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

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HOWARD G. O'CONNOR, EDWIN D. GOEBEL, AND NORMAN PLUMMER

PART 3

GROUND-WATER RESOURCES OF LYON COUNTY

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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 23⅔ 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

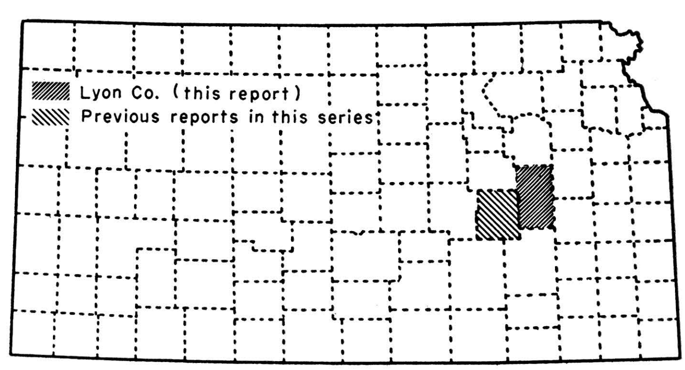


Fig. 1.—Index map of Kansas showing location of Lyon County and areas for which reports of this series have been published.

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 (NE¼ NW¼ 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.

Schroyer limestone member.—The average thickness of the Schroyer 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 variableness 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 gypsiferous, 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

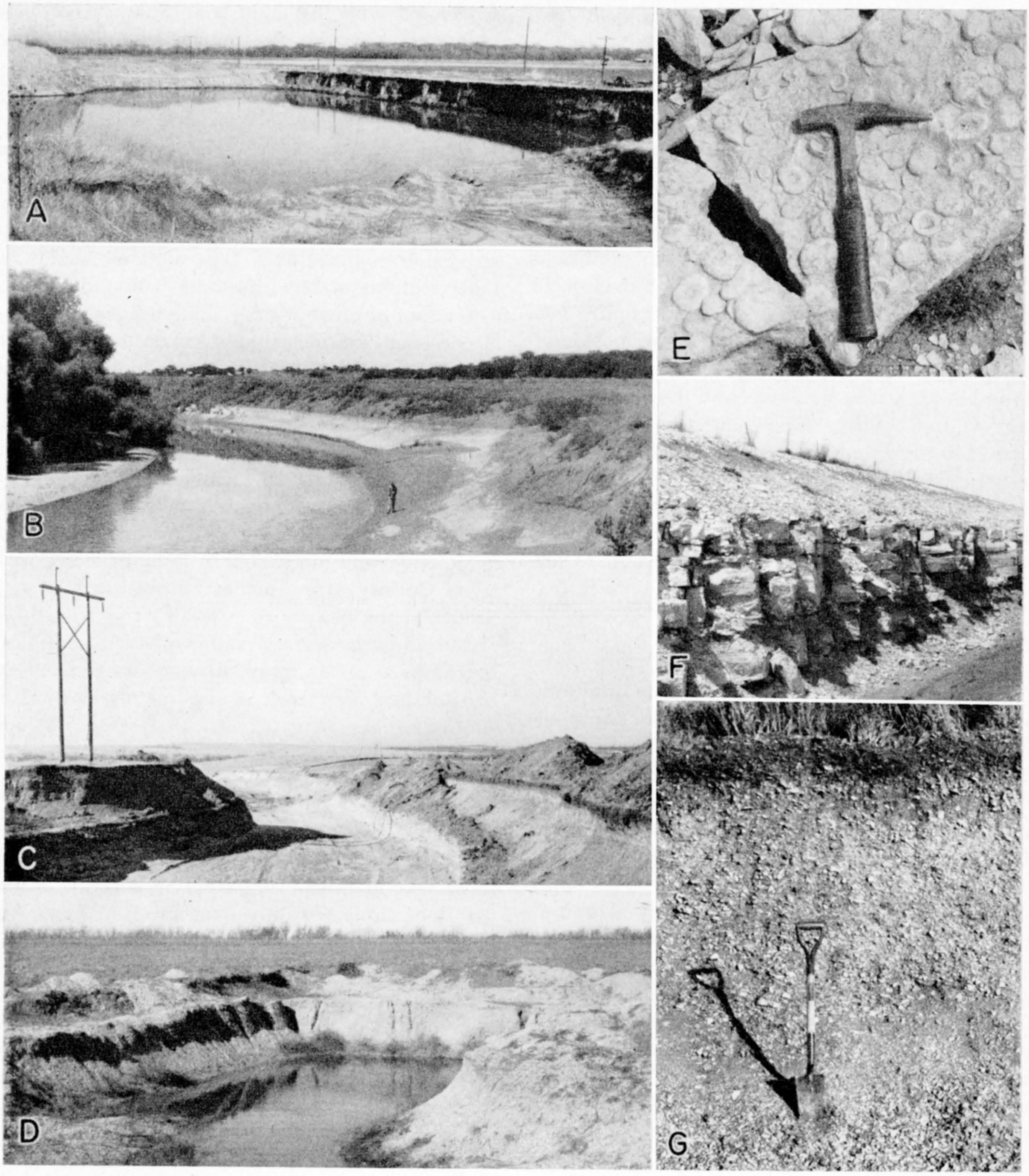


PLATE 4. **A**, Gravel pit in Neosho River alluvium, NE¼ SE¼ sec. 6, T. 20 S., R. 13 E. Pond surface is water table. **B**, Cut bank of Neosho River, SE¼ SE¼ sec. 14, T. 19 S., R. 12 E., showing profile of alluvial materials. Effluent seepage from gravel below point where man stands indicates water table. **C**, Quarry in Tertiary terrace gravel (upper 8 to 12 feet) and sandstone of Pierson Point-Willard shale (lower part of quarry), NW¼ NE¼ sec. 5, T. 19 S., R. 12 E. **D**, Small gravel pit in Emporia terrace on Bechtold farm, NW¼ NW¼ 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, SE¼ SE¼ 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, SE¼ sec. 7, T. 16 S., R. 10 E., **G**, Soil development on high terrace chert gravel, SW¼ 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 nonfossiliferous 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, echinoderms, 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, echinoderms, 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 3½ 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 Americus 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, bryozoans, 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 bryozoan *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, Ambocoelia,* 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. Nonsandy 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 limestone 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, bryozoans, 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, bryozoans, 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, bryozoans, 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 *Linoproductus,* bryozoans, 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, Ottonosia, Dictyoclostus* and other brachiopods, horn corals, crinoids, and bryozoans 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 NW¼ sec. 35, T. 17 S., R. 13 E., it is represented by thick, slightly cross-bedded, coquinoid 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. Bryozoans, 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 disconformity and 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 disconformity 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 disconformity 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, Neospirifer*, 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.

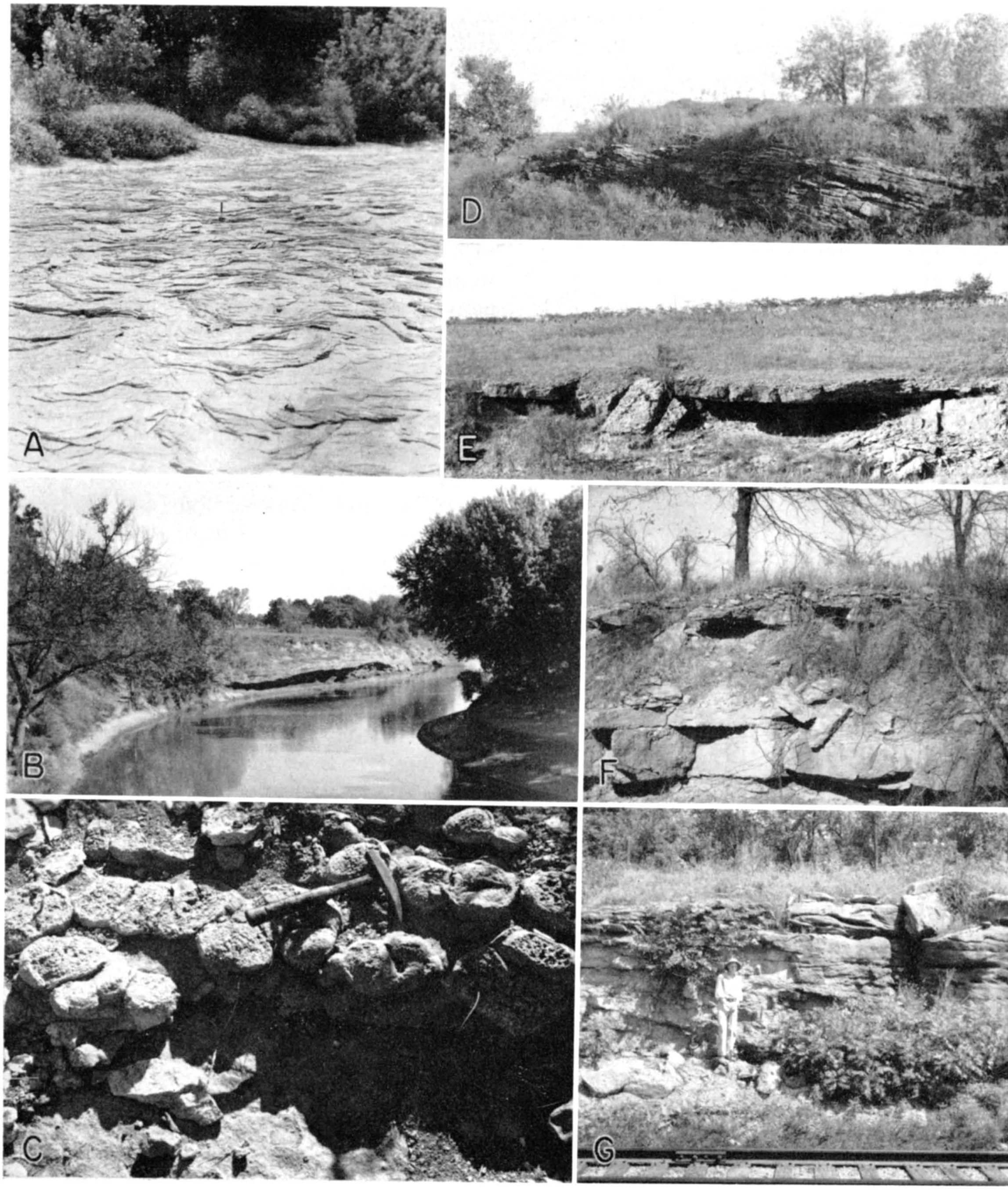


PLATE 5. **A**, Channel-filling cross-bedded limestone conglomerate of Silver Lake shale exposed in Neosho River bed, Cen. NW¼ sec. 19, T. 19 S., R. 13 E. **B**, Channel-filling sandstone of Silver Lake or Cedar Vale shale age, more than 30 feet thick, exposed in cut bank of Neosho River, SW cor. sec. 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 SW¼ 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.

Utopia limestone member.—The thickness of the Utopia 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 member.—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 member.—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. *Cryptozoon,* crinoids, and brachiopods are the characteristic and abundant fossils. Fusulinids, bryozoans, and sparse mollusks are observed in a few outcrops.

Aarde shale member.—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 *Cryptozoon,* 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 member.—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 member.—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, *Linoproductus,* and crinoid remains.

