey shale	2.5	40.0
Shale, light-gray	4.0	44.0
Limestone, soft, upper weathered surface bluish-gray	3.0	47.0

22-24E-2dda.—Sample log of test hole in NE¼ SE¼ SE¼ sec. 2, T. 22 S., R. 24 E., in west road shoulder 0.26 mile south of E¼ corner; drilled July 12, 1961. Altitude of land surface, 890 feet.

	Thickness, feet	Depth, feet
QUATERNARY SYSTEM		
Pleistocene Series, undifferentiated		
Colluvial clay, yellowish-gray	15.0	15.0
PENNSYLVANIAN SYSTEM		
Upper Pennsylvanian Series		
Missourian stage		
Pleasanton Group		
Shale, clay, light yellowish-gray	5.0	20.0
Shale, clay, gray	5.0	25.0
Shale, sandy, yellow	4.0	29.0
Sandstone, asphaltic, bluish-gray	5.0	34.0
Shale, interbedded with sandstone, bluish-gray	6.0	40.0
Middle Pennsylvanian Series		
Desmoinesian stage		
Marmaton(?) Group		
Shale, bluish-gray; hard bed 0.1 foot at 40 feet	10.0	50.0

	Thickness, feet	Depth, feet
Shale, clay, bluish-gray	5.0	55.0
Shale, fissile, black	2.0	57.0
Shale, light-gray	3.0	60.0
Shale, blue	2.0	62.0
Shale, light-gray	4.0	66.0
Sandstone, calcareous, light-gray	2.0	68.0
Sandstone, asphaltic, bluish-gray (asphaltic smell)	2.0	70.0
Sandstone, asphaltic, interbedded with limonitic clay	7.0	77.0
Sandstone, asphaltic	3.0	80.0

22-24E-3cba.—Sample log of test hole in NE¼ NW¼ SW¼ sec. 3, T. 22 S., R. 24 E., in south road shoulder 100 yards west of south driveway; drilled July 19, 1961. Altitude of land surface, 940 feet.

	Thickness, feet	Depth, feet
QUATERNARY SYSTEM		
Pleistocene Series, undifferentiated		
Colluvial clay, red	20.0	20.0
Colluvial clay, yellow	8.0	28.0
PENNSYLVANIAN SYSTEM		
Upper Pennsylvanian Series		
missourian stage		
Pleasanton Group		
Shale, yellowish-gray	2.0	30.0
Shale, blue	10.0	40.0
Shale, bluish-green	5.0	45.0
Limestone	0.5	45.5
Shale, interbedded locally with thin limestone lenses	4.5	50.0
Shale, bluish-green	9.0	59.0
Shale, bluish-green, interbedded with thin limestone lenses	1.0	60.0
Shale, bluish-gray	2.0	62.0
Shale, interbedded with black sandstone	1.0	63.0
Shale, bluish-gray	6.0	69.0
Middle Pennsylvanian Series		
desmoinesian stage		
Marmaton Group		
Coal	1.0	70.0
Shale, interbedded gray and black	6.0	76.0
Shale, light grayish-green	3.0	79.0
Limestone (incomplete penetration)	1.0	80.0

22-24E-7bdd.—Sample log of test hole in SE¼ SE¼ NW¼ sec. 7, T. 22 S., R. 24 E., in center of road intersection; augered August 17, 1961. Altitude of land surface, 840 feet; depth to water, 11.29 feet.

	Thickness, feet	Depth, feet
Soil, dark-brown	3.5	3.5
QUATERNARY SYSTEM		
Pleistocene Series		
Clay, silty, yellowish-tan	5.0	8.5
Clay, reddish-gray grading to yellowish-red	5.0	13.5
Clay, dark reddish-brown	13.0	26.5
PENNSYLVANIAN SYSTEM		
Middle Pennsylvanian Series		
desmoinesian stage		
Siltstone, blue	2.0	28.5

22-24E-10daa.—Sample log of test hole in NE¼ NE¼ SE¼ sec. 10, T. 22 S., R. 24 E.; augered August 23, 1961. Altitude of land surface, 873 feet.

