Geology, Mineral Resources, and Ground-Water Resources of Lyon County, Kansas

PART 1
ROCK FORMATIONS OF LYON COUNTY

By
Howard G. O'Connor

PART 2
MINERAL RESOURCES OF LYON COUNTY

By
Howard G. O'Connor, Edwin D. Goebel, and Norman Plummer

PART 3
GROUND-WATER RESOURCES OF LYON COUNTY

By
Howard G. O'Connor

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Chancellor of the University, and ex officio Director of the Survey

JOHN C. FEYE, Ph.D.,
Executive Director and
State Geologist

RAYMOND C. MOORE, Ph.D. Sc.D.,
Director of Research and
State Geologist

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PART 3

GROUND-WATER RESOURCES OF LYON COUNTY

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

By

HOWARD G. O'CONNOR

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PART 1
ROCK FORMATIONS OF LYON COUNTY
By
HOWARD G. O'CONNOR

INTRODUCTION

This is the second of a series of reports on the stratigraphy, economic geology, and ground-water resources of eastern Kansas counties, consisting primarily of maps (Pls. 1, 2, and 3), but containing brief descriptive stratigraphy and discussions of minerals and ground-water resources.

Location and Geography

Lyon County is located in central eastern Kansas (Fig. 1). It is bordered on the north by Wabaunsee County, on the east by Osage and Coffey Counties, on the south by Greenwood County, and on the west by Chase and Morris Counties. It contains about 23% townships and has an area of about 852 square miles.

The population of Lyon County is 26,576 (1950 census). Emporia, the county seat, has a population of 15,669 (1950 census). Other city population figures, according to the 1950 census, are: Admire, 181; Allen, 241; Americus, 339; Bushong, 93; Hartford, 395; Neosho Rapids, 204; Olpe, 293; and Reading, 289.

Land surfaces in Lyon County range from approximately 1,050 to 1,450 feet above sea level. Physiographically the area is a part of the Osage Cuesta Plains section of the Central Lowlands province. Schoewe (1949) describes the main topographic features as the Osage Cuesta Plains and the Flint Hills Upland. Most of Lyon County is drained by the Cottonwood-Neosho River system but smaller parts are drained by the Marais des Cygnes and Verdigris Rivers.

Field Work

The field work on which this report is based was done by me during parts of 1948, 1949, and 1950. I was assisted at various times by Raymond K. Mann, James Keller, and Ralph E. O'Connor. Areal geology was mapped on aerial photographs (scale 1:20,000). Rock sections were measured in detail, using a rule, Locke level with stadia, and telescopic level with a 12-foot rod.

Previous Geologic Work

The earliest geologic map and report on the geology of Lyon County were published by Smith (1903). Earlier Haworth and Kirk (1894) published a geologic section along the Neosho and Cottonwood Rivers across the county. The sequence of rocks which crop out in Lyon County and adjacent areas has been described in several publications (Prosser, 1895; Smith, 1901; Wooster, 1915; Moore, 1936, 1949; Elias, 1937; Schoewe, 1946, 1951; Mudge and Burton, 1950; Moore, Jewett, and O'Connor, 1951; Jewett and O'Connor, 1951; O'Connor and Jewett, 1952).

The subsurface geology has been described by McClellan (1930), and by Lee and others (1946). Mineral resources were described briefly by Landes (1937).

Acknowledgments

Residents of the area were very cooperative in allowing access to their land, supplying information about their wells and quarries, and permitting test drilling on their land and pumping tests on their wells.

Special thanks are expressed to Paul Fairchild, Weldon Julander, George Galensen, George Emrich, and the late W. D. Jones for time spent and

![Fig. 1.—Index map of Kansas showing location of Lyon County and areas for which reports of this series have been published.](image-url)
aid in study of stratigraphic problems. Appreciation is expressed to Hazen Bledsoe and C. W. Kippy, drillers, for information on several water wells in the area.

**STRATIGRAPHY OF OUTCROPPING ROCKS**

The rocks which crop out in Lyon County are of sedimentary origin; their areal extent is shown on Plate 1. The rocks exposed at the surface range in age from Pennsylvanian to Recent. In pages devoted to descriptions of the rock succession of Lyon County, statements of thickness and distribution apply to this county only, unless otherwise indicated.

**QUATERNARY SYSTEM**

**Pleistocene Series**

**Recent and Wisconsinan Stages**

*Stream-Valley Alluvium*

Deposits of stream-laid gravel, sand, silt, and clay, together with occasional cobbles and boulders, occur in the principal stream valleys and constitute the flood plains of the valley. The maximum accumulations are 40 to 50 feet thick. Deposits in the smaller valleys are thinner and more variable in lithology.

The coarse fraction of the alluvium of Cottonwood River Valley contains considerable amounts of well-rounded quartz sand derived from Cretaceous sandstones in the headwaters area of the river. Marais des Cygnes and Verdigris Rivers and Neosho River above its junction with Cottonwood River contain only small amounts of rounded quartz sand in the coarse fraction of the alluvial deposits, derived entirely from rocks of Permian and Pennsylvanian age which they drain.

All the larger streams contain large amounts of coarse chert gravel in the basal part of the alluvium and commonly considerable amounts of sand-size chert grains. Limestone and shale detritus, mollusk shells, and locally woody plant material occur with the quartz and chert sand and gravel. The finer material, which occurs chiefly in the upper and middle parts of the deposits, consists of silt and clay generally sandy in the lower part and nearly free of sand in the upper part (Pl. 4 A and B). The lower part of the silt-clay section generally is calcareous. Descriptions of the alluvium are given in the record of test holes at the end of this report and are shown in cross sections in Figure 3. These deposits constitute the alluvial flood plain and are subject to frequent flooding.

The extent of stream valley alluvium, except very narrow belts in small valleys, is shown on Plate 1. It is one of the most important sources of ground water. In the small tributary valleys older Pleistocene terrace deposits are included with the alluvium.

**Loess Deposits**

Of the several widespread loesses in Kansas, only the Peoria loess is present in amounts sufficient to be recognized, and it forms only a thin and discontinuous mantle on the upland flats and some of the terraces along the major stream valleys. It ranges in thickness from a featheredge to about 5 feet locally. Because of their thinness, irregular and patchy distribution, and unimportance as a source of ground water, loess deposits were not mapped.

**Illinoian Stage (?)**

*Terrace Deposits*

Two Pleistocene terraces can be recognized and mapped above the valley alluvium.

Wiggam terrace.—The youngest of these terraces has a surface and basal elevation 5 to 20 feet higher than corresponding parts of the alluvium. The sediments comprising these deposits are similar to those of the alluvium and have a maximum thickness of about 45 feet (Fig. 3, and record of test hole logs at end of report).

For the purposes of this report this terrace is named the Wiggam terrace for Wiggam Station on the Atchison, Topeka, and Santa Fe Railway east of Emporia (NE 34 NW 34 sec. 21, T. 19 S., R. 12 E.). It is a well-defined and extensive terrace along Cottonwood and Neosho Rivers. Cross section D-D' (Fig. 3), just west of Wiggam Station,
illustrates the relation between Cottonwood and Neosho River alluvium and this terrace. It is probably represented along the Verdigris and Marais des Cygnes Rivers but was not differentiated on Plate 1. This terrace is not subject to flooding by Neosho or Cottonwood River.

The age of these terrace deposits is not certain. Although probably Illinoian in age they may be younger, as the relation of the thin discontinuous mantle of Peoria loess in the area to the terrace is not clear. It is an important source of ground water.

**KANSAN STAGE**

**Terrace Deposits**

*Emporia terrace.*—The City of Emporia is built largely on an extensive terrace above the Wiggam terrace (Pl. 1; Fig. 3). This terrace has been named the Emporia terrace (Moore, Jewett, and O'Connor, 1951, p. 6). Basal deposits of this terrace rest on an eroded surface which ranges from about the level of the present alluvial flood-plain surface to approximately 20 feet above the flood-plain surface. It consists of sand and gravel in the basal 3 to 20 feet, silt, volcanic ash, caliche nodules, and clay in the remaining upper part. Maximum thickness of these deposits is about 50 feet. Except for local deposits of Pearlette volcanic ash which occur within this terrace it is similar in lithology to material in the alluvium and Wiggam terrace. Most of the deposit, where thick, is calcareous.

Plate 4D shows a gravel pit in the basal part of the Emporia terrace on the Bechtold farm (NW¼ NW¼ sec. 9, T. 19 S., R. 10 E.). From this and adjacent quarries several teeth and other vertebrate skeletal remains were recovered in quarrying operations. According to W. D. Frankforter (personal communication) the fossil material from this quarry indicates a post-Kansan climax age for the gravels, equivalent to the Grand Island member of the Meade formation in other areas of Kansas.

A 3- to 4-foot lentil of Pearlette volcanic ash occurs locally in the silt and clay (Sappa) just above the basal sand and gravel of this terrace and was mined at one time within the City of Emporia (Frye, Swineford, and Leonard, 1948, pp. 508-510; Carey and others, 1951).

According to John C. Frye (personal communication), exposures of this terrace in new road cuts along U.S. 50-S (near Cen. sec. 10, T. 19 S., R. 10 E.) show a partial Sangamon soil developed on top of the Sappa member, overlain by about 3 or 4 feet of Peoria loess.

The various lines of evidence indicate a Kansan age for the Emporia terrace.

The extent of this terrace along Cottonwood and Neosho River Valleys is shown on Plate 1. It is an important source of ground water and is not flooded by Cottonwood or Neosho River. Terrace deposits of Kansan age are probably represented along the Verdigris and Marais des Cygnes Rivers also, but were not differentiated from Illinoian (?) terrace deposits on Plate 1.

**TERTIARY SYSTEM**

Chert gravels east of the Flint Hills have been considered at various times and by various persons as having represented (1) scattered remnants of a once vast peneplain covered with essentially residual chert gravels, (2) dissected remnants of stream terrace deposits, and (3) the results of the last marine submergence of the area in which wave and current action distributed the resistant chert of the “Carboniferous” limestones into the present widely distributed deposits of today (West, 1885).

Although many problems concerning these high-level chert gravel deposits remain, certain conclusions can be drawn from the facts now known. Recent studies in Chase, Lyon, Elk, and Wilson Counties indicate that the high-level chert gravels have a linear pattern as would be produced by streams, and that both the pre-Kansan and Kansan or younger gravels closely parallel modern major drainage lines in the upper parts of the drainage systems. Along Neosho and Verdigris drainage east and southeast of Lyon County, reconnaissance studies indicate that the high-level gravels diverge from the present drainage trend to continue in an easterly direction.

Similarly the high-level chert gravels near their source beds in the Flint Hills occur in high relative positions of topography, but considerably lower than the highest elements of topography. As they are traced eastward their position in local topography becomes higher and higher. Easternmost chert gravel deposits in Anderson County, Kansas, occur on the highest topographic positon of the area.
Present data also indicate that there are probably three separate levels of these dissected chert-gravel terrace deposits older than Kansan. In Lyon County they occur at levels of approximately 70 to 80 feet, 90 to 100 feet, and the highest and least well-preserved deposits at 150 feet above the present alluvial flood-plain surface.

The deposits consist of siliceous sand and gravel, principally chert fragments derived from the cherty lower Permian limestones exposed in the Flint Hills, together with quartz sand and sufficient deep brownish-red clay to bind the material together. In most occurrences the sand and gravel is covered by less than 1 foot of clay and silt; frequently the sand and gravel occurs directly at the surface (Pl. 4C and G).

Thickness of the gravels ranges from a few inches to about 15 feet. No fossils have been found in any of these high gravel deposits which would indicate their age. They are lithologically similar and completely leached of all calcareous material. For these reasons all the terrace gravel deposits older than the Emporia terrace (Kansan) are mapped together on Plate 1.

It is probable that the lower of these high terrace deposits is Nebraskan in age. However, because of lack of evidence with which to date any of the high terrace gravel, other than relative topographic position, no attempt has been made to differentiate them.

They are generally above the water table and are of little importance as a source of ground water.

PERMIAN SYSTEM
WOLFCAMPIAN SERIES
CHASE GROUP
BARNESTON LIMESTONE

The Barneston limestone consists of three members, Fort Riley limestone at the top, Oketo shale, and Florence limestone. Only the lower member crops out in Lyon County. It is not an aquifer.

Florence limestone member.—The complete thickness of the Florence limestone is 35 to 40 feet. In the few exposures of this limestone in Lyon County somewhat less than the full thickness is present as small outliers in the northwest corner of the county. It consists of light-gray to yellowish-gray fossiliferous limestone containing an abundance of dense blue-gray fossiliferous chert nodules. Thin fossiliferous shale breaks occur in the lower part. Fossils include fusulinids, bryozoans, brachiopods, corals, and mollusks.

Matfield Shale

The Matfield shale, including two shale members and one limestone member, has a thickness of about 55 to 60 feet. It is of little importance as an aquifer.

Blue Springs shale member.—Exposures of the Blue Springs shale in Lyon and adjacent counties indicate a thickness of about 15 to 18 feet of gray, gray-green, and red shale, with one or more limy zones in the upper part.

Kinney limestone member.—Gray limy shale and shaly limestone about 16 feet in thickness comprise the Kinney limestone. The shales and limestones are abundantly fossiliferous. Fossils include bryozoans, brachiopods, echinoids, crinoids, pelecypods, and abundant ostracodes. It is nonresistant to weathering and makes little or no bench in the topography. The limestones in the basal part are the most massive resistant beds. The abundant fossils and limyness of the Kinney limestone serve to distinguish these beds from essentially nonfossiliferous red and green shales of adjacent members and to correlate them with areas in which the Kinney limestone contains resistant hard zones which make prominent outcrops.

Wymore shale member.—The average thickness of the Wymore shale is approximately 27 feet. Tan to gray-green shale occurs in the upper part, red and green blocky shale in the middle, and hard tan, gray, or olive shale in the basal part. It is unfossiliferous except for sparse fossils locally in the upper part.

WREFORD LIMESTONE

The thickness of the Wreford limestone is about 40 feet. Small supplies of ground water are obtained from this limestone locally.

Schroer limestone member.—The average thickness of the Schroer limestone is about 8 or 9 feet, the lower 4 feet of which contains abundant nodules of dense, blue-gray chert. Frequently a thin shale occurs near the middle of the member. Fossils include brachiopods, bryozoans, and echinoderms, none of which is abundant. The limestone is dolomitic in the lower cherty part, ranging from gray to light-brown in color.
Havensville shale member.—Excellent exposures in the Missouri Pacific Railroad cuts west of Bushong and along U.S. 50-N show the Havensville shale to average 15 to 17 feet in thickness. It consists chiefly of gray and tan shale with a thin band of green near the middle. The lower half contains many fossils, especially brachiopods. Two thin limestones are persistent, one near the middle of the member is impure and shaly, the other about 3 feet higher is hard, shelly, and abundantly fossiliferous.

Threemile limestone member.—The Threemile limestone forms a strong rounded bench along its line of outcrop. Massive thick beds of light-gray limestone with abundant nodules and bands of dense gray chert comprise the entire thickness of the member, except for a thin gray to olive shale about 3 feet above the base. Numerous fossils, many of which are silicified, occur in the limestone, shale, and chert; brachiopods, bryozoans, and echinoderms are the most abundant. The member ranges in thickness from 13 to 17 feet.

COUNCIL GROVE GROUP

Speiser Shale

The upper 3 feet of the Speiser shale is gray calcareous shale with a thin shaly limestone or mudstone at its base. This part contains abundant brachiopods, bryozoans, and echinoderm fragments. The middle and lower parts comprise red and green shale, locally with an intraformational conglomerate a few feet above the base. The conglomerate consists of pebbles of lithified red and green shale together with gray and tan limestone pebbles which range in size from one-fourth to 2 inches in diameter. Fragments of bones and several teeth were observed in the conglomerate. Thickness of the Speiser shale is about 15 feet. It is not important as an aquifer.

Funston Limestone

In measured sections the Funston limestone ranges from 22 to 28 feet in thickness and shows variability in the lithology of its parts. However, in this area a persistent algal limestone is present at the base (Pl. 4E), as was observed in Chase County (Moore, Jewett, and O'Connor, 1951, p. 11, pl. 4E). The top of the limestone is frequently, though not always, marked by dense platy beds of algal limestone. The change to bright red or green shales of the Speiser shale readily marks the top of the formation where other identifying features are absent. Between the algal limestones at top and base occur platy hard limestones, coarse detrital beds of limestone, bedded sandy limestone or limy sandstone, and tan, gray, and black shales. Common fossils in addition to calcareous algae are mollusks, bryozoans, and brachiopods. Resistant beds which make prominent hillside outcrops (Pl. 4F) are not restricted to a particular part of the formation, but may occur in the lower, middle, or upper part. Locally it is a source of small supplies of ground water.

Blue Rapids Shale

The Blue Rapids shale ranges in thickness from about 21 to 25 feet. Green and red shale with an impure "boxwork" limestone near the middle comprise most of the unit. Tan or gray shale occurs in the upper part and commonly a thin coal smut or carbonized plant remains are present a short distance below the algal limestone at the base of the Funston. Ostracodes occur abundantly locally above the coal smut. The formation supplies little or no water to wells.

Crouse Limestone

The easily recognized Crouse limestone consists of two persistent beds of limestone separated by 8 to 12 feet of gray or tan shale which is abundantly fossiliferous in the lower and middle parts. The upper limestone is gray to tan platy limestone in the upper part, with banded or lobate algal (?) structures exhibited locally. The lower part of this upper limestone is massive, hard, tan or gray limestone containing small rounded pebbles of hard shale and limestone and abundant mollusks. This ledge typically makes a prominent outcrop. The underlying shale is tan, gray, or gray blue, locally gysiferous, with abundant bryozoans, brachiopods, and sparse echinoderms in the lower half or less. The basal limestone is 2 to 3 feet in thickness, somewhat shaly or silty, and less prominent as an outcrop maker. Mollusks and algae are the common fossils of this bed. Thickness of the formation is about 18 feet. It is the source of small supplies of ground water for a considerable number of farm wells.
Easly Creek Shale

The average thickness of the nonfossiliferous Easly Creek shale is about 10 feet. It consists chiefly of red and green shale but locally contains some gray or tan shale. A zone of nodular limestone or “boxwork” occurs near the middle. It supplies little or no water to wells.

Bader Limestone

The thickness of the Bader limestone is about 33 feet. It is a source of small supplies of ground water for stock and domestic wells.

Middleburg limestone member.—The Middleburg limestone has an average thickness of 7 or 8 feet. At the top is 0.5 to 2 feet of tan to gray platy limestone and massive molluscan limestone. Underlying this is 2 to 4 feet of tan, gray, or black shale. Next below is 1 to 2 feet of gray limy shale or shaly limestone containing sparse brachiopods. At the base is a 3-foot light-gray slightly shaly limestone containing abundant mollusks, bryozoans, and a few echinoderms.

Hooser shale member.—Measured sections of the Hooser shale show it to consist of tan or gray shale in the upper part, green and red shale in the middle and lower parts. Frequently a nodular or “boxwork” limestone occurs near the middle. The member commonly is about 9 feet thick.

Eiss limestone member.—The Eiss limestone comprises about 17 feet of limestone and shale beds. The upper 1.5 to 3 feet is light- to dark-gray granular to dense limestone which weathers pitted and rough. Locally the bed may have a lavender tint or may contain sparse chert nodules. Simple forms of calcareous algae and mollusks are the chief fossils but locally other fossils are present. Gray, olive, green, or nearly black shale about 9 feet in thickness including abundant mollusks, bryozoans, brachiopods, and echinoderms occurs in the middle part. In the northern part of Lyon County the lower limestone is essentially one bed of gray shaly limestone but when traced southward it expands into two limestones separated by several feet of shale. Locally the lower beds may contain sparse chert nodules.

Stearns Shale

Measured sections of the Stearns shale show it to thin southward from about 11 feet in northern Lyon County to approximately 5 feet in exposures near the southwest corner of the county. In northern areas it consists of gray and olive shale in the upper part together with a thin coal bed or abundant carbonized plant remains. Locally ostracodes are abundant above the coal bed zone. Near the middle a nodular or “boxwork” limestone commonly occurs. The lower part consists of green shale with occasional streaks of red. Exposures of this shale in southern areas lack the coal but in other respects are very similar. It is not important as a source of ground water.

Beattie Limestone

The thickness of the Beattie limestone averages about 21 feet in Lyon County. Both limestone members are important aquifers and supply numerous stock and domestic wells.

Morrill limestone member.—Measured sections of the Morrill limestone range from about 3 to 5 feet in thickness. It consists of gray, tan, and brown limestone generally with one or more thin shale partings. Lithology of the beds varies from hard, dense, or granular limestone to soft porous limestone, or occasionally limestone beds with considerable detrital limestone and shale grains included in them. Algae and mollusks are the most abundant fossils but foraminifera and sparse brachiopods are observed occasionally. In the northern outcrops a siliceous bed occurs at the base of the member.

Florena shale member.—The middle member of the Beattie limestone comprises 11 to 14 feet of blue-gray or tan calcareous shale with abundant brachiopods, bryozoans, and crinoids especially in the lower and middle parts. Fusulinids sometimes occur in the basal few inches just above the Cottonwood limestone.

Cottonwood limestone member.—The Cottonwood limestone averages about 6 feet in thickness and is characterized by the prominent outcrop which it makes. It is the youngest or uppermost bed in the Council Grove group which regularly contains fusulinids. Fusulinids are abundant in the upper half or less and weather into relief on outcrops. Brachiopods and echinoderms are the principal fossils in the remainder of the bed but zones of algal limestone are conspicuous locally. Scattered nodules of chert commonly occur in a zone near the middle of the bed. Solution channels and cavernous zones are observed in many
exposures. The rock is light gray in color and weathers nearly white.

Eskridge Shale

The average thickness of the Eskridge shale is about 34 feet. The upper few feet is generally gray or tan calcareous shale, whereas the middle and lower parts consist chiefly of green and red shale with two rather persistent thin molluscan limestones. Locally, gray or tan shale may occur in the middle or lower part. A thin impure coal is observed locally between the lowermost molluscan limestone and the top of the Neva limestone between Neosho River and the south boundary of the county. Elsewhere this part of the section is represented by a “boxwork” limestone and green, red, and gray shale. The formation exhibits marked variations in its composition over short distances. Although not a consistent aquifer it supplies small amounts of ground water to several wells in this area.

Grenola Limestone

The average thickness of the Grenola limestone, which comprises three limestone and two shale members, is about 35 feet. It is the principal aquifer for many small stock and domestic wells.

Neva limestone member.—The Neva limestone ranges in thickness from about 9 to 15 feet, being thinnest in the northern part of the county. Several persistent zones are recognized. The upper bed consists of 1 to 3 feet of hard gray algal molluscan limestone which frequently contains numerous brachiopod and echinoderm remains. The main ledge of the Neva, 3 to 8 feet thick, occurs near the middle of the member and is distinguished by its pitted rough-weathering character, its cavernous zones, and its fossils. Fossils in this bed are chiefly brachiopods and echinoderms with fusulinids near the base. Separating the two limestones is a gray or tan shale, 0.7 to 6 feet thick containing brachiopods, bryozoans, and echinoderms. The lower 2 to 5 feet of the Neva limestone comprises two or three thin limestones separated by tan, gray, or black shales. The shales are frequently but not always fossiliferous. The thin limestones contain abundant fusulinids together with brachiopods, bryozoans, and echinoderms. The basal limestone is everywhere observed to be algal. Mollusks and ostracodes are associated with the algal bed. Sparse chert nodules may occur in the middle and lower limestones.

Salem Point shale member.—The thickness of the Salem Point shale averages about 7 feet. It is gray to olive, silty, calcareous shale which weathers tan. Locally it is sandy in the lower part.

Burr limestone member.—The Burr limestone, averaging 8 feet in thickness, generally consists of several thin limestones separated by shales. In most sections a thin limestone bed underlain by 1 to 4 feet of olive or gray shale occurs at the top. A persistent tan platy limestone occurs next lower underlain by shaly or silty gray molluscan limestones and dark or black shale. Ostracodes occur commonly at the top of the platy beds. Calcareous algae are abundant; other fossils, including bryozoans and brachiopods, occur less abundantly.

Legion shale member.—At measured exposures the Legion shale is 5 to 9 feet thick, unfossiliferous, gray, olive, and tan shale. In the northern part of Lyon County a few inches of black fissile shale occurs at the base.

Sallyards limestone member.—The Sallyards limestone is a thin, gray, silty or shaly molluscan bed 0.3 to 2 feet thick in the north and thickens southward to about 5 feet. Where thick it contains mollusks and echinoderms.

Roca Shale

Exposures of the Roca shale average about 18 to 21 feet in thickness except in T. 15 S. where the Roca thins abruptly over the Red Eagle bioherm. Less than 4 feet of Roca occurs in parts of this area. It comprises chiefly red, green, and olive shale, locally with a “boxwork” type limestone in the upper part. The lower part contains one or more beds of gray dense limestone and limy nodules with specks and veinlets of clear crystalline calcite.