Turner Creek shale member.—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-bedded 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 *Cryptozoon* 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 1.—*Chemical analyses of selected outcropping limestones from Lyon County*

Stratigraphic unit, thickness, and type of sample	Location	SiO_2	Al_2O_3*	Fe_2O_3	CaO	MgO	P_2O_5	SO_3	Ignition loss	Calculated $CaCO_3$**	Calculated $MgCO_3$
Howe ls., composite of lower 4.0 ft. of 4.4 ft. bed.	SE NE 34-15-11E	5.40	0.74	0.27	51.97	0.73	0.01	0.07	41.33	92.55	1.53
Upper Crouse ls., composite of upper 5.6 ft.	NE NW 15-16-10E	14.09	2.76	1.03	43.71	1.01	0.05	0.06	36.47	77.76	2.11
Upper Crouse ls., composite of lower 2.9 ft. of bed.	NE NW 15-16-10E	3.61	0.98	1.12	51.78	0.74	0.03	0.09	41.25	92.83	1.55
Funston ls., composite of lower 5.6 ft. of upper bed.	NW NE 18-16-10E	7.90	1.49	0.70	49.11		0.04	0.15	39.24	87.30	1.72
Funston ls., composite of 2.0 ft., entire middle detrital bed	NW NE 18-16-10E	4.99	1.25	1.01	50.72	0.79	0.06	0.02	40.46	90.26	1.65
Morrill ls., composite of entire bed, 2.4 ft.	SW NE 17-16-11E	5.65	0.37	0.42	51.93	0.82	0.05	0.08	41.14	92.37	1.72
Cottonwood ls., composite of upper 5.3 ft. of member.	SE NW 17-16-11E	9.70	0.97	0.51	48.30	0.73	0.12	0.39	38.70	85.34	1.53
Upper Neva ls., composite of entire 1.7 ft. bed.	NW SW 20-16-11E	4.18	0.62	0.46	52.25	0.64	0.03	0.03	41.42	93.06	1.34
Middle Neva ls., composite of entire 5.7 ft. middle bed.	NW SW 20-16-11E	3.92	0.93	0.53	52.07	0.77	0.05	0.02	41.53	92.76	1.61
Brownville ls., composite of entire 3.0 ft. bed.	NW NW 21-16-12E	6.19	1.38	1.83	47.65	2.09	0.29	0.69	39.19	83.52	4.37
Dover ls., composite of entire bed, 1.5 ft.	NW SW 25-16-12E	36.62	5.67	1.86	29.39	0.92	0.13	nil	23.84	52.41	1.92
Reading ls., entire bed, 2.8 ft.	SE SE 12-17-12E	6.53	1.43	1.38	49.45	0.93	0.09	0.47	39.48	87.39	1.95
Grandhaven ls., composite of entire lower bed, 2.6 ft.	SW SW 15-17-12E	9.56	2.93	3.08	44.36	2.04	0.15	0.01	37.41	78.82	4.27
Upper Grandhaven ls., composite entire bed, 2.6 ft.	NE NE 21-17-12E	3.55	0.98	1.23	52.19	0.81	0.04	0.19	41.63	92.74	1.69
Cottonwood ls., composite of upper 4.7 ft. of member.	SW NW 7-18-10E	5.97	1.09	0.37	51.22	0.65	0.08	0.12	40.65	91.16	1.36
Aspinwall ls., composite of upper 4.6 ft. of bed.	NE SW 16-18-11E	1.99	0.61	1.24	53.12	0.62	0.06	0.04	42.17	94.58	1.30
Upper Grandhaven ls., composite of upper 7.5 ft. of bed.	SE SW 29-19-11E	4.22	1.49	2.12	51.60	0.79	0.07	nil	40.54	92.01	1.65
Wakarusa ls., composite of 3 ledges, 4.3 ft.	SW SE 9-19-12E	5.32	1.60	3.24	45.26	3.94	0.08	0.16	40.22	80.33	8.24
Silver Lake sh. ? (ls. conglomerate filling channel cut down into White Cloud sh., composite ± 20 ft.	NE NE 30-19-13E	6.06	1.54	2.79	47.76	2.02	0.19	0.20	39.56	84.52	4.23
Americus ls., composite of entire lower bed, 1.8 ft.	SW SE 4-20-10E	4.25	0.75	0.72	51.63	0.73	0.39	0.14	40.68	91.08	1.52
Reading ls., composite of entire bed, 2.75 ft.	SW SE 33-21-11E	4.44	1.56	3.44	47.55	2.74	0.10	0.13	40.53	84.79	5.73
Reading ls., composite of upper "super" ls., entire bed, 5.0 ft.	SW SE 33-21-11E	4.75	0.73	0.99	51.75	0.70	0.11	0.08	40.67	91.94	1.46

* Includes MnO and TiO_2.
** 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 biohermal 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 Permian 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-

TABLE 2.—*Ceramic data on clay and shale samples from Lyon county*

PLASTIC AND DRY PROPERTIES

Sample No.	Location	Stratigraphic position	Thickness sampled, feet	Water of plasticity, percent	Shrinkage water, percent	Pore water, percent	Volume shrinkage, percent	Measured linear shrinkage, percent	Calculated linear shrinkage, percent
		Pennsylvanian							
LY-9	NW 18-19-13 E.	Silver Lake shale	18	20.62	4.33	16.29	8.03	3.41	2.60
LY-1	SW 2-20-11 E.	Willard-Langdon shale	30	27.38	12.77	14.61	23.94	5.53	7.40
LY-2	NW 19-16-13 E.	Langdon shale	11	23.57	6.02	17.55	10.60	2.83	3.42
LY-3	SE 32-19-11 E.	do	12.5	24.88	9.56	15.32	17.56	4.87	5.55
LY-4	SW 35-17-12 E.	do	11	26.02	8.23	17.79	14.64	4.13	4.65
LY-5	NW 22-18-12 E.	Pierson Point shale	20	27.06	13.05	14.01	24.88	6.16	7.69
LY-6	SE 34-21-10 E.	French Creek shale	14.5	28.26	10.93	17.33	19.68	4.75	6.18
		Permian							
LY-8	SE 13-16-10 E.	Speiser shale	8.4	24.15	11.36	12.79	22.40	6.44	6.97
LY-7	SW 26-15-11 E.	Roca shale	6.8	21.63	9.78	11.85	18.59	5.37	5.94
		Pleistocene							
LY-11	SW 16-19-11 E.	Emporia terrace	7.	29.94	18.56	10.38	36.31	11.94	10.87
		Pleistocene-Recent and Wisconsinan							
LY-10	SE 14-19-12 E.	Neosho River alluvium	11.8	28.86	19.09	9.77	38.29	11.16	11.41
LY-12	NW 22-19-10 E.	Cottonwood River alluv.	9.8	25.47	14.85	10.62	29.33	8.48	8.94

FIRED PROPERTIES

Sample No.	Ignition loss, percent	Firing range, cones	Fired to cone	Color	Measured linear shrinkage, percent	Total linear shrinkage, percent	Percent absorption: 24 hrs. cold water	Percent absorption: 3 hrs. boiling water	Saturation coefficient	Hardness, as to steel
LY-9	6.37	03-2	05	red	2.66	6.07	11.18	13.80	0.81	harder
			02	red	3.84	7.25	8.06	11.19	0.72	do
			2	red	7.41	10.82	0.91	1.62	0.56	do
LY-1	5.63	07-01	06	red	5.06	10.59	6.39	6.94	0.93	do
			04	red	6.03	11.56	4.86	5.46	0.89	do
			01	red	7.68	13.21	1.02	1.91	0.53	do
LY-2	4.78	03-1	06	light red	0.96	3.79	17.37	19.61	0.89	softer
			04	red	3.40	6.23	12.42	15.31	0.81	do
			01	red	7.49	10.32	3.54	5.41	0.65	harder
LY-3	5.82	05-01	06	orange red	3.05	7.92	11.18	12.89	0.87	do
			04	bright red	5.16	10.03	6.58	8.88	0.74	do
			01	red	6.80	11.67	2.86	4.85	0.59	do
LY-4	5.32	05-02	06	light red	2.72	6.85	13.63	14.78	0.92	softer
			04	red	7.20	11.33	5.06	5.70	0.88	harder
LY-5	7.22	06-04	06	red	4.04	10.20	8.17	9.04	0.90	do
			04	red	6.38	12.54	2.00	4.15	0.48	do
LY-6	6.65	06-04	06	orange	4.96	9.71	9.47	9.87	0.96	do
			04	bright red	8.67	13.42	1.50	2.45	0.61	do
LY-8	16.04	2 plus	05	buff	2.98	9.42	15.32	17.76	0.86	softer
			02	yellow	2.85	9.29	15.65	18.42	0.85	as hard
			2	green-buff	3.37	9.49	12.35	15.72	0.79	harder
LY-7	13.96	2 plus	05	buff	1.23	6.60	17.56	20.54	0.85	softer
			02	gray-buff	1.37	6.77	16.91	20.22	0.84	as hard
			2	green-buff	2.61	7.93	13.04	16.64	0.78	harder
LY-11	3.78	04-2	05	orange red	1.41	13.35	9.38	12.66	0.74	do
			02	red	2.36	14.30	8.02	11.09	0.72	do
			2	red	6.29	18.75	2.30	5.65	0.41	do
LY-10	6.09	07-02	05	orange red	4.23	15.39	4.14	4.67	0.89	do
			02	red	5.63	16.79	1.57	2.33	0.67	do
LY-12	4.37	05-2	05	orange red	1.97	10.45	8.59	11.26	0.76	do
			02	red	3.13	11.65	6.58	8.97	0.73	do
			2	red	5.99	14.41	1.34	2.13	0.63	do

TABLE 3.—*Results of experimental production of lightweight aggregate from Lyon County Pennsylvanian shales*

Sample No.	Thickness sampled, feet	Thickness available, feet	Firing temperatures, degrees F. Initial softening	Firing temperatures, degrees F. Optimum for bloating	Firing temperatures, degrees F. Maximum attained	Unit weight, lbs. per cu. ft. Crushed, unsized	Unit weight, lbs. per cu. ft. Crushed, sized	Color of crushed aggregate
LY-1	15	30	2190	2220	2280	46.1	52.2	gray
LY-2	11	18	2140	2170	2240	48.7	55.1	do
LY-3	12.5	25	2130	2140	2170	62.0	71.9	pink & gray
LY-4	11	11	2080	2120	2180	38.8	40.4	red & gray
LY-5	20	20	2200	2230	2250	61.5	76.6	dark gray
LY-6	14.5	22	2160	2175	2200	64.7	72.3	do

terial 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 pelletizing 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, pelletized, 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-Pierson 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.

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 (Ockerman, 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 produced 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.