	Thickness, feet	Depth, feet
QUATERNARY SYSTEM		
Pleistocene Series, undifferentiated		
Colluvial clay, silty, light-yellow	3.5	3.5
Colluvial clay, grayish-yellow	5.0	8.5
Colluvial clay, silty, yellow	7.0	15.5
PENNSYLVANIAN SYSTEM		
Middle Pennsylvanian Series		
desmoinesian stage		
Bedrock	....	15.5

22-24E-11ddd.—Sample log of test hole in SE¼ SE¼ SE¼ sec. 11, T. 22 S., R. 24 E.; augered August 23, 1961. Altitude of land surface, 838 feet.

	Thickness, feet	Depth, feet
QUATERNARY SYSTEM		
Pleistocene Series		
Clay, silty, brown	3.5	3.5
Clay, silty, yellow	5.0	8.5
Clay, silty, tan	7.0	15.5
PENNSYLVANIAN SYSTEM		
Middle Pennsylvanian Series		
desmoinesian stage		
Siltstone, gray	....	15.5

22-24E-16ccb.—Sample log of test hole in NW¼ SW¼ SW¼ sec. 16, T. 22 S., R. 24 E., at head of driveway in the Greer farm barnyard; drilled July 13, 1961. Altitude of land surface, 910 feet.

	Thickness, feet	Depth, feet
QUATERNARY SYSTEM		
Pleistocene Series, undifferentiated		
Colluvial clay, yellow	5.0	5.0
PENNSYLVANIAN SYSTEM		
Upper Pennsylvanian Series		
missourian stage		
Pleasanton Group		
Siltstone, interbedded with thin limonitic zones, yellowish-gray	5.0	10.0
Shale, light-gray	10.0	20.0
Shale, maroon	5.0	25.0
Middle Pennsylvanian Series		
desmoinesian stage		
Marmaton Group		
Shale, light-gray	4.0	29.0
Coal, very soft	1.0	30.0
Shale, medium-gray	3.0	33.0
Shale, light-gray	6.0	39.0
Limestone, sandy, soft (probably weathered zone)	1.0	40.0
Limestone, very hard	3.0	43.0

22-24E-31dcc.—Sample log of test hole in SW¼ SW¼ SE¼ sec. 31, T. 22 S., R. 24 E., in north road shoulder; drilled July 12, 1961. Altitude of land surface, 905 feet.

	Thickness, feet	Depth, feet
QUATERNARY SYSTEM		
Pleistocene Series, undifferentiated		
Colluvial clay, yellow	14.0	14.0
PENNSYLVANIAN SYSTEM		
Upper Pennsylvanian Series		
missourian stage		
Pleasanton Group		
Shale, hard, weathered, yellow	0.1	14.1
Shale, calcareous	5.9	20.0

	Thickness, feet	Depth, feet
Shale, light bluish-gray	9.0	29.0
Limestone, sandy	1.0	30.0

22-25E-5ccc.—Sample log of test hole in SW¼ SW¼ SW¼ sec. 5, T. 22 S., R. 25 E., in north road shoulder 100 feet east of SW corner; augered August 23, 1961. Altitude of land surface, 831 feet.

	Thickness, feet	Depth, feet
QUATERNARY SYSTEM		
PLEISTOCENE SERIES		
Clay, dark-brown	3.5	3.5
Clay, silty, yellowish-gray	10.0	13.5
Clay, yellow	10.0	23.5
Clay, yellow (moist)	2.0	25.5
PENNSYLVANIAN SYSTEM		
MIDDLE PENNSYLVANIAN SERIES		
DESMOINESIAN STAGE		
Bedrock	....	25.5

22-25E-5dcc1.—Sample log of test hole in SW¼ SW¼ SE¼ sec. 5, T. 22 S., R. 25 E., at head of driveway 50 feet south of the Kelley farm home; drilled July 20, 1961. Altitude of land surface, 812 feet.