The Roca shale is not important as an aquifer.

Red Eagle Limestone

The thickness of the Red Eagle limestone ranges from about 10 to 33 or more feet. Throughout most of its line of outcrop it has a thickness of 12 to 16 feet. A considerable number of wells derive water supplies from the Red Eagle limestone chiefly from limestone in the Bennett shale and from the Howe limestone. Member boundaries
PLATE 4. A, Gravel pit in Neosho River alluvium, NE\(\frac{1}{4}\) SE\(\frac{1}{4}\) sec. 6, T. 20 S., R. 13 E. Pond surface is water table. B, Cut bank of Neosho River, SE\(\frac{1}{4}\) SE\(\frac{1}{4}\) sec. 14, T. 19 S., R. 12 E., showing profile of alluvial materials. Effluent seepage from gravel below point where man stands indicates water table. C, Quarry in Tertiary terrace gravel (upper 8 to 12 feet) and sandstone of Pierson Point-Willard shale (lower part of quarry), NW\(\frac{1}{4}\) NE\(\frac{1}{4}\) sec. 5, T. 19 S., R. 12 E. D, Small gravel pit in Emporia terrace on Bechtold farm, NW\(\frac{1}{4}\) NW\(\frac{1}{4}\) sec. 9, T. 19 S., R. 10 E., from which vertebrate remains have been recovered. E, Basal algal bed of Funston limestone showing abundant algal colonies, SE\(\frac{1}{4}\) SE\(\frac{1}{4}\) sec. 7, T. 16 S., R. 10 E. F, Speiser shale and upper platy and massive beds of Funston limestone along U.S. 50-N, SE\(\frac{1}{4}\) sec. 7, T. 16 S., R. 10 E., G, Soil development on high terrace chert gravel, SW\(\frac{1}{4}\) sec. 1, T. 19 S., R. 10 E.
conform with those of O'Connor and Jewett (1952).

*Howe limestone member.*—The Howe limestone is a gray to gray-brown algal (Pl. 5C) and foraminiferal limestone ranging in thickness from about 1 to 6 feet. Its lithology and fauna are exceedingly persistent and uniform all along its outcrop in central Kansas, small foraminifera, calcareous algae, tiny snails, and ostracodes being exceedingly abundant. Except in the thicker sections it ordinarily does not make a conspicuous outcrop. It is thickest in T. 15 S., in the area of the Red Eagle bioherm (O'Connor and Jewett, 1952).

*Bennett shale member.*—Measured sections of the Bennett shale range from about 6 to 27 feet in thickness. It comprises olive, gray, and black shale beds and tan, light-gray, or nearly white limestone and dolomitic limestone. The upper and middle parts, except in the bioherm developed in T. 15 S., comprise chiefly gray and olive-gray calcareous or limy shale containing abundant echinoid and crinoid fragments, brachiopods, and bryozoans. In a few exposures this part of the Bennett may contain sparsely fossiliferous or non-fossiliferous shale adjacent to or within the abundantly fossiliferous parts. Next lower is a persistent dolomitic limestone, light gray to nearly white in color, massive, cavernous, occasionally sparsely cherty and generally the best bench maker of the Red Eagle formation. In many outcrops it contains few or no recognizable fossils, and has a somewhat brecciated appearance. In other outcrops sparse horn corals, brachiopods, echiinoderms, and calcareous algae are observed. The lower part of this limestone or adjacent underlying gray or black fissile to thin-bedded shale beds contains specimens of shiny red-brown *Orbiculoidea*. Although the lithology of the Bennett shale may change laterally from shale to limestone or limestone to shale the *Orbiculoidea* zone and the mixed fauna zone of the upper and middle parts persist entirely across Lyon County and almost without exception can be traced entirely across the State (O'Connor and Jewett, 1952).

Locally in secs. 23, 24, and 26, T. 15 S., R. 11 E., the Howe and Bennett members expand abruptly in a bioherm development and are entirely limestone and dolomitic limestone except for a thin shale at the base of the Bennett member. In the bioherm the Bennett comprises about 12 or 13 feet of light-gray coarsely crystalline and brecciated limestone which contains at one outcrop in sec. 23, T. 15 S., R. 11 E., masses of beautifully preserved segments of crinoids, large brachiopods, and other fossils. This part of the Bennett in most of the bioherm does not form a strong outcrop. Next lower is about 14 feet of light-gray to light-tan cavernous cherty and massive dolomitic limestone or dolomite which makes a strong bench. Fossils are not abundant but include corals, calcareous algae, echiinoderms, brachiopods, and fusulinids. Stylolites are common in this bed and it is evident that diagenetic processes have altered the original sediment considerably.

Next lower occurs generally less than 1 foot of tan dolomite containing *Orbiculoidea* underlain by about 1 to 5 feet of gray to black thin-bedded or fissile shale generally also with *Orbiculoidea*.

*Glenrock limestone member.*—The Glenrock limestone is light-gray to tan limestone which ranges from a featheredge to about 1.5 feet in thickness. It is characterized by abundant fusulinids in the upper part of the bed or locally the entire bed. The lower part is a detrital nonfusulinid bed in some exposures.

*Johnson Shale*

The average thickness of the Johnson shale is about 20 feet. North of Cottonwood River the upper 1 to 5 feet is gray or tan shale with carbonized plant remains in the lower part. In southern parts of the county the entire thickness of this part may be black carbonaceous shale. Next below is an unfossiliferous dense or fine-grained limestone or platy mudstone which ranges in thickness from less than 0.5 to about 5 feet. Beds below this are variable in lithology but comprise calcareous tan, gray, and green shales, impure limestones, and locally thin beds of gypsum. The formation generally yields little or no water to wells; however, gypsiferous zones in the lower part occasionally yield small supplies of ground water.

*Foraker Limestone*

Exposures of the Foraker limestone average about 40 feet in thickness. The upper member is an important aquifer and supplies numerous wells with small to moderate amount of generally good quality water.
Long Creek limestone member.—The Long Creek limestone is a nonresistant dolomitic limestone. It contains a zone of geodes and scattered crystals of red, orange, or colorless quartz and chert together with colorless celestite at or near the top of the member. Upon weathering the distinctive quartz-celestite zone makes an easily recognized marker along the outcrop of the bed. The limestone is 3 1/2 to 6 feet in thickness, sucrosic to granular or fine-grained, and brown or tan in color. Frequently cavernous zones develop in the part containing the quartz-celestite geodes. Recognizable fossils are sparse in many exposures but calcareous algae and mollusks are the principal fossils observed.

Hughes Creek shale member.—Near the top of the Hughes Creek shale a 2- to 3-foot bed of shaly gray limestone containing abundant fusulinids is present, separated from the overlying Long Creek limestone by a few inches to about 3 feet of gray to olive thin-bedded shale. The remainder of the member consists of gray to nearly black shale containing abundant brachiopods, bryozoans, and echinoid and crinoid fragments, generally associated with very abundant fusulinids. In many places where the Hughes Creek shale outcrops across secondary roads the small wheat-shaped fusulinids form a veneer of unusual “gravel” on the surface. Approximately 5 feet above the Americus limestone a thin, gray molluscan limestone less than 1 foot thick occurs as a marker bed, distinct from the brachiopod and fusulinid limestones in the remainder of the member.

Americus limestone member.—The Americus limestone comprises two limestones separated by several feet of shale. Its average thickness is about 11 or 12 feet. The upper limestone is medium- to dark-gray hard limestone 1 to 2 feet thick containing chiefly brachiopods and crinoids. Next below is 2 to 4 feet of olive to gray calcareous shale underlain by 2 to 4 feet of black fissile shale mottled with brown. Gray shaly limestone 0.5 to 2 feet thick containing fusulinids, brachiopods, bryozoans, and crinoids occurs below the black shale. At the base is the “main ledge” of the Americaus limestone, 0.8 to 1.5 feet in thickness, with the same fauna as the overlying shaly limestone. This ledge can be quarried in large rectangular blocks because of its widely spaced joints.

Admire Group

Hamlin Shale

The Hamlin shale has an average thickness of about 55 feet. It is of little importance as a source of ground water.

Oaks shale member.—Measured sections of the Oaks shale range from 2 to 9 feet in thickness and average about 5 feet. It is chiefly olive-gray and black shale, occasionally gypsiferous.

Houchen Creek limestone member.—Gray limestone composed largely of calcareous algae and yellow-brown sandy, conglomeratic, or “honeycomb” limestone make this bed a distinctive marker. It ranges in thickness from 0.5 to about 3 feet.

Stine shale member.—The Stine shale ranges from about 49 to 53 feet in thickness. The upper one-third generally consists of gray or olive shale locally containing a thin sparsely fossiliferous limestone. A few feet above the middle a thin sandstone or pebbly conglomerate frequently is observed. The middle and lower parts comprise red and green silty or sandy micaceous shale, gray and olive shale, and locally thin impure limestones. Terrestrial plant remains and Lingula are the common fossils observed.

Five Point Limestone

In most exposures the Five Point limestone is a single bed of abundantly fossiliferous gray limestone, but occasionally it contains one or more thin shale partings. Thickness of the formation ranges from 1.4 to 2.5 feet. Fossils include fusulinids, brachiopods, bryozoans, horn corals, and crinoids. It is of little importance as an aquifer.

West Branch Shale

Measured sections of the West Branch shale range in thickness from 25 to 29 feet. A persistent coal ranging in thickness from about 0.8 foot to little more than a smut occurs about 1 foot below the Five Point limestone. Locally there are two thin coals separated by shale beds. The upper part, below the coal, consists of thin gray shale and friable micaceous sandstone or sandy shale. The sandstone ranges upward to about 8 feet in thickness, is gray to gray green in color, and weathers brown. Plant remains are associated with the sandstone. In the lower middle part, a
very pyritic or limonitic limestone or zone containing limonite pseudomorphs of pyrite crystals occurs underlain by red shale locally. The basal beds are gray shale, frequently with numerous dense siltstone concretions. Beds of sandstone in the West Branch shale frequently yield small supplies of ground water to wells.

_Falls City Limestone_

The Falls City limestone ranges in thickness from about 10 to 16 feet. The upper part consists of one limestone, or two limestones and a thin shale, associated with one or more zones of cone-in-cone. The limestone beds are dark gray, silty, and fine-grained with abundant fossils, mostly mollusks but including bryozoans, crinoids, and brachiopods. Lower beds generally include two or more thin silty or clayey gray or tan limestones containing coquinas of small crystalline mollusks interbedded with gray, olive, or tan shale. In southern Lyon County these beds become very shaly but retain their abundant fossils. Over most of the line of outcrop the limestones are too thin and weak to form a bench in the topography. Locally this formation is a source of small supplies of ground water of variable quality.

_Hawxby Shale_

The average thickness of the Hawxby shale is about 10 or 12 feet. It comprises olive, gray, green, and red unfossiliferous shale. Locally, near the middle of the formation a zone of mudcracks and pebbles of limestone occurs at the top of red shale. It supplies little or no ground water to wells.

_Aspinwall Limestone_

The Aspinwall limestone, overlain and underlain by the nonfossiliferous red, green, and olive Hawxby and Towle shales, is variable in thickness, lithology, and position with respect to the next lower limestone formation. In some exposures it comprises several thin mollusk-, brachiopod-, and bryozoan-bearing limestones and separating beds of shale. Other exposures show a shell hash or lag concentrate of mollusks, bryo- zoans, and brachiopods. This is interpreted as indicating shallow marine conditions just prior to Hawxby time, in which the thin fossiliferous limestones and shales of the Aspinwall formation locally were subject to wave and current action for a short length of time. During this time the finer sediments of the original thin fossiliferous limestone and shale beds and varying amounts of the underlying Towle shale were removed and redeposited elsewhere, leaving a coquina of the relatively coarse and heavy fossil shells behind. In some areas these shells were left as essentially even-bedded lag deposits; elsewhere they were concentrated into banks of shells as much as 6 or more feet in thickness, unconformably on the beds below. Where the Aspinwall is represented by good beds of “shell hash” limestone it is a source of good supplies of water for stock and domestic wells but quality of water is variable.

_Towle Shale_

The Towle shale ranges in thickness from a featheredge to about 20 feet. It comprises an unnamed shale in the upper part and the discontinuous Indian Cave sandstone in the lower part. It is of little importance as an aquifer.

Unnamed shale member.—These strata generally display gray, tan, or olive shale in the upper part, red or red and green in the middle, and olive, gray, or green shale in the basal part. The beds are slightly sandy and micaceous in some exposures.

Indian Cave sandstone member.—No beds assignable to the Indian Cave sandstone were recognized in Lyon County. However, were the variations in the nature of the Aspinwall limestone not recognized and proper attention given to the stratigraphic sequence, it is possible that certain facies of the Aspinwall limestone could be mistaken for the Indian Cave member.

**PENNSYLVANIAN SYSTEM**  
**Virgilian Series**  
**Wabaunsee Group**  

_Brownville Limestone_

The Brownville limestone ranges from about 1.5 to 3 feet in thickness and has an average thickness of about 2 feet. It is a massive, hard, blue-gray limestone which occurs as a single ledge or occasionally with one or two thin partings. Abundant fusulinids, the brachiopods Marginifera wabashensis and Chonetes granulifer, the bryo- zoan Meekopora, and crinoid fragments are the characteristic and abundant fossils. The Brownville is not an important aquifer; however, a few
wells do obtain small supplies of water from it at shallow depths.

Pony Creek Shale

The average thickness of the Pony Creek shale is about 10 feet in the northern part of Lyon County and 11 feet in the southern part. It comprises mostly gray and olive silty or sandy micaceous shale. Fossiliferous shale containing brachiopods and bryozoans occurs just below the Brownville limestone in many places. Locally a thin coal bed occurs just below the fossiliferous zone. It supplies little or no water to wells in this area.

Caneyville Limestone

The Caneyville limestone consists of two named limestone members and an unnamed shale. Thickness of the formation ranges from 10.5 to 20 feet. It is not an important aquifer, although a few wells do obtain small amounts of water from this formation.

Grayhorse limestone member.—The Grayhorse limestone is a gray to brown coarsely crystalline to sandy and silty chiefly molluscan bed which ranges in thickness from about 0.5 to 2.5 feet.

Unnamed shale member.—Shale beds separating the Grayhorse and Nebraska City limestone members range in thickness from about 10 to 17 feet. The shale beds are mostly gray or green gray in color, locally sandy and micaceous. Some exposures in the northern part of Lyon County exhibit a yellow-brown “boxwork” limestone in the upper part, locally overlain by a thin red shale. Some southern outcrops show a sandstone or thin conglomerate adjacent to the Grayhorse limestone.

Nebraska City limestone member.—The Nebraska City limestone is a single bed of somewhat shaly, shelly weathering gray or gray-brown limestone, 1 to 3 feet thick in exposures in northern Lyon County. In exposures near the middle of the county a shale parting divides the member into two separate limestone beds. The upper bed is massive to slabby, gray to gray-brown limestone about 1 foot thick containing abundant Osagia algae and brachiopods, together with other fossils. The lower bed is olive to gray in color, silty to shaly, and much less resistant to weathering. It ranges in thickness from about 1 to 1½ feet and contains chiefly a molluscan fauna. The shale separating the limestone beds thickens southward to about 5 feet near the Greenwood-Lyon County line. Locally the Nebraska City may be cut out by a disconformity in the unnamed shale of the Caneyville limestone.

French Creek Shale

Measured sections of the French Creek shale range from about 25 to 40 feet in thickness. It progressively thickens southward across the county. The persistent Lorton coal occurs below the Nebraska City limestone separated from it by a shale which ranges in thickness from a featheredge to about 8 feet. The coal ranges in thickness from a featheredge to about 20 inches (Schoewe, 1946, p. 102). Occasionally there are two coals in the upper part of the French Creek shale. Gray sandy micaceous shale containing plant remains or sandstone and sandy shale occur below the coal. The lower part is gray to olive blocky shale, generally more argillaceous than shale beds of the upper part. Claystone and limonite concretions occur in the basal part in many exposures. Locally, sandstone or sandy shale filled channels originating in the French Creek shale cut downward into underlying beds. Sandy zones in the French Creek shale are a source of small supplies of ground water for shallow stock and domestic wells.

Jim Creek Limestone

The Jim Creek limestone is a thin but persistent light- to medium-gray fine-grained hard limestone which ranges in thickness from about 0.5 to 1.5 feet. The top becomes red or red brown from limonite or hematite in the upper part and the weathered ledge becomes shelly in many exposures. It contains fusulinids, brachiopods, crinoids, bryozoans, and other fossils. Locally the formation is cut out by a disconformity in the French Creek shale. It is of little importance as an aquifer.

Friedrich Shale

Outcrops of the Friedrich shale in northern and central parts of Lyon County are chiefly gray, green, and olive argillaceous shale averaging 10 to 12 feet in thickness. A thin carbonaceous zone is observed near the base in a few exposures. At the SE cor. sec. 9, T. 17 S., R. 12 E., a conglomerate
of shale and limestone pebbles was observed about 4 feet below the Jim Creek limestone. The formation is 8 to 25 feet or more in thickness south of Cottonwood River, where it becomes gray, tan, and buff sandy micaceous shale with abundant carbonized plant remains. Sandstone-filled channels 25 feet or more thick locally cut nearly to the Dover limestone. Alternating very thin beds of dark carbonaceous shale and tan or buff sandy shale give the appearance of varved shale in some exposures.

The Friedrich shale yields small supplies of generally hard water to wells where the formation contains beds of sandstone, especially in T. 21 S. Elsewhere it yields little or no water to wells.

**Grandhaven Limestone**

There are commonly two limestones separated by a few feet of shale in the Grandhaven limestone. It ranges in thickness from about 3.5 to 12 feet. The upper limestone ranges in thickness from less than 1 to more than 8 feet. In some exposures south of Cottonwood River the upper limestone is absent. The upper bed is characterized by abundant Osagia algae together with less numerous clams, bryozoans, brachiopods, and crinoids. It is light gray, tan, or buff in color, weathering nearly white in most exposures. Cross bedding is evident in many exposures (Pl. 5D).

Middle beds are mostly gray, yellow, or green silty or calcareous shales but locally red shale or brownish-green sandy micaceous shale occurs between the limestones.

The lower limestone averages 2 to 3 feet in thickness in northern and central outcrops but thins to 0.5 to 1 foot in southern outcrops. Where thick it is massive gray to yellow-brown limestone containing fusulinids, crinoids, bryozoans, brachiopods, and occasionally horn corals or algae. Where thin the bed is medium-gray, hard, massive limestone which contains mollusks, brachiopods, bryozoans, and crinoids but no fusulinids. The bed, where thin, is very similar to the Jim Creek limestone. Locally part or all the Grandhaven limestone is cut out by a post-Grandhaven disconformity.

The Grandhaven limestone generally yields little or no water to wells, but in a few areas small supplies of good quality water are obtained.

**Dry Shale**

The Dry shale is gray and tan thin-bedded to blocky shale with silty, sandy, and limy zones. Fossils, including clams, snails, brachiopods, crinoids, ammonites, and bryozoans, while not observed in all outcrops, locally are abundant. Locally a part of the fauna, especially Yoldia, Leda, Ambucoelia, and ammonites are replaced with limonite and are distinctive of the Dry shale. Some exposures of the Dry shale are chiefly dark-red and green shale. Thickness, except in Ts. 20 and 21 S., is about 8 to 10 feet.

The Dry shale in T. 21 S. and most of T. 20 S. is considerably different than in areas north of T. 20 S. It is thicker, as much as 26 feet thick, along Verdigris River. At the top a rather persistent thin coal occurs just below the lower Grandhaven limestone. Myalina and other pelecypods, brachiopods, crinoids, and bryozoans occur in the thin shale above the coal in some exposures. Frequently 5 to 10 feet from the top there is a yellow-brown or gray siltstone or cross-bedded algal and molluscan limestone separated from the coal by gray, tan, olive, or green shale. These beds formerly (Jewett and O'Connor, 1951, pp. 11, 14, 15) were erroneously included as a part of the Grandhaven limestone. Below the algal-molluscan limestone zone are several feet of olive or green silty to sandy shale beds. About 5 to 8 feet from the base a medium-gray to nearly black very fossiliferous limestone about 0.8 foot thick is present. Some exposures show a purple-red cast on the top surface. It is underlain by 1 to 2 feet of gray shale. Both the shale and limestone contain abundant fossils, chiefly Chonetes and Derbyia with fewer crinoids and bryozoans. The basal 4 to 6 feet is gray micaceous sandstone and gray thin-bedded sandy shale with abundant carbonized plant remains.

Locally, in sec. 28, T. 21 S., R. 11 E., and adjacent areas sandstone beds in the Dry shale fill deep channels cut into underlying beds as low as the Pierson Point-Willard shale. Where thick sandstone beds are present good stock and domestic wells can be developed; elsewhere the Dry shale yields little or no water to wells.

**Dover Limestone**

The average thickness of the Dover limestone is about 2 feet, but it ranges in thickness from less
than 0.5 to nearly 3 feet. It is light gray to yellow brown in color, weathering yellow brown. In some exposures part of the bed has a green cast. It occurs as massive limestone, silty and sandy somewhat impure limestone, or as limy sandstone in various outcrops. In exposures where it is sandy it frequently overlies massive beds of sandstone in the Langdon shale. It is evident in many such instances that percolating ground water has locally redeposited much of the Dover limestone as large sand-calcite crystals in the underlying sandstone. In such places the boundaries of the Dover limestone are poorly defined. Large robust fusulinids, which in northern outcrops frequently weather free of the matrix, Osagia and Cryptozoon algae are the most abundant fossils. Crinoids, brachiopods, horn corals, and bryozoans are present in less abundance. The formation generally yields little or no water to wells.

**Langdon Shale**

In Ts. 15, 16, and 17 S. the Langdon shale ranges in thickness from about 30 to 35 feet. In most exposures it comprises massive to shaly gray or brown sandstone beds in the upper part underlain by sandy, micaceous, gray, tan, or olive, thin-bedded shale, parts of which contain plant remains and ferruginous concretions. The lower one-third of the formation is blue-gray, blocky, argillaceous shale. In T. 18 S. and the northern part of T. 19 S. the formation thins rapidly southward. Outcrops of the formation in Emporia show it to have thinned to about 3 or 4 feet of gray silty and olive argillaceous shale. South of Emporia in Ts. 19, 20, and part of 21 S. the underlying Maple Hill and Tarkio limestones are absent and shale beds, 50 to 60 feet thick, between the Dover and Elmont limestones are considered as the Langdon-Willard shale. In part of T. 21 S., especially the southern part, the Maple Hill limestone is recognized and the Langdon can be differentiated. The Langdon ranges in thickness from a featheredge to about 5 feet in this area, and is gray to green, argillaceous, blocky shale.

Small supplies of well water are obtained locally from sandstone beds in the Langdon shale. Non-sandy beds yield little or no water to wells.

**Maple Hill Limestone**

Exposures of the Maple Hill limestone range in thickness from 1 to 1.5 feet except in T. 21 S. where some exposures show it to be slightly more than 2 feet thick. It is absent in T. 20 S. and parts of Ts. 19 and 21 S. Where present the Maple Hill is easily recognized. It is light to medium gray in color, weathering brown gray or gray, frequently with a red top, hard, massive and has widely spaced joints unlike the overlying Dover which cause it to weather out along outcrops in large rhomb-shaped blocks. Joints are locally much enlarged by solution. It becomes shelly on weathering in some exposures. Fossils include numerous small fusulinids, brachiopods, crinoids, bryozoans, and Cryptozoon algae, together with less numerous clams, snails, and horn corals.

The Maple Hill limestone is not an important aquifer.

**Pierson Point Shale**

Strata, chiefly shale beds, averaging between 25 and 35 feet in thickness between the Maple Hill and Tarkio limestones are designated the Pierson Point shale in northeastern Lyon County. South of the point where the Tarkio limestone pinches out, strata between the Maple Hill and Elmont limestones are termed the Pierson Point-Willard shale and the thickness of the unit ranges from 45 to 55 feet. In areas where the Maple Hill limestone is also absent the formation cannot be differentiated from overlying and underlying shales and is included as a part of the Langdon-Willard shale.

As far south as Emporia the Pierson Point or Pierson Point-Willard shale everywhere contains a thin coal, coal smut, or carbonaceous zone just below the Maple Hill limestone. In many exposures gray to tan micaceous sandstone or sandy shale underlies the coal. Three thin limestones or limy siltstones occur near the middle of the shale and are characterized by abundant fossils. The upper two fossiliferous zones contain abundant Leda, Yoldia, Pharkidonotus, Euphemus, Myalina, Bellerophon, and Worthenia, as well as other snails and clams, bryozoans, and crinoids. South of Emporia these two thin limestones are less well represented but can still be identified although the fauna comprises chiefly bryozoans, crinoids, and brachiopod remains. The lower of these three limestones, near the middle of the Pierson Point shale, averages 1 to 4 feet in thickness. This lime-
stone is persistent at least across Osage and Lyon Counties.