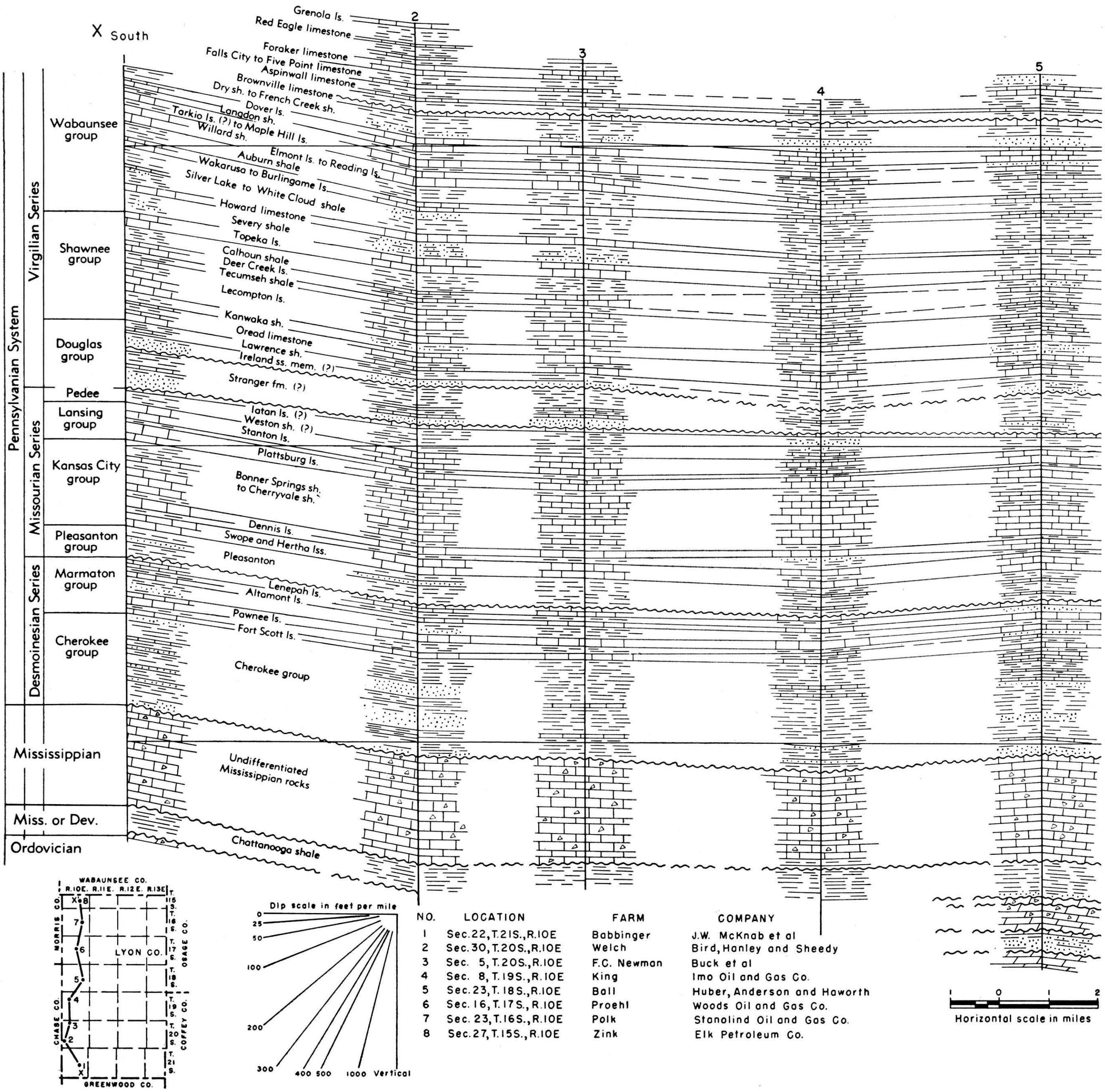
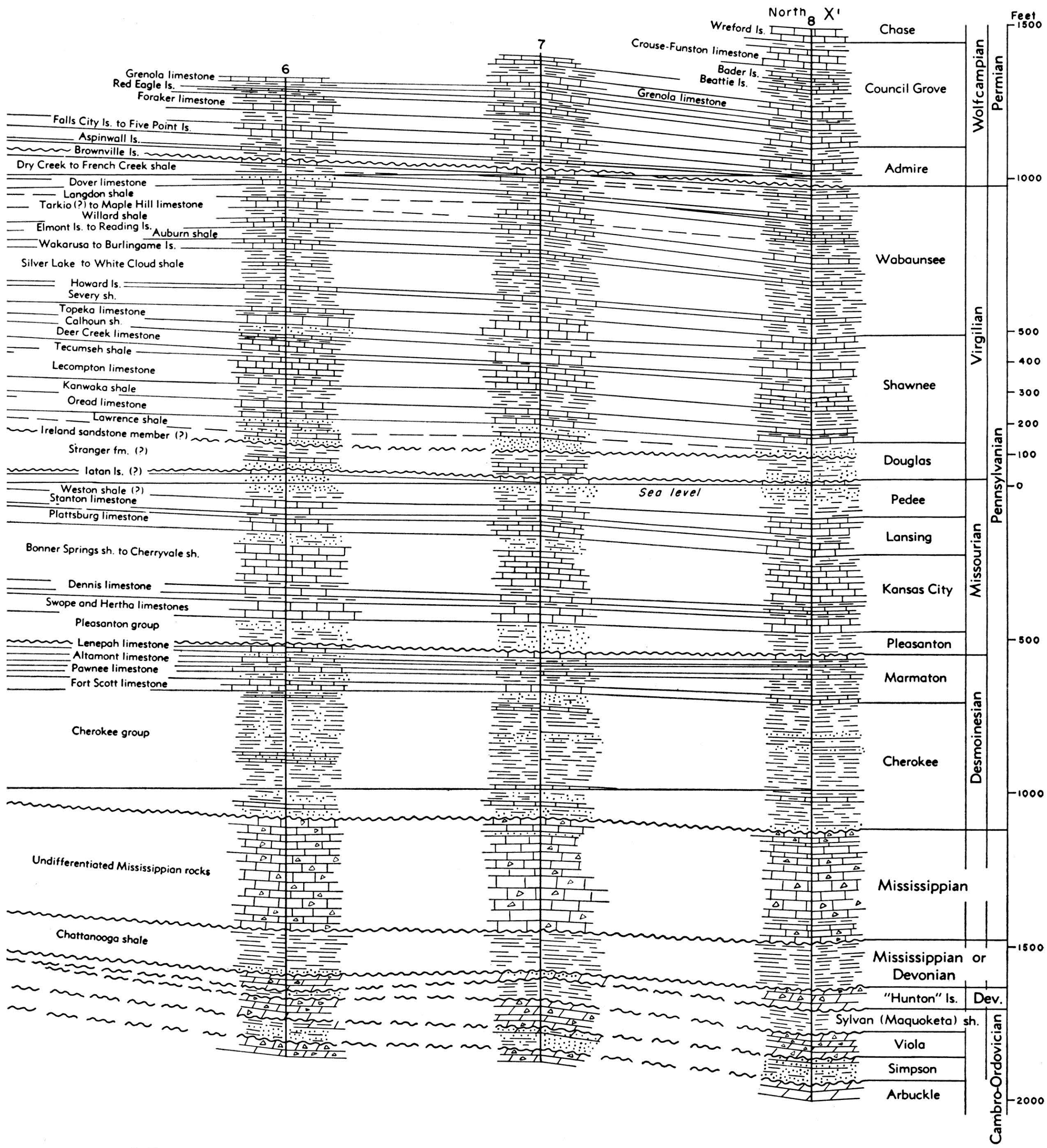


FIG. 2.—Geologic cross section showing conditions along a north-south line through the western part of

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 NE¼ NE¼ NE¼ 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 SE¼ SW¼ 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 NE¼ NE¼ NE¼ 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 NE¼ SE¼ SE¼ 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. SW¼ 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 NW¼ NW¼ NE¼ 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$_1$). 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$_2$) 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-

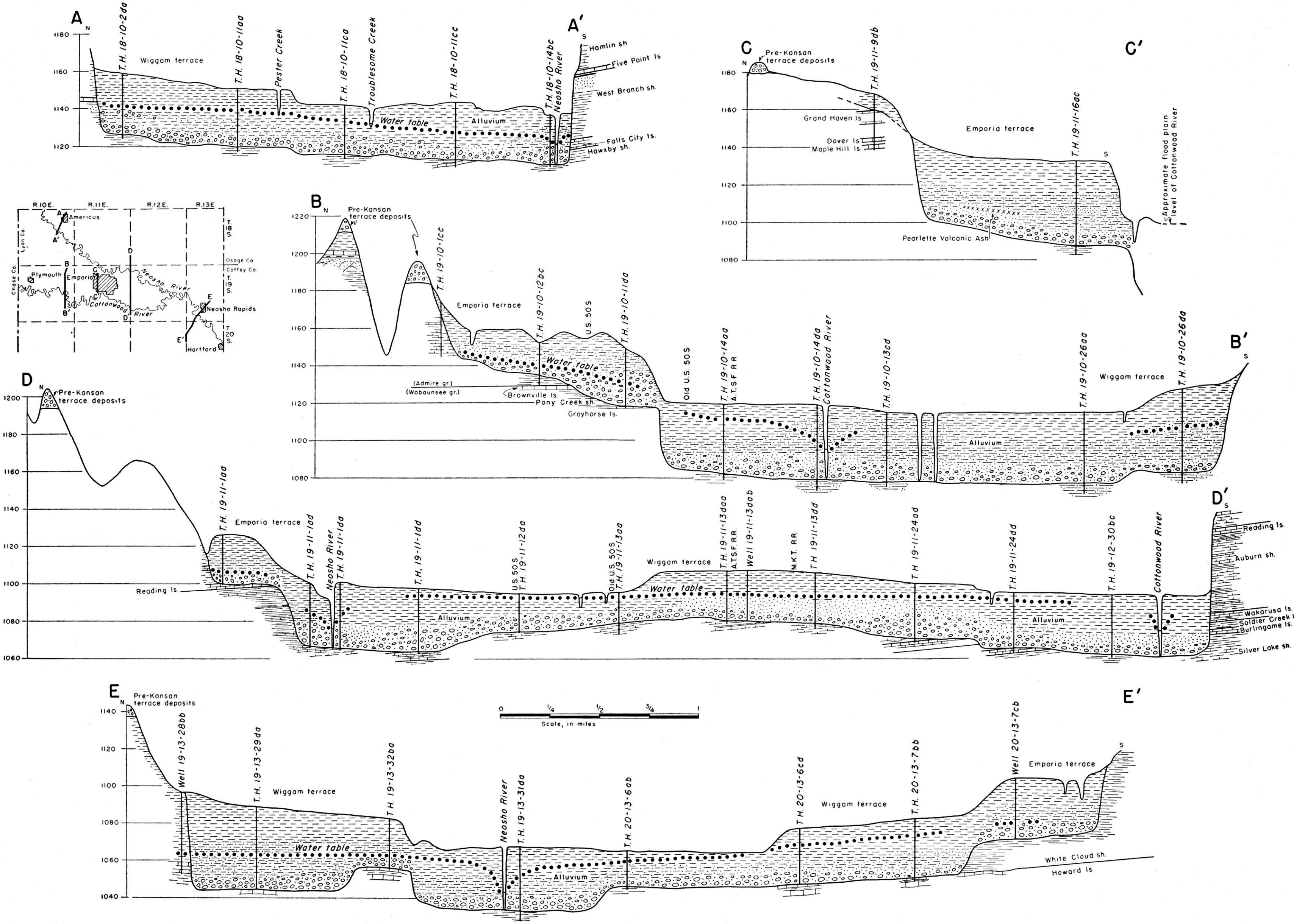


FIG. 3.—Geologic cross sections across the Cottonwood and Neosho River Valleys.

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, Fanistel 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

TABLE 4.—*Analyses of water from typical wells in Lyon County*
Analyzed by H. A. Stoltenberg.—Dissolved constituents given in parts per million[a]

Well no.	Location	Depth, feet	Geologic source	Date of collection	Temperature (°F)	Dissolved solids	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium & potassium (Na+K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Hardness as $CaCO_3$: Total	Hardness as $CaCO_3$: Carbonate	Hardness as $CaCO_3$: Noncarbonate
	T. 15 S., R. 10 E.																		
15-10-23dc	SW SE sec. 23	18.2	Threemile limestone	9-13-51	....	1,040	6.4	0.30	183	35	97	382	135	71	0.2	319	600	313	287
	T. 15 S., R. 13 E.																		
15-13-19ca	NE SW sec. 19	16.4	Falls City limestone and/or Hawxby shale	9-13-51	56	656	8.6	0.82	117	57	36	464	177	20	0.5	12	526	380	146
	T. 16 S., R. 10 E.																		
16-10-9cc	SW SW sec. 9	56.9	Beattie limestone (?)	9-13-51	....	530	2.2	0.84	85	43	52	417	73	45	0.2	25	388	342	46
16-10-34dd	SE SE sec. 34	26.6	Crouse limestone	9-12-51	....	716	6.0	0.68	118	42	68	403	195	14	0.3	75	467	330	137
	T. 16 S., R. 11 E.																		
16-11-21da	NE SE sec. 21	39.5	Long Creek limestone	9-12-51	57	556	3.2	0.07	114	26	48	344	145	33	0.3	18	392	282	110
16-11-22ad$_1$	SE NE sec. 22 City of Allen, Ks.[b]	32	Long Creek limestone	3-7-51	....	1,880	15	0.23	337	79	113	390	914	48	0.5	89	1,166	320	846
	T. 16 S., R.13 E.																		
16-13-20da	NE SE sec. 20	25.3	Terrace alluvium	9-13-51	....	803	5.6	0.35	148	20	112	514	226	13	0.2	25	451	422	29
	T. 17 S., R. 10 E.																		
17-10-14da	NE SE sec. 14	87.1	Long Creek limestone	9-12-51	....	626	2.4	1.3	103	44	58	417	142	28	0.4	43	438	342	96
17-10-16ad	SE NE sec. 16	53.2	Grenola limestone	9-13-51	....	849	2.4	0.06	200	43	12	388	127	52	0.3	221	676	318	358
	T. 17 S., R. 13 E.																		
17-13-5cd	SE SW sec. 5	30.6	Pierson Point-Willard shale	9-13-51	....	630	3.6	0.14	82	22	98	202	110	90	0.5	124	295	166	129
17-13-34da	NE SE sec. 34 City of Reading, Ks.[b]	35	Alluvium	10-5-51	....	417	7.8	0.10	84	18	48	354	65	17	0.3	7.1	284	284	0
	T. 18 S., R. 10 E.																		
18-10-12cb	NW SW sec. 12	18.1	Terrace alluvium	9-12-51	58	1,180	2.6	0.12	200	39	115	324	111	142	0.1	407	660	266	394
	T. 18 S., R. 11 E.																		
18-11-1cc	SW SW sec. 1	31.1	Terrace alluvium	9-12-51	57	998	3.2	0.55	188	29	103	396	266	63	0.3	150	588	324	264
18-11-22ad	SE NE sec. 22	28.1	Terrace alluvium	9-12-51	57	1,430	2.6	0.19	292	56	92	427	519	99	0.3	159	958	350	608
	T. 18 S., R. 12 E.																		
18-12-6cc	SW SW sec. 6	10.9	French Creek shale	9-12-51	....	1,600	10	9.9	230	78	176	383	892	24	0.7	0.8	894	314	580
	T. 18 S., R. 13 E.																		
18-13-27bc$_1$	SW NW sec. 27	14.2	Cedar Vale shale	9-11-51	60	512	2.2	0.05	118	28	28	395	116	10	0.4	14	410	324	86
	T. 19 S., R. 10 E.																		
19-10-4ab$_2$	NW NE sec. 4	75	West Branch shale	10-30-50	60	323	14	3.2	77	19	8.7	218	64	27	0.1	6.2	270	179	91
	T. 19 S., R. 11 E.																		
19-11-8cb$_1$	NW SW sec. 8	62	Terrace alluvium	9-12-51	....	864	4.4	0.06	176	39	63	364	338	55	0.4	8.8	600	298	302
19-11-13da	NE SE sec. 13	24	Terrace alluvium	9-11-51	....	762	5.0	0.07	148	25	86	442	170	52	0.2	58	472	362	110