	Thickness, feet	Depth, feet
QUATERNARY SYSTEM		
PLEISTOCENE SERIES		
Clay, yellow	10.0	10.0
Clay, slightly sandy, yellow	5.0	15.0
Limonitic nodules	0.5	15.5
Clay, slightly sandy, yellow	4.5	20.0
PENNSYLVANIAN SYSTEM		
MIDDLE PENNSYLVANIAN SERIES		
DESMOINESIAN STAGE		
Nowata Shale		
Shale, clay, gray	3.0	23.0
Altamont Limestone		
Limestone, moderately hard, light-gray	4.0	27.0
Bandera Shale		
Shale, bluish gray-green	3.0	30.0
Shale, light-gray	5.0	35.0
Sandstone, asphaltic, interbedded with thin shale	5.0	40.0
Sandstone, asphaltic, dark-blue	5.0	45.0
Shale, bluish-gray	32.0	77.0
Coal (Mulberry)	2.0	79.0
Shale, clay, gray	5.0	84.0
Pawnee Limestone		
Limestone (not penetrated)	2.0	86.0

22-25E-5dcc2.—Sample log of test hole in SW¼ SW¼ SE¼ sec. 5, T. 22 S., R. 25 E.; augered August 23, 1961. Altitude of land surface, 824 feet.

	Thickness, feet	Depth, feet
QUATERNARY SYSTEM		
PLEISTOCENE SERIES		
Clay, silty, light-tan	3.5	3.5
Clay, silty, yellowish-tan	5.0	8.5
Clay, some silt and sand, yellow	5.0	13.5
Clay, sandy, yellow	8.0	21.5
PENNSYLVANIAN SYSTEM		
Bedrock (limestone?)	....	21.5

22-25E-6bbb.—Sample log of test hole in NW¼ NW¼ NW¼ sec. 6, T. 22 S., R. 25 E.; augered August 22, 1961. Altitude of land surface, 860 feet.

	Thickness, feet	Depth, feet
QUATERNARY SYSTEM		
PLEISTOCENE SERIES, undifferentiated		
Colluvial (?) clay, silty, yellow	3.5	3.5
Colluvial(?) clay, yellowish-red	5.0	8.5
Colluvial(?) clay, light yellowish-gray	5.0	13.5
PENNSYLVANIAN SYSTEM		
UPPER PENNSYLVANIAN SERIES		
MISSOURIAN STAGE		
Hepler Sandstone Member of Seminole Formation		
Sandstone(?)	....	13.5

22-25E-8aaa.—Sample log of test hole in NE¼ NE¼ NE¼ sec. 8, T. 22 S., R. 25 E.; augered August 23, 1961. Altitude of land surface, 808 feet; depth to water, 8.60 feet.

	Thickness, feet	Depth, feet
QUATERNARY SYSTEM		
PLEISTOCENE SERIES		
Clay, silty, reddish-brown	3.5	3.5
Clay, loose chert gravel, reddish-tan	5.0	8.5
Clay, sandy, loose chert gravel, reddish-tan	5.0	13.5
PENNSYLVANIAN SYSTEM		
MIDDLE PENNSYLVANIAN SERIES		
DESMOINESIAN STAGE		
Siltstone, gray	....	13.5

22-25E-8aab.—Sample log of test hole in NW¼ NE¼ NE¼ sec. 8, T. 22 S., R. 25 E.; augered August 23, 1961. Altitude of land surface, 812 feet; depth to water, 15.50 feet.

	Thickness, feet	Depth, feet
QUATERNARY SYSTEM		
PLEISTOCENE SERIES		
Clay, silty, grayish-brown	3.5	3.5
Clay, silty, contains some loose chert gravel, grayish-tan	5.0	8.5
Clay, silty, yellowish-tan	5.0	13.5
Clay, contains some loose chert gravel, dark yellowish-gray (moist)	5.0	18.5
PENNSYLVANIAN SYSTEM		
MIDDLE PENNSYLVANIAN SERIES		
DESMOINESIAN STAGE		
Siltstone, gray	....	18.5

23-21E-2aaa.—Sample log of test hole in NE¼ NE¼ NE¼ sec. 2, T. 23 S., R. 21 E.; augered August 16, 1961.

	Thickness, feet	Depth, feet
Soil, brown	1.5	1.5
Subsoil clay, yellowish-tan	2.0	3.5
Subsoil clay, reddish-brown	5.0	8.5
PENNSYLVANIAN SYSTEM		
UPPER PENNSYLVANIAN SERIES		
MISSOURIAN STAGE		
Cherryvale Shale		
Shale	....	8.5

23-23E-10aaa.—Sample log of test hole in NE¼ NE¼ NE¼ sec. 10, T. 23 S., R. 23 E., in west road shoulder 100 yards south of bend in road; drilled July 17, 1961. Altitude of land surface, 920 feet.