The name Stormont limestone is here proposed for this bed, named for exposures along the road and in ravines in the NW¼ sec. 9, T. 14 S., R. 14 E., about 1 mile northwest of the former Stormont postoffice, Osage County, Kansas, where the overlying Maple Hill and underlying Tarkio limestones are also typically exposed. The Stormont limestone occurs about 12 feet below the Maple Hill limestone and 13.5 feet above the Tarkio limestone at the type locality. It is also very well exposed in the NE¼ sec. 15, T. 15 S., R. 13 E., along Dragoon Creek.

The Stormont limestone occurs about 12 to 18 feet above the Tarkio limestone where the Tarkio is present, and about 10 to 20 feet above the Elmont where the Tarkio limestone is absent. The Stormont is variable in character, but generally is sandy or silty and very nonresistant to weathering. Mollusks, crinoids, brachiopods, fusulinids, and calcareous algae are the commonly observed fossils but microscopic inspection of one sample of this bed showed ostracodes, gastropods, foraminifers, sponge spicules, and echinoderm fragments also. Because of its position between the Elmont and Maple Hill limestones it has been erroneously called Tarkio limestone in parts of Lyon County where the Tarkio is absent.

The Pierson Point shale below the Stormont limestone comprises blue-green and dark blue-gray blocky to massive shale, the lower part of which contains dense siltstone concretions and septaria. The septaria commonly have vein fillings of sphalerite and white, red, or orange calcite.

The basal 2 or 3 feet of the Pierson Point-Willard shale frequently contains abundant crinoids and brachiopods.

The Pierson Point-Willard shale is not an important aquifer.

**Tarkio Limestone**

The Tarkio limestone is recognized in one small outcrop along Salt Creek along the Lyon-Osage County line. It comprises about 2 feet of gray hard limestone which weathers yellow brown. Fossils include large fusulinids which weather in relief, crinoids, bryozoa, and Cryptozoon. In T. 15 S., R. 13 E., it very closely resembles the Reading limestone in color, thickness, and fossil content, and could be easily confused with Reading limestone where associated overlying or underlying beds cannot be observed. It apparently thins to a featheredge in the area between Salt Creek and Marais des Cygnes River and is absent to the south of this area. It is unimportant as an aquifer.

**Willard Shale**

The Willard shale comprises about 12 to 15 feet of gray or tan shale in northeastern Lyon County. Where the Tarkio limestone is absent it is included with the Pierson Point shale as the Pierson Point-Willard shale.

It is unimportant as an aquifer.

**Elmont Limestone**

The Elmont limestone ranges in thickness from about 1.5 to 6 feet, averaging about 3 feet. The upper limestone, about 1 to 1.5 feet thick, is a dense, hard, brittle, gray bed which characteristically has numerous very closely spaced joints and includes abundant small fusulinids, together with brachiopods, bryozoa, crinoids, and Cryptozoon algae. A thin zone of blue-gray fine-grained pebbles or conglomerate included in the Elmont by Moore (1936, pp. 226-227) occurs at the base of the formation and is separated from the overlying fusulinid bed by 0.5 to 4 feet of gray or olive shale. This pebble zone or conglomeratic limestone ranges from less than 0.1 foot to about 2 feet in thickness.

The Elmont limestone is of little importance as a source of ground water.

**Harveyville Shale**

Gray and olive shale beds ranging from about 0.5 to 6 feet in thickness are included in the Harveyville shale. Locally Myalina and other invertebrates occur in the shale or in a thin limestone in the shale. The Harveyville is of little importance as a source of ground water.

**Reading Limestone**

The Reading limestone averages about 3 feet in thickness and nearly everywhere consists of one massive gray-blue limestone which weathers yellow brown. Most exposures of this limestone show a parting near the top, above which no fusulinids
or algae occur. The entire bed contains crinoids, brachiopods, bryozaans, and echinoid remains. Locally in T. 21 S., a cross-bedded algal-molluscan limestone as much as 5 feet thick occurs above the persistent fusulinid limestone and is separated from it by 1 to 2 feet of gray shale. The Reading limestone ordinarily yields little or no water to wells.

Auburn Shale

The Auburn shale comprises gray, olive, and tan shale beds, and several thin gray or tan limestones which together have an average thickness of about 44 feet. Most outcrops of the upper half of the Auburn shale are gray and tan shale with three to five thin limestones which contain abundant Linopropactus, bryozaans, and crinoid and mollusk remains. Locally, as in secs. 28 and 33, T. 21 S., R. 12 E., sandstone occurs near the middle of the formation and is overlain by sandy shale containing one or two thin coals and a limestone conglomerate at the top directly under the Reading limestone. The lower half comprises calcareous shale with one to five generally unfossiliferous shaly or silty limestones that have little resistance to weathering. The basal 2 or 3 feet is fossiliferous in some exposures, however.

The Auburn shale is not an important source of ground water, although a few wells obtain small supplies of water from it at shallow depths.

Wakarusa Limestone

Massive, thick-bedded, hard, blue-gray, unevenly colored limestone which commonly weathers brown and contains a large and varied assemblage of fossils comprises the Wakarusa limestone. Typically it consists of two or three beds of limestone separated by partings or thin shale breaks and has an average thickness of about 4.5 feet (Pl. 5F). Large fusulinids, Cryptozoon, Ottonisia, Dictyoclostus and other brachiopods, horn corals, crinoids, and bryozaans are the common fossils.

In Lyon County the Wakarusa limestone is as effective in producing a topographic bench as is the next lower Burlingame limestone to which the bench is usually attributed. Because only a few feet of shale separate the two limestones a single bench is usually all that is present.

Except for a few wells which obtain small water supplies from joints or fractures in the Wakarusa limestone, it generally is of little importance as an aquifer.

Soldier Creek Shale

The Soldier Creek shale occurs between the Wakarusa limestone and the Burlingame limestone. It ranges from about 1 to 7 feet in thickness, is olive green, gray, or buff, and frequently contains a thin coal and carbonized plant remains in the middle or upper part (Pl. 5F). It is not important as a source of ground water.

Burlingame Limestone

Measured sections of the Burlingame limestone range from about 2 to 8 feet and average about 3 feet in thickness (Pl. 5F). In many exposures the Burlingame limestone is a somewhat massive, brecciated, uneven-colored, light-gray to buff limestone in which the fossils weather tan or light gray and the limestone matrix weathers a rich brown. Other exposures of the bed are nonresistant and make little or no bench along its outcrop. Locally, as in the NW 1/4 sec. 35, T. 17 S., R. 13 E., it is represented by thick, slightly cross-bedded, coquinal algal-molluscan limestone. Mollusks, together with Derbyia and Juresania, sometimes occur in the lower part. Small fusulinids occur in many, but not all, outcrops and Osagia algae are abundant in nearly every exposure. Bryozaans, crinoid fragments, and brachiopods are generally associated with the fusulinid and algal beds.

The Burlingame is not an important source of ground water; however, a few shallow wells obtain small supplies, chiefly from joints and fractures.

Silver Lake Shale

The Silver Lake shale comprises olive, gray, or nearly black sandy micaceous shale and sandstone containing carbonized land plant remains and locally thin coal beds or coaly streaks. Some exposures show the upper part to be nonsandy and contain a thin "boxwork" or conglomerate limestone. Measured sections of the Silver Lake shale range from 30 to 40 feet in thickness. Outcrops of this shale and underlying shale and limestone beds along the Neosho River Valley near Neosho Rapids suggest a local disconformity in the lower part of the Silver Lake shale. Some of
these exposures show a limestone conglomerate a few feet above the underlying Rulo limestone in this area. In other good exposures in near-by ravines and gullies the Rulo limestone cannot be found and in the same area the Happy Hollow limestone also seems to be absent. Where the Rulo and Happy Hollow limestones are absent there is present locally a cross-bedded, detrital, or conglomeratic limestone as much as 21 feet in thickness (Pl. 5A and G), the base of which is cut into the middle or lower part of the White Cloud shale. Also, at the SW cor. sec. 18, T. 19 S., R. 13 E., along the north bank of Neosho River (Pl. 5B) massive sandstone beds at least 30 feet thick are observed to cut out the Happy Hollow limestone. It is uncertain whether this diagenetic or sand-filled channel is of Silver Lake or Cedar Vale age; however, good exposures of the limestone conglomerate were observed in the Atchison, Topeka, and Santa Fe Railway cut (NE cor. sec. 30, T. 19 S., R. 13 E.) and in the river bed in SW¼ SE¼ and Cen. NW¼ sec. 19, T. 19 S., R. 13 E.

The conglomerate or detrital limestone consists of fragments of gray- and yellow-brown or buff limestone, similar to the Rulo and Happy Hollow limestones. Lithified shale fragments, coal, and fossil detritus including fusulinids, Osagia, bryozoans, and brachiopods occur in the bed also. The detritus ranges from sand size to pieces 1 foot or more in maximum length.

Smith (1903, p. 99) named this conglomerate the Neosho limestone and gave its thickness as 30 to 40 feet in the vicinity of Neosho Rapids. Smith (1903, p. 99) states the limestone is “well exposed in the ravines to the north and northeast [of the railroad cut], and is also found 40 feet thick in a well at the foot of Chicago mound, five miles southwest of this locality.”

Inasmuch as no single exposure was found in which one diagenetic could be observed to cut out the Rulo limestone, Cedar Vale shale, Happy Hollow limestone, and part of the White Cloud shale, it is possible that there is a local diagenetic in the Silver Lake shale, cutting just into the Cedar Vale shale and overlying an area in which the Happy Hollow has been removed by Cedar Vale erosion. This would mean a slightly older age for this thick conglomeratic limestone.

A few wells obtain small supplies of ground water from sandy parts of the Silver Lake shale and locally from the conglomerate at its base.

**Rulo Limestone**

Measured sections of the Rulo limestone average 1.5 to 2 feet in thickness. It comprises a single massive bed of gray to brown-gray limestone which has rather widely spaced joints allowing it to break into large blocks. It becomes shelly on weathering, and makes little outcrop except in actively eroding areas such as along creeks and gullies (Pl. 5E). It contains Dictyoclostus, Neo- spirifer, and other brachiopods, crinoid and echinoid fragments, Cryptozoon (?), a few snails and clams, and occasionally small horn corals. A feature distinctive of this limestone is the nodular or nobby appearance slightly weathered surfaces have, probably caused by slightly different weathering characteristics of the algal (?) and nonalgal parts of the limestone.

It is not important as a source of ground water.

**Cedar Vale Shale**

Gray, olive-green, and tan shale, sandy micaceous shale, and sandstone beds, together with the persistent Elmo coal which occurs a few inches or a few feet from the top, comprise the Cedar Vale shale. Average thickness is about 25 feet. Plant remains occur commonly in the sandy shale and shale parts. Locally where the formation is a nearly complete sandstone section, it yields small supplies of water to shallow wells from sandy zones. Elsewhere it yields little or no water to wells.

**Happy Hollow Limestone**

Measured sections of the Happy Hollow limestone range from about 2 to 10 feet in thickness. It is not observed in all outcrops of this part of the stratigraphic column, however. It is best developed in Ts. 20 and 21 S., where locally it makes a noticeable bench along its outcrop. It ranges from a hard, massive, brown, sandy limestone to a soft, silty or sandy, gray-green to pink-brown or buff limestone. Fossils include abundant large fusulinids and Osagia in most of its outcrops as well as crinoids, brachiopods, and pelecypods. In the area around Reading the limestone becomes thicker, has several shale partings, and contains few or no fusulinids.

It ordinarily yields little or no water to wells.
PLATE 5. **A.** Channel-filling cross-bedded limestone conglomerate of Silver Lake shale exposed in Neosho River bed, Cen. NW¼ sec. 19, T. 19 S., R. 13 E.  **B.** Channel-filling sandstone of Silver Lake or Cedar Vale shale age, more than 30 feet thick, exposed in cut bank of Neosho River, SW cor. sec. 18, T. 19 S., R. 13 E.  **C.** Unidentified algal colonies at the top of the Howe limestone, Cen. E. line sec. 34, T. 15 S., R. 11 E.  **D.** Cross-bedded upper bed of Grandhaven limestone in quarry face, SW¼ SW¼ sec. 29, T. 19 S., R. 11 E.  **E.** Typical shelly weathering of Rulo limestone, SE¼ SE¼ sec. 12, T. 19 S., R. 12 E.  **F.** Wakarusa limestone, Soldier Creek shale, and Burlingame limestone along road cut, SW cor. sec. 25, T. 18 S., R. 12 E.  **G.** Channel-filling limestone conglomerate (20 feet thick) of Silver Lake shale age cut into middle White Cloud shale: exposed in railroad cut, NE¼ NE¼ sec. 30, T. 19 S., R. 13 E.
White Cloud Shale

The White Cloud shale consists of about 80 feet of gray, olive, and tan or buff shale, sandy shale, and sandstone. It contains few or no fossils in most outcrops except land plant remains. Locally, as in the SW1/4 sec. 35, T. 21 S., R. 12 E., the lower part contains numerous ocherous concretions filled chiefly with sphalerite.

The White Cloud yields little or no water to wells ordinarily and is not an important aquifer.

Howard Limestone

The thickness of the Howard limestone ranges from about 20 to 28 feet. It supplies small quantities of water to a few shallow wells, chiefly from joints and fractures in the limestones.

Upotia limestone membre.—The thickness of the Upotia limestone ranges from about 5 to 8 feet. It generally comprises three limestones separated by thin shales. The upper bed is a slightly shaly gray or gray-brown limestone having an “oatmeal” texture. It contains abundant fusulinids and Osagia as well as bryozoans, brachiopods, and crinoid fragments. The shale beds are gray, olive, or buff, the upper one sometimes containing small clams and ostracodes. The middle and lower limestones are gray to gray-brown, shelly or shaly limestones. Mollusks, Osagia, and bryozoans are the most abundant fossils.

Winzeler shale membre.—The Winzeler shale comprises 5 to 7 feet of gray to tan shale. Most outcrops of Winzeler shale in Lyon County are very poorly exposed. No fossils were observed.

Church limestone membre.—The Church limestone is a distinctive easily recognized part of the Howard limestone. It ranges from about 1.8 to 2.3 feet in thickness and occurs as a single massive bed of deep-brown weathering, blue or blue-gray, brittle, hard limestone. Cryptozocon, crinoids, and brachiopods are the characteristic and abundant fossils. Fusulinids, bryozoans, and sparse mollusks are observed in a few outcrops.

Aarde shale membre.—The average thickness of the Aarde shale is about 7 feet. The upper part, comprising beds above the persistent Nodaway coal, is generally blue-gray or yellow-buff argillaceous shale. Locally a thin gray limestone 0.5 foot or less in thickness, containing Cryptozocon, crinoids, and brachiopods, occurs above the coal in this shale and is overlain by a few inches of black fissile shale. The Nodaway coal ranges from about 0.5 to 1 foot in thickness and generally occurs near the middle of the member but locally it may occur in the lower or upper part. The coal commonly is underlain by an underclay. Strata below the coal or underclay consist of gray or tan sandy micaceous shale.

Bachelor Creek limestone membre.—The basal member of the Howard limestone comprises gray or blue-gray, very sandy limestone which weathers yellow brown. Fossils are not abundant in any of the outcrops but sparse crinoids, bryozoans, and brachiopod fragments are generally observed. Mollusks occur in some outcrops. The thickness of the Bachelor Creek limestone ranges from about 1.5 to 5 feet and averages about 3 feet.

Severy Shale

On the basis of partial and rather poor outcrops of the Severy shale observed in Lyon County it is chiefly gray and tan shale, in part sandy and micaceous, together with beds of shaly sandstone. The formation has a thickness of about 65 to 80 feet. Sandy parts may yield small supplies of ground water to a few shallow wells.

Shawnee Group

Topeka Limestone

The Topeka limestone crops out in a small area along Eagle Creek. Of the nine named members of the formation only the lower two limestones are easily identified. The thickness of the formation is about 25 to 30 feet. The Coal Creek limestone member and Holt shale members are absent in Lyon County.

A few wells obtain small supplies of water from shallow wells in the Topeka limestone.

Du Bois limestone membre.—Silty or earthy gray limestone about 2 feet thick occurs in the uppermost part of the Topeka limestone and may represent the Du Bois limestone. It contains numerous clams including Myalina, Pinna, Aviculopectin, and Leda together with sparse snails, Linoproduxus, and crinoid remains.

Turner Creek shale membre.—Shale beds thought to correlate with the Turner Creek shale comprise about 4 feet of gray clayey and calcareous shale, with a thin mudstone near the middle. Fossils were not observed in the member.
Sheldon limestone member.—One exposure of light-gray to cream-weathering limestone mottled with brown probably represents the Sheldon limestone in Lyon County. It has a thickness of about 2 feet. Small clams were the only fossils observed.

Jones Point shale member.—Greenish-gray shale beds about 1 foot thick probably represent the Jones Point shale member in this area.

Curzon limestone member.—Interbedded limestone and limy shale 8 to 10 feet thick comprise the Curzon limestone. Abundant fusulinids throughout nearly the entire member make this limestone easily recognized. The fusulinids weather free in the shaly parts and are conspicuous along its outcrop. Bryozoans, echinoderm and crinoid fragments, several species of brachiopods, and Osagia occur in parts of the limestone also.

Iowa Point shale member.—No shale beds correlatable with the Iowa Point shale in its type area are believed present in Lyon County. The Curzon limestone directly overlies the Hartford limestone.

Hartford limestone member.—The lowermost member of the Topeka limestone is represented by 6 to 9 feet of light-gray to nearly white brecciated-appearing uneven-beded limestone with brown limonitic or ocherous stains on fractures and as replacement material of fossils. Darker gray, dense, nonbrecciated limestone occurs in the lowermost part and contains conspicuous Cryptozoan algae. Together with the Curzon limestone it makes a prominent bench in the topography.

Calhoun Shale

Only a few feet of the upper part of the Calhoun shale crops out in Lyon County. It comprises chiefly sandy micaceous olive to gray shale and sandstone containing carbonized plant remains.

It yields small supplies of water to a few wells.

PART 2
MINERAL RESOURCES OF LYON COUNTY
By
HOWARD G. O'CONNOR, EDWIN D. GOEBEL, AND NORMAN PLUMMER

INTRODUCTION

The known mineral resources of Lyon County comprise oil, coal, limestone, shale, gravel, sand, silt and clay, and volcanic ash. Ground water, also an important mineral resource, is discussed separately in Part 3 of this report. Limestone, gravel, sand, and coal have been exploited for local use for many years, but extensive reserves remain. Oil has been produced since 1922 but much of the county remains inadequately explored for petroleum. Volcanic ash was mined in what is now the City of Emporia for several years beginning about 1910. Clay resources have been utilized to a very small extent or not at all.

Plate 2 is an economic geologic map of Lyon County. Locations of active and inactive pits, quarries, and mines, names of exploited stratigraphic units, and test data on several of the limestones, shales, and clays are shown on the map. Locations of all wells that have been drilled for oil or gas for which any information is available also are indicated. The map shows the lowest stratigraphic depth reached and present status of all wells. Areas of oil fields, location of roads, railroads, streams, oil and gas pipe lines, pumping stations, and benchmarks are indicated.

ECONOMIC GEOLOGY OF OUTCROPPING ROCKS

Properties and the sequence of outcropping rocks are discussed in Part 1 of this report. Their distribution is shown on Plate 1.

Limestone

Many of the limestones occurring in the exposed portion of the geologic column are of economic
<table>
<thead>
<tr>
<th>Stratigraphic unit, thickness, and type of sample</th>
<th>Location</th>
<th>SiO₂</th>
<th>Al₂O₃*</th>
<th>Fe₂O₃</th>
<th>CaO</th>
<th>MgO</th>
<th>P₂O₅</th>
<th>SO₃</th>
<th>Ignition loss</th>
<th>Calcd CaCO₃**</th>
<th>Calcd MgCO₃*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Howe Is., composite of lower 4.0 ft. of 4.4 ft. bed.</td>
<td>SE NE 34-15-11E</td>
<td>5.40</td>
<td>0.74</td>
<td>0.27</td>
<td>51.97</td>
<td>0.73</td>
<td>0.01</td>
<td>0.07</td>
<td>41.33</td>
<td>92.55</td>
<td>1.53</td>
</tr>
<tr>
<td>Upper Crouse Is., composite of upper 5.6 ft.</td>
<td>NE NW 15-16-10E</td>
<td>14.09</td>
<td>2.76</td>
<td>1.03</td>
<td>43.71</td>
<td>1.01</td>
<td>0.05</td>
<td>0.06</td>
<td>36.47</td>
<td>77.76</td>
<td>2.11</td>
</tr>
<tr>
<td>Upper Crouse Is., composite of lower 2.9 ft. of bed.</td>
<td>NE NW 15-16-10E</td>
<td>3.61</td>
<td>0.98</td>
<td>1.12</td>
<td>51.78</td>
<td>0.74</td>
<td>0.03</td>
<td>0.09</td>
<td>41.25</td>
<td>92.83</td>
<td>1.55</td>
</tr>
<tr>
<td>Funston Is., composite of lower 5.6 ft. of upper bed.</td>
<td>NW NE 18-16-10E</td>
<td>7.90</td>
<td>1.49</td>
<td>0.70</td>
<td>49.11</td>
<td>0.04</td>
<td>0.15</td>
<td>39.24</td>
<td>87.30</td>
<td>1.72</td>
<td></td>
</tr>
<tr>
<td>Funston Is., composite of 2.0 ft., entire middle detrital bed.</td>
<td>NW NE 18-16-10E</td>
<td>4.99</td>
<td>1.25</td>
<td>1.01</td>
<td>50.72</td>
<td>0.79</td>
<td>0.06</td>
<td>0.02</td>
<td>40.46</td>
<td>90.26</td>
<td>1.65</td>
</tr>
<tr>
<td>Morrill Is., composite of entire bed, 2.4 ft.</td>
<td>SW NE 17-16-11E</td>
<td>5.65</td>
<td>0.37</td>
<td>0.42</td>
<td>51.93</td>
<td>0.82</td>
<td>0.05</td>
<td>0.08</td>
<td>41.14</td>
<td>92.37</td>
<td>1.72</td>
</tr>
<tr>
<td>Cottonwood Is., composite of upper 5.3 ft. of member.</td>
<td>SE NW 17-16-11E</td>
<td>9.70</td>
<td>0.97</td>
<td>0.51</td>
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<td>0.39</td>
<td>38.70</td>
<td>85.34</td>
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</tr>
<tr>
<td>Upper Neva Is., composite of entire 1.7 ft. bed.</td>
<td>NW SW 20-16-11E</td>
<td>4.18</td>
<td>0.62</td>
<td>0.46</td>
<td>52.25</td>
<td>0.64</td>
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<td>41.42</td>
<td>93.06</td>
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<td>Middle Neva Is., composite of entire 5.7 ft. middle bed.</td>
<td>NW SW 20-16-11E</td>
<td>3.92</td>
<td>0.93</td>
<td>0.53</td>
<td>52.07</td>
<td>0.77</td>
<td>0.05</td>
<td>0.02</td>
<td>41.53</td>
<td>92.76</td>
<td>1.61</td>
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<tr>
<td>Brownville Is., composite of entire 3.0 ft. bed.</td>
<td>NW NW 21-16-12E</td>
<td>6.19</td>
<td>1.38</td>
<td>1.83</td>
<td>47.65</td>
<td>2.09</td>
<td>0.29</td>
<td>0.69</td>
<td>39.19</td>
<td>83.52</td>
<td>4.37</td>
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<tr>
<td>Dover Is., composite of entire bed, 1.5 ft.</td>
<td>NW SW 25-16-12E</td>
<td>36.62</td>
<td>5.67</td>
<td>1.86</td>
<td>29.39</td>
<td>0.92</td>
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<td>nil</td>
<td>23.84</td>
<td>52.41</td>
<td>1.92</td>
</tr>
<tr>
<td>Reading Is., entire bed, 2.8 ft.</td>
<td>SE SE 12-17-12E</td>
<td>6.53</td>
<td>1.43</td>
<td>1.38</td>
<td>49.45</td>
<td>0.93</td>
<td>0.09</td>
<td>0.47</td>
<td>39.48</td>
<td>87.39</td>
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</tr>
<tr>
<td>Grandhaven Is., composite of entire lower bed, 2.6 ft.</td>
<td>SW SW 15-17-12E</td>
<td>9.56</td>
<td>2.93</td>
<td>3.08</td>
<td>44.36</td>
<td>2.04</td>
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<td>0.01</td>
<td>37.41</td>
<td>78.82</td>
<td>4.27</td>
</tr>
<tr>
<td>Upper Grandhaven Is., composite entire bed, 2.6 ft.</td>
<td>NE NE 21-17-12E</td>
<td>3.55</td>
<td>0.98</td>
<td>1.23</td>
<td>52.19</td>
<td>0.81</td>
<td>0.04</td>
<td>0.19</td>
<td>41.63</td>
<td>92.74</td>
<td>1.69</td>
</tr>
<tr>
<td>Cottonwood Is., composite of upper 4.7 ft. of member.</td>
<td>SW NW 7-18-10E</td>
<td>5.97</td>
<td>1.09</td>
<td>0.37</td>
<td>51.22</td>
<td>0.65</td>
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<td>40.65</td>
<td>91.16</td>
<td>1.36</td>
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<td>Aspinwall Is., composite of upper 4.6 ft. of bed.</td>
<td>NE NE 16-18-11E</td>
<td>1.99</td>
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<td>53.12</td>
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<td>42.17</td>
<td>94.58</td>
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<tr>
<td>Upper Grandhaven Is., composite of upper 7.5 ft. of bed.</td>
<td>NW SE 29-19-11E</td>
<td>4.22</td>
<td>1.49</td>
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<td>Wakarusa Is., composite of 3 ledges, 4.3 ft.</td>
<td>SW SE 9-19-12E</td>
<td>5.32</td>
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<tr>
<td>Silver Lake sh. ? (Is. conglomerate filling channel cut down into White Cloud sh., composite ± 20 ft.</td>
<td>NE NE 30-19-13E</td>
<td>6.06</td>
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<td>2.79</td>
<td>47.76</td>
<td>2.02</td>
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<td>0.20</td>
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<td>84.52</td>
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<tr>
<td>Americus Is., composite of entire lower bed, 1.8 ft.</td>
<td>SW SE 4-20-10E</td>
<td>4.25</td>
<td>0.75</td>
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<td>0.73</td>
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<td>91.08</td>
<td>1.52</td>
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<tr>
<td>Reading Is., composite of entire bed, 2.75 ft.</td>
<td>SW SE 33-21-11E</td>
<td>4.44</td>
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<td>3.44</td>
<td>47.55</td>
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<td>84.79</td>
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<tr>
<td>Reading Is., composite of upper &quot;super&quot; Is., entire bed, 6.0 ft.</td>
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<td>4.75</td>
<td>0.73</td>
<td>0.99</td>
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<td>0.70</td>
<td>0.11</td>
<td>0.08</td>
<td>40.67</td>
<td>91.94</td>
<td>1.46</td>
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</table>

* Includes MnO and TiO₂.
** Not corrected for small percentages of calcium in phosphates and sulfates.
importance because of their physical or chemical properties. Included as the more common uses for which these rocks are suitable are concrete and other aggregate, crushed rock for road metal and other uses, agricultural limestone, riprap, subgrade and embankment material, and building stone. Some of the limestones, because of chemical composition, may be suited to more specialized uses. Chemical analyses of rock samples from the more important ledges are listed in Table 1. Location of all active and inactive limestone quarries together with the stratigraphic unit represented is shown on Plate 2.