	T. 19 S., R. 12 E.																		
19-12-4ab	NE NW sec. 4	45.4	Pierson Point-Willard shale	9-12-51	57	1,018	12	0.25	179	58	68	316	419	60	0.5	66	685	259	426
19-12-32cc	SW SW sec. 32	27.5	Pierson Point-Willard shale	9-12-51	....	835	9.0	0.13	99	26	149	327	226	68	0.4	97	354	268	86
	T. 19 S., R. 13 E.																		
19-13-19dd	SE SE sec. 19	47.3	White Cloud shale	9-11-51	57	769	3.8	0.06	137	57	47	398	198	68	0.2	62	576	326	250
	T. 20 S., R. 10 E.																		
20-10-17dc	SW SE sec. 17	12.7	Howe limestone	9-11-51	61	625	7.4	0.23	131	37	30	366	173	17	0.6	49	479	300	179
	T. 20 S., R. 12 E.																		
20-12-24aa	NE NE sec. 24	16.5	Happy Hollow ls.	9-11-51	57	2,251	14	0.22	152	163	337	523	816	153	0.3	358	1,049	429	620
20-12-31bb	NW NW sec. 31	48.2	Langdon-Willard shale	9-11-51	57	1,246	7.2	0.26	158	54	224	710	151	200	0.3	102	616	582	34
	T. 20 S., R. 13 E.																		
20-13-7cb	NW SW sec. 7	34	Terrace alluvium	9-11-51	....	479	6.6	0.07	114	13	44	355	65	41	0.2	20	338	291	47
20-13-14bd	SE NW sec. 14 City of Hartford, Ks.	30-35	Alluvium	5-14-51	....	495	23	0.11	133	16	10	415	37	19	0.1	17	398	340	58
20-13-28dc	SW SE sec. 28	22.5	Terrace alluvium	9-11-51	57	1,037	14	0.21	182	38	148	278	24	464	0.2	30	610	228	382
	T. 21 S., R. 10 E.																		
21-10-26cd$_2$	SE SW sec. 26	30.8	Friedrich-Dry shale	9-11-51	53	1,074	4.6	0.11	284	22	23	329	180	119	0.2	279	799	270	529
	T. 21 S., R. 11 E.																		
21-11-2aa	NE NE sec. 2	26.5	Alluvium	9-11-51	57	337	10	0.11	74	20	25	337	28	6.0	0.1	8.0	266	266	0
21-11-28dd	SE SE sec. 28	38.1	Dry-Willard shale	9-11-51	....	822	11	0.21	95	43	109	344	120	36	0.2	239	414	282	132
	T. 21 S., R. 12 E.																		
21-12-29bc	SW NW sec. 29	51.2	Auburn shale and/or Wakarusa limestone	9-11-51	57	613	8.0	1.3	112	31	70	465	141	20	0.5	1.3	407	382	25
	T. 21 S., R. 13 E.																		
21-13-27aa	NE NE sec. 27	26.0	Severy shale	9-11-51	57	511	5.0	0.64	101	21	42	239	196	9.0	0.4	19	338	196	142

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*

Cation	Conversion factor	Anion	Conversion factor
Ca^{++}	0.0499	HCO_3^-	0.0164
Mg^{++}	0.0822	SO_4^{--}	0.0208
Na^+	0.0435	Cl^-	0.0282
		NO_3^-	0.0161
		F^-	0.0526

TABLE 6.—*Analyses of ground water taken from three principal water-producing zones at depths of 380, 600, and 865 feet at the Kansas Soya Products Company well*[a] (Dissolved constituents in parts per million. Analyzed by Russell T. Runnels. Fresh surface water cased off)

	Depth[b] and chief geologic source		
	380 feet, Calhoun shale	600 feet, Kanwaka shale	865 feet, Tonganoxie sandstone
Calcium (Ca^{++})	683	1,460	4,600
Magnesium (Mg^{++})	286	619	1,600
Sulfate (SO_4^{--})	728	521	53
Chloride (Cl^-)	23,000	45,700	108,000
Sum	24,800	48,000	115,000
Dissolved solids (140°C)	25,200	48,900	117,000
Undetermined difference, chiefly bicarbonates	448	605	2,200
pH at 21°C	7.38	7.03	6.37

(a) NE¼ SW¼ NW¼ NW¼ 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).

TABLE 7.—*Dissolved solids in water samples from wells in Lyon County*

Dissolved solids, parts per million	Number of samples
300 or less	0
301- 400	2
401- 500	3
501- 600	4
601- 700	5
701- 800	3
801- 900	5
901-1,000	1
1,001-1,500	7
1,501-2,000	2
2,001-2,500	1

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

TABLE 8.—*Hardness of water samples from wells in Lyon County*

Hardness, parts per million	Number of samples
200 or less	0
201- 300	4
301- 400	6
401- 500	8
501- 600	5
601- 700	5
701- 800	1
801- 900	1
901-1,000	1
1,001-1,500	2

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 NO_3 in drinking water is considered

TABLE 9.—*Iron content of water samples from wells in Lyon County*

Iron, parts per million	Number of samples
Less than 0.1	7
0.1-1.0	22
1.1-2.0	2
2.1-3.0	0
More than 3.0	2

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 (NO_3) 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 (SO_4) in ground water is derived chiefly from gypsum and the oxidation of marcasite and pyrite. Sulfate (SO_4) 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 NE¼ SE¼ 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*

Well No. (1)	Location	Owner or tenant	Type of well (2)	Depth of well, feet (3)	Diameter of well, in.	Type of casing (4)	Principal water-bearing bed: Character of material	Principal water-bearing bed: Geologic source	Method of lift (5)	Use of water (6)	Measuring point: Description	Measuring point: Feet above land surface	Depth to water level, feet (7)	Date of measurement	Remarks (Yield given in gallons a minute; drawdown in ft.)
	T. 15 S., R. 10 E.														
15-10-23 dc	SW SE sec. 23	C. M. Sobke	Du	19.4	96	R	Limestone	Threemile ls.	Cy, E	S	Top of board cover	1.2	13.96	10-25-49	Reported adequate
	T. 15 S., R. 12 E.														
15-12-21 cc	SW SW sec. 21	A. Pollock	Du	18.6	48(?)	R	Limestone or sandstone	Five Point ls. or West Branch sh.	Cy, H	P	Top of concrete cover	0.3	11.02	8-31-49	
15-12-33 cb	NW SW sec. 33	G. Coats	Du	23.6	48	R	Shale (?)	West Branch sh. (?)	Cy, H	S	Top of board cover	1.1	1.10	7-12-50	Partly an encased spring
15-12-34 cc	SW SW sec. 34	Elmer Stinson	Du	19.9	90	R	Sand and gravel	Alluvium	Cy, H, E	S	Top of 2x6 board curbing	1.0	11.48	7- 2-50	Reported adequate
15-12-35 cc	SW SW sec. 35	J. B. Hume	Du	22.4	30	R	Shale (?)	Caneyville ls. or French Creek sh.	Cy, H	D	Top of back porch floor	2.0	17.72	7- 2-50	Not used for drinking, has mineral taste
	T. 15 S., R. 13 E.														
15-13-19 ca	NE SW sec. 19	O. M. Clayton	Du	17.2	60	R	Limestone or shale	Falls City ls. and/or Hawxby sh.	Cy, H	D, S	Top of board cover	0.8	8.08	7- 2-50	Reported adequate
15-13-32 dc	SW SE sec. 32	Maude DeShazer	Du	10	96	R,C	Limestone or shale	Grandhaven ls. and/or Friedrich sh.	Cy, H	D, S	Top of concrete curbing	1.3	4.03	7- 2-50	Reported adequate, yield ± 10
	T. 16 S., R. 10 E.														
16-10-2 bb	NW NW sec. 2	Glen Shellenberger	Dr	67.5	7(?)	(?)	Limestone and shale	Crouse ls.	Cy, H	S	Top of concrete curbing under pump	0.6	26.07	10-25-49	Use cistern for dom.
16-10-9 cc	SW SW sec. 9	L. C. Case	Dr	56.9	6	GI	Limestone and shale	Beattie ls. (?)	Cy, H	N	Top of concrete curbing	0	41.85	10-25-49	
16-10-11 da	NE SE sec. 11	E. J. Eckel	Dr	64	6	GI	Limestone	Crouse ls.	Cy, W	S	Land surface	0	12-15	10-25-49	Struck water at 33 ft., reported yield 3, adequate
16-10-34 dd	SE SE sec. 34	Fred Buchman	Du	27.4	36	R	Limestone and shale	Crouse ls.	Cy, H	D, S	Top of board cover	0.8	17.96	7-26-50	Reported adequate
16-10-36 cc	SW SW sec. 36	Leo Fitch	Dr	84	6(?)	(?)	Limestone or shale	Grenola ls.	Cy, E	S	Land surface	0	50-55	10-25-49	Reported yield + 5 Reported adequate
	T. 16 S., R. 11 E.														
16-11-2 bc	SW NW sec. 2	Mason Rust	Du	24.6	36	R	Limestone or shale	Grenola ls. and/or Roca sh.	Cy, H	S	Top of 2x6 board cover	3.0	8.43	9-13-49	Reported inadequate in dry times
16-11-8 dc	SW SE sec. 8	B. Johnson	Du	32.9	36(?)	R	Limestone	Beattie ls.	Cy, W	S	Top of stone slab cover	0.6	27.41	7-26-50	
16-11-10 cc	SW SW sec. 10	A. L. Riegel	Du	22.3	36	R	Limestone	Grenola ls.	J, E	D, S	Top of concrete cover	1.0	16.80	9-15-49	Reported adequate
16-11-16 ab	NW NE sec. 16	Robert Rees	Du	60	36(?)	R	Limestone or shale	Neva ls. or Eskridge sh.	Cy, E	D, S	Top of concrete curbing	1.0	51.31	7-26-50	Reported adequate. Pumped prior to measuring
16-11-19 aa	NE NE sec. 19	Lee Rowley	Du	27.2	36	R	Limestone	Neva ls.	Cy, H	D	Top of concrete curbing	1.9	23.70	7-26-50	Not in use
16-11-21 da	NE SE sec. 21	Porter Estes	Du	41.2	48(?)	R	Limestone	Long Creek ls.	Cy, W	D, S	Top of concrete curbing	1.7	30.45	9-15-49	Reported adequate. Used by Allen City residents in 1934-36
16-11-22 ad_1	SE NE sec. 22	City of Allen, Kans.	Dr	32	6	I	Limestone	Long Creek ls.	T, E	P	Land surface	0	(?)	9-13-49	Reported yield 20
16-11-22 ad_2	SE NE sec. 22	City of Allen, Kans.	Dr	28	6	I	Limestone	Long Creek ls.	N	N	Land surface	0	(?)	9-13-49	