	Thickness, feet	Depth, feet
QUATERNARY SYSTEM		
Pleistocene Series, undifferentiated		
Colluvial clay, red	10.0	10.0
Colluvial clay, compact, yellow	0.5	10.5
Colluvial clay, yellow	16.5	27.0
PENNSYLVANIAN SYSTEM		
Upper Pennsylvanian Series		
Missourian stage		
Pleasanton(?) Group		
Limestone(?)	1.0	28.0
Shale, blue	4.0	32.0
Coal	0.5	32.5
Shale, light-gray	7.5	40.0
Shale, bluish-gray	6.0	46.0
Shale, fissile, black	0.5	46.5
Shale, bluish-gray	3.5	50.0
Shale, bluish-green	7.0	57.0
Shale, interbedded bluish-green and maroon	3.0	60.0
Shale, maroon	2.0	62.0
Middle Pennsylvanian Series		
Desmoinesian stage		
Marmaton(?) Group		
Shale, interbedded with thin sandstone beds, bluish-green	8.0	70.0
Shale, interbedded with thin hard sandstone beds	10.0	80.0
Shale, hard, brittle, calcareous, dark	7.0	87.0
Limestone	....	87.0

23-23E-10aad.—Sample log of test hole in SE¼ NE¼ NE¼ sec. 10, T. 23 S., R. 23 E., in west road shoulder 100 yards south of driveway; augered August 16, 1961. Altitude of land surface, 925 feet.

	Thickness, feet	Depth, feet
Clay, silty, yellowish-tan	3.5	3.5
QUATERNARY SYSTEM		
Pleistocene Series		
Clay, dark reddish-brown	5.0	8.5
Clay, reddish-tan	10.0	18.5
Clay, silty, tan	5.0	23.5
Clay, yellowish-gray	1.5	25.0
PENNSYLVANIAN SYSTEM		
Shale	3.5	28.5

23-23E-10daa.—Sample log of test hole in NE¼ NE¼ SE¼ sec. 10, T. 23 S., R. 23 E.; augered August 16, 1961. Altitude of land surface, 895 feet.

	Thickness, feet	Depth, feet
Clay soil, dark-brown	3.5	3.5
QUATERNARY SYSTEM		
Pleistocene Series		
Clay, dark grayish-brown	5.0	8.5
Clay, light yellowish-tan	2.5	11.0
Clay and loose chert gravel, yellow	0.5	11.5
Clay, light yellowish-tan	2.0	13.5
PENNSYLVANIAN SYSTEM		
Siltstone, yellowish-tan	5.0	18.5

23-23E-11ccc.—Sample log of test hole in SW¼ SW¼ SW¼ sec. 11, T. 23 S., R. 23 E.; augered August 17, 1961. Altitude of land surface, 877 feet.

	Thickness, feet	Depth, feet
Soil, brown	1.0	1.0
QUATERNARY SYSTEM		
Pleistocene Series		
Clay, yellowish-gray	2.5	3.5
Clay, gray	3.0	6.5
PENNSYLVANIAN SYSTEM		
Upper Pennsylvanian Series		
Missourian stage		
Shale, red	2.0	8.5

23-24E-6ccc.—Sample log of test hole in SW¼ SW¼ SW¼ sec. 6, T. 23 S., R. 24 E., in north road shoulder opposite farm pond; drilled July 17, 1961. Altitude of land surface, 895 feet.

	Thickness, feet	Depth, feet
QUATERNARY SYSTEM		
Pleistocene Series, undifferentiated		
Colluvial clay, yellowish-gray	20.0	20.0
PENNSYLVANIAN SYSTEM		
Upper Pennsylvanian Series		
Missourian(?) stage		
Pleasanton(?) Group		
Shale, interbedded with thin limestone lenses, limonitic	5.0	25.0
Shale, gray	3.0	28.0
Limestone	1.0	29.0

23-24E-8bba.—Sample log of test hole in NE¼ NW¼ NW¼ sec. 8, T. 23 S., R. 24 E.; augered August 17, 1961. Altitude of land surface, 873 feet.