AGRICULTURAL LIMESTONE

Limestone having a calcium carbonate equivalent of 80 percent or more occurring in ledges sufficiently thick to allow economical quarrying is regarded as potential material for agricultural limestone. Physical requirements for agricultural limestone largely are dependent on processing and are not considered here.

Of 22 samples of limestone collected for chemical analysis, 20 met minimum requirements for calcium carbonate equivalent (Table 1). Limestones which are of proved or potential value as material for agricultural limestone include the Funston, Crouse, Morrill, Cottonwood, Neva, Howe, limestone parts of the Bennett shale, Long Creek, Five Point, Aspinwall, Grandhaven, Reading, Wakarusa, Burlingame, limestone conglomerate phases of the Silver Lake shale, Curzon, Hartford, and possibly others.

BUILDING STONE

Many of the limestone ledges in Lyon County have been used as sources of building stone but greatest use has been made of the Funston, Crouse, Cottonwood, Neva, Americus, Brownville, and Reading limestones. Other limestones have been used locally for farm buildings and small engineering works such as small bridge foundations and abutments. Factors considered for suitability as building stone include durability, color on weathering, thickness of ledges and individual beds, and spacing of joints. Not considered are such factors as markets and other economic considerations.

Crouse limestone.—Parts of the Crouse limestone have been quarried and used for trimmed structural stone for some of the older school houses, farm buildings, and bridge foundations in Lyon and adjacent counties. Although it is durable and easy to cut and handle, its weathered color is not as pleasing as Cottonwood or Fort Riley limestone and it has never attained much popularity.

Cottonwood limestone.—The Cottonwood limestone has long been regarded as an important building stone in Kansas. It is massive, durable, even textured, light gray to nearly white in color, and can be quarried in large blocks. It has been quarried for building stone at three localities in Lyon County and several large commercial quarries were formerly active in adjacent Chase County.

Howe limestone.—The Howe limestone, although used to little or no extent in the past, seems to have physical properties that would make it a very desirable building stone. It is a spergenite similar in color, texture, and appearance to the Salem ("Bedford") limestone of Indiana, one of the most widely used building stones in the United States. It is finer textured than the Cottonwood limestone but not as fine as the "Bedford" limestone. Its light gray-white color, durability on the outcrop, and occurrence in usable beds 4 feet or more in thickness, locally, without shale partings or chert nodules, suggest that it would make a durable and attractive building stone.

Americus limestone.—Both the lower and upper ledges of the Americus limestone have been quarried and used extensively in eastern Kansas, chiefly for farm buildings, bridge foundations and abutments and for sidewalk construction. The rock is durable and has no tendency to become slabby after long exposure. It can be quarried in large blocks 1 to 2 feet thick. Its gray color is too dark to make it appealing as a building stone for residential or business building uses.

CRUSHED ROCK AND RIPRAP

Nearly all the thicker limestone ledges in Lyon County are potential sources of rock for crushing and riprap material. No recommendations of individual ledges for aggregate or riprap material are made because of the many current sets of specifications for aggregate for specialized uses and because no physical tests on any of the limestones were made.
Limestones known to have been used as sources of crushed rock for concrete aggregate include Cottonwood, Grandhaven, Wakarusa, and Burlingame limestones and possibly others. Those used as sources of crushed rock for road metal and other purposes include Funston, Crouse, Cottonwood, Neva, Aspinwall, Brownville, Grandhaven, Reading, Wakarusa, Burlingame, and Utopia limestones.

Not utilized as yet but believed suitable for crushing include the thick biothermal limestone in the Bennett shale which is more than 20 feet thick locally, and the limestone conglomerate which occurs in the basal deposits of Silver Lake shale in the Neosho Rapids area, also more than 20 feet thick locally.

Limestones used for riprap include nearly half the named limestones cropping out in the county. Most projects requiring riprap for road, bridge, or railroad fill and embankment protection have utilized the nearest local limestone that occurred in suitable quantities and had the necessary physical requirements. An example is the use of Maple Hill limestone as riprap for the dam impounding Lake Wilhite in Lyon County State Park.

CERAMIC MATERIALS
CLAY FOR STRUCTURAL PRODUCTS

Several samples of clay and shale obtained in Lyon County were tested in the ceramics laboratory of the State Geological Survey (Pl. 2, Table 2). These samples included shales of Pennsylvanian and Permin age and alluvial materials of Pleistocene age. Since these materials are mostly red-firing, their range of usefulness is confined largely to structural products such as brick and tile and to lightweight aggregate.

Shales of Pennsylvanian age are exposed at the surface over a proportionately large area in Lyon County. The shales occur in thick beds that could be mined economically by surface methods, and compare favorably with the lower Pennsylvanian shales that are used extensively for the manufacture of brick, building tile, roofing tile, sewer pipe, and lightweight aggregate in southeastern Kansas.

The Pennsylvanian shales are easily formed into the desired shapes by the almost universally employed extrusion method. Usually the more clayey shales have to be extruded with care in the choice of die shapes in order to avoid a laminated product. Drying shrinkages are low to moderate, and warpage is usually not a problem in drying. These shales fire to shades of red varying with both the formation and the temperature of firing. Light or orange reds are obtained at low temperatures and dark reds are obtained at higher temperatures, close to vitrification. Most of the shales can be fired to vitrification, that is, they can be fired to a temperature high enough to reduce the absorption to less than 3 percent. Such shales and clays are suitable for use in the manufacture of sewer pipe and vitrified bricks.

Despite the similarity of the Pennsylvanian shales tested, significant differences in ceramic data can be noted in Table 2. In general, those showing the least change in absorption and shrinkage over a given temperature range are the most suitable for use. The saturation coefficient, also shown in Table 2, is the ratio of cold water absorption to the absorption obtained by immersion in boiling water. Fired clay products having a saturation coefficient below 0.80 are generally resistant to severe weathering conditions such as freezing and thawing.

The two Permian shales for which ceramic data are given in Table 2 fire to buff or greenish-buff colors. This fired color is due primarily to the influence of calcium carbonate which is present in amounts sufficient to mask, or neutralize, the red color normally caused by iron oxide. Although the buff color is desirable, the calcium carbonate produces a ceramic material with a short firing range. Furthermore, a product made from such shales must be fired to a temperature high enough to take the calcium into permanent combination with other ingredients. If fired below this temperature, the fired product will disintegrate due to the hydration of quick lime produced during the firing process. The Speiser and Roca shales for which data are given, are steel hard at cone 2 (about 2100°F) and seemingly are sound at this temperature. Absorptions are rather high, however, and the materials would probably be improved by firing to a slightly higher temperature.

The alluvial clays, or clayey silts, produce a finished ceramic product very similar to those made from Pennsylvanian shales. The raw ma-
### Plastic and Dry Properties

<table>
<thead>
<tr>
<th>Sample No.</th>
<th>Location</th>
<th>Stratigraphic position</th>
<th>Thickness sampled, feet</th>
<th>Water of shrinkage, percent</th>
<th>Shrinkage, percent</th>
<th>Pore water, percent</th>
<th>Volume shrinkage, percent</th>
<th>Measured linear shrinkage, percent</th>
<th>Calculated linear shrinkage, percent</th>
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<tbody>
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<td>LY-9</td>
<td>NW 19-19-13 E.</td>
<td>Silver Lake shale</td>
<td>18</td>
<td>20.62</td>
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<td>Willard-Langdon shale</td>
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<td>LaPorte shale</td>
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<td>17.56</td>
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<td>26.02</td>
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### Fired Properties

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<th>Fired to cone</th>
<th>Color</th>
<th>Measured linear shrinkage, percent</th>
<th>Total linear shrinkage, percent</th>
<th>Percent absorption</th>
<th>24 hrs. cold water</th>
<th>3 hrs. boiling water</th>
<th>Saturation coefficient</th>
<th>Hardness, as to steel</th>
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<td>0.96</td>
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<tr>
<td></td>
<td>04</td>
<td></td>
<td></td>
<td></td>
<td>8.67</td>
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<td>1.50</td>
<td>2.45</td>
<td>0.61</td>
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<td>2 plus</td>
<td>05</td>
<td>buff</td>
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<td>9.42</td>
<td>15.32</td>
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<td></td>
<td>02</td>
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<td></td>
<td>2.85</td>
<td>9.29</td>
<td>15.65</td>
<td>18.42</td>
<td>0.85</td>
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<td>LY-7</td>
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<td>2 plus</td>
<td>05</td>
<td>buff</td>
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<td>9.49</td>
<td>12.35</td>
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<td>05</td>
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<td>1.41</td>
<td>13.35</td>
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<td>0.74</td>
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<td></td>
<td></td>
<td>2.36</td>
<td>14.30</td>
<td>8.02</td>
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<td>07-02</td>
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<td>orange red</td>
<td>4.23</td>
<td>15.39</td>
<td>4.14</td>
<td>4.67</td>
<td>0.89</td>
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<tr>
<td></td>
<td>02</td>
<td></td>
<td></td>
<td></td>
<td>5.63</td>
<td>16.79</td>
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<td>3.13</td>
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<td>5.99</td>
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<td>1.34</td>
<td>2.13</td>
<td>0.63</td>
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</table>
TABLE 3.—Results of experimental production of lightweight aggregate from Lyon County Pennsylvanian shales

<table>
<thead>
<tr>
<th>Sample No.</th>
<th>Thickness sampled, feet</th>
<th>Thickness available, feet</th>
<th>Firing temperatures, degrees F.</th>
<th>Unit weight, lbs. per cu. ft.</th>
<th>Color of crushed aggregate</th>
</tr>
</thead>
<tbody>
<tr>
<td>LY-1</td>
<td>15</td>
<td>30</td>
<td>2190</td>
<td>2220</td>
<td>2280</td>
</tr>
<tr>
<td>LY-2</td>
<td>11</td>
<td>18</td>
<td>2140</td>
<td>2170</td>
<td>2240</td>
</tr>
<tr>
<td>LY-3</td>
<td>12.5</td>
<td>25</td>
<td>2130</td>
<td>2140</td>
<td>2170</td>
</tr>
<tr>
<td>LY-4</td>
<td>11</td>
<td>11</td>
<td>2080</td>
<td>2120</td>
<td>2180</td>
</tr>
<tr>
<td>LY-5</td>
<td>20</td>
<td>20</td>
<td>2200</td>
<td>2230</td>
<td>2250</td>
</tr>
<tr>
<td>LY-6</td>
<td>14.5</td>
<td>22</td>
<td>2160</td>
<td>2175</td>
<td>2200</td>
</tr>
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</table>

Material differs markedly in appearance, however, and the forming, drying, and firing behavior differ more than the data in Table 2 indicate. These materials contain a relatively large proportion of nonplastic materials and are therefore somewhat harsh in contrast to the outstanding smoothness of the Pennsylvanian shales. Ordinarily clayey materials containing a large proportion of nonplastic silt have a low drying shrinkage, and show no tendency to warp. The materials tested, however, warped slightly, and had a rather high drying shrinkage. If used for structural clay products, these materials should be altered slightly either by the addition of sand, or by low-temperature roasting of the raw material.

The fired colors of the alluvial materials are good clear reds. The fired products should have an unusually good resistance to freezing and thawing, and other agencies of weathering.

LIGHTWEIGHT AGGREGATES

Six samples of Pennsylvanian shale were tested in the State Geological Survey ceramics laboratory for their bloating characteristics by the rotary kiln method. The results of these tests were reported in a previous publication (Plummer and Hladik, 1951), and data on the six samples are reported in Table 3.

The unit weight of bloated shale lightweight aggregate should range from 40 to 55 pounds per cubic foot. Unit weights on crushed but unsized aggregate from three Lyon County localities, LY-1, LY-2, and LY-4, were less than 51 pounds per cubic foot. Unit weights on the other three were less than 65 pounds per cubic foot. These three, LY-3, LY-5, and LY-6, were sampled from oxidized exposures of the shale. Under commercial production conditions, such shales usually bloat satisfactorily, even when oxidized, but there is little doubt that unoxidized samples of the same shale would bloat sufficiently even under laboratory conditions of testing.

The quality of lightweight aggregate produced from Pennsylvanian shales is high. In general, they combine light weight with high strength.

Although data on the bloating characteristics of the Lyon County alluvial clays or clayey silts were not obtained in the laboratory, similar materials were tested (Plummer and Hladik, 1951). Since these materials are friable, it is necessary to form them into pellets before firing in a rotary kiln. In most cases a rather dense aggregate is formed at temperatures ranging from 2250 to 2400°F. The addition of 2 percent powdered coal or a mixture of powdered gypsum and powdered coal during the pelleting process usually results in the production of a high-grade lightweight aggregate. A sample from the Emporia terrace, taken in the SW¼ sec. 11, T. 19 S., R. 11 E., was fired in a rotary kiln at 2470°F, in the experimental production of a material suitable for heavy aggregate or railroad ballast (Plummer and Hladik, 1948). An excellent high density aggregate was produced. The addition of a small percentage of powdered coal or other combustible material would make possible the production of a lightweight aggregate at about 2300°F.

These alluvial clays and clayey silts are well adapted to production of lightweight aggregate by the sintering process. In this process the raw material is mixed with 5 to 15 percent powdered coal or coke, pelleted, and sintered on a moving grate-type machine. Pennsylvanian shales can also be made into lightweight aggregate by the sintering method.

GRAVEL AND SAND

Large deposits of gravel and sand composed chiefly of chert occur in the terraces (Pl. 4G) along Cottonwood, Neosho, Marais des Cygnes,
and Verdigris Rivers and some of their tributary streams (Pl. 2). These gravel deposits have been used as a source of road metal for county and township roads for many years but extensive reserves remain. To some extent washed gravel from these deposits has also been used as an aggregate for concrete. The Bechtold pits (Pl. 4D) in sec. 9, T. 19 S., R. 10 E., are the only presently active pits having washing and screening equipment mining terrace sand and gravel.

Accumulations of sand and gravel, chiefly chert and quartz but including limestone also, in the alluvium of Cottonwood River and of Neosho River below its junction with Cottonwood River, are extensive and large. Wesley Parks operates a large pit (Pl. 4A) in sec. 6, T. 20 S., R. 13 E. with hydraulic mining equipment. The washed and sized sand and gravel are used chiefly as road metal for county, township, and bituminous mat roads. One other pit using alluvium of Cottonwood River is operated in sec. 20, T. 19 S., R. 11 E.

Alluvial deposits of sand and gravel in Marais des Cygnes and Verdigris River Valleys are similar to those of Cottonwood River Valley except for a smaller percentage of quartz grains.

Large deposits of very fine to medium quartz sand and friable sandstone occur in several of the outcropping shale formations. Mica, together with varying amounts of clay minerals, generally is present in the Pennsylvanian and Permian sands and sandstones. In a pit (Pl. 4C) in sec. 5, T. 19 S., R. 12 E., the Pierson Point-Willard shale (sandstone) has been exploited for use as subgrade and embankment material on highway projects in the county.

Volcanic Ash

Volcanic ash (Pearlette) has been mined commercially for use as an abrasive from one pit in Lyon County. Mining operations were carried on for several years commencing about 1910 in the area between Sixth and Seventh Streets just east of Garfield Street (SE¼ SE¼ SW¼ sec. 9, T. 19 S., R. 11 E.) in the City of Emporia. Thickness of the bed at the mine is reported to have been 3 to 4 feet. A thickness of 5 inches of ash was penetrated in a well about one-half mile east of the mine (Carey and others, 1952, p. 51). The ash occurs in the Emporia terrace.

Inasmuch as this area is now a residential section of Emporia the deposit is not accessible for mining. Other deposits may be present in the county; however, no outcrops of volcanic ash were observed nor were any deposits penetrated in the test drilling program of the Geological Survey during the ground-water investigations.

Coal

At least four coals have been mined in Lyon County since Swallow (1866) first recorded the occurrence of coal in the area. Coals mined include the Lorton and Nodaway coals and coals in the Langdon-Pieront Point shale and Auburn shale. At least 18 shaft, drift, and strip mines have been operated which together have produced approximately 18,000 tons of coal. Schoewe (1946) presents detailed data on the history, location of mines, production, and reserves of coal in the Wabaunsee group in Lyon County.

At least 15 separate coal beds have been identified in outcrops (stratigraphic column, Pl. 2). According to Schoewe (1946) there are approximately 5,520,000 tons of proved coal reserves and 303,180,000 tons of potential coal reserves in the Wabaunsee group in Lyon County. Permian coals and some of the Wabaunsee coals were not considered in these estimates.

Subsurface Rocks

Stratigraphy and Structure

Conditions along a north-south line through the western part of Lyon County are shown on Figure 2, on which major rock units are differentiated.

Lyon County lies within the Forest City basin, being near the western flank of the basin and on the north flank of the Bourbon arch.

The surface rocks generally dip west by northwest, but as indicated by Figure 2, the subsurface units dip more northerly into the North Kansas basin.

The stratigraphy of the major rock units encountered in the subsurface of Lyon County is discussed in the following paragraphs.
MINERAL RESOURCES OF LYON COUNTY

PERMIAN ROCKS

Thickness of the Council Grove group is uniformly about 320 feet in Lyon County. The Admire group is uniformly about 130 feet thick throughout the county.

PENNSYLVANIAN ROCKS

Pennsylvanian rocks do not have a constant thickness in Lyon County due to slight lateral changes in thickness of the formations and because Pennsylvanian rocks present in the subsurface of the western part of the county have been removed from the eastern exposed part by erosion. The westward-dipping surface rocks have been beveled by erosion. Pennsylvanian rock groups in Lyon County do not differ greatly in thickness and lithology from those of the surrounding counties.

The Wabaunsee and Shawnee groups are typically composed of shale and thin limestone beds. The Douglas group is predominantly composed of clastic materials with known formations difficult to differentiate. Thickness of Douglas rocks differs as shown by Figure 2, indicating local erosion of Missourian rocks (Pedee) before deposition of Douglas rocks. The Lansing and Kansas City groups are made up almost entirely of limestones. The Pleasanton shale averages about 100 feet in thickness throughout the county. The Marmaton limestones are separated by thin shales, their thicknesses remaining nearly constant. Cherokee rocks are composed of about 300 feet of shales with some thin limestones and sandstones. In the southern part of the county, the “Bartlesville sand,” in the lower part of the Cherokee group, has yielded oil.

MISSISSIPPIAN ROCKS

Thickness of Mississippian rocks in Lyon County ranges from about 300 feet in the northeastern corner to more than 400 feet in the central eastern part (Lee, 1943, fig. 16). The Chattanooga shale, averaging slightly more than 100 feet in thickness, progressively overlaps from north to south on beveled older rocks ranging in age from Devonian to middle Ordovician.

PRE-CHATTANOOGA ROCKS

The Chattanooga shale in most of Lyon County is believed to lie on the Viola limestone (Ocker- man, 1935, fig. 2). In the northern part of the county, the “Hunton” limestone underlies the Chattanooga shale and the pre-Chattanooga outcrops of the “Hunton” and Viola limestones are separated by about 75 feet of Sylvan (Maquoketa) shale (Fig. 2). The interval between the base of the Chattanooga shale and the top of the Sylvan (Maquoketa) shale is about 100 feet (Lee, 1943, fig. 12) in the northern part of the county. The total thickness of the rocks between the top of the Sylvan (Maquoketa) shale and the top of the St. Peter sandstone is probably less than 150 feet everywhere in the county, and the interval from the top of the St. Peter to the Pre-Cambrian ranges from about 300 to 800 feet.

The thickness of the Jefferson City-Cotter sequence in Lyon County has been estimated by Keroher and Kirby (1948, figs. 4, 6, 8, 9) as ranging from about 100 feet in the northwestern part of the county to about 375 feet in the southeastern part; the Roubidoux dolomite, from less than 100 feet in the southeastern part to slightly more than 150 feet in the northwestern part; the Van Buren-Gasconade sequence, believed to be absent in the western half of the county, from a featheredge to a thickness of less than 50 feet in the eastern part; the Bonneterre dolomite from a featheredge in the southeast corner to a maximum of more than 100 feet in the northeast part.

OIL AND GAS

SECONDARY RECOVERY

The first reported secondary recovery operation in Lyon County was in the Lyon County portion of the Fankhouser field in 1943 (Jewett, 1949, table 3). This project grew from 30 acres in extent to more than 100 acres at the end of 1951. Secondary recovery is being carried on in the Atyeo field at the present time also. More than 85 percent of the oil produced in the county during the past three years is credited to recovery by water-flood projects. The calculated water-flood reserves as of January 1, 1948, were more than 4 million barrels of oil (Sweeney, 1949, p. 23).

EXPLORATION AND PRODUCTION

Until the discovery of commercial quantities of oil in the Bushong field in 1950, oil was pro-
duced only in the southern part of Lyon County. Exploration has been concentrated in the western and southern parts of the county. According to available records, 446 holes have been drilled in Lyon County in search for oil or gas. Of these, 122 have produced oil in the past or are producing at present.

Producing formations.—The rocks in which oil has been found are the “Bartlesville shoestring sand” in the Cherokee shale of middle Pennsylvanian age, the Osagian Series of the Mississippian System, the “Hunton” limestone of late Devonian age, and the Viola (Kimmswick) limestone of middle Ordovician age. No commercial quantities of gas have been reported as produced in the county.

Fig. 2.—Geologic cross section showing conditions along a north-south line through the western part of
Although 20 holes have been drilled into Arbuckle dolomite or older rocks, no oil or gas has been found in them. Survey files contain records of only one hole drilled to Pre-Cambrian rocks. Locations of oil wells and dry holes and their stratigraphic depths are shown on Plate 2.