16-11-27 da	NE SE sec. 27	C. J. Frederiksen	Du	20.9	106	R	Limestone and shale	Americus ls.	Cy, H	D	Top of 3/4 in. bd. over stone slab	0.1	10.22	9-13-49	Inadequate in dry yrs. Reported less than 1
	T. 16 S., R. 12 E.														
16-12-24 cc	SW SW sec. 24	Paul J. Swanson	Du	13.2	42	R	Sandstone and shale	French Creek sh.	Cy, H	D	Top of concrete curbing	0.2	10.85	11- 4-49	Tree roots in well
	T. 16 S., R. 13 E.														
16-13-6 cc	SW SW sec. 6	Otto Wolf	Du	16.8	36(?)	R(?)	Sand and gravel	Alluvium	Cy, H	P	Top of steel cover	0.4	2.53	8- 2-50	Well at school house
16-13-15 bc	SW NW sec. 15	R. R. Sanders	Sp	......	....	....	Limestone and shale	Maple Hill ls., and Langdon sh.	Cy, H	D, S	....	....	....	11- 4-49	Flow ±3/4, encased with rock and concrete
16-13-20 da	NE SE sec. 20	Norton Sanders	Du	25.6	72	R	Sand and gravel	Terrace alluvium	J, E	D, S	Top of concrete curbing	0.3	10.39	9-13-51	Reported adequate except once in 1934
	T. 17 S., R. 10 E.														
17-10-4da	NE SE sec. 4	L. Wildhack	Dr	25.0	6	GI	Limestone and shale	Lower Grenola ls.	N	N	Top of casing	0.6	14.14	7-26-50	Former school well
17-10-7 aa	NE NE sec. 7	Sch. Dist. 64	Du	37.8	42	R	Limestone and shale	Lower Grenola ls.	Cy, H	P	Top of 2x12 board cover	0.5	26.14	7-26-50	
17-10-14 da	NE SE sec. 14	Henry Proehl	Dr	89.1	6	I	Limestone	Long Creek ls.	Cy, W	D, S	Base of concrete curbing at manhole	2.0	66.76	10-25-49	Pumped for 1 hr. preceding measurement. Reported adequate
17-10-16 ad	SE NE sec. 16	Ferd Blanken	Dr	54.0	6	GI (?)	Limestone and shale	Grenola ls.	Cy, W	D, S	Top of concrete curbing	0.8	43.19	10-25-49	Reported adequate, neighbors haul from well in dry years
17-10-16 cb	NW SW sec. 16	H. Proehl	Du	34.9	60	R	Limestone	Neva ls.	N	N	Top of 2x4 board, w. side of well	3.3	22.16	7-26-50	Yield+5
17-10-21 cc	SW SW sec. 21	School District	Du	17.0	36	R	Limestone or shale	Long Creek ls. or Johnson sh.	Cy, H	P	Top of concrete curbing	2.5	12.57	7-26-50	
17-10-23 da	NE SE sec. 23	Fred Johnson	Dr	50	6	I	Limestone	Long Creek ls.	Cy, E	S	Land surface	0	25	10-25-49	Reported yield+15
	T. 17 S., R. 11 E.														
17-11-4 cb	NW SW sec. 4	Ivan Harder	Du	21.0	48(?)	R	Limestone and shale	Americus ls. or upper Hamlin sh.	Cy, H	S	Top of stone cover	2.0	18.53	9-15-49	Reported yield -1/4, not adequate
17-11-14 cc	SW SW sec. 14	J. B. Mounkes	DD	+100	48 & 6(?)	R-(?)	(?)	Admire group, lower part	Cy, W	D, S	Top of rock cover	1.0	14.71	9-13-49	Reported adequate, salty if pumped hard
17-11-21 da	NE SE sec. 21	C. E. Douglas	Du	24.1	48(?)	R	Limestone or shale	Falls City ls. or West Branch sh.	Cy, H	D	Top of pump base	1.4	10.68	9-15-49	Inadequate, reported yield -1/2, high sulfate
17-11-26 ab	NW NE sec. 26	Frank Safford	Du	30	36(?)	R	Limestone or sand and gravel	Caneyville ls. and/or alluvium	Cy, W	S	Land surface	0	20	9-15-49	Reported adequate
17-11-27 bc	SW NW sec. 27	N. W. Jones	Du	14.6	48(?)	R	Limestone and shale	Aspinwall ls., and Hawxby sh.	Cy, W	S	Top of board cover	0.3	9.04	9-15-49	Reported yield 1/2, water has bitter taste, very corrosive
17-11-28 cc	SW SW sec. 28	O. J. Hale	Dr	72.6	6(?)	GI(?)	Sandstone or shale	Pony Creek-French Creek sh.	Cy, W	S	Top of concrete curbing of pit	1.0	43.49	6-29-50	Reported yield -1/4, has salty taste, corrosive
17-11-33 cc	SW SW sec. 33	Ed. Daharsh	Du	55.6	42	R	Sandstone or shale	Caneyville ls. and/or French Creek sh.	Cy, W	D, S	Top edge of concrete curbing	0.5	28.36	6-29-50	Too salty and hard for dom. drinking, blackens pipe
17-11-34 dd	SE SE sec. 34	J. H. Shields	Du	40	48	R	Limestone or sandstone	Brownville ls. or Pony Creek sh.	Cy, H	D	Top of stone cover	1.0	12.40	9-13-49	Reported yield +1/4, not adequate in dry years
	T. 17 S., R. 12 E.														
17-12-13 dd	SE SE sec. 13	V. J. Volz	Du	22	36 to 96	R	Sandstone and shale	Pierson Point-Willard sh.	Cy, H	D, S	Top of board cover	0	9-10	11- 3-49	Not used for dom. drinking, very hard water
17-12-25 ad	SE NE sec. 25	C. & W. Duggan	Du	22	42	R	Sand and gravel	Alluvium	Cy, W	D, S	Land surface	0	16	11- 3-49	Reported adequate

TABLE 10.—*Record of wells and springs in Lyon County, continued*

Well No. (1)	Location	Owner or tenant	Type of well (2)	Depth of well, feet (3)	Diameter of well, in.	Type of casing (4)	Principal water-bearing bed: Character of material	Principal water-bearing bed: Geologic source	Method of lift (5)	Use of water (6)	Measuring point: Description	Measuring point: Feet above land surface	Depth to water level, feet (7)	Date of measurement	Remarks (Yield given in gallons a minute; drawdown in ft.)
	T. 17 S., R. 13 E.														
17-13-5 cd	SE SW sec. 5	Helen Cline	Du	31.4	36	R	Shale and sandstone	Pierson Point-Willard sh.	Cy, H	D	Top of concrete curbing	0.8	11.89	7-13-50	Not adequate in dry years, very hard water
17-13-28 bc	SW NW sec. 28	Geo. Hopkins	Du	30.5	72	R	Shale and sandstone	Cedar Vale sh.	Cy, E	D, S	Top of 2x12 board cover	1.0	10.04	7-13-50	Goes dry occasionally
17-13-34 da	NE SE sec. 34	City of Reading, Kans.	Du	35	36	C & GI	Sand and gravel	Alluvium	C	P	Land surface	0	(?)	12- 4-51	Gravel-packed well
	T. 18 S., R. 10 E.														
18-10-4 aa	NE NE sec. 4	A. C. Aimes	Du	25.3	42	R	Sand and gravel	Alluvium	Cy, E	S	Top of 2x8 board cover	1.3	11.15	7-26-50	Reported adequate, yield+10
18-10-5 cc	SW SW sec. 5	School District	Du	38.1	36(?)	R	Limestone	Long Creek ls.	Cy, H	P	Top of concrete curbing	0.3	34.04	6-27-50	
18-10-12 cb	NW SW sec. 12	W. B. Bamesberger	Du	19.6	42	R	Sand and gravel	Terrace alluvium	Cy, W	D, S	Top of 2x10 board cover	1.5	11.33	7-24-50	Reported adequate
18-10-13 db	NW SE sec. 13	D. Z. Foster	Du	24.8	30	R	Sand and gravel	Alluvium	N	N	Top of concrete curb of enclosure	3.6	7.18	7-24-50	
18-10-17 bb	NW NW sec. 17	J. B. Moore	Du	48.0	54	R	Limestone and shale	Sallyards ls. and Legion sh.	Cy, W	D, S	Top of stone curbing	1.0	36.40	6-27-50	Reported yield ±1. Reported adequate
18-10-20 ad	SE NE sec. 20	Albert Collins	Du	28.5	60	R	Limestone and shale	Lower Grenola ls.	Cy, W	D, S	Top of 2x10 board cover	0.8	8.69	6-27-50	
18-10-22 cc	SW SW sec. 22	Clarence Marcotte	Du	32.7	60	R	Limestone and shale	Foraker ls.	Cy, H	D	Top of board curbing flush with concrete cover	0.4	8.97	6-27-50	Reported yield-½. Has mineral taste
18-10-29 cd	SE SW sec. 29	O. A. Wiley	Du	30	48	R	Limestone and shale	Hughes Creek sh. and Americus ls.	Cy, H	D	Land surface	0	6-8	11- 3-49	Reported adequate, yield -½
18-10-35 cb	NW SW sec. 35	F. T. Bourland	Du	21.1	48	R	Shale and sandstone	Stine sh. or West Branch sh.	Cy, H	S	Top of board cover	2.0	9.57	6-27-50	Water has mineral taste
18-10-36 cc	SW SW sec. 36	Clarence Stanton	DD	+113 (?)	66 & 6	R-(?)	Sandstone and limestone	Falls City-Aspinwall ls. (?) and/or French Creek sh. (?)	Cy, H	S	Land surface	0	22.5	6-27-50	Water has bitter taste
	T. 18 S., R. 11 E.														
18-11-1 cc	SW SW sec. 1	Clarence O. Pine	Du	31.1	48-96	R	Sand and gravel	Terrace alluvium	Cy, W	S	Top of concrete curbing	0	16.23	8- 2-49	Measured yield 20, drawdown 8.5, reported adequate
18-11-2 dc	SW SE sec. 2	Ferd Thompson	Du	37.1	36(?)	R	Sand and gravel (?)	Terrace alluvium	J, E	D. S	Top of concrete curbing	0.8	17.64	1-17-51	Reported adequate
18-11-4 bc	SW NW sec. 4	Floyd Louder	Du	16.8	48	R	Sand and gravel	Alluvium	Cy, W	S	Top W. edge of concrete curbing	1.3	10.12	6-29-50	Reported adequate Reported yield +5
18-11-4 cd	SE SW sec. 4	Frank H. Ketcha	Du	22.2	36	R,B	Sandstone and shale	French Creek sh.	J (?), E	D	Top of brick casing, east edge	2.9	15.16	6-29-50	Reported adequate, use cistern also
18-11-7 cc	SW SW sec. 7	Geo. Luinsland	Du	28.6	54	R	Sand and gravel	Terrace alluvium	C, E	D	Top of concrete curbing, W. side	1.7	10.96	7-24-50	Reported adequate
18-11-10 ad	SE NE sec. 10	Chi Stevenson	Du	40	36(?)	R	Sandstone (?) or limestone	French Creek sh. and/or Caneyville ls.	Cy, E	S	Top of well covering	1.5	28	9-13-49	Reported adequate
18-11-15 cb	NW SW sec. 15	Roy Cratewell	Dr	132	6	I	Sandstone or shale	Pierson Point-Willard sh.	Cy, E	D	Land surface	....	80	9-15-49	Reported inadequate and salty. Not used for drinking
18-11-22 ad	SE NE sec. 22	J. W. Priefert	Du	28.1	30	R	Sand and gravel	Terrace alluvium	Cy, W	D, S	Top of stone cover over well	0	18.88	9-13-49	Reported adequate except in drouth years