	Thickness, feet	Depth, feet
Soil, dark-brown	1.0	1.0
QUATERNARY SYSTEM		
Pleistocene Series		
Clay, yellowish-gray	2.5	3.5
Clay, reddish-brown	5.0	8.5
Clay, yellow and red	2.0	10.5
Clay, some loose chert gravel, reddish-yellow	1.0	11.5
PENNSYLVANIAN SYSTEM		
Middle Pennsylvanian Series		
Desmoinesian stage		
Shale	....	11.5

23-25E-9bbb.—Sample log of test hole in NW¼ NW¼ NW¼ sec. 9, T. 23 S., R. 25 E., in east road shoulder 50 feet south of intersection; drilled July 20, 1961. Altitude of land surface, 843 ± feet.

	Thickness, feet	Depth, feet
Soil and road fill	5.0	5.0
PENNSYLVANIAN SYSTEM		
Middle Pennsylvanian Series		
Desmoinesian stage		
Pawnee Limestone		
Shale, gray with some black	5.0	10.0
Labette Shale		
Shale, gray, sandy, locally quite hard, several inches of black platy shale at 20 feet	10.0	20.0
Shale, gray, sandy, local thin limy zones present	10.0	30.0
Shale, gray, sandy, becomes gradually darker	10.0	40.0
Shale, light-gray	5.0	45.0
Sandstone, gray	4.0	49.0
Shale, gray	1.0	50.0
Shale, bluish-gray	6.0	56.0
Fort Scott Limestone		
Limestone	....	56.0

23-25E-11abb.—Sample log of test hole in NW¼ NW¼ NE¼ sec. 11, T. 23 S., R. 25 E., in north bank of lead zinc strip pit, 0.51 mile east and 530 feet south of NW cor. sec. 11; drilled July 20, 1961. Altitude of land surface, 830 feet.

	Thickness, feet	*Depth, feet*
Road fill and clay	10.0	10.0
QUATERNARY SYSTEM		
PLEISTOCENE SERIES, undifferentiated		
Colluvial clay	7.0	17.0
PENNSYLVANIAN SYSTEM		
MIDDLE PENNSYLVANIAN SERIES		
DESMOINESIAN STAGE		
Coal and shale, gray	3.0	20.0
Bandera Shale		
Shale	2.0	22.0
Pawnee Limestone		
Limestone	....	22.0