**Drilling activity in recent years.**—In 1949, 11 dry holes were reported drilled in the county. Of these, 1 was an extension well in the Fankhouser field, 1 was an extension well in the Ott (Greenwood County) field, and 9 were dry wildcat wells (drilled more than 2 miles from existing production). Only one of the dry wildcats did not penetrate the Arbuckle dolomite (lower Ordovician). They were concentrated in the western half of the county (Ver Wiebe and others, 1950).

Lyon County, differentiating major rock units. In center column for “Dry Creek shale” read Dry shale.
In April 1950 the Stanolind Oil and Gas and Winkler and Koch No. 1 Cornwell well in the NE\(\frac{1}{4}\) SE\(\frac{1}{4}\) NE\(\frac{1}{4}\) sec. 26, T. 16 S., R. 10 E. discovered a new producing formation, the “Hunton” limestone (late Devonian age) resulting in a new oil field, the Bushong. During 1950, 1 dry extension well was added to the new field. In all, 27 tests were made in Lyon County in 1950. Extension wells added 1 dry hole to the Bradfield field (now inactive), 6 oil wells and 4 dry holes to the Fankhouser field, and 1 oil well and 1 dry hole to the Rock Creek field. The remaining 13 tests were dry wildcats concentrated in the western half of the county (Ver Wiebe and others, 1951).

During 1951, 15 wells were drilled in the county. Of these, 1 dry hole was added to the Bushong field, 2 oil wells and 3 dry holes to the Fankhouser field, 1 dry hole to the Richey-Moore field (now inactive), and 1 oil well and 1 dry hole to the Rock Creek field. Three of the 6 dry wildcat tests penetrated the Arbuckle dolomite (Ver Wiebe and others, 1952).

**OIL FIELDS**

*Atyeo field.*—The Atyeo field straddles the junction of Lyon, Chase, and Greenwood Counties. The Lyon County part is located in secs. 19, 30, and 31, T. 21 S., R. 10 E. The discovery well of the field is believed to be in the SE\(\frac{1}{4}\) SW\(\frac{1}{4}\) sec. 30, T. 21 S., R. 10 E. Production comes from the “Bartlesville sand” at an average depth of about 2,200 feet. The daily initial production of various wells ranged from less than 10 to more than 500 barrels of oil per day. Of 95 holes drilled in the field, 11 were dry and 55 have produced oil; only 34 now produce in the Lyon County part of the field. In 1949, production from 45 wells was 391,013 barrels. In 1950, 45 wells produced 296,131 barrels, and in 1951, 34 wells produced 229,271 barrels of oil (Ver Wiebe and others, 1950, 1951, 1952).

*Bradfield field.*—According to Landes (1937, p. 57), oil was first discovered in Lyon County in the Bradfield field in Ordovician sandstone in 1922. The Bradfield field (now inactive), is in secs. 24 and 25, T. 21 S., R. 10 E. Some wells in the area had reported initial production of more than 1,000 barrels of oil daily, production coming from depths of 2,200 to 2,600 feet, probably from the Viola (Kimmswick) limestone. According to Survey records, of 22 holes drilled in the field, 7 were dry and 15 produced oil in the past. Production during 1925 was reported as 27,515 barrels of oil. No field production figures are available for succeeding years.

*Bushong field.*—The Bushong field was discovered in 1950 by the Stanolind Oil and Gas Company and Winkler and Koch No. 1 Cornwell well in the NE\(\frac{1}{4}\) NE\(\frac{1}{4}\) NE\(\frac{1}{4}\) sec. 26, T. 16 S., R. 10 E. The discovery well was rated at 257 barrels of oil per day from the “Hunton” limestone at depths of 2,950 to 2,967 feet. Later in the year a dry extension well was added to the field in the NE\(\frac{1}{4}\) SE\(\frac{1}{4}\) SE\(\frac{1}{4}\) sec. 23, T. 16 S., R. 10 E. From April to November 1950, 4,334 barrels of oil were marketed from this one well. During 1951 the well produced 5,705 barrels of oil (Ver Wiebe and others, 1951, 1952).

*Fankhouser field.*—The Lyon County part of the Fankhouser oil field is located in secs. 29, 31, 32, and 33, T. 21 S., R. 12 E. The field was extended from Greenwood County in 1926. The depth to the producing “Bartlesville sand” is about 1,850 feet. Of 62 holes drilled in the Lyon County part of the field 22 were dry and 40 have produced oil, 23 wells now producing. In 1949, the total production of the Lyon County part was 28,224 barrels, in 1950, 50,380 barrels, and in 1951, 48,683 barrels of oil (Ver Wiebe and others, 1950, 1951, 1952).

*Richey-Moore field.*—The Richey-Moore oil field formerly produced from the upper part of the Mississippian limestone. The discovery well, drilled in 1925, is believed to have been in the SE cor. SW\(\frac{1}{4}\) sec. 34, T. 21 S., R. 10 E. Production came from a depth of about 2,200 feet. Of 12 wells drilled in the field, 9 were dry and 3 produced oil. No Richey-Moore field production figures are available.

*Rock Creek field.*—The Rock Creek field is located in secs. 29 and 32, T. 21 S., R. 11 E. The discovery well, the Murphy et al. No. 1 Fee well in the NW\(\frac{1}{4}\) NW\(\frac{1}{4}\) NE\(\frac{1}{4}\) sec. 32, T. 21 S., R. 11 E., found initial daily production of 35 barrels daily from the “Bartlesville sand” at depths of 1,930 to 1,942 feet. Four producing wells were completed during 1947, the discovery year, and reported production was 4,440 barrels. Six dry extension wells were added to the field during 1948, when marketed production was listed as 5,544 barrels of oil (Jewett, 1949). In 1949, 4 producing wells yielded 4,371 barrels. In 1950, 1 oil well and 1 dry hole were
added to the field; production from 4 wells was 3,089 barrels. Three producing wells reported 3,131 barrels of oil marketed in 1951 (Ver Wiebe and others, 1950, 1951, 1952).

PART 3
GROUND-WATER RESOURCES OF LYON COUNTY
By
HOWARD G. O'CONNOR

GROUND-WATER RESOURCES*

SOURCE

Ground water is the water below the surface of the land that supplies water to wells and springs. It is derived largely from precipitation falling as rain or snow. Part of the water falling as rain or snow enters the soil, either directly or from streams, and percolates downward to the zone of saturation, part of the water after entering the soil is returned to the atmosphere by evaporation and transpiration without becoming a part of the ground-water body, and part of the water is carried away by streams as surface runoff.

The ground water percolates slowly through the rocks in a direction determined by the topography and geologic structure until it is discharged through wells, through springs or seeps, or by evaporation and transpiration in the valley areas.

PRINCIPLES OF OCCURRENCE

Basic principles of the occurrence of ground water were described by Meinzer (1923) and the reader is referred to this publication for more detailed discussion of ground-water principles. A general discussion of ground-water occurrence in Kansas has been made by Moore and others (1940).

The rocks that form the outer crust of the earth are not solid but contain numerous voids or interstitial openings that may contain air, water, or other fluid. The number, size, shape, and arrangement of these openings in different rock types vary greatly, and the water-bearing characteristics of rocks vary accordingly. With respect to water supplies, the original or primary interstices, are of primary importance in the unconsolidated rocks and certain types of consolidated rocks. Secondary interstices, such as joints, other fracture openings, and solution openings, are of greater importance in many of the consolidated rocks. Thus, the geology is a primary factor in the mode of occurrence of ground water in any area.

The amount of water that can be stored in a rock is determined by the porosity, or the percent of the rock occupied by voids. The amount of water that a saturated rock will yield by gravity is termed its specific yield; the amount retained or held in the voids of the rock is termed the specific retention. Thus, if 10 cubic feet of saturated rock yields 2 cubic feet of water, the specific yield is 20 percent. If 1 cubic foot of water is retained in the rock, the specific retention is 10 percent. The porosity is the sum of the specific yield and specific retention, or 30 percent.

The permeability of a water-bearing rock is its capacity to transmit water under hydraulic head and is a function of the size, shape, arrangement, and degree of interconnection of the voids, rather than the porosity.

Below a certain level in the earth's crust the permeable rocks generally are saturated with water under hydrostatic pressure and are said to be in the zone of saturation. The upper surface of the zone of saturation is called the water table. The rocks above the zone of saturation are in the zone of aeration, which ordinarily consists of three parts: the belt of soil water just below the surface, the intermediate or vadose zone, and the capillary fringe.

UNCONFINED WATER

Unconfined, or free ground water, is water in the zone of saturation that does not have a confining or impermeable body restricting its upper surface. The upper surface of unconfined ground

* Although the ground-water section of this report is a cooperative product of the State Geological Survey of Kansas and the United States Geological Survey, the stratigraphic nomenclature used is that of the State Geological Survey of Kansas.
water is called the water table. Changes in permeability and amounts of recharge to and discharge from the ground-water reservoir cause irregularities in the water table which, on a reduced scale, are generally similar to those of the surface topography. The height to which small openings in rocks above the water table are filled with capillary water is generally several inches to several feet in fine-grained granular materials but much less where it occurs in fissures, fractures, or solution channels.

Confined Water

Ground water is said to be confined if it occurs in permeable zones between relatively impermeable confining beds. Slightly permeable confining beds are probably much more abundant than impermeable confining beds and considered over a wide area probably no bed is strictly impermeable.

In areas where water is confined by alternating permeable and impermeable beds, a well may pass through several beds in the zone of saturation that have sufficient permeability to yield water to the well.

Artesian conditions.—The level at which water stands in a well is called the piezometric, or pressure indicating, surface. Where the top of the zone of saturation is in permeable material, the piezometric surface coincides with the water table and the water is said to be under normal pressure. If water is confined between relatively impermeable beds, the level at which water will stand in a well may be above or below the top of the zone of saturation. Confined water is said to be under artesian pressure if the water level stands above the water table or under subnormal pressure if the water level in a well is lower than the water table. If the water has sufficient pressure, or head, to flow at the surface of a well it is a flowing artesian well.

Many wells obtaining water from the Pennsylvanian and Permian limestones and sandstones in Lyon County obtain artesian water, but no areas were found in which the head was sufficient to cause the wells to flow at the surface.

GROUND-WATER RECHARGE

The addition of water to the underground reservoir is called recharge and may be accomplished in several ways. Local precipitation is the principal source of recharge. Lesser amounts are contributed by influent seepage from streams and ponds and by subsurface inflow from adjacent areas.

Recharge and Disposition of Precipitation

The normal annual precipitation in Lyon County is approximately 34 inches or nearly 600 million gallons of water per square mile. Only a very small part of this reaches the zone of saturation. Of this precipitation, a part runs off directly, a part is discharged by evaporation and transpiration, and a part is added as recharge to the ground-water reservoir, later being discharged into streams or by transpiration and evaporation, or pumped from wells.

Runoff, including both direct runoff and ground-water discharge into streams, accounts for only a small part of the precipitation except after prolonged or intense rains. According to records of the Division of Water Resources of the Kansas State Board of Agriculture, the annual net runoff in the drainage area of Neosho River, at Iola, Kansas, the nearest gaging station below Lyon County, during the 17 years 1928 to 1945 inclusive averaged 5.66 inches. The runoff ranged from 0.74 inch in 1939 to 15.79 inches in 1941. If related to precipitation records at Emporia, which has a total precipitation approximating an average for the drainage area above Iola, for the same period of time, a runoff of approximately 15 percent of the precipitation is indicated. The percent of runoff for the Lyon County area only, probably averages between 10 and 20 percent.

The amount of water discharged by transpiration and evaporation depends on the temperature, humidity, vegetative covering, wind velocity, depth to the water table below land surface, and the length of time the processes of evaporation have access to the moisture. In Lyon County most of the water that does not run off into streams, averaging about 28 or 29 inches, is discharged by transpiration and evaporation.

Seepage from Streams and Ponds

Stream beds generally are cut below the soil zone; therefore, the seepage rate depends on the character and structure of the rock between the stream bed and the water table. In upland areas intermittent streams contribute to the recharge
of the ground-water reservoir chiefly through open joints and fractures, or granular beds such as sandstone. In lowlands, streams contribute influent seepage to the unconsolidated alluvial sediments during times when stream levels are above the level of the adjacent water table.

Ponds and lakes in the upland areas contribute small amounts of recharge to the unconsolidated surface deposits below the lake or pond but to some extent to the stratified rocks also.

**Percolation from Outside the Area**

The amount of ground-water recharge by subsurface percolation from adjacent areas is probably small and is approximately equal to the amount leaving the county in the same manner.

**Discharge of Subsurface Water**

Meinzer (1923, pp. 48-56) divided the discharge of subsurface water into ground-water discharge (discharge of water from the zone of saturation) and vadose-water discharge (discharge of soil water not derived from the zone of saturation).

Ground water moves out of Lyon County by subsurface percolation in both the consolidated and unconsolidated rocks, eventually to be discharged by evaporation or transpiration or through springs and seeps or wells.

**Evaporation and Transpiration**

Evaporation and transpiration from the vadose zone account for most of the precipitation that falls in Lyon County. The use of this water is of primary importance to agriculture. Significant amounts of ground water from the capillary fringe and the zone of saturation are discharged in the valley areas. This is illustrated in Plate 4, A, B, and D and Figure 3 where the water table or capillary fringe is within the reach of the deep-rooted plants (phreatophytes) and many of the shallow-rooted trees and grasses.

In the upland areas where the vegetation is mostly grass, little or no ground water is lost to plants except along the outcrops of strata such as fractured or cavernous limestones which transmit ground water laterally from the zone of saturation into the surficial slope deposits along their outcrop. Such seepage zones are generally indicated by a change in type of vegetation or a heavier growth of vegetation.

**Springs and Seeps**

The largest springs in Lyon County are in the northwestern part of the county and flow from the limestones of the Council Grove group. Springs in other parts of the county emerging from rocks of the Admire, Wabaunsee, and Shawnee groups are smaller in size and more variable in flow.

Low flows in the streams following intervals of no precipitation are maintained chiefly by ground-water discharge through springs and seeps into the stream (Pl. 4B).

**Discharge by Wells**

Ground water derived from wells supplies much of the domestic and stock water used in Lyon County. The amount discharged by wells, however, is very small compared with amounts discharged by the methods discussed in preceding paragraphs.

**Public Water Supplies**

Allen, Hartford, and Reading obtain municipal water supplies from wells. Other towns utilize ground water for domestic needs although they do not have municipal water systems. Emporia utilizes surface water from Neosho River for its public water supply.

*Allen.*—The water supply of Allen, Kansas, is derived from one 6-inch well drilled in 1948, (16-11-22ad.). The well is 32 feet deep and is about 0.5 mile south of the city. It is equipped with a vertical turbine pump having a capacity of 20 gallons per minute and powered by an electric motor. Reservoir storage is limited to a small metal pressure storage tank in the pump house. A second 6-inch drilled well (16-11-22ad.) is 28 feet deep and is about 0.1 mile north of the first well. This well is not equipped with a pump. The well in use obtains water from cavernous zones in the Long Creek limestone. Dissolved solids, total hardness, and sulfate content are unusually high. The nitrate content of the water also is high.

A chemical analysis of the water is given in Table 4.

*Hartford.*—The Hartford water supply is obtained from two wells. The city well, known as the "Pete Rich" well, penetrates alluvium and is east of Neosho River in Coffey County. It is a dug well 30 or 35 feet deep and 12 to 16 feet in diam-
Fig. 3.—Geologic cross sections across the Cottonwood and Neosho River Valleys.
eter. Pumping equipment consists of a Deming triplex pump, rated at 100 gallons per minute, powered by a 10-horsepower electric motor. The pump empties the well in about 40 minutes. The second well (20-13-15dd) is a dug well about 4 feet in diameter and 30 feet deep. The well is in the southeast part of the city and obtains water from terrace deposits. It is equipped with a motor driven thresher-type pump having a capacity of 1,000 gallons per hour. This well is used only in emergencies.

A chemical analysis of the water is given in Table 4.

Reading.—The Reading water supply is derived from two dug wells. One well (17-13-34da) is about 0.5 mile north of town in the alluvium of Marais des Cygnes River. It consists of a 6-foot square concrete pit about 15 feet deep with a 24-inch diameter perforated galvanized iron casing about 17 feet long extending from the bottom of the concrete pit to the base of the well. The galvanized iron casing is surrounded by an 18-inch layer of gravel. The well is equipped with a 100 gallons per minute centrifugal pump powered by a 5-horsepower electric motor.

A second well (18-13-3bd) about 0.3 mile south of Reading obtains water from creek alluvium. It is similar in construction to the north city well and is equipped with a 100-gallon-per-minute centrifugal pump powered by an electric motor. This well is not used regularly but only in emergencies.

INDUSTRIAL SUPPLIES

The large industrial users of water, including the Atchison, Topeka, and Santa Fe Railway Company, Panhandle Eastern Pipe Line Company, Panister Packing Company, and Kansas Soya Products Company use water supplied by the City of Emporia.

AVAILABILITY OF LARGE GROUND-WATER SUPPLIES

Wells developed in the alluvium of Cottonwood River Valley generally yield the largest amounts of water of any in the county. Wells properly constructed and located to penetrate the maximum thickness of saturated alluvial material should supply 75 to 150 gallons a minute without excessive drawdown. The capacity of wells obtaining water from alluvium in Neosho River Valley below its junction with Cottonwood River is about equal to or slightly less than those in Cottonwood River Valley. Alluvium in Neosho River Valley above its junction with Cottonwood River is generally less permeable and thinner than below the junction and wells generally yield less than 100 gallons a minute. Supplies of 10 to 100 gallons a minute can be developed locally from alluvial terraces along the major valleys.

During the investigation 32 test holes were drilled with the hydraulic-rotary drilling machine owned by the State Geological Survey of Kansas on five lines in Cottonwood and Neosho River Valleys. The locations of the test holes are shown on Plate 3, and graphic cross sections along the five lines are shown in Figure 3.

Wells penetrating stratified Permian or Pennsylvanian rocks generally have a much lower yield than those in Pleistocene deposits, but a few wells, chiefly in the northwestern part of the county, obtain yields of 5 to 10 gallons a minute, and in some places, 40 gallons per minute or more.

CHEMICAL CHARACTER OF WATER

The chemical character of the ground water in Lyon County is shown by the analyses of samples of water from 33 wells given in parts per million in Table 4. Factors for converting parts per million of mineral constituents to equivalents per million are given in Table 5. These water samples were collected from the principal water-bearing formations and from different parts of the county as evenly as possible. Table 4 includes analyses of three public water supplies. The samples of water were analyzed by Howard A. Stoltenberg, Chemist, in the Water and Sewage Laboratory of the Kansas State Board of Health.

The analyses of three water samples taken from successively deeper water-bearing beds in a well drilled at the Kansas Soya Products Company plant at the east edge of Emporia show the progressively higher mineralization that occurs with depth. The figures given in Table 6 represent composite samples of water from the aquifers penetrated by the well at the depth the water sample was collected. Samples were collected at the three levels at which considerable amounts of water entered the well. The analyses clearly show the
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<th>Well no.</th>
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<th>Depth, feet</th>
<th>Geologic source</th>
<th>Date of collection</th>
<th>Temperature (°F)</th>
<th>Dissolved solids</th>
<th>Silica (SiO₂)</th>
<th>Iron (Fe₂O₃)</th>
<th>Calcium (Ca)</th>
<th>Magnesium (Mg)</th>
<th>Sodium &amp; Potassium (Na₂O+K₂O)</th>
<th>Bicarbonate (CO₃)</th>
<th>Chloride (Cl⁻)</th>
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<td>9-11-51</td>
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<td>710</td>
<td>151</td>
<td>200</td>
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<td>102</td>
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<td>20-13-7cb</td>
<td>20-13-51</td>
<td>34</td>
<td>9-11-51</td>
<td>.....</td>
<td>479</td>
<td>6.6</td>
<td>0.07</td>
<td>114</td>
<td>13</td>
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<td>0.2</td>
<td>20</td>
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<tr>
<td>20-13-14bd</td>
<td>20-13-51</td>
<td>30-35</td>
<td>5-14-51</td>
<td>.....</td>
<td>495</td>
<td>23</td>
<td>0.11</td>
<td>133</td>
<td>16</td>
<td>10</td>
<td>415</td>
<td>37</td>
<td>19</td>
<td>0.1</td>
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<td>T. 21 S., R. 10 E.</td>
<td>SE NW sec. 14</td>
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</tr>
<tr>
<td>20-13-28dc</td>
<td>20-13-51</td>
<td>22.5</td>
<td>9-11-51</td>
<td>57</td>
<td>1,037</td>
<td>14</td>
<td>0.21</td>
<td>182</td>
<td>38</td>
<td>148</td>
<td>278</td>
<td>24</td>
<td>464</td>
<td>0.2</td>
<td>30</td>
<td>610</td>
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<tr>
<td>T. 21 S., R. 10 E.</td>
<td>SW SE sec. 28</td>
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<td>21-10-26cd</td>
<td>21-10-51</td>
<td>30.8</td>
<td>9-11-51</td>
<td>53</td>
<td>1,074</td>
<td>4.6</td>
<td>0.11</td>
<td>284</td>
<td>22</td>
<td>23</td>
<td>329</td>
<td>180</td>
<td>119</td>
<td>0.2</td>
<td>279</td>
<td>799</td>
</tr>
<tr>
<td>T. 21 S., R. 11 E.</td>
<td>SE SW sec. 26</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>21-11-2aa</td>
<td>21-11-51</td>
<td>26.5</td>
<td>9-11-51</td>
<td>57</td>
<td>337</td>
<td>10</td>
<td>0.11</td>
<td>74</td>
<td>20</td>
<td>25</td>
<td>337</td>
<td>28</td>
<td>6.0</td>
<td>0.1</td>
<td>8.0</td>
<td>266</td>
</tr>
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<td>T. 21 S., R. 11 E.</td>
<td>NE NE sec. 2</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>21-11-28dd</td>
<td>21-11-51</td>
<td>38.1</td>
<td>9-11-51</td>
<td>.....</td>
<td>822</td>
<td>11</td>
<td>0.21</td>
<td>95</td>
<td>43</td>
<td>109</td>
<td>344</td>
<td>120</td>
<td>36</td>
<td>0.2</td>
<td>239</td>
<td>414</td>
</tr>
<tr>
<td>T. 21 S., R. 12 E.</td>
<td>SE SE sec. 28</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>21-12-28bc</td>
<td>21-12-51</td>
<td>51.2</td>
<td>9-11-51</td>
<td>57</td>
<td>613</td>
<td>8.0</td>
<td>1.3</td>
<td>112</td>
<td>31</td>
<td>70</td>
<td>465</td>
<td>141</td>
<td>20</td>
<td>0.5</td>
<td>1.3</td>
<td>407</td>
</tr>
<tr>
<td>T. 21 S., R. 12 E.</td>
<td>SW NW sec. 29</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>21-13-27aa</td>
<td>21-13-51</td>
<td>26.0</td>
<td>9-11-51</td>
<td>57</td>
<td>511</td>
<td>5.0</td>
<td>0.64</td>
<td>101</td>
<td>21</td>
<td>42</td>
<td>239</td>
<td>196</td>
<td>9.0</td>
<td>0.4</td>
<td>19</td>
<td>338</td>
</tr>
<tr>
<td>T. 21 S., R. 13 E.</td>
<td>NE NE sec. 27</td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

a 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.
b Water sample from municipal distribution system.

Table 5.—Factors for converting parts per million of mineral constituents to equivalents per million.

<table>
<thead>
<tr>
<th>Cation</th>
<th>Conversion factor</th>
<th>Anion</th>
<th>Conversion factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ca++</td>
<td>0.0499</td>
<td>HCO₃⁻</td>
<td>0.0164</td>
</tr>
<tr>
<td>Mg++</td>
<td>0.0822</td>
<td>SO₄⁻</td>
<td>0.0208</td>
</tr>
<tr>
<td>Na⁺</td>
<td>0.0435</td>
<td>Cl⁻</td>
<td>0.0282</td>
</tr>
<tr>
<td></td>
<td></td>
<td>NO₃⁻</td>
<td>0.0161</td>
</tr>
<tr>
<td></td>
<td></td>
<td>F⁻</td>
<td>0.0526</td>
</tr>
</tbody>
</table>
TABLE 6.—Analyses of ground water taken from three principal water-producing zones at depths of 360, 600, and 865 feet at the Kansas Soy Products Company well\(^a\) (Dissolved constituents in parts per million. Analyzed by Russell T. Runnels. Fresh surface water cased off)

<table>
<thead>
<tr>
<th>Depth(^b) and chief geologic source</th>
<th>360 feet, Calhoun shale</th>
<th>600 feet, Kanwoka shale</th>
<th>865 feet, Tonganoxie sandstone</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calcium (Ca(^{++}))</td>
<td>683</td>
<td>1,460</td>
<td>4,600</td>
</tr>
<tr>
<td>Magnesium (Mg(^{++}))</td>
<td>286</td>
<td>619</td>
<td>1,600</td>
</tr>
<tr>
<td>Sulfate (SO(_4^{--}))</td>
<td>728</td>
<td>521</td>
<td>53</td>
</tr>
<tr>
<td>Chloride (Cl(^-))</td>
<td>23,000</td>
<td>45,700</td>
<td>168,000</td>
</tr>
<tr>
<td>Sum</td>
<td>24,800</td>
<td>48,000</td>
<td>115,000</td>
</tr>
<tr>
<td>Dissolved solids (140 °C)</td>
<td>25,200</td>
<td>48,900</td>
<td>117,000</td>
</tr>
<tr>
<td>Undetermined difference, chiefly bicarbonates</td>
<td>448</td>
<td>605</td>
<td>2,200</td>
</tr>
<tr>
<td>pH at 21 °C</td>
<td>7.38</td>
<td>7.03</td>
<td>6.37</td>
</tr>
</tbody>
</table>

\(^a\) NE14 SW1/4 NW1/4 NW1/4 sec. 14, T. 18 S., R. 11 E.