18-11-26 cc	SW SW sec. 26	Catherine Johnson	Du	35.1	36	R	Sand and gravel	Terrace alluvium	Cy, W	D, S	Top of concrete cover	0	22.45	9-13-49	Reported adequate
18-11-26 cd	SE SW sec. 26	Max Smith	Du	30.3	36	B & C	Sand and gravel	Terrace alluvium	Cy, W	D	Top of concrete cover	1.2	24.67	1-17-51	Reported adequate
18-11-28 aa	NE NE sec. 28	Glenn Felten	Du	40.5	48	R	Sand and gravel	Terrace alluvium	J, E	D, S	Top of concrete curbing	0.5	20.43	9-15-49	Reported adequate
18-11-29 ba	NE NW sec. 29	Chas. R. Hurst	D-B	28	36-8	R-I	Sand and gravel	Alluvium	Cy, H	D, S	Top of concrete and rock curbing	0.8	6.06	7-24-50	Reported adequate Dug 21, bored 7
	T. 18 S., R. 12 E.														
18-12-3 ba	NE NW sec. 3	W. G. Collins	Du	23.0	48	R	Sandstone or shale	French Creek sh. Friedrich sh.	Cy, H	S	Top of concrete curbing	1.4	7.82	7-13-50	Reported not adequate
18-12-6 cc	SW SW sec. 6	Earl Keller	Du	12.5	60	R & C	Sandstone and shale	French Creek sh.	Cy, H	D, S	Top of concrete curbing	1.6	6.45	11- 4-49	Reported adequate. use cistern for drinking
18-12-13 da	NE SE sec. 13	Frank Schlageter	Du	9.1	54	R	Sandstone or limestone	Willard sh. or Elmont ls.	C, E	D, S	Top of R.R. ties over well	2.5	2.50	6-30-50	An encased spring flows at surface
18-12-16 dc	SW SE sec. 16	Iracc Ridenour	Du	21.3	48	R	Limestone	Grandhaven ls.	B, H	D, S	Top of concrete curbing	0.4	12.69	6-30-50	Reported adequate, Reported yield +25
18-12-17 cc	SW SW sec. 17	W. H. Wanser	Du	30.7	36-60	R	Shale and sandstone	Langdon-Willard sh.	Cy, W	S	Top of concrete curbing	2.1	15.50	6-29-50	Reported not adequate
18-12-18 cc	SW SW sec. 18	Earl Hollingsworth	Du	25.1	30(?)	R	Shale and sandstone	Dry-Langdon sh.	Cy, H	S	Top of concrete curbing	0.3	8.86	6-29-50	Reported not adequate
18-12-20 ba	NE NW sec. 20	James Lyons	Du	33.7	30(?)	R	Limestone or shale	Dover ls. or Langdon sh.	Cy, H	S	Top of 2x12 board cover	0.4	15.09	6-29-50	Reported not adequate, yield-½
18-12-31 cd	SE SW sec. 31	Otis Weeks	Du	29.4	36	R	Sandstone	Pierson Point-Willard sh.	Cy, E	D, S	Top of concrete curbing	0.3	18.74	9-16-49	Reported low specific yield
	T. 18 S., R. 13 E.														
18-13-3 bd	SE NW sec. 3	City of Reading, Kans.	Du	16	24	GI	Sand and gravel	Alluvium	C, E	P	Top of GI casing	(?)	....	12- 4-51	
18-13-16 cb	NW SW sec. 16	L. R. Cowden	Du	17.1	84	R	Shale	Harveyville sh.	Cy, H	D	Top of concrete curbing	0.7	7.86	6-30-50	
18-13-18 cc	SW SW sec. 18	Hugh Jones	Du	31.9	72-96	R	Shale and sandstone	Pierson Point-Willard sh.	Cy, H	D	Top of 2x8 board cover	1.0	15.69	6-30-50	Reported not adequate
18-13-27 bc_1	SW NW sec. 27	F. H. Jennings	Du	15.0	48(?)	R	Shale and sandstone	Cedar Vale sh.	Cy, E	D	Top edge of angle iron	0.8	4.96	6-30-50	Reported adequate Well adjacent to house
18-13-27 bc_2	SW NW sec. 27	F. H. Jennings	Du	30.7	48	R	Sandstone and shale	Cedar Vale sh.	Cy, E	S	Top of 2x6 board cover	1.0	4.19	6-30-50	Reported adequate. Well near barn
18-13-31 dd	SE SE sec. 31	H. C. Omara	Du	19.9	36(?)	R	Shale or sandstone	Silver Lake sh.	Cy, H	D	Top edge of pump base	0.3	10.12	9-16-49	Reported not adequate
18-13-33 cc	SW SW sec. 33	A. E. Mounkes	Du	49.5	24-30	R	Sandstone	White Cloud sh.	B, H	D	Top of concrete curbing	0.3	32.28	9-16-49	Reported adequate except in seven drouth-years
	T. 19 S., R. 10 E.														
19-10-1 dc	SW SE sec. 1	E. H. Rees	Du	48.6	60(?)	B & C	Sand and gravel	Terrace alluvium	Cy, W	D, S	Top of brick casing	1.0	40.15	11-18-49	
19-10-4 ab_1	NW NE sec. 4	Wade Myers	Dr	82(?)	8	I	Sandstone	West Branch sh.	Cy, E	S	Top of center wooden 4x4 under cover	0.8	53.39	11- 3-49	Reported adequate
19-10-4 ab_2	NW NE sec. 4	Wade Myers	Dr	75	7	GI	Sandstone	West Branch sh.	Cy, (?)	D, S	Land surface	....	53	11- 3-49	Reported adequate
19-10-7 bb	NW NW sec. 7	Henry Wittker	Dr	50	6	GI	Sand and gravel	Terrace alluvium	Cy, H	S	Top of 2x12 board cover	0.8	12.82	11-18-49	Reported adequate
19-10-21 dc	SW SE sec. 21	Fay Miles	Du	31.8	36	R	Limestone (?)	Brownsville ls. (?)	Cy, H	D, S	Top of 2x12 board cover	1.0	15.72	1-17-51	Reported adequate
19-10-27 ad	SE NE sec. 27	Albert Nelson	Du	25.4	30	R	Sand and gravel	Alluvium	Cy, W	D, S	Top of concrete platform over well pit	0.5	20.76	1-17-51	Reported adequate
19-10-27 cb	NW SW sec. 27	F. E. Whipple	Du	16.5	30	R	Limestone	Aspinwall or Brownville ls.	Cy, W	D, S	Top of concrete curbing	0.7	7.78	1-17-51	Reported adequate

TABLE 10.—*Record of wells and springs in Lyon County, continued*

Well No. (1)	Location	Owner or tenant	Type of well (2)	Depth of well, feet (3)	Diameter of well, in. (4)	Type of casing (4)	Principal water-bearing bed: Character of material	Principal water-bearing bed: Geologic source	Method of lift (5)	Use of water (6)	Measuring point: Description	Measuring point: Feet above land surface	Depth to water level, feet (7)	Date of measurement	Remarks (Yield given in gallons a minute; drawdown in ft.)
19-10-29 dd	SE SE sec. 29	J. D. Vorse	Du	20.6	(?)	R	Limestone or shale	Falls City ls. and/or West Branch sh.	Cy, H	D	Top of board cover over well	0.8	14.75	9-22-49	Reported adequate for dom. uses
19-10-34 dd	SE SE sec. 34	James Henderson	Du	22	60(?)	R	Shale	Towle sh.	Cy, W	D, S	Top of concrete cover	1.0	5	9-22-49	Reported not adequate in dry years
	T. 19 S., R. 11 E.														
19-11-7 bc	SW NW sec. 7	F. L. Clausen	B	34	6	T	Sand and gravel	Terrace alluvium	Cy, W	D, S	Land surface	....	30	9- 3-49	Reported yield+10, adequate
19-11-8 bd	SE NW sec. 8	W. Hatcher	Du	52.9	48	R	Sand and gravel	Terrace alluvium	Cy, W	S	Top of concrete curbing	1.0	37.47	9- 3-49	Reported yield+10, adequate
19-11-8 cb_1	NW SW sec. 8	Wayne Boling	Dr	62	6(?)	(?)	Sand and gravel	Terrace alluvium	J (?), E	P	Land surface	....	39	6-27-50	Reported adequate Fred's Derby Ser. Restaurant Sup.
19-11-8 cb_2	NW SW sec. 8	Mr. Hart	Dr	56.4	6½	I	Sand and gravel	Terrace alluvium	N	N	Top edge of casing	1.1	38.21	6-27-50	50-S Motel, w. well reported adequate
19-11-13 aa	NE NE sec. 13	C. W. Eaton	Dr	22	8	GI	Sand and gravel	Terrace alluvium	C (?), E	D, S	Top of casing	-3.2	9.06	11-16-49	Reported yield+6, adequate
19-11-13 da	NE SE sec. 13	D. C. Anderson	Du	24.2	22	R	Sand and gravel	Terrace alluvium	Cy, E	D	Top of concrete curbing	0.2	14.54	9-23-49	Measured yield 40
	T. 19 S., R. 12 E.														
19-12-4 ab	NW NE sec. 4	F. H. Sickler	Du	46.5	60	R & N	Sandstone	Pierson Point-Willard sh.	Cy, E	D, S	Top edge of concrete curb	1.1	27.38	9-16-49	
19-12-6 bb	NW NW sec. 6	V. M. Jacob	Du	20.8	48	R	Sand and gravel	Terrace alluvium	Cy, W	D, S	Top edge of steel rim curbing	1.5	7.65	9-16-49	Reported adequate
19-12-7 cc	SW SW sec. 7	E. D. Hodges	Du	26	42	R	Sand and gravel	Alluvium	Cy, E	D, S	Land surface	....	4	6-29-50	Reported adequate
19-12-7 dc	SW SE sec. 7	School District	Dr(?)	18.3	(?)	(?)	Sand and gravel	Alluvium	Cy, H	P	Top of 2x8 board water pump base	2.5	6.50	6-29-50	
19-12-12 ad	SE NE sec. 12	G. W. Jones	Du	38.9	36(?)	R	Shale and sandstone	Silver Lake sh.	Cy, H	S	Top edge of pump base	0.5	17.63	9-16-49	
19-12-32 cc	SW SW sec. 32	C. L. Jones	Du	27.8	120	R	Shale and sandstone	Pierson Point-Willard sh.	Cy, E	D, S	Top of 2x12 board cover	0.3	12.03	9-23-49	Reported adequate
	T. 19 S., R. 13 E.														
19-13-16 dd	SE SE sec. 16	E. C. Mounkes	Du	34.6	48	R	Sandstone or limestone	Happy Hollow ls. (?) or White Cloud sh.	Cy, H	D, S	Top of metal pump base	1.0	17.76	9-16-49	Reported adequate. Measured yield less than 1. Reported 170 ppm. NO_3
19-13-17 aa	NE NE sec. 17	Earnest Genter	Du	25.8	38	R	Sandstone or shale	White Cloud sh.	B, H	D	Top edge of concrete curbing	0.6	16.00	11-15-49	Reported adequate
19-13-18 ab	NW NE sec. 18	C. McAuly	Du	16.5	48	R	Shale or limestone	White Cloud sh. or Happy Hollow ls.	N	N	Top of concrete curbing	0.4	15.30	11-15-49	Reported not adequate. Not in use
19-13-19 bd	SE NW sec. 19	A. G. Sattler	Du	38.2	48	R & N	Sandstone and shale	White Cloud sh.	N	D, S	Top of concrete curbing	1.2	31.44	8- 9-49	Not in use
19-13-19 dd	SE SE sec. 19	Max Andrews	Du	50.8	39	R & N	Sandstone and shale	White Cloud sh.	B, H	D	Top of 2x4 board where lid hinged to well cover	3.5	35.15	11-29-49	Reported adequate
19-13-20 bc	SW NW sec. 20	William Kern	Du	32.6	36	R(?)	Sandstone and shale	White Cloud sh.	Cy, H	D, S	Top of board cover	0.5	24.89	8- 9-49	
19-13-28 bb	NW NW sec. 28	....	Du	44.7	36	R	Sand and gravel	White Cloud sh.	N	N	Top edge, E. side, concrete curbing	0.3	33.32	11-15-49	Abandoned well, measured yield -1
	T. 20 S., R. 10 E.														
20-10-6 ab	NW NE sec. 6	Ralph Williams	Du	19.8	48(?)	R	Shale or sandstone	Stine sh.	Cy, W	S	Top of concrete curbing	1.0	8.50	9-22-49	Reported not adequate in dry years