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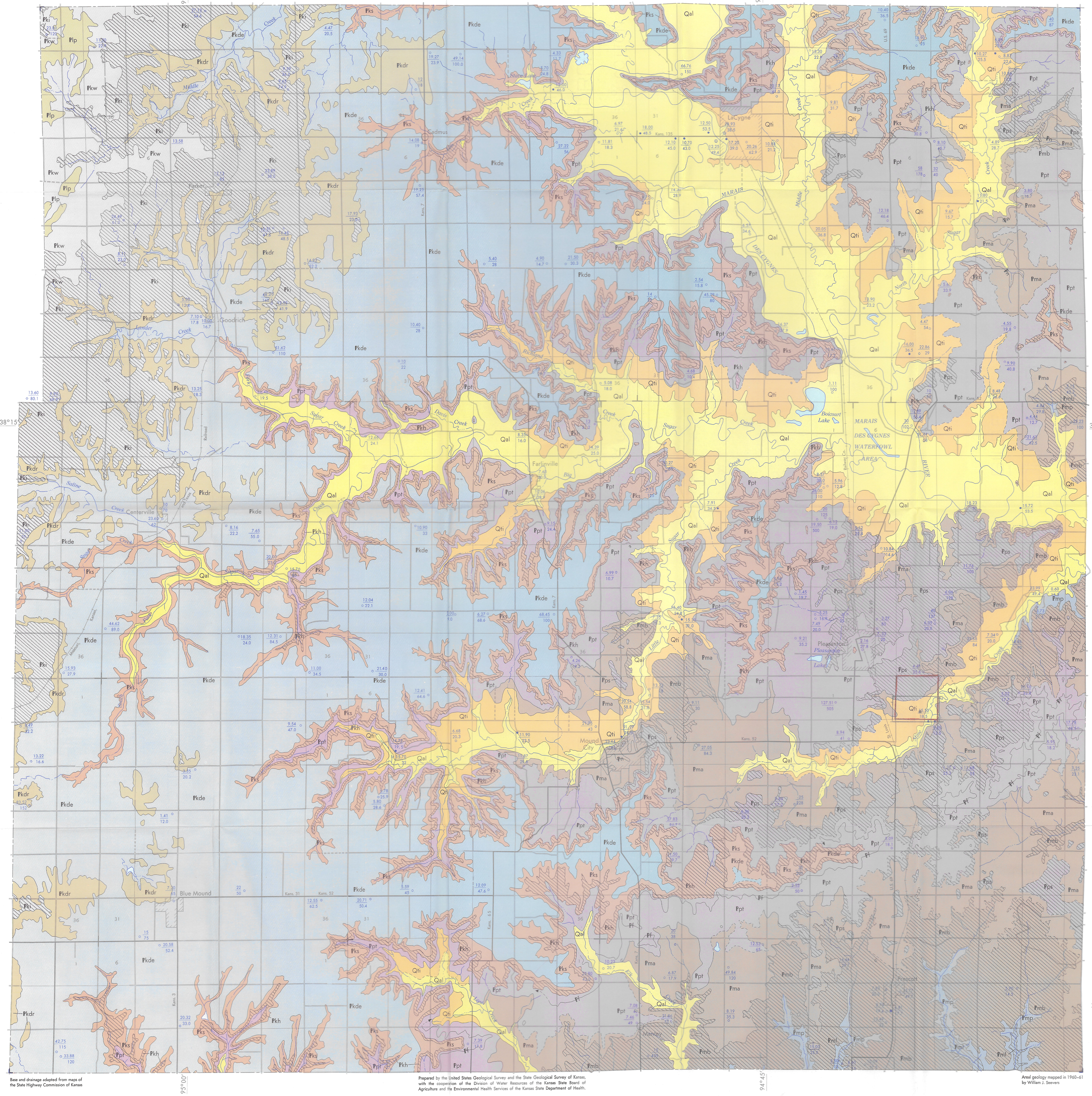
State Geological Survey
of Kansas

GEOLOGIC MAP OF LINN COUNTY, KANSAS

Bulletin 193
Plate 1



Base and drainage adapted from maps of the State Highway Commission of Kansas

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

Areal geology mapped in 1960–61 by William J. Seevers

0 1 2 3 4 MILES

EXPLANATION

QUATERNARY SYSTEM

Pleistocene Series

Qal

Wisconsinan and Recent alluvial deposits

Silt, clay, sand, and gravel in and adjacent to present streams and underlying the surface of a low terrace in the principal stream valleys. Generally small supplies of water are available; however, locally yields up to 100 gpm can be obtained.

Qti

Illinoisan terrace deposits

Silt, clay, sand, and gravel underlying a prominent intermediate terrace adjacent to the major stream valleys. Yields commonly 10 gpm or less; however, yields of 30 gpm can be obtained locally.

PENNSYLVANIAN SYSTEM

Upper Pennsylvanian Series

LANSING GROUP

Plp

Plattsburg Limestone

Erosional remnants of a fine- to medium-crystalline and fossiliferous limestone. Generally only small quantities of water are available from this unit.

KANSAS CITY GROUP

Pkw

Wyandotte Limestone and Bonner Springs Shale

The Wyandotte Limestone is best developed in the northwestern part of the area where it is a light bluish-gray, wavy-bedded limestone. This unit thins southward. The Bonner Springs Shale is a gray to buff shale with a persistent sandstone bed in the basal part. The Wyandotte yields only small supplies of water. Small quantities of water are available to wells from the sandstone of the Bonner Springs in local areas.

Pki

Iola Limestone and Lane Shale

The Iola Limestone consists of two limestone members and an intervening shale member. The lower member is a dense blue massive limestone, and the upper member is a thin wavy-bedded light-gray limestone. The middle shale member is gray clay shale in the upper part and dark platy shale in the lower part. The Lane Shale is a noncalcareous bluish-gray clay shale. Only meager supplies of water are available from these units in the area.