\(^b\) Sample collected from this level when well had been drilled to this depth or slightly deeper and bailed rapidly several times.

progressively higher amount of dissolved mineral matter with increasing depth.

Although large amounts of water are available from deep wells penetrating Pennsylvanian and older sediments (Fig. 2) the water is too highly mineralized for most uses.

**Dissolved Solids**

When water is evaporated, the residue consists mainly of the dissolved mineral constituents and usually a little water of crystallization. Water containing less than 500 parts per million of dissolved solids generally is satisfactory for domestic use, except for difficulties resulting from its hardness or occasional excessive iron content. Water containing more than 1,000 parts per million may include enough of certain constituents to produce a noticeable taste or to make the water unsuitable in some other respect. The amount of dissolved solids in 33 samples of ground water from Lyon County ranged from 323 to 2,251 parts per million (Table 7).

**Hardness**

Hardness of water is the property that generally receives the most attention and in washing is recognized by the quantity of soap required to produce lather. Calcium and magnesium cause virtually all the hardness of ordinary water and are the active agents in the formation of the greater part of the scale formed in steam boilers and other vessels in which water is heated or evaporated.

In addition to the total hardness, the table of analyses shows the carbonate hardness and the noncarbonate hardness. The carbonate hardness, sometimes called temporary hardness, can be removed almost entirely by boiling. The noncarbonate hardness is due to the presence of sulfates or chlorides of calcium and magnesium; it cannot be removed by boiling and is sometimes called permanent hardness. So far as their use with soap is concerned, there is no difference.

Water having a hardness of less than 50 parts per million generally is rated as soft, and treatment for the removal of hardness is not necessary under ordinary circumstances. Hardness between 50 and 150 parts per million increases the consumption of soap, but does not seriously interfere with the use of water for most purposes. Hardness above 150 parts per million can be noticed by anyone, and if the hardness is 200 or 300 parts per million, the water commonly is softened for household use or cisterns installed to collect soft rain water. Where municipal water supplies are softened, the hardness is generally reduced to 60 or 80 parts per million. The further softening of a public water supply generally is not deemed worth the additional cost.

The hardness of 33 samples of ground water collected in Lyon County ranged from 266 to 1,166 parts per million (Table 8).

**Iron**

Next to hardness, iron is the constituent of natural waters that in general receives the most attention. The quantity of iron in ground water may differ greatly from place to place, even in water from the same formation. If a water contains much more than 0.1 part per million of iron, the
excess may precipitate as a reddish sediment. Iron, if present in sufficient quantity to give a disagreeable taste or stain cooking utensils, may be removed from most water by simple aeration and filtration or the addition of lime or some other substance.

The iron content of 33 samples of ground water collected in Lyon County ranged from 0.05 to 9.9 parts per million (Table 9).

**FLUORIDE**

The quantity of fluoride present in natural water is generally much less than the quantity of other constituents, but the fluoride content of water to be used by children should be known. The dental defect known as mottled enamel may appear on the teeth of children who drink water containing excessive amounts of fluoride during the period of formation of their teeth. Water containing 1.7 to 1.8 parts per million of fluoride is likely to produce mottled enamel in about half the children continuously using such water, although the percentage distribution would be largely of the very mild and mild types (Dean, 1936). Contents of fluoride up to 1.5 parts per million are believed to be beneficial in inhibiting tooth decay.

The fluoride content of the 33 samples of ground water collected in Lyon County ranged from 0.1 to 0.7 part per million.

**NITRATE**

The discovery in 1945 that nitrate in water can cause cyanosis, or oxygen starvation, of infants gave increased significance to the nitrate content of natural water (Metzler and Stoltenberg, 1950). A concentration of 90 parts per million of nitrate as NO₃ in drinking water is considered by the Kansas State Board of Health as being dangerous to infants, and some authorities recommend that water containing more than 45 parts per million should not be used for formula preparation. Cyanosis is not produced in older children or adults by these concentrations of nitrate.

The relation of nitrate content to well construction, ground-water level, geologic formation, bacterial activity of soils, seasonal variations, and other factors is not yet clear. Observations show that shallow dug wells are generally more susceptible to nitrate contamination than are deeper drilled wells. Nitrate concentrations seem to be highest in the winter season and lowest during the growing season of late spring and summer (Metzler and Stoltenberg, 1950, p. 202).

More than one-half of the 33 water samples analyzed contained more than 45 parts per million of nitrate (NO₃) and one-third contained 90 parts per million or more. The nitrate content of the 33 samples ranged from 1.3 to 407 parts per million (Table 4).

**SULFATE**

Sulfate (SO₄) in ground water is derived chiefly from gypsum and the oxidation of marcasite and pyrite. Sulfate (SO₄) occurring in ground water as magnesium sulfate (Epsom salts) and sodium sulfate (Glauber’s salts), in excess of about 500 parts per million may have a laxative effect on persons not accustomed to drinking water containing large amounts of sulfate.

**CHLORIDE**

Chloride (Cl) is dissolved in small quantities from rock materials, from connate waters in the sediments, or in some instances may come from sewage. Chloride has little effect on the suitability of water for ordinary use unless the quantity is enough to give the taste of salt (300 parts per million or more). Waters high in chloride are very corrosive.
Sanitary Considerations

The water analyses shown in Table 4 show only the amounts of dissolved mineral matter and do not indicate the sanitary quality of the water. However, abnormal amounts of dissolved mineral matter, such as nitrate or chloride, may indicate pollution.

A dug well is more likely to become contaminated than a properly constructed drilled well, generally because the opening at the top of a dug well is not adequately covered and generally is not effectively protected from surface water. A drilled well is protected generally by the casing, but many are not properly sealed at the top. A well should not be located near possible sources of pollution such as barnyards, privies, and cesspools.

Ground Water Regions in Lyon County

Ground water resources in Lyon County are determined primarily by the nature of the underlying rock materials, or the geology, and the structure of the area. On this basis the county is divided into several ground water regions in which ground water occurs under similar conditions and is obtained chiefly from one dominant rock type. The region boundaries are necessarily generalized and within each region the discussion is not applicable to some wells.

Region A

Within the region designated A (Pl. 3) most wells derive water from alluvium. Wells having the largest yields are in Cottonwood River Valley, Neosho River Valley, Marais des Cygnes River Valley, Verdigris River Valley, and the larger tributary valleys of these streams. Wells in alluvium are preferred generally to other ground water sources because of their larger yields, better chemical character (Table 4), and greater reliability during drought periods.

The thickness of alluvium ranges from a maximum of about 50 feet in Cottonwood River Valley to less than 5 feet in small tributary valleys. Maximum yields which can be developed are about 150 gallons of water per minute. Excellent stock and domestic supplies can be developed in this area as well as small to moderate municipal supplies.

Region B

Pleistocene terrace deposits of Kansan age or younger are the chief water-bearing beds in region B (Pl. 3). Terrace deposits older than Kansan are generally above the water table or contain only an intermittent zone of saturation and are not included in this region. Thickness of the terrace deposits ranges from a featheredge to a maximum of about 50 feet.

Ground water in region B generally has greater hardness and larger amounts of dissolved solids than water in alluvium of region A (Table 4). Yields of wells in region B reach a maximum of about 100 gallons of water per minute. Locally in region B little or no water can be obtained from wells in terrace deposits because the saturated thickness of the deposits is thin or because they are above the water table. In most of this area, however, excellent stock and domestic water supplies and locally small municipal supplies can be developed.

Region C

Region C includes the area underlain by Permian rocks of the Chase and Council Grove groups between the Florence limestone and the base of the Americus limestone. Wells in this area derive water supplies chiefly from jointed and fractured limestones and cavernous limestones, secondarily from open joints and fractures in the calcareous shales. Except for local limy sandstone beds in the Funston limestone, there are no sandy beds which contain fresh water in this area.

The most important aquifers of region C are the Wreford, Beattie, Grenola, and Long Creek limestones. Other limestones such as the Crouse, Eiss, and Red Eagle are local sources of good supplies of well water. A few wells, generally rather shallow in depth, obtain small supplies of ground water from open joints or fractures in shale or from cherty or gypsiferous zones in shales. Many, if not most of the wells in this region are drilled wells ranging in depth from about 30 to 90 feet, depending in part on topographic position. Dug wells range from about 12 to 60 feet in depth. Yields of 5 to 10 gallons per minute are not uncommon and supplies of 40 gallons per minute or more can be obtained locally. In most parts of this region supplies of ground water adequate for domestic and stock use are available.
Many ponds have been constructed in parts of this region to supplement water supplies from wells or in preference to wells. In some places cisterns are used where soft water is desired, or to supplement well-water supplies. Springs and seeps are numerous along the creeks.

Ground water in this region is variable in quality but generally good.

**REGION D**

Region D (Pl. 3) includes areas underlain by rocks of the Admire and Wabaunsee groups of early Permian and late Pennsylvanian age. In this region an adequate and dependable water supply from wells is difficult to obtain.

The predominant rock type is argillaceous shale, which is an extremely poor aquifer. Next in the order of abundance is sandstone and sandy shale. Limestone is the least abundant of the common rock types and most of the limestone beds are very thin.

The principal water-bearing beds in this region are the sandstones and sandy zones in the shales. Most of the sandstones are composed of very fine to medium sand grains which have enough mica and clay minerals associated with them to render the sandstones low in permeability. Most of the sandstones are shallow channel fillings in the shales rather than extensive sheet sands, and commonly, the channel sandstones are separated by areas of shale or shaly sandstone. These sandy beds are present locally in nearly all the shale formations. A few wells, which are constructed in locally thick sandstone beds, obtain yields of 10 gallons per minute or more, enough for good stock and domestic supplies.

The Aspinwall, Grandhaven, Wakarusa, and Burlingame limestones, where present in the zone of saturation and not too deeply buried, locally are the principal aquifers and may yield adequate supplies for stock or domestic wells. Other limestones generally yield little or no water to wells.

Many farm wells are large-diameter, shallow dug wells constructed in shale. Many of these are inadequate for even small domestic or stock supplies. Numerous farms have no water wells, but depend on cisterns for domestic water supplies and ponds for stock water supplies. Ponds and cisterns are important supplements to ground-water supplies in this region.

The water in this region is generally hard and high in dissolved solids as indicated by the 14 water samples collected from wells in this region. The dissolved solids ranged from 323 to 2,251 parts per million and averaged 919 parts per million. Hardness ranged from 270 to 1,049 parts per million with an average of 545 parts per million. The sampled wells ranged in depth from 10.9 to 75 feet and averaged 34 feet.

Wells obtain fresh water at depths of 10 feet or less to as much as 75 feet depending in part on topographic location. In some places wells less than 30 feet in depth may yield water that is too highly mineralized for ordinary domestic use.

**REGION E**

Pennsylvanian rocks of the upper part of the Shawnee group are the principal aquifers in region E. Shallow wells in the Topeka limestone and sandstone in the Calhoun shale yield small amounts of water to wells in this region. Deeper water is highly mineralized.

**WELL-NUMBERING SYSTEM**

The well and test hole numbers used in this report give the location of wells and test holes according to the General Land Office Surveys and according to the following formula: township, range, section, 160-acre tract within that section, and the 40-acre tract within that quarter section. If two or more wells are located within a 40-acre tract, the wells are numbered according to the order they were inventoried. The 160-acre and 40-acre tracts are designated, a, b, c, or d in a counterclockwise direction, beginning in the northeast quarter. For example, a well located in the NE 1/4 SE 1/4 sec. 10, T. 20 S., R. 12 E., would be numbered 20-12-10da.

**RECORD OF WELLS**

Information pertaining to water wells in Lyon County is given in Table 10. The measured depths of water levels are given to the nearest 0.01 foot, whereas reported depths are given only to the nearest foot. Similarly, measured depths of wells are given only to the nearest 0.1 foot, reported depths are given only to the nearest foot.
### Table 10.—Record of wells and springs in Lyon County

<table>
<thead>
<tr>
<th>Well No. (1)</th>
<th>Location</th>
<th>Owner or tenant</th>
<th>Type of well (2)</th>
<th>Depth of well, feet (3)</th>
<th>Diameter of well, in. (4)</th>
<th>Principal water-bearing bed</th>
<th>Method of lift (5)</th>
<th>Use of water (6)</th>
<th>Measuring point</th>
<th>Depth to water level, feet (7)</th>
<th>Date of measurement</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>15-10-23 dc</td>
<td>SW SE sec. 23</td>
<td>C. M. Sobke</td>
<td>Du</td>
<td>19.4</td>
<td>96</td>
<td>R</td>
<td>Limestone</td>
<td>Threemile Is.</td>
<td>Cy, E</td>
<td>S</td>
<td>Top of board cover</td>
<td>1.2</td>
</tr>
<tr>
<td>15-12-21 cc</td>
<td>SW SW sec. 21</td>
<td>A. Pollock</td>
<td>Du</td>
<td>18.6</td>
<td>48(?)</td>
<td>R</td>
<td>Limestone or sandstone</td>
<td>Five Point Is.</td>
<td>Cy, H</td>
<td>P</td>
<td>Top of concrete cover</td>
<td>0.3</td>
</tr>
<tr>
<td>15-12-33 cb</td>
<td>NW SW sec. 33</td>
<td>G. Coats</td>
<td>Du</td>
<td>23.6</td>
<td>48</td>
<td>R</td>
<td>Shale (?)</td>
<td>Cy, H</td>
<td>S</td>
<td>Top of board cover</td>
<td>1.1</td>
<td>11.0</td>
</tr>
<tr>
<td>15-12-34 cc</td>
<td>SW SW sec. 34</td>
<td>Elmer Stinson</td>
<td>Du</td>
<td>19.9</td>
<td>90</td>
<td>R</td>
<td>Sand and gravel</td>
<td>Alluvium</td>
<td>Cy, H</td>
<td>E S</td>
<td>Top of 2 x 6 board curbing</td>
<td>1.0</td>
</tr>
<tr>
<td>15-12-35 cc</td>
<td>SW SW sec. 35</td>
<td>J. B. Hume</td>
<td>Du</td>
<td>22.4</td>
<td>30</td>
<td>R</td>
<td>Shale (?)</td>
<td>Caneyville Is.</td>
<td>Cy, H</td>
<td>D</td>
<td>Top of back porch floor</td>
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<td>15-13-19 ca</td>
<td>NE SW sec. 19</td>
<td>O. M. Clayton</td>
<td>Du</td>
<td>17.2</td>
<td>60</td>
<td>R</td>
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<td>Falls City Is. and/or Hawxby sh.</td>
<td>Cy, H</td>
<td>D, S</td>
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<td>15-13-32 dc</td>
<td>SW SE sec. 32</td>
<td>Maude DeShazer</td>
<td>Du</td>
<td>10</td>
<td>96</td>
<td>R,C</td>
<td>Limestone or shale</td>
<td>Grandhaven Is.</td>
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<td>D, S</td>
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<td>1.3</td>
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<tr>
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<td>NW NW sec. 2</td>
<td>Glen Shellenberger</td>
<td>Dr</td>
<td>67.5</td>
<td>7(?) (?)</td>
<td>Limestone and shale</td>
<td>Crouse Is.</td>
<td>Cy, H</td>
<td>S</td>
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<td>L. C. Case</td>
<td>Dr</td>
<td>56.9</td>
<td>6</td>
<td>GI</td>
<td>Limestone and shale</td>
<td>Beattie Is. (?)</td>
<td>Cy, H</td>
<td>N</td>
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<td>E. J. Eckel</td>
<td>Dr</td>
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<td>6</td>
<td>GI</td>
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<td>Crouse Is.</td>
<td>Cy, W</td>
<td>S</td>
<td>Land surface</td>
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<td>Fred Buchanan</td>
<td>Du</td>
<td>27.4</td>
<td>36</td>
<td>R</td>
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<td>Crouse Is.</td>
<td>Cy, H</td>
<td>D, S</td>
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<td>Leo Fitch</td>
<td>Dr</td>
<td>84</td>
<td>6(?) (?)</td>
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<td>Grenola Is.</td>
<td>Cy, E</td>
<td>S</td>
<td>Land surface</td>
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<td>Mason Rust</td>
<td>Du</td>
<td>24.6</td>
<td>36</td>
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<td>B. Johnson</td>
<td>Du</td>
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<td>36(?)</td>
<td>R</td>
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<td>Beattie Is.</td>
<td>Cy, W</td>
<td>S</td>
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<td>36</td>
<td>R</td>
<td>Limestone</td>
<td>Grenola Is.</td>
<td>J, E</td>
<td>D, S</td>
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<td>Robert Rees</td>
<td>Du</td>
<td>60</td>
<td>36(?)</td>
<td>R</td>
<td>Limestone or shale</td>
<td>Neva Is. or Eskridge sh.</td>
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<td>D, S</td>
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<td>Lee Rowley</td>
<td>Du</td>
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<td>36</td>
<td>R</td>
<td>Limestone</td>
<td>Neva Is.</td>
<td>Cy, H</td>
<td>D</td>
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<td>City of Allen, Kans.</td>
<td>Dr</td>
<td>32</td>
<td>6</td>
<td>I</td>
<td>Limestone</td>
<td>Long Creek Is.</td>
<td>T, E</td>
<td>P</td>
<td>Land surface</td>
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<td>28</td>
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<td>I</td>
<td>Limestone</td>
<td>Long Creek Is.</td>
<td>N</td>
<td>N</td>
<td>Land surface</td>
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<td>Section</td>
<td>Description</td>
<td>Location</td>
<td>Depth</td>
<td>Type</td>
<td>Color</td>
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<td>C. J. Frederiksen</td>
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<td>Americus ls.</td>
<td>Cy, H D</td>
<td>0.1 10.22</td>
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<td>Paul J. Swanson</td>
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<td>Sandstone and shale</td>
<td>French Creek sh.</td>
<td>Cy, H D</td>
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<td>Otto Wolf</td>
<td>Du</td>
<td>16.8 36 (?) R (?)</td>
<td>Sand and gravel</td>
<td>Alluvium</td>
<td>Cy, H P</td>
<td>0.4 2.53</td>
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<td>NE SE sec. 20</td>
<td>Norton Sanders</td>
<td>Du</td>
<td>25.6 72 R</td>
<td>Terrace alluvium J. E D, S</td>
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<td>0.3 10.39</td>
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<td>L. Wildhack</td>
<td>Dr</td>
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<td>Limestone and shale</td>
<td>Lower Grenola ls.</td>
<td>N N</td>
<td>0.6 14.14</td>
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<td>Sch. Dist. 64</td>
<td>Du</td>
<td>37.8 42 R</td>
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<td>Lower Grenola ls.</td>
<td>Cy, H P</td>
<td>0.5 26.14</td>
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<td>Henry Proehl</td>
<td>Dr</td>
<td>89.1 6 I</td>
<td>Limestone</td>
<td>Long Creek ls.</td>
<td>Cy, W D, S</td>
<td>2.0 66.76</td>
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<td>Ferd Blanken</td>
<td>Dr</td>
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<td>Limestone and shale</td>
<td>Grenola ls.</td>
<td>Cy, W D, S</td>
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<td>H. Proehl</td>
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<td>3.3 22.16</td>
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<td>Du</td>
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<td>Limestone or shale</td>
<td>Long Creek ls. or Johnson sh.</td>
<td>Cy, H P</td>
<td>2.5 12.57</td>
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<td>Fred Johnson</td>
<td>Dr</td>
<td>50 6 L</td>
<td>Limestone</td>
<td>Long Creek ls.</td>
<td>Cy, E S</td>
<td>0 25</td>
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<td>Ivan Harder</td>
<td>Du</td>
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<td>Limestone and shale</td>
<td>Americus ls. or upper Hamlin sh.</td>
<td>Cy, H S</td>
<td>2.0 18.53</td>
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<td>J. B. Mounkes</td>
<td>DD</td>
<td>+100 48 &amp; 6 (?) R- (?) (?)</td>
<td>Limestone or shale or sand and gravel</td>
<td>Falls City ls. or West Branch sh.</td>
<td>Caneyville ls. and/or alluvium</td>
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<td>Frank Safford</td>
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<td>30 36 (?) R</td>
<td>Limestone and shale</td>
<td>Aspinwall ls. and Hawxby sh.</td>
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<td>0 20</td>
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<td>N. W. Jones</td>
<td>Du</td>
<td>14.6 48 (?) R</td>
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<td>Pony Creek-French Creek sh.</td>
<td>Cy, W S</td>
<td>0.3 9.04</td>
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<td>O. J. Hale</td>
<td>Dr</td>
<td>72.6 6 (?) GI (?)</td>
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<td>Cy, W S</td>
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<td>Du</td>
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<td>J. H. Shields</td>
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<td>SE SE sec. 13</td>
<td>V. J. Volz</td>
<td>Du</td>
<td>22 36 to 96 R</td>
<td>Sandstone and shale</td>
<td>Pierson Point-Willard sh.</td>
<td>Cy, H D, S</td>
<td>0 9-10</td>
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<td>C. &amp; W. Duggan</td>
<td>Du</td>
<td>22 42 R</td>
<td>Sand and gravel</td>
<td>Alluvium</td>
<td>Cy, W D, S</td>
<td>0 16</td>
<td>11-3-49</td>
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</table>