20-10-16 cc	SW SW sec. 16	J. J. Rees	Dr	64.3	7	I	Limestone	Red Eagle ls.	Cy, W	S	Top of casing	1.5	59.28	9-22-49	Reported adequate
20-10-17 dc	SW SE sec. 17	Alonzo Haworth	Du	14.2	36	R	Limestone	Howe ls.	Cy, H	D	Top of concrete curbing	1.5	4.82	9-22-49	Reported adequate
20-10-33 aa	NE NE sec. 33	C. L. Patton	Du	17.8	36	R	Limestone and shale	Foraker ls.	Cy, H	N	Top of concrete curbing	0	11.60	11-17-49	Measured yield, less than 1
20-10-34 ab	NW NE sec. 34	W. A. Patch	Du	23.2	84	R	Shale or sandstone	Stine sh.	Cy, H	D, S	Base of board cover	1.5	10.01	9-21-49	Reported adequate
	T. 20 S., R. 11 E.														
20-11-1 ab	NW NE sec. 1	James Kittle	Du	33	36	R & N	Sandstone and shale	Landgon-Willard sh.	Cy, W	S	Top of 2x8 board cover	0.3	19.45	9-23-49	Reported not adequate in drouth yrs.
20-11-5 ac	SW NE sec. 5	Tony Burenheide	Du	33.2	48	R	Sandstone and shale	Landgon-Willard sh.	Cy, E	D, S	Top of 2x10 bd. under pump	0.5	17.39	9-22-49	Reported adequate
20-11-22 cd	SE SW sec. 22	Lou Brown	Du	19.9	96	R	Shale	Friedrich-Dry sh. (?)	Cy, H	S	Top of concrete curbing	0.8	8.66	9-21-49	Not in use. stock do not like water
20-11-26 ab	NW NE sec. 26	Leo Redeker	Du	40.6	36-48	R & N	Limestone or shale	Grandhaven ls. and/or Dry-Langdon	Cy, H	S	Top of pump base	1.2	7.80	9-20-49	Reported not adequate
20-11-33 ca	NE SW sec. 33	Conrad Schade	Du	34.4	36-48	R & N	Shale or sandstone	Friedrich-Dry sh.	Cy, W	S	Top of limestone slab cover	1.3	23.27	9-19-49	Reported not adequate in dry yrs.
20-11-34 ca_1	NE SW sec. 34	Matt Krenzer	Du	19.3	36	R	Sand and gravel	Alluvium	Cy, H	S	Top of limestone slab cover	0.6	13.27	9-19-49	Reported adequate. Well at house
20-11-34 ca_2	NE SW sec. 34	Matt Krenzer	Du	21.4	36(?)	R	Sand and gravel	Alluvium	J, E	S	Top of 2x8 board cover over well	2.0	13.63	9-19-49	Reported adequate, well in corral
20-11-34 dd	SE SE sec. 34	S. F. Wendling	Du	24.1	36	R & N	Shale or limestone	Langdon sh. or Dover ls.	Cy, H	S	Top of stone cover over well	0.8	10.89	9-20-49	Reported not adequate in dry years
	T. 20 S., R. 12 E.														
20-12-12 bc	SW NW sec. 12	G. E. Poycer	Du	20	36	R	Sandstone	White Cloud sh.	Cy, G	S	Top of 2x6 board cover	0	11.85	9-23-49	Reported adequate
20-12-19 cc	SW SW sec. 19	Leo Miller	Du	30	48	R	Sandstone and shale	Landgon-Willard sh.	Cy, E	D, S	Land surface	0	14	9-20-49	
20-12-24 aa	NE NE sec. 24	Ray Summa	Du	17.5	48	R	Limestone	Happy Hollow ls.	Cy, W	D, S	Top of board cover	1.0	7.39	8- 3-50	Reported not adequate in dry years
20-12-25 aa	NE NE sec. 25	John Bigler	Du	32.4	48	R	Sandstone and shale	White Cloud sh.	Cy, E	D, S	Top of porch flooring	1.8	23.26	9-20-49	
20-12-25 da	NE SE sec. 25	H. E. Scoggin	Du	25	60	R	Sand and gravel	Terrace alluvium	J, E	D, S	Land surface	0	19	5-25-51	Reported adequate
20-12-27 ba	NE NW sec. 27	R. W. Emeley	Du	24.6	72	R	Shale and limestone	Rulo ls. and Silver Lake sh.	Cy, H	D, S	Top of 2x12 board cover	0.8	19.86	9-20-49	
20-12-31 bb	NW NW sec. 31	Lema Waechter	Du	49.1	48	R	Sandstone	Landgon-Willard sh.	Cy, W	D, S	Top of 3x12 board cover	0.9	21.68	9-20-49	Reported adequate
20-12-33 cb	NW SW sec. 33	School District	Du	15.6	48	R	Limestone or shale	Wakarusa ls. or Auburn sh.	Cy, H	P	Top of concrete curbing	0.4	5.48	8- 3-50	
20-12-34 db	NW SE sec. 34	W. A. Immache	Du	17.3	42(?)	R	Shale	Silver Lake sh. and/or Cedar Vale sh.	Cy, H	S	Top of rods and concrete curbing	2.0	12.73	8- 3-50	Yield, less than 1 bbl/day
20-12-34 dc	SW SE sec. 34	W. A. Immache	Du	27.9	54	R	Sand and gravel	Alluvium	Cy, H	D, S	Top of 3x12 board cover over well	4.9	9.15	8- 3-50	Reported adequate
20-12-35 cb	NW SW sec. 35	School District	Du	27.9	48(?)	R	Shale or sandstone	Cedar Vale sh. (?)	Cy, H	N	Top of concrete curbing	0.4	9.79	8- 3-50	
20-12-36 bc	SW NW sec. 36	Rex Mcilain	B	26	8	T	Sand and gravel	Terrace alluvium	Cy, H	D, S	Land surface	0	22	5-25-51	Reported adequate
	T. 20 S., R. 13 E.														
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 SW 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	Used regularly
20-13-15 dd	SE 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

TABLE 10.—*Record of wells and springs in Lyon County, concluded*

Well No. (1)	Location	Owner or tenant	Type of well (2)	Depth of well, feet (3)	Diameter of well, in.	Type of casing (4)	Principal water-bearing bed: Character of material	Principal water-bearing bed: Geologic source	Method of lift (5)	Use of water (6)	Measuring point: Description	Measuring point: Feet above land surface	Depth to water level, feet (7)	Date of measurement	Remarks (Yield given in gallons a minute; drawdown in ft.)
20-13-16 ad	SE NE sec. 16	L. L. Shelem	D	32.5	36(?)	R	Sand and gravel	Terrace alluvium	Cy, E	D, S	Top of 3x12 board cover	0.9	27.58	11-15-49	Reported adequate
20-13-16 dd	SE SE sec. 16	J. L. Ambrose	D	48	36	R	Sand and gravel	Terrace alluvium	Cy, W	D, S	Land surface	0	38	5-25-51	Reported adequate, yield + 10
20-13-17 da	NE SE sec. 17	A. W. Becker	D	36	36-48	R	Sand and gravel	Terrace alluvium	C, E	D, S	Top of concrete curbing	0.7	32	11-15-49	Reported adequate
20-13-18 ad	SE NE sec. 18	Lula Holforty	D	31.4	48	R	Sand and gravel	Terrace alluvium	J. E	D, S	Top of concrete curbing	0.8	25.46	7-27-50	Reported adequate
20-13-28 dc	SW SE sec. 28	Lee Webster	D	23.0	42	R	Sand and gravel	Terrace alluvium	Cy, H	D, S	Top of concrete curbing	0.5	13.63	5-25-51	Reported adequate
20-13-29 da	NE SE sec. 29	Ralph M. Hoch	D	25.2	60	R	Sand and gravel	Terrace alluvium	J-E	D, S	Top edge of angle iron under concrete cover	0	9.19	7-27-50	Reported adequate
	T. 21 S., R. 10 E.														
21-10-17 ab	NW NE sec. 17	Fred Mockry	D	14.6	36	R	Limestone and shale	Foraker ls.	B, H	D, S	Top of 2x4 bd, inside of enclosure	1.3	6.28	8- 4-50	Reported adequate
21-10-26 cd_1	SE SW sec. 26	Cecil Farthing	DD	50	36-8	R & T	Sandstone	Friedrich-Dry sh.	J-E	D	Top of steel rim in concrete cover	0.5	22.90	8- 4-50	Adequate except in severe drouths
21-10-26 cd_2	SE SW sec. 26	Cecil Farthing	D	33.3	48-96	R & N	Sandstone	Friedrich-Dry sh.	Cy, W	S	Top of 2x12 board cover	2.5	24.44	8- 4-50	Will yield 40 bbl. water/day
21-10-27 dd	SE SE sec. 27	School District	Dr	80	10	GI	Sandstone (?)	Friedrich-Dry sh.	N	P	Top of casing	4.7	9.35	8- 4-50	Water at 14 ft. and one other deeper zone
21-10-35 da	NE SE sec. 35	Citizens Bldg. & Loan Assoc.	Du	20.0	36	R	Sandstone and shale	French Creek and/or Friedrich sh.	Cy, H	D	Top edge 2x4 flush with concrete cover	0.5	12.39	8-10-49	Not in use
	T. 21 S., R. 11 E.														
21-11-2 aa	NE NE sec. 2	Marie Rossillion	Du	27.6	72	R	Sand and gravel	Alluvium	Cy, H	N	Top of concrete curbing	1.1	10.88	11- 1-49	Measured yield+30
21-11-3 ba	NE NW sec. 3	S. J. Brown	Du	32.0	60	R & N	Shale and limestone	Friedrich sh. and Grandhaven ls.	Cy, H	S	Top of stone slab over well	0.5	13.28	9-19-49	Measured yield less than 6 gal. per hr.
21-11-16 aa	NE NE sec. 16	A. H. Lewry	Dr	60	6	GI	Sandstone and shale	Friedrich sh. and/or Langdon-Willard sh.	Cy, H	D, S	Land surface	0	15	11- 2-49	Reported not adequate
21-11-21 ad	SE NE sec. 21	Ed. Whitehurst	Du	26.7	48	R	Sandstone and shale	Friedrich-Dry sh.	Cy, H	S	Top of concrete curbing	0.5	12.20	11- 2-49	Reported not adequate
21-11-28 dd	SE SE sec. 28	Will Schroder	Du	39.4	48	R	Sandstone	Dry-Willard sh.	Cy, W	D, S	Top of 2x12 board cover	1.3	8.19	9-11-51	Reported adequate
21-11-34 cd	SE SW sec. 34	Dale Curry	Du	18.2	84	R	Sand and gravel	Alluvium	Cy, W	D, S	Top of 2x12 board cover	....	12.57	11- 2-49	Reported adequate
	T. 21 S., R. 12 E.														
21-12-1 cc	SW SW sec. 1	School District	Du	31.6	(?)	R	Sandstone or shale	White Cloud sh.	Cy, H	P	Top of concrete curbing	0.2	3.24	8- 3-50	
21-12-13 dd	SE SE sec. 13	School District	Du	25.0	36	R	Limestone	Wakarusa and/or Burlingame ls.	Cy, H	N	Top of concrete curbing	0.3	10.26	11- 1-49	Measured yield -½, abandoned
21-12-17 cd	SE SW sec. 17	J. S. Trear	Du	17	48	R	Sandstone	Langdon-Willard sh.	Cy, W	S	Land surface	0	5	11- 1-49	Reported adequate
21-12-21 ba	NE NW sec. 21	Joe B. Scheve	Du	12	120	R	Shale	Harveyville sh. and/or colluvium	Cy, E	S	Land surface	0	2	11- 1-49	Reported adequate

21-12-29 bc	SW NW sec. 29	Sch. Dist. 80	Dr	51.5	6	GI	Shale and limestone	Auburn sh. and/or Wakarusa ls.	Cy, H	P	Top of casing	0.3	17.64	8-23-49	
	T. 21 S., R. 13 E.														
21-13-22 cd	SE SW sec. 22	C. A. McGee	Du	19.1	72	R	Shale	Severy sh. and/or colluvium	Cy, W	D, S	Top of concrete curbing	0	9.30	11- 1-49	Reported adequate
21-13-27 aa	NE NE sec. 27	Carl Thompsen	Du	26.3	72	R & N	Sandstone or shale	Severy sh.	Cy, W	D	Top of concrete curbing	0.3	23.10	11- 1-49	Reported adequate except in dry yrs.
21-13-30 dd	SE SE sec. 30	A. Norton	Du	15.3	60	R	Limestone and shale	Happy Hollow ls. and/or White Cloud sh.	Cy, W	S	Top of 2x8 board cover	0.3	12.02	11- 1-49	
21-13-33 ac	SW NE sec. 33	Roy L. Smith	Du	15	(?)	R	Shale or limestone	Howard ls. and/or colluvium	Cy, W	D, S	Land surface	0	5	11- 1-49	Reported adequate except in dry yrs.
21-13-33 dd	SE SE sec. 33	Alma Haehe	DD	40	(?)	R & N	Shale and limestone	Howard ls. (?)	Cy, H	D	Top of concrete curbing	0.7	15	11- 1-49	Reported adequate, yield -½

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 serially 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 quarter. For example well 18-6-1cd is located in the SE¼ SW¼ 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: Cy, 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.