Pkdr

Drum Limestone and Chanute Shale

The Drum Limestone consists of two limestone members locally separated by a thin shale. The lower member is brown massive-bedded fossiliferous limestone. The upper member is a reddish-brown oölitic limestone. The Chanute Shale consists of sandstone in the upper part and an olive-green clay shale in the lower part. The two beds are separated by a coal bed. Little or no water is available from the Drum Limestone, but locally small supplies of water are available from the sandstone in the Chanute.

Pkde

Dennis Limestone and Cherryvale Shale

The Dennis Limestone is composed of two limestone members separated by a shale member which is a gray blocky shale in the upper part and a black platy shale in the lower part. The lower limestone member is a thin dense blue limestone displaying vertical joints. The upper limestone member is a thick wavy-bedded cherty limestone. The Cherryvale Shale is composed of three shale members and two limestone members. The lower limestone is a thin dense bluish-gray limestone. The upper limestone is discontinuous. The shales are gray and olive-green. Small to moderate supplies of water are available from the Dennis Limestone.

Pks

Swope Limestone and Galesburg Shale

The Swope Limestone is composed of two limestone members separated by a black fissile shale. The lower limestone member is a dark-blue dense limestone. The upper member is massive to thin-bedded, cherty limestone with a thin oölitic limestone at the top. The Galesburg Shale is a thin gray shale locally containing a thin sandstone bed in the basal part. Small to moderate supplies of water are available from the Swope Limestone.

Pkh

Hertha Limestone and Ladore Shale

The Hertha Limestone is composed of two limestone members separated by a gray to dark-gray shale member. The lower limestone member is a silty, nodular brown limestone, but locally it is composed of an algal limestone. The upper member is a brown massive-bedded limestone. The Ladore Shale is a brown-weathering calcareous shale locally containing a thin limestone bed. Little or no water is obtained from these units.

PLEASANTON GROUP

Ppt
— **Pf** —

Tacket Formation

The Tacket Formation is composed primarily of gray to buff, thin-bedded, micaceous siltstone but locally contains sandstone beds in the upper part and a flaggy limestone bed, the base of which is mapped as Pf. Only very small quantities of water are obtained from wells in this formation.

Pps

Seminole Formation

This formation is composed primarily of sandstone having a considerable range in thickness over the area. Small supplies of water are available where the sandstone is favorably situated to receive recharge.

Middle Pennsylvanian Series

MARMATON GROUP

Pma
— **Pn** —

Altamont Limestone, Nowata Shale, Lenapah Limestone, and Holdenville Shale

This unit is composed of two limestone formations and two shale formations. Pn marks the base of the Lenapah Limestone. Each of the limestone formations is divided into two limestone members and an intervening shale member. The Nowata Shale is a light-gray shale locally containing a fine-grained sandstone in the basal part. The Holdenville Shale is a gray clay shale which locally contains a coal bed in the lower part. Small quantities of water may be obtained locally from weathered limestones in this unit.

Pmb

Bandera Shale

Thick beds of sandy siltstone and sandstone comprise this unit. A persistent coal occurs near the base of the unit, and sandstone is common in the upper part. Little or no water is obtained from the Bandera.

Pmp

Pawnee Limestone

This formation is composed of two shale members and two limestone members. The lower shale member is black fissile shale and gray clay shale. The upper shale member is gray containing carbonaceous streaks and a persistent limestone near the top. The lower limestone member is dense bluish-gray limestone, and the upper limestone is a light-gray crystalline limestone. Little water is available from the Pawnee limestone.

Pml

Labette Shale

The Labette Shale is composed of gray sandy shale and black shale. Little or no water is obtained from this unit in the area.

Geologic contact (dashed where approximate)

- Test hole
- Domestic or school well
- Public supply well
- Observation well
- Spring

True North
Magnetic North
8°
APPROXIMATE MEAN DECLINATION, 1966

$\frac{5.90}{14.5}$

Upper number is depth to water below land surface, in feet. Reported depths shown to nearest foot; measured depths shown to nearest hundredth of foot. Lower number is depth of well below land surface, in feet. Reported depths shown to nearest foot; measured depths shown to nearest tenth of foot.