Notes:
- Top of concrete curbing
- Yield - ½ high sulfate
- Pumped for 1 hr. preceding measurement. Reported adequate
- Reported adequate, neighbors haul from well in dry years
- Reported yield - ½, not adequate
- Reported adequate, salty if pumped hard
- Inadequate, reported yield - ½, high sulfate
- Not used for dom. drinking, very hard water
<table>
<thead>
<tr>
<th>Well No.</th>
<th>Location</th>
<th>Owner or tenant</th>
<th>Type of well</th>
<th>Depth of well, feet</th>
<th>Diam of well, in.</th>
<th>Type of casing</th>
<th>Principal water-bearing bed</th>
<th>Method of lift</th>
<th>Use of water</th>
<th>Measuring point</th>
<th>Depth to water level, feet</th>
<th>Date of measurement</th>
<th>Remarks</th>
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<td>36</td>
<td>R</td>
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<td>Piersont-Willard sh.</td>
<td>Cy, H D</td>
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<td>Geo. Hopkins</td>
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<td>72</td>
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<td>Cedar Vale sh.</td>
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<td>36</td>
<td>C &amp; GI</td>
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<td>C</td>
<td>Land surface</td>
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<td>R</td>
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<td>Alluvium</td>
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<td>R</td>
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<td>Cy, W D S</td>
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<td>R</td>
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<td>Alluvium</td>
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<td>Du</td>
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<td>Cy, W D S</td>
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<td>Foraker Is.</td>
<td>Cy, H D</td>
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<td>R</td>
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<td>Reproduced Is.</td>
<td>Cy, H D</td>
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<td>French Creek sh.</td>
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<td>SW SW sec. 36</td>
<td>Clarence Stanton</td>
<td>DD</td>
<td>31.1</td>
<td>48-96</td>
<td>R</td>
<td>Sand and sandstone</td>
<td>Terrace alluvium</td>
<td>Cy, W S</td>
<td>Top of concrete curbing</td>
<td>0</td>
<td>16.23</td>
<td>8-2-49</td>
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**Table 10. Record of wells and springs in Lyon County, continued.**
<table>
<thead>
<tr>
<th>Date</th>
<th>Section</th>
<th>Name</th>
<th>Driller</th>
<th>Depth</th>
<th>Material</th>
<th>Description</th>
<th>Topo</th>
<th>Notes</th>
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<td>18-11-26</td>
<td>SW sec. 26</td>
<td>Catherine Johnson</td>
<td>Du</td>
<td>35.1</td>
<td>Sand and gravel</td>
<td>Terrace alluvium Cy, W, D, S</td>
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<tr>
<td>18-11-26</td>
<td>cd</td>
<td>Max Smith</td>
<td>Du</td>
<td>30.3</td>
<td>Sand and gravel</td>
<td>Terrace alluvium Cy, W D</td>
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<td>18-11-28</td>
<td>NE sec. 28</td>
<td>Glenn Felten</td>
<td>Du</td>
<td>40.5</td>
<td>Sand and gravel</td>
<td>Terrace alluvium J, E D, S</td>
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<td>Reported adequate</td>
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<td>18-11-29</td>
<td>NE sec. 29</td>
<td>Chas. R. Hurst</td>
<td>D-B</td>
<td>28</td>
<td>Sand and gravel</td>
<td>Alluvium Cy, H, D, S</td>
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<td>18-12-3</td>
<td>NE sec. 3</td>
<td>W. G. Collins</td>
<td>Du</td>
<td>23.0</td>
<td>Sandstone or shale</td>
<td>French Creek sh. Friedrich sh. Cy, H S</td>
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<td>Reported not adequate</td>
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<tr>
<td>18-12-6</td>
<td>SW sec. 6</td>
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<td>Du</td>
<td>12.5</td>
<td>Sandstone and shale</td>
<td>French Creek sh. Willard sh. or Elmont Is. Cy, H D, S</td>
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<td>NE sec. 13</td>
<td>Frank Schlager</td>
<td>Du</td>
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<td>Sandstone or limestone</td>
<td>Grandhaven Is. Langdon-Willard sh. Cy, W S</td>
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<td>18-12-16</td>
<td>SE sec. 16</td>
<td>Irace Ridenour</td>
<td>Du</td>
<td>21.3</td>
<td>Limestone</td>
<td>Dry-Langdon sh. Cy, H S</td>
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<td>W. H. Wanser</td>
<td>Du</td>
<td>30.7</td>
<td>Shale and sandstone</td>
<td>Dover Is. or Langdon sh. Cy, E D, S</td>
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<td>18-12-18</td>
<td>SW sec. 18</td>
<td>Earl Hollingsworth</td>
<td>Du</td>
<td>25.1</td>
<td>Shale and sandstone</td>
<td>Pierson Point-Willard sh. Cy, E D, S</td>
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<td>James Lyons</td>
<td>Du</td>
<td>33.7</td>
<td>Limestone</td>
<td>Top of 2x12 board cover Cy, E D</td>
<td>0.4</td>
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<tr>
<td>18-12-31</td>
<td>SE sec. 31</td>
<td>Otis Weeks</td>
<td>Du</td>
<td>29.4</td>
<td>Sandstone</td>
<td>Top of 2x12 board cover Cy, E D</td>
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<td>18-13-3</td>
<td>NE sec. 3</td>
<td>City of Reading, Kans.</td>
<td>Du</td>
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<td>Alluvium C, E P</td>
<td>(?)</td>
<td>12-4-51</td>
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<td>18-13-16</td>
<td>NW sec. 16</td>
<td>L. R. Cowden</td>
<td>Du</td>
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<td>Shale</td>
<td>Harveyville sh. Pierson Point-Willard sh. Cy, H D</td>
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<td>SW sec. 18</td>
<td>Hugh Jones</td>
<td>Du</td>
<td>31.9</td>
<td>Shale and sandstone</td>
<td>Top of 2x8 board cover Cy, H D</td>
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<td>18-13-27</td>
<td>NW sec. 27</td>
<td>F. H. Jennings</td>
<td>Du</td>
<td>15.0</td>
<td>Shale and sandstone</td>
<td>Top edge of angle iron Cy, E D</td>
<td>0.8</td>
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<td>18-13-27</td>
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<td>F. H. Jennings</td>
<td>Du</td>
<td>30.7</td>
<td>Sandstone and shale</td>
<td>Top of 2x6 board cover Cy, E S</td>
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<td>SE sec. 31</td>
<td>H. C. Omara</td>
<td>Du</td>
<td>19.9</td>
<td>Shale or sandstone</td>
<td>Top of pump base Cy, H D</td>
<td>0.3</td>
<td>Reported not adequate</td>
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<td>18-13-33</td>
<td>SW sec. 33</td>
<td>A. E. Mounkes</td>
<td>Du</td>
<td>49.5</td>
<td>Sandstone</td>
<td>Top of concrete cover Cy, E D</td>
<td>0.3</td>
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<tr>
<td>19-10-1</td>
<td>SE sec. 1</td>
<td>E. H. Rees</td>
<td>Du</td>
<td>48.6</td>
<td>Sand and gravel</td>
<td>Top of brick casing Cy, W D, S</td>
<td>1.0</td>
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<tr>
<td>19-10-4</td>
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<td>Wade Myers</td>
<td>Dr</td>
<td>82(?)</td>
<td>Sandstone</td>
<td>Top of center wooden 4x4 under cover Cy, E S</td>
<td>0.8</td>
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<td>NW sec. 4</td>
<td>Wade Myers</td>
<td>Dr</td>
<td>75</td>
<td>Sandstone</td>
<td>Top of center wooden 4x4 under cover Cy, E S</td>
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<td>Henry Wittker</td>
<td>Dr</td>
<td>50</td>
<td>Sand and gravel</td>
<td>Terrace alluvium Cy, H S</td>
<td>0.8</td>
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<td>19-10-21</td>
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<td>Fay Miles</td>
<td>Du</td>
<td>31.8</td>
<td>Limestone (?)</td>
<td>Top of 2x12 board cover Cy, H D, S</td>
<td>1.0</td>
<td>Reported not adequate</td>
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<td>Du</td>
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<td>F. E. Whipple</td>
<td>Du</td>
<td>16.5</td>
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<td>Alluvium Cy, W D, S</td>
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<tr>
<td>Well No. (1)</td>
<td>Location</td>
<td>Owner or tenant</td>
<td>Type of well (2)</td>
<td>Depth of well, feet (3)</td>
<td>Diameter of well, in. (4)</td>
<td>Principal water-bearing bed</td>
<td>Character of material</td>
<td>Geologic source</td>
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<td>19-10-29 dd</td>
<td>SE SE sec. 29</td>
<td>J. D. Vorse</td>
<td>Du 20.6 (7) R</td>
<td>Limestone or shale</td>
<td>Falls City Is. and/or West Branch sh.</td>
<td>Cy, H D</td>
<td>Top of board cover over well</td>
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<td>James Henderson</td>
<td>Du 22 60(?) R</td>
<td>Shale</td>
<td>Towle sh.</td>
<td>Cy, W D, S</td>
<td>Top of concrete cover</td>
<td>1.0</td>
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<td>19-11-7 bc</td>
<td>SW NW sec. 7</td>
<td>F. L. Clausen</td>
<td>B 34 6 T</td>
<td>Sand and gravel</td>
<td>Terrace alluvium</td>
<td>Cy, W D, S</td>
<td>Land surface</td>
<td>...</td>
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<td>19-11-8 bd</td>
<td>SE NW sec. 8</td>
<td>W. Hatcher</td>
<td>Du 52.9 48 R</td>
<td>Sand and gravel</td>
<td>Terrace alluvium</td>
<td>Cy, W S</td>
<td>Top of concrete curbing</td>
<td>1.0</td>
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<td>19-11-8 cb₁</td>
<td>NW SW sec. 8</td>
<td>Wayne Boling</td>
<td>Dr 62 6(?) (?)</td>
<td>Sand and gravel</td>
<td>Terrace alluvium</td>
<td>J (?), E P</td>
<td>Top of concrete curbing</td>
<td>...</td>
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<td>19-11-10 cb₁</td>
<td>NW SW sec. 8</td>
<td>Mr. Hart</td>
<td>Dr 56.4 6½ I</td>
<td>Sand and gravel</td>
<td>Terrace alluvium</td>
<td>N</td>
<td>Top edge of casing</td>
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<td>NE NE sec. 13</td>
<td>C. W. Eaton</td>
<td>Dr 22 8 GI</td>
<td>Sand and gravel</td>
<td>Terrace alluvium</td>
<td>C (?), E D, S</td>
<td>Top of casing</td>
<td>-3.2</td>
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<td>NE SE sec. 13</td>
<td>D. C. Anderson</td>
<td>Dr 24.2 22 R</td>
<td>Sand and gravel</td>
<td>Terrace alluvium</td>
<td>Cy, E D</td>
<td>Top of concrete curbing</td>
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<td>NW NE sec. 4</td>
<td>F. H. Sickler</td>
<td>Du 46.5 60 R &amp; N</td>
<td>Sandstone or sand and gravel</td>
<td>Pierson Point-Willard sh.</td>
<td>Cy, E D, S</td>
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<td>NW NW sec. 6</td>
<td>V. M. Jacob</td>
<td>Du 20.8 48 R</td>
<td>Sand and gravel</td>
<td>Terrace alluvium</td>
<td>Cy, W D, S</td>
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<tr>
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<td>SW SW sec. 7</td>
<td>E. D. Hodges</td>
<td>Du 26 42 R</td>
<td>Sand and gravel</td>
<td>Alluvium</td>
<td>Cy, E D, S</td>
<td>Top of 2x12 board cover</td>
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<td>19-12-12 dd</td>
<td>SE SE sec. 12</td>
<td>G. W. Jones</td>
<td>Dr (?) 18.3 (?) (?)</td>
<td>Shale and sandstone</td>
<td>Silver Lake sh.</td>
<td>Cy, H S</td>
<td>Top of 2x12 board cover</td>
<td>0.3</td>
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<td>19-12-32 cc</td>
<td>SW SW sec. 32</td>
<td>C. L. Jones</td>
<td>Du 27.8 120 R</td>
<td>Sandstone or sandstone</td>
<td>Pierson Point-Willard sh.</td>
<td>Cy, E D, S</td>
<td>Reported adequate, Measured yield less than 1. Reported 170 ppm. NO₃</td>
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<td>19-13-16 dd</td>
<td>SE SE sec. 16</td>
<td>E. C. Mounkes</td>
<td>Du 34.6 48 R</td>
<td>Sandstone or limestone</td>
<td>Happy Hollow ls. (?) or White Cloud sh.</td>
<td>Cy, H D, S</td>
<td>Top of metal pump base</td>
<td>1.0</td>
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<tr>
<td>19-13-17 aa</td>
<td>NE NE sec. 17</td>
<td>Earnest Genter</td>
<td>Du 25.8 38 R</td>
<td>Sandstone or shale</td>
<td>White Cloud sh.</td>
<td>Cy, H D</td>
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<tr>
<td>19-13-18 ab</td>
<td>NW NE sec. 18</td>
<td>C. McAuly</td>
<td>Du 16.5 48 R</td>
<td>Shale or limestone</td>
<td>White Cloud sh. or Happy Hollow ls.</td>
<td>N</td>
<td>Top of concrete curbing</td>
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<td>SE SE sec. 19</td>
<td>Max Andrews</td>
<td>Du 50.8 39 R &amp; N</td>
<td>Sandstone and shale</td>
<td>White Cloud sh.</td>
<td>B, H D</td>
<td>Top of 2x4 board where lid hinged to well cover</td>
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<tr>
<td>19-13-20 bc</td>
<td>SW NW sec. 20</td>
<td>William Kern</td>
<td>Du 32.6 36 R (?)</td>
<td>Sandstone and shale</td>
<td>White Cloud sh.</td>
<td>Cy, H D, S</td>
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<td>19-13-28 bb</td>
<td>NW NW sec. 28</td>
<td>..................</td>
<td>Du 44.7 36 R</td>
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<td>White Cloud sh.</td>
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<td>NW NE sec. 6</td>
<td>Ralph Williams</td>
<td>Du 19.8 48(?) R</td>
<td>Shale or sandstone</td>
<td>Stine sh.</td>
<td>Cy, W S</td>
<td>Top of concrete curbing</td>
<td>1.0</td>
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<td>Description</td>
<td>Dr</td>
<td>M</td>
<td>R</td>
<td>Type</td>
<td>Location</td>
<td>Yield</td>
<td>Season</td>
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<td>J. J. Rees</td>
<td>Dr</td>
<td>64.3</td>
<td>7</td>
<td>I</td>
<td>Limestone</td>
<td>Red Eagle Is.</td>
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<td>20-10-17 dc</td>
<td>SW SE sec. 17</td>
<td>Alfonso Haworth</td>
<td>Du</td>
<td>14.2</td>
<td>36</td>
<td>R</td>
<td>Limestone</td>
<td>Howe Is.</td>
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<tr>
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<td>NE NE sec. 33</td>
<td>C. L. Patton</td>
<td>Du</td>
<td>17.8</td>
<td>36</td>
<td>R</td>
<td>Limestone and shale</td>
<td>Foraker Is.</td>
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<td>20-10-34 ab</td>
<td>NW NE sec. 34</td>
<td>W. A. Patch</td>
<td>Du</td>
<td>23.3</td>
<td>84</td>
<td>R</td>
<td>Shale or sandstone</td>
<td>Stine sh.</td>
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<tr>
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<td>NW NE sec. 1</td>
<td>James Kittle</td>
<td>Du</td>
<td>33</td>
<td>36</td>
<td>R &amp; N</td>
<td>Sandstone and shale</td>
<td>Sandstone and shale</td>
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<tr>
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<td>SW NE sec. 5</td>
<td>Tony Burenheld</td>
<td>Du</td>
<td>33.2</td>
<td>48</td>
<td>R</td>
<td>Sandstone and shale</td>
<td>Sandstone and shale</td>
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<td>SE SW sec. 22</td>
<td>Lou Brown</td>
<td>Du</td>
<td>19.9</td>
<td>96</td>
<td>R</td>
<td>Shale</td>
<td>Shale or sandstone</td>
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<td>NW NE sec. 26</td>
<td>Leo Redeker</td>
<td>Du</td>
<td>40.6</td>
<td>36-48</td>
<td>R &amp; N</td>
<td>Limestone or shale</td>
<td>Limestone or sandstone</td>
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<td>20-11-33 ca</td>
<td>NE SW sec. 33</td>
<td>Conrad Schade</td>
<td>Du</td>
<td>34.4</td>
<td>36-48</td>
<td>R &amp; N</td>
<td>Sand and gravel</td>
<td>Friedich-Dry sh. (?)</td>
</tr>
<tr>
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<td>NE SW sec. 34</td>
<td>Matt Kriner</td>
<td>Du</td>
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<td>36</td>
<td>R</td>
<td>Sand and gravel</td>
<td>Alluvium</td>
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<tr>
<td>20-11-34 ca</td>
<td>NE SW sec. 34</td>
<td>Matt Kriner</td>
<td>Du</td>
<td>21.4</td>
<td>36(? )</td>
<td>R</td>
<td>Sand and gravel</td>
<td>Alluvium</td>
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<td>SE SE sec. 34</td>
<td>S. F. Wendling</td>
<td>Du</td>
<td>24.1</td>
<td>36</td>
<td>R &amp; N</td>
<td>Shale or limestone</td>
<td>Langdon sh. or Dover Is.</td>
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<td>SW NW sec. 12</td>
<td>G. E. Poycer</td>
<td>Du</td>
<td>30</td>
<td>48</td>
<td>R</td>
<td>Sandstone and shale</td>
<td>White Cloud sh.</td>
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<tr>
<td>20-12-19 cc</td>
<td>SW SW sec. 19</td>
<td>Leo Miller</td>
<td>Du</td>
<td>30</td>
<td>48</td>
<td>R</td>
<td>Sandstone and shale</td>
<td>Langdon-Willard sh.</td>
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<td>NE NE sec. 24</td>
<td>Ray Summa</td>
<td>Du</td>
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<td>48</td>
<td>R</td>
<td>Limestone</td>
<td>Happy Hollow Is.</td>
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<tr>
<td>20-12-25 aa</td>
<td>NE NE sec. 25</td>
<td>John Bigler</td>
<td>Du</td>
<td>32.4</td>
<td>48</td>
<td>R</td>
<td>Sand and gravel</td>
<td>White Cloud sh.</td>
</tr>
<tr>
<td>20-12-25 da</td>
<td>NE SE sec. 25</td>
<td>H. E. Scoogg</td>
<td>Du</td>
<td>25</td>
<td>60</td>
<td>R</td>
<td>Shale and limestone</td>
<td>Terrace alluvium</td>
</tr>
<tr>
<td>20-12-27 ba</td>
<td>NE NW sec. 27</td>
<td>R. W. Emely</td>
<td>Du</td>
<td>24.6</td>
<td>72</td>
<td>R</td>
<td>Shale and gravel</td>
<td>Rulo Is. and Silver Lake sh.</td>
</tr>
<tr>
<td>20-12-31 bb</td>
<td>NW NW sec. 31</td>
<td>Lema Waechter</td>
<td>Du</td>
<td>49.1</td>
<td>48</td>
<td>R</td>
<td>Sandstone and shale</td>
<td>Wakarusa Is. or Auburn sh.</td>
</tr>
<tr>
<td>20-12-33 cb</td>
<td>NW SW sec. 33</td>
<td>School District</td>
<td>Du</td>
<td>15.6</td>
<td>48</td>
<td>R</td>
<td>Shale and gravel</td>
<td>Silver Lake sh. and/or Cedar Vale sh.</td>
</tr>
<tr>
<td>20-12-34 db</td>
<td>NW SE sec. 34</td>
<td>W. A. Immache</td>
<td>Du</td>
<td>17.3</td>
<td>42(?)</td>
<td>R</td>
<td>Shale</td>
<td>Sand and gravel</td>
</tr>
<tr>
<td>20-12-35 cb</td>
<td>NW SW sec. 35</td>
<td>School District</td>
<td>Du</td>
<td>27.9</td>
<td>54</td>
<td>R</td>
<td>Sand and gravel</td>
<td>Sand or sandstone</td>
</tr>
<tr>
<td>20-12-36 bc</td>
<td>SW NW sec. 36</td>
<td>Rex McIlain</td>
<td>B</td>
<td>26</td>
<td>8</td>
<td>T</td>
<td>Sand and gravel</td>
<td>Terrace alluvium</td>
</tr>
</tbody>
</table>

<p>| Notes | |
|-------||
| 20-13-3 aa | NE NE sec. 3 | T. H. Moore | Du | 23.4 | 36 | R | Sand and gravel | Terrace alluvium | J-E | D, S | Top of stone casing | -0.4 | 18.47 | 7-27-50 | Reported adequate |
| 20-13-7 cb | NW NW sec. 7 | Guy Whitaker | B | 34.5 | 8 | T | Sand and gravel | Terrace alluvium | J-E | D | Top of concrete curbing | 0.7 | 22.90 | 1-18-51 | Reported adequate |
| 20-13-7 dd | SE SE sec. 7 | Earl Love | D | 33.3 | 42 | R | Sand and gravel | Terrace alluvium | Cy, W | D, S | Top of steel rim in concrete cover | 0 | 27.11 | 11-15-49 | Reported adequate |
| 20-13-14 bd | SE NW sec. 14 | City of Hartford, Kans. | D | 30-35 | 144 | R | Sand and gravel | Alluvium | (?) | E | P | Land surface | 0 | 1-1-51 | Reported adequately |
| 20-13-15 dd | SE sec. 15 | City of Hartford, Kans. | D | 35 | 72 | R | Sand and gravel | Terrace alluvium | (?) | P | Land surface | 0 | 1-1-51 | Used intermittently |</p>
<table>
<thead>
<tr>
<th>Well No. (1)</th>
<th>Location</th>
<th>Owner or tenant</th>
<th>Type of well (2)</th>
<th>Depth of well, feet (3)</th>
<th>Diameter of well, in.</th>
<th>Type of casing (4)</th>
<th>Character of material</th>
<th>Principal water-bearing bed</th>
<th>Method of lift (5)</th>
<th>Use of water (6)</th>
<th>Measuring point</th>
<th>Depth to water level, feet (7)</th>
<th>Date of measurement</th>
<th>Remarks (Yield given in gallons a minute; drawdown in ft.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>20-13-16 ad</td>
<td>SE NE sec. 16</td>
<td>L. L. Shellen</td>
<td>D</td>
<td>32.5</td>
<td>36 (?)</td>
<td>R</td>
<td>Sand and gravel</td>
<td>Terrace alluvium</td>
<td>Cy, E</td>
<td>D, S</td>
<td>Top of 3x12 board cover</td>
<td>0.9</td>
<td>27.58</td>
<td>11-15-49</td>
</tr>
<tr>
<td>20-13-16 dd</td>
<td>SE SE sec. 16</td>
<td>J. L. Ambrose</td>
<td>D</td>
<td>48</td>
<td>36</td>
<td>R</td>
<td>Sand and gravel</td>
<td>Terrace alluvium</td>
<td>Cy, W</td>
<td>D, S</td>
<td>Land surface</td>
<td>0</td>
<td>38</td>
<td>5-25-51</td>
</tr>
<tr>
<td>20-13-18 ad</td>
<td>SE NE sec. 18</td>
<td>Lula Holfordy</td>
<td>D</td>
<td>31.4</td>
<td>48</td>
<td>R</td>
<td>Sand and gravel</td>
<td>Terrace alluvium</td>
<td>J, E</td>
<td>D, S</td>
<td>Top of concrete curbing</td>
<td>0.8</td>
<td>25.46</td>
<td>7-27-50</td>
</tr>
<tr>
<td>20-13-28 dc</td>
<td>SW SE sec. 28</td>
<td>Lee Webster</td>
<td>D</td>
<td>23.0</td>
<td>42</td>
<td>R</td>
<td>Sand and gravel</td>
<td>Terrace alluvium</td>
<td>Cy, H</td>
<td>D, S</td>
<td>Top edge of angle iron under concrete cover</td>
<td>0.5</td>
<td>13.63</td>
<td>5-25-51</td>
</tr>
<tr>
<td>20-13-29 da</td>
<td>NE SE sec. 29</td>
<td>Ralph M. Hoch</td>
<td>D</td>
<td>25.2</td>
<td>60</td>
<td>R</td>
<td>Sand and gravel</td>
<td>Terrace alluvium</td>
<td>J-E</td>
<td>D, S</td>
<td>Top of 3x12 board cover</td>
<td>0</td>
<td>9.19</td>
<td>7-27-50</td>
</tr>
<tr>
<td>21-10-17 ab</td>
<td>NW NE sec. 17</td>
<td>Fred Mockry</td>
<td>D</td>
<td>14.6</td>
<td>36</td>
<td>R</td>
<td>Limestone and shale</td>
<td>Foraker Is.</td>
<td>B, H</td>
<td>D, S</td>
<td>Top of 2x4 bd. inside of enclosure</td>
<td>1.3</td>
<td>6.28</td>
<td>8- 4-50</td>
</tr>
<tr>
<td>21-10-26 cd</td>
<td>SE SW sec. 26</td>
<td>Cecil Farthing</td>
<td>DD</td>
<td>50</td>
<td>36-8</td>
<td>R &amp; T</td>
<td>Sandstone</td>
<td>Friedrich-Dry sh.</td>
<td>J-E</td>
<td>D</td>
<td>Top of steel rim in concrete cover</td>
<td>0.5</td>
<td>22.90</td>
<td>8- 4-50</td>
</tr>
<tr>
<td>21-10-26 cd</td>
<td>SE SW sec. 26</td>
<td>Cecil Farthing</td>
<td>D</td>
<td>33.3</td>
<td>48-96</td>
<td>R &amp; N</td>
<td>Sandstone</td>
<td>Friedrich-Dry sh.</td>
<td>Cy, W</td>
<td>S</td>
<td>Top of 2x12 board cover</td>
<td>2.5</td>
<td>24.44</td>
<td>8- 4-50</td>
</tr>
<tr>
<td>21-10-27 dd</td>
<td>SE SE sec. 27</td>
<td>School District</td>
<td>Dr</td>
<td>80</td>
<td>10</td>
<td>GI</td>
<td>Sandstone (?)</td>
<td>Friedrich-Dry sh.</td>
<td>N</td>
<td>P</td>
<td>Top of casing</td>
<td>4.7</td>
<td>9.35</td>
<td>8- 4-50</td>
</tr>
<tr>
<td>21-10-35 da</td>
<td>NE SE sec. 35</td>
<td>Citizens Bldg. &amp; Loan Assoc.</td>
<td>Du</td>
<td>20.0</td>
<td>36</td>
<td>R</td>
<td>Sandstone and shale</td>
<td>French Creek and/or Friedrich sh.</td>
<td>Cy, H</td>
<td>D</td>
<td>Top edge 2x4 flush with concrete cover</td>
<td>0.5</td>
<td>12.39</td>
<td>8-10-49</td>
</tr>
<tr>
<td>21-11-2 ba</td>
<td>NE NW sec. 3</td>
<td>Marie Rossillon</td>
<td>Du</td>
<td>27.6</td>
<td>72</td>
<td>R</td>
<td>Sand and gravel</td>
<td>Friedrich sh. and Shale and Shale</td>
<td>Alluvium</td>
<td>Cy, H</td>
<td>N</td>
<td>Top of concrete curbing</td>
<td>1.1</td>
<td>10.88</td>
</tr>
<tr>
<td>21-11-3 ba</td>
<td>NE NW sec. 3</td>
<td>S. J. Brown</td>
<td>Du</td>
<td>32.0</td>
<td>60</td>
<td>R &amp; N</td>
<td>Sandstone and shale</td>
<td>Friedrich sh. and Shale and Shale</td>
<td>Alluvium</td>
<td>Cy, H</td>
<td>S</td>
<td>Top of stone slab over well</td>
<td>0.5</td>
<td>13.28</td>
</tr>
<tr>
<td>21-11-16 aa</td>
<td>NE NE sec. 16</td>
<td>A. H. Lewry</td>
<td>Dr</td>
<td>60</td>
<td>6</td>
<td>GI</td>
<td>Sandstone and shale</td>
<td>Sandstone and shale</td>
<td>Sandstone and shale</td>
<td>Cy, H</td>
<td>D, S</td>
<td>Top of concrete curbing</td>
<td>0</td>
<td>15</td>
</tr>
<tr>
<td>21-11-28 dd</td>
<td>SE SE sec. 28</td>
<td>Will Schroeder</td>
<td>Du</td>
<td>39.4</td>
<td>48</td>
<td>R</td>
<td>Sandstone and gravel</td>
<td>Alluvium</td>
<td>Cy, W</td>
<td>D, S</td>
<td>Top of 2x12 board cover</td>
<td>1.3</td>
<td>8.19</td>
<td>9-11-51</td>
</tr>
<tr>
<td>21-11-34 cd</td>
<td>SE SW sec. 34</td>
<td>Dale Curry</td>
<td>Du</td>
<td>18.2</td>
<td>84</td>
<td>R</td>
<td>Alluvium</td>
<td>White Cloud sh.</td>
<td>Cy, H</td>
<td>P</td>
<td>Top of concrete curbing</td>
<td>0.5</td>
<td>12.71</td>
<td>11- 2-49</td>
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<tr>
<td>21-12-1 cc</td>
<td>SW SW sec. 1</td>
<td>School District</td>
<td>Du</td>
<td>31.6</td>
<td>(?!)</td>
<td>R</td>
<td>Sandstone or shale</td>
<td>Wakarusa and/or Burlington sh.</td>
<td>Cy, H</td>
<td>P</td>
<td>Top of concrete curbing</td>
<td>0.2</td>
<td>3.24</td>
<td>8- 3-50</td>
</tr>
<tr>
<td>21-12-13 dd</td>
<td>SE SE sec. 13</td>
<td>School District</td>
<td>Du</td>
<td>25.0</td>
<td>36</td>
<td>R</td>
<td>Limestone</td>
<td>Burlington sh.</td>
<td>Cy, H</td>
<td>N</td>
<td>Top of concrete curbing</td>
<td>0.3</td>
<td>10.26</td>
<td>11- 1-49</td>
</tr>
<tr>
<td>21-12-17 cd</td>
<td>SW SE sec. 17</td>
<td>J. S. Tread</td>
<td>Du</td>
<td>17</td>
<td>48</td>
<td>R</td>
<td>Sandstone</td>
<td>Harveyville sh. and/or collium</td>
<td>Cy, W</td>
<td>S</td>
<td>Land surface</td>
<td>0</td>
<td>5</td>
<td>11- 1-49</td>
</tr>
<tr>
<td>21-12-21 ba</td>
<td>NE NW sec. 21</td>
<td>Joe B. Scheve</td>
<td>Du</td>
<td>12</td>
<td>120</td>
<td>R</td>
<td>Shale</td>
<td>Everson sh.</td>
<td>Cy, E</td>
<td>S</td>
<td>Land surface</td>
<td>0</td>
<td>2</td>
<td>11- 1-49</td>
</tr>
<tr>
<td>Date</td>
<td>Section</td>
<td>Surveyor</td>
<td>Material</td>
<td>Shale and limestone</td>
<td>Auburn sh. and/or Wakarusa ls.</td>
<td>Top of casing</td>
<td>Reported adequate except in dry yrs.</td>
<td></td>
<td></td>
<td></td>
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<tr>
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<tr>
<td>21-12-29</td>
<td>29</td>
<td>Dr</td>
<td>51.5 6 GI</td>
<td>Shale and limestone</td>
<td>Cy, H P</td>
<td>0.3</td>
<td>17.64 8-23-49</td>
<td></td>
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<td></td>
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<tr>
<td>21-13-22</td>
<td>22</td>
<td>C. A. McGee</td>
<td>Du 19.1 72 R</td>
<td>Shale</td>
<td>Cy, W D S</td>
<td>0</td>
<td>9.30 11-1-49</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>21-13-27</td>
<td>27</td>
<td>Carl Thompson</td>
<td>Du 26.3 72 R &amp; N</td>
<td>Shale</td>
<td>Cy, W D</td>
<td>0.3</td>
<td>23.10 11-1-49</td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td>21-13-30</td>
<td>30</td>
<td>A. Norton</td>
<td>Du 15.5 60 R</td>
<td>Limestone and shale</td>
<td>Cy, W S</td>
<td>0.3</td>
<td>12.02 11-1-49</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>21-13-33</td>
<td>33</td>
<td>Roy L. Smith</td>
<td>Du 15 (?) R</td>
<td>Shale or limestone</td>
<td>Cy, W D S</td>
<td>0.7</td>
<td>15 11-1-49</td>
<td></td>
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<td></td>
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<tr>
<td>21-13-33</td>
<td>33</td>
<td>Alma Haehl</td>
<td>DD 40 (?) R &amp; N</td>
<td>Shale or limestone</td>
<td>Howard is. (?)</td>
<td>0</td>
<td>11-1-49</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1. Location number: Well numbers give the location of wells according to General Land Office surveys and according to the following formula: Township-Range-Section. 160-acre tract within that section, and the 40-acre tract within the quarter section. If two or more wells are located within a 40-acre tract, the wells are numbered sequentially according to the order in which they were inventoried. The 160-acre and 40-acre tracts are designated a, b, c, or d in a counterclockwise direction beginning in the northeast corner. For example well 18-6-1cd is located in the SE1/4 SW1/4 sec. 1, T. 18 S., R. 6 E.

2. DD, dug and drilled well; Dr, drilled well; Du, dug well; Sp, spring; B, bored.

3. Reported depths below the land surface are given in feet; measured depths are given in feet and tenths below measuring points.

4. Br, Brick; C, concrete; GI, galvanized sheet iron; I, iron; N, none; OW, oil-well casing; R, rock; T, tile.

5. Method of lift: C, cylinder; F, natural flow; N, none; P, pitcher pump; T, turbine; J, jet; C, centrifugal; B, bucket and rope. Type of power: E, electric; G, gas engine; H, hand operated; N, none; W, windmill.

6. D, domestic; I, irrigation; N, not being used; S, stock; P, public supply.

7. Measured depths to water level are given in feet, tenths, and hundredths; reported depths to water level are given in feet. All depths are below measuring point.

Listed on the following pages are the logs of 31 test holes drilled by the State Geological Survey for the State of Kansas. The test holes were studied by K. L. Waters and me. The geologic cross sections shown on Figure 2 were obtained from data obtained from the test drilling. Samples from the test holes were studied by K. L. Waters and me. The geologic cross sections shown on Figure 2 were obtained from the test drilling. The test drilling was confined to alluvial deposits in the valley areas.

<table>
<thead>
<tr>
<th>Road Hill</th>
<th>Total depth of test hole</th>
<th>Wortman Formation, T. 18 S., R. 6 E., drilled July 25, 1948, Surface altitude 1,441.6 feet. Water level 1 foot below land surface, June 22, 1948.</th>
</tr>
</thead>
<tbody>
<tr>
<td>18-10-12a</td>
<td>Sample log of test hole in NE1/4 NE1/4, sec. 11, T. 18 S., R. 6 E., drifted July 25, 1948. Surface altitude 1,441.6 feet. Water level 1 foot below land surface, June 22, 1948.</td>
<td></td>
</tr>
</tbody>
</table>
PERMIAN–Wolfcampian
West Branch shale
Shale, gray ........................................ 2.5
Total depth of test hole ...................... 29

18-10-11cc Sample log of test hole in SW 1/4 SW 1/4 sec. 11, T. 19 S., R. 10 E., drilled July 1948. Surface altitude 1,149.4 feet. Water level, 17.6 feet below land surface, July 14, 1948.

QUATERNARY–Pleistocene
Alluvium
Silt and clay, light-brown ..................... 5
Silt and clay, gray-black ...................... 6.5
Silt and clay, tan to light-brown ............ 10.5
Silt and clay, sandy, tan to light-brown .... 3
Gravel and sand, predominantly chert ...... 4

Pennsylvania–Virgilian
Pony Creek shale
Shale, calcareous, gray-green ............... 0.5
Total depth of test hole ..................... 31.5

PERMIAN–Wolfcampian
Falls City limestone
Shale, blue-gray, and thin limestone beds... 4
Total depth of test hole ..................... 33

18-10-14bc Sample log of test hole in SW 1/4 NW 1/4 sec. 14, T. 19 S., R. 10 E., drilled July 1948. Surface altitude 1,137.4 feet. Water level, 12.2 feet below land surface, July 14, 1948.

QUATERNARY–Pleistocene
Alluvium
Silt and sandy clay, brown .................. 7
Silt and clay, buff; contains considerable chert sand .................. 9.5
Gravel and sand, predominantly chert ...... 10

PERMIAN–Wolfcampian
Hawxby shale
Shale, gray-green ............................... 2
Total depth of test hole ..................... 28.5


QUATERNARY–Pleistocene
Terrace deposits
Silt and clay, brown-black ................... 2
Silt and clay, red-buff; contains a little fine sand .................. 2
Silt and clay, calcareous, tan to red-buff; contains considerable sand and gravel .............. 8
Gravel and sand, predominantly brown chert and colorless quartz .................. 19

Pennsylvania–Virgilian
Pony Creek shale
Shale, calcareous, gray-green ................ 0.5
Total depth of test hole ..................... 31.5

19-10-12bc Sample log of test hole in SW 1/4 NW 1/4 sec. 12, T. 19 S., R. 10 E., drilled July 1948. Surface altitude, 1,152.8 feet.

Road fill ........................................ 2.5

QUATERNARY–Pleistocene
Terrace deposits
Silt and clay, sandy, red-buff ................ 4.5
Silt and clay, very sandy, red-buff ........... 5
Sand and gravel, predominantly colorless quartz and brown chert .................. 6

PERMIAN–Wolfcampian
Towle shale
Shale, noncalcareous, dark-gray ................ 4
Total depth of test hole ..................... 22


Road fill ........................................ 2

QUATERNARY–Pleistocene
Alluvium
Silt and clay, calcareous, buff-tan; contains a little fine sand .................. 18
Silt and clay, calcareous, tan; contains considerable sand .................. 6
Sand, fine to very coarse, rounded, predominantly quartz .................. 2
Gravel and sand, predominantly brown chert and colorless quartz .................. 9

Pennsylvania–Virgilian
French Creek shale (?)
Shale, very sandy, micaceous, gray-green .................. 3
Total depth of test hole ..................... 40

Road fill .................................................. 3

Quaternary-Pleistocene

Alluvium
Silt and clay, noncalcareous, black ......................... 2
Silt and clay, calcareous, tan; contains a little fine sand ........................................ 14
Silt and clay, calcareous, slightly sandy, dark-gray and tan ........................................ 2
Clay, slightly sandy, gray-tan ................................ 3
Sand, predominantly fine to coarse rounded quartz .................................................................. 5
Gravel and sand, brown chert and colorless quartz ................................................................. 6.5

Pennsylvanian-Virgilian

French Creek shale (?)
Shale, calcareous, green-gray ................................ 3.5
Total depth of test hole .................................................. 41


Quaternary-Pleistocene

Alluvium
Silt and clay, gray-black ........................................... 3.5
Silt and clay, brown-black ......................................... 4
Silt and clay, dark-brown to gray, slightly sandy .................................................................... 20
Sand and gravel, chiefly colorless quartz and brown chert .................................................. 11
Gravel and sand, chiefly brown chert and colorless quartz .................................................... 1.5

Pennsylvanian-Virgilian

French Creek shale (?)
Shale, sandy, micaceous, green-gray ................................ 7
Total depth of test hole .................................................. 47


Quaternary-Pleistocene

Alluvium
Silt and clay, noncalcareous, tan ................................ 5
Silt and clay, noncalcareous, black to brown .......... 1.5
Silt and clay, noncalcareous, dark-brown ............ 10.5
Silt and clay, calcareous, slightly sandy, tan ...... 12
Sand and gravel, chiefly rounded colorless quartz sand and brown chert gravel ..................... 6
Silt and clay, black; contains much sand and gravel and mollusk shells ................................. 2.5

Pennsylvanian-Virgilian

French Creek shale (?)
Shale, very sandy, micaceous, green-gray .............. 6.5
Total depth of test hole .................................................. 44


Road fill .................................................. 2.5

Quaternary-Pleistocene

Terrace deposits
Silt and clay, gray-brown .......................................... 3.5
Silt and clay, slightly calcareous, red-brown .......... 10
Silt and clay, sandy, tan ........................................... 10
Silt and clay, sandy, red-brown ......................... 12
Sand, chiefly colorless rounded medium to very coarse quartz ............................................ 2
Gravel and sand, brown chert, and colorless quartz ......................................................... 4

Pennsylvanian-Virgilian

French Creek shale (?)
Shale, sandy, micaceous, green-gray ..................... 6
Total depth of test hole .................................................. 50


Quaternary-Pleistocene

Terrace deposits
Silt and clay, noncalcareous, slightly sandy, tan .......... 10
Silt and clay, noncalcareous, red-tan .................... 5
Silt and clay, gray and tan; contains a little chert gravel ................................................. 4
Silt and clay, slightly sandy, light-gray; contains much chert gravel .................................. 3.5
Gravel, predominantly brown chert; contains considerable chert and quartz sand ............... 4

Pennsylvanian-Virgilian

Reading limestone
Limestone, hard, gray ............................................. 0.2
Total depth of test hole .................................................. 28.7


Quaternary-Pleistocene

Alluvium
Silt, noncalcareous, black to dark-gray .................. 9
Silt and clay, noncalcareous, dark-brown ............. 10
Silt and clay, noncalcareous, slightly sandy, brown .. 2
Gravel and sand, predominantly brown chert; contains very little quartz sand .................. 13
<table>
<thead>
<tr>
<th>Lithology</th>
<th>Description</th>
<th>Thickness, feet</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Pennsylvania-Virgilian</strong></td>
<td>Auburn shale</td>
<td>0.2</td>
</tr>
<tr>
<td>Limestone, hard, gray</td>
<td>0.2</td>
<td></td>
</tr>
<tr>
<td>Total depth of test hole</td>
<td>34.2</td>
<td></td>
</tr>
</tbody>
</table>


<table>
<thead>
<tr>
<th>Lithology</th>
<th>Description</th>
<th>Thickness, feet</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quaternary-Pleistocene</td>
<td>Alluvium</td>
<td>5</td>
</tr>
<tr>
<td>Soil, black</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Clay and silt, noncalcareous, slightly sandy, dark-brown</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Clay and silt, noncalcareous, slightly sandy, gray-brown</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Silt and clay, noncalcareous, light-brown; contains a little chert sand and gravel</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td>Gravel and sand, predominantly brown chert</td>
<td>4.5</td>
<td></td>
</tr>
</tbody>
</table>

**Pennsylvania-Virgilian** | Auburn shale | 0.2 |
| Limestone, hard, gray | 0.2 |
| Total depth of test hole | 35.7 |

**19-11-1dd Sample log of test hole in SE¼ SE¼ sec. 1, T. 19 S., R. 11 E., drilled July 1949. Surface altitude, 1,097.7 feet. Water level, 1.9 feet below land surface, July 23, 1949.**

<table>
<thead>
<tr>
<th>Lithology</th>
<th>Description</th>
<th>Thickness, feet</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quaternary-Pleistocene</td>
<td>Alluvium</td>
<td>4</td>
</tr>
<tr>
<td>Soil, black</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Clay and silt, gray to gray-brown</td>
<td>1.5</td>
<td></td>
</tr>
<tr>
<td>Clay and silt, yellow-gray</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Silt and clay, slightly sandy, brown to gray-brown</td>
<td>3.5</td>
<td></td>
</tr>
<tr>
<td>Gravel and sand, brown chert, and colorless quartz; predominantly chert</td>
<td>9</td>
<td></td>
</tr>
</tbody>
</table>

**Pennsylvania-Virgilian** | Auburn shale | 0.4 |
| Limestone, brown | 0.4 |
| Total depth of test hole | 20.4 |

**19-11-13aa Sample log of test hole in NW¼ NE¼ sec. 13, T. 19 S., R. 11 E., drilled July 1948. Surface altitude, 1,096.0 feet. Water level, 2.6 feet below land surface, August 12, 1948.**

<table>
<thead>
<tr>
<th>Lithology</th>
<th>Description</th>
<th>Thickness, feet</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quaternary-Pleistocene</td>
<td>Alluvium</td>
<td>2</td>
</tr>
<tr>
<td>Silt and clay, brown-black</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Silt and clay, brown-gray</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Silt and clay, brown; contains a small amount of brown chert gravel</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>Gravel and sand, chiefly brown chert</td>
<td>1.5</td>
<td></td>
</tr>
</tbody>
</table>

**Pennsylvania-Virgilian** | Auburn shale | 5.5 |
| Shale, very calcareous, gray | 5.5 |
| Total depth of test hole | 22 |

**19-11-13daa Sample log of test hole in NE¼ NE¼ SE¼ sec. 13, T. 19 S., R. 11 E., drilled July 1948. Surface altitude, 1,107.0 feet. Water level, 11.2 feet below land surface, July 12, 1948.**

<table>
<thead>
<tr>
<th>Lithology</th>
<th>Description</th>
<th>Thickness, feet</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quaternary-Pleistocene</td>
<td>Terrace deposits</td>
<td>2</td>
</tr>
<tr>
<td>Soil, black</td>
<td>2</td>
<td></td>
</tr>
</tbody>
</table>
Clay and silt, hard, gray-brown .......... 3
Clay and silt, noncalcareous, light-gray ........ 2.5
Clay and silt, noncalcareous, mottled light-gray and tan; contains a small amount of chert sand .......... 14.5
Gravel and sand, brown chert, and colorless quartz .......... 4

Pennsylvania-Virgilian
Auburn shale
Shale, fossiliferous, pyritic, yellow and gray .......... 1
Shale, gray-black, and thin gray limestones .......... 1
Total depth of test hole .......... 28


Quaternary-Pleistocene
Terrace deposits
Soil, black .......... 4.5
Silt and clay, gray to red-gray .......... 4.5
Clay and silt, noncalcareous, mottled gray and buff .......... 7
Sand, chiefly very fine- to medium-grained colorless quartz .......... 6.5
Gravel and sand, brown chert, and colorless quartz .......... 5.5

Pennsylvania-Virgilian
Auburn shale
Shale, calcareous, yellow and gray .......... 1
Shale and limy shale, green-gray .......... 1
Total depth of test hole .......... 30

19-11-16ac Sample log of test hole in SW¼ NE¼ sec. 16, T. 19 S., R. 11 E., 100 feet west of South Pine Street and 10 feet north of West South Avenue, drilled July 1949. Surface altitude, 1,133.5 feet.

Quaternary-Pleistocene
Terrace deposits
Soil, black to dark-gray .......... 3
Silt and clay, noncalcareous, red-tan .......... 7
Silt and clay, tan with gray motting .......... 7
Silt and clay, tan; contains much fine sand in lower part .......... 10
Silt and clay, tan; contains chert and quartz sand .......... 12
Sand and gravel; chiefly colorless fine- to very coarse-grained quartz sand and brown chert gravel .......... 4
Gravel and sand, brown chert, and colorless quartz .......... 2

Pennsylvania-Virgilian
Pierson Point-Willard shale
Shale, sandy, micaceous, blue-gray .......... 5
Total depth of test hole .......... 50


Quaternary-Pleistocene
Terrace deposits
Soil, black .......... 2
Clay and silt, sandy, tan and brown-gray .......... 4.5
Clay and silt, sandy, mottled buff and gray .......... 1
Clay and sand, buff; contains a little chert gravel and quartz sand .......... 11
Sand, fine- to coarse-grained quartz, and brown chert gravel .......... 11

Pennsylvania-Virgilian
Auburn shale
Shale, calcareous, fossiliferous, yellow .......... 2
Wakarusa limestone
Limestone, light-gray .......... 0.5
Total depth of test hole .......... 32


Quaternary-Pleistocene
Alluvium
Silt and clay, black .......... 5.5
Clay and silt, dark-gray .......... 2.5
Clay and silt, brown-tan .......... 6
Silt and clay, brown-tan; contains brown chert gravel and colorless quartz sand .......... 9
Sand, fine- to coarse-grained quartz, and brown chert gravel .......... 7

Pennsylvania-Virgilian
Burlingame limestone
Limestone, fossiliferous, light-gray to yellow-tan .......... 2
Total depth of test hole .......... 32


Quaternary-Pleistocene
Terrace deposits
Soil, gray-black .......... 3
Silt and clay, noncalcareous, gray with light-tan motting .......... 2
Silt and clay, noncalcareous, slightly micaceous, yellow to yellow-brown .......... 5
Silt and clay, noncalcareous, slightly micaceous, yellow to yellow brown; contains numerous manganese shot .......... 15
Silt and clay, noncalcareous, slightly sandy, light-gray with yellow-brown motting .......... 5
Silt and clay, noncalcareous, slightly sandy, gray and tan .......... 8
Gravel and sand, predominantly colorless quartz and brown chert ........................................ 5.5

**Pennsylvania-Virgilian**

Howard limestone

Limestone, hard ......................................................... 0.1

Total depth of test hole ........................................... 42.8


### QUATERNARY-Pleistocene

Alluvium

- Soil, black .................................................. 4
- Clay and silt, noncalcareous, gray to tan-gray ........................................ 6
- Clay and silt, calcareous, gray to tan-gray ........................................ 5
- Silt and clay, slightly sandy, friable, calcareous; contains sparse mollusk shells ......... 10.5
- Gravel and sand, predominantly brown chert and colorless quartz, numerous mollusk shells ........................................ 9.5

**Pennsylvania-Virgilian**

Howard limestone

- Shale, micaceous, gray ........................................ 5

Total depth of test hole ........................................... 40


### QUATERNARY-Pleistocene

Terrace deposits

- Soil, gray-black ............................................... 3
- Silt and clay, noncalcareous, slightly sandy, red-tan mottled with brown ................. 10
- Silt and clay, noncalcareous, slightly sandy, red-tan ........................................ 5
- Gravel and sand, predominantly brown chert and colorless quartz ......................... 8.5

**Pennsylvania-Virgilian**

Howard limestone

- Limestone, hard, gray .......................................... 0.1

Total depth of test hole ........................................... 26.6


### QUATERNARY-Pleistocene

Alluvium

- Soil, gray-black ............................................... 3

Clay and silt, slightly calcareous, light tan-gray to gray ............................................. 5
- Silt and clay, slightly calcareous, slightly sandy, light tan-gray to gray .................. 5
- Silt and clay, calcareous, sandy, friable, tan-gray to gray .................................... 3.5
- Gravel and sand, predominantly brown chert and colorless quartz; contains lime-stone detritus ........................................ 2.5

**Pennsylvania-Virgilian**

Howard limestone

- Shale, slightly sandy, pyritic, medium dark-gray .................................................... 2

Total depth of test hole ........................................... 21


### QUATERNARY-Pleistocene

Terrace deposits

- Soil, black .................................................. 4
- Silt and clay, noncalcareous, mottled red-brown and red-tan .................................. 4.5
- Silt and clay, calcareous, friable, slightly sandy, light red-tan mottled with brown .... 14
- Sand and gravel, predominantly brown chert and colorless quartz ........................... 7.5

**Pennsylvania-Virgilian**

Howard limestone

- Limestone, hard, gray .......................................... 0.1

Total depth of test hole ........................................... 30.1


### QUATERNARY-Pleistocene

Terrace deposits

- Silt and clay, noncalcareous, light-gray ................. 5
- Silt and clay, slightly calcareous, tan mottled with gray .................................... 5.5
- Silt and clay, very calcareous, sandy, friable, tan ............................................... 4.5
- Silt and clay, very calcareous, sandy, pink-gray; contains mollusk shells .................. 5

**Pennsylvania-Virgilian**

Howard limestone

- Shale, very limy, dark-gray .................................. 3
- Limestone, with two thin shale partings, abundant fusulinids, dark-gray .................. 2.5

Total depth of test hole ........................................... 34.5
REFERENCES


Moore, R. C., and others (1940) Ground-water resources of Kansas: Kansas Geol. Survey, Bull. 27, pp. 1-112.


——— (1952) Oil and gas developments in Kansas during 1951: Kansas Geol. Survey, Bull. 97, pp. 1-188.