LOGS OF TEST HOLES

Listed on the following pages are the logs of 31 test holes drilled by the State Geological Survey in Lyon County (Pl. 3). The test drilling was confined to alluvial deposits in the valley areas. Samples from the test holes were studied by K. L. Walters and me. The geologic cross sections shown on Figure 3 are based largely on data obtained from this test drilling.

18-10-2da Sample log of test hole in the NE¼ SE¼ sec. 2, T. 18 S., R. 10 E., drilled July 1948. Surface altitude, 1,159.2 feet. Water level, 18.0 feet below land surface, July 22, 1948.

	Thickness, feet
Road fill	3
QUATERNARY-Pleistocene	
Terrace deposits	
Clay and silt, tan	3
Clay and silt, mottled buff and white	1.5
Silt and clay, tan; contains considerable chert sand	2.5
Silt and clay, light-tan; contains very fine sand	9.5
Gravel, red chert and tan limestone	2.5
Clay, tan; contains much fine to medium chert sand	5.5
Gravel, chert, very coarse	5
PERMIAN-Wolfcampian	
West Branch shale	
Shale, yellow and tan	4
Shale, blue-green	2
Total depth of test hole	38.5

18-10-11aa Sample log of test hole in NE¼ NE¼ sec. 11, T. 18 S., R. 10 E., drilled July 1948. Surface altitude, 1,151.6 feet. Water level, 11.9 feet below land surface July 22, 1948.

	Thickness, feet
QUATERNARY-Pleistocene	
Terrace deposits	
Silt and clay, gray-black, noncalcareous	4
Silt and clay, sandy, noncalcareous, red-buff	12.5
Silt, red-buff, and very fine sand	10
Gravel and sand, predominantly chert	5
PERMIAN-Wolfcampian	
West Branch shale	
Shale, calcareous, gray; contains thin limestones	3
Total depth of test hole	34.5

18-10-11ca Sample log of test hole in NE¼ SW¼ sec. 11, T. 18 S., R. 10 E., drilled July 1948. Surface altitude, 1,142.7 feet.

	Thickness, feet
QUATERNARY-Pleistocene	
Alluvium	
Soil, black	7
Clay and silt, brown to gray	5
Clay and silt, white to tan	4
Sand and gravel, predominantly chert	10.5

	Thickness, feet
PERMIAN-Wolfcampian	
West Branch shale	
Shale, gray	2.5
Total depth of test hole	29

18-10-11cc Sample log of test hole in SW¼ SW¼ sec. 11, T. 18 S., R. 11 E., drilled July 1948. Surface altitude 1,142.1 feet. Water level, 14.1 feet below land surface, July 14, 1948.

	Thickness, feet
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
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 SW¼ NW¼ sec. 14, T. 18 S., R. 10 E., drilled July 1948. Surface altitude 1,137.4 feet. Water level, 12.2 feet below land surface, July 14, 1948.

	Thickness, feet
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

19-10-1cc Sample log of test hole in SW¼ SW¼ sec. 1, T. 19 S., R. 10 E., drilled July 1948. Surface altitude, 1,173.3 feet. Water level, 6.9 feet below land surface, July 2, 1948.

	Thickness, feet
QUATERNARY-Pleistocene	
Terrace deposits	
Silt and clay, brown-black	2.5
Silt and clay, red-buff; contains chert gravel and sand	4
PERMIAN-Wolfcampian	
West Branch-Hawxby shale	
Shale, calcareous, yellow-tan	3.5
Shale, calcareous, olive	15
Shale, calcareous, dark-gray	3
Total depth of test hole	28

19-10-11da Sample log of test hole in NE¼ SE¼ 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 7, 1948.

	Thickness, feet
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
PENNSYLVANIAN-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 SW¼ NW¼ sec. 12, T. 19 S., R. 10 E., drilled July 1948. Surface altitude, 1,152.8 feet.

	Thickness, 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

19-10-13cd Sample log of test hole in SE¼ SW¼ sec. 13, T. 19 S., R. 10 E., drilled July 1948. Surface altitude, 1,115.1 feet. Water level, 18.9 feet below land surface, July 13, 1948.

	Thickness, feet
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
PENNSYLVANIAN-Virgilian	
French Creek shale (?)	
Shale, very sandy, micaceous, gray-green	3
Total depth of test hole	40

19-10-14aa Sample log of test hole in NE¼ NE¼ sec. 14, T. 19 S., R. 10 E., drilled July 1948. Surface altitude, 1,119.8 feet. Water level, 8.4 feet below land surface, July 7, 1948.

	Thickness, feet
Road fill	5
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

19-10-14da Sample log of test hole in NE¼ SE¼ sec. 14, T. 19 S., R. 10 E., drilled July 1948. Surface altitude, 1,119.5 feet. Water level, 19.7 feet below land surface, July 10, 1948

	Thickness, feet
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

19-10-26aa Sample log of test hole in NE¼ NE¼ sec. 26, T. 19 S., R. 10 E., drilled July 1948. Surface altitude, 1,115.4 feet. Water level, 19.0 feet below land surface, July 10, 1948.

	Thickness, feet
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

19-10-26da Sample log of test hole in NE¼ SE¼ sec. 26, T. 19 S., R. 10 E., drilled July 1948. Surface altitude, 1,127.2 feet. Water level, 19.7 feet below land surface, July 10, 1948.

	Thickness, feet
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

19-11-1aa Sample log of test hole in NE¼ NE¼ sec. 1, T. 19 S., R. 11 E., drilled July 1949. Surface altitude, 1,126.5 feet. Water level, 20.1 feet below land surface, July 23, 1949.

	Thickness, feet
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	26.7

19-11-1ad Sample log of test hole in SE¼ NE¼ sec. 1, T. 19 S., R. 11 E., drilled July 1949. Surface altitude, 1,101.1 feet. Water level, 18.4 feet below land surface, July 26, 1949.

	Thickness, feet
QUATERNARY-Pleistocene	
Alluvium	
Soil, 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

PENNSYLVANIAN-Virgilian	
Auburn shale	
Limestone, hard, gray	0.2
Total depth of test hole	34.2

19-11-1da Sample log of test hole in NE¼ SE¼ sec. 1, T. 19 S., R. 11 E., drilled July 1949. Surface altitude, 1,101.1 feet. Water level, 18.3 feet below land surface, July 23, 1949.

	Thickness, feet
QUATERNARY-Pleistocene	
Alluvium	
Soil, black	5
Clay and silt, noncalcareous, slightly sandy, dark-brown	10
Clay and silt, noncalcareous, slightly sandy, gray-brown	4
Silt and clay, noncalcareous, light-brown; contains a little chert sand and gravel	12
Gravel and sand, predominantly brown chert	4.5
PENNSYLVANIAN-Virgilian	
Auburn shale	
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.

	Thickness, feet
QUATERNARY-Pleistocene	
Alluvium	
Soil, black	4
Clay and silt, noncalcareous with calcareous spots, gray-brown	6
Silt and clay, noncalcareous, gray-brown	10
Sand and gravel, brown chert, and colorless quartz; predominantly chert	2.5
Gravel and sand, brown chert, and colorless quartz; predominantly chert	12
PENNSYLVANIAN-Virgilian	
Wakarusa limestone	
Limestone, hard, gray	0.1
Total depth of test hole	34.6

19-11-9db Sample log of test hole in NW¼ SE¼ sec. 9, T. 19 S., R. 11 E., at SW cor. 12th and Elm Street, Emporia, drilled July 1949. Surface altitude, 1,169.0 feet.

	Thickness, feet
QUATERNARY-Pleistocene	
Slope deposits, colluvium	
Soil, black	2
Silt and clay, dark gray-tan	5
Silt and clay, slightly sandy, tan	1.5
PENNSYLVANIAN-Virgilian	
Grandhaven limestone	
Limestone and shale, slightly sandy, buff, fossiliferous	1.5
Shale, mottled gray and buff; contains limonite concretions	2
Shale, slightly sandy, yellow-buff	3
Limestone, brown	1
Dry shale	
Shale, hard, gray	5
Shale, soft, olive to dark-gray	2.5
Dover limestone	
Limestone, hard, light-gray; contains fusulinids	1.8
Langdon shale	
Shale, green	1.2
Maple Hill limestone	
Limestone, very sandy, gray and brown	3
Pierson Point shale	
Shale, yellow	0.5
Total depth of test hole	30

19-11-12da Sample log of test hole in NE¼ SE¼ sec. 12, T. 19 S., R. 11 E., drilled July 1949. Surface altitude, 1,095.1 feet. Water level, 2.1 feet below land surface, July 23, 1949.

	Thickness, feet
QUATERNARY-Pleistocene	
Alluvium	
Soil, black	4
Clay and silt, gray to gray-brown	1.5
Clay and silt, gray to yellow-gray	3
Silt and clay, slightly sandy, brown to gray-brown	3.5
Gravel and sand, brown chert, and colorless quartz; predominantly chert	9
PENNSYLVANIAN-Virgilian	
Auburn shale	
Limestone, brown	0.4
Total depth of test hole	20.4

19-11-13aa Sample log of test hole in NE¼ 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.

	Thickness, feet
QUATERNARY-Pleistocene	
Alluvium	
Silt and clay, brown-black	2
Silt and clay, brown-gray	5
Silt and clay, brown; contains a small amount of brown chert gravel	8
Gravel and sand, chiefly brown chert	1.5
PENNSYLVANIAN-Virgilian	
Auburn shale	
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.

	Thickness, feet
QUATERNARY-Pleistocene	
Terrace deposits	
Soil, black	2

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

19-11-13dd Sample log of test hole in SE¼ SE¼ sec. 13, T. 19 S., R. 11 E., drilled July 1948. Surface altitude, 1,106.5 feet. Water level, 12.5 feet below land surface, August 12, 1948.

	Thickness, feet
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
PENNSYLVANIAN-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.

	Thickness, feet
QUATERNARY-Pleistocene	
Terrace deposits	
Soil, black to dark-gray	3
Silt and clay, noncalcareous, red-tan	7
Silt and clay, tan with gray mottling	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
PENNSYLVANIAN-Virgilian	
Pierson Point-Willard shale	
Shale, sandy, micaceous, blue-gray	5
Total depth of test hole	50

19-11-24ad Sample log of test hole in SE¼ NE¼ sec. 24, T. 19 S., R. 11 E., drilled July 1948. Surface altitude, 1,100.8 feet.

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

19-11-24dd Sample log of test hole in SE¼ SE¼ sec. 24, T. 19 S., R. 11 E., drilled July 1948. Surface altitude, 1,096.1 feet. Water level, 4.3 feet below land surface, August 12, 1948

	Thickness, feet
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
PENNSYLVANIAN-Virgilian	
Burlingame limestone	
Limestone, fossiliferous, light-gray to yellow-tan	2
Total depth of test hole	32

19-13-29da Sample log of test hole in NE¼ SE¼ sec. 29, T. 19 S., R. 13 E., drilled December 1950. Surface altitude, 1,089.2 feet. Water level, 26.4 feet below land surface, December 16, 1950.

	Thickness, feet
QUATERNARY-Pleistocene	
Terrace deposits	
Soil, gray-black	3
Silt and clay, noncalcareous, gray with light-tan mottling	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 mottling	5
Silt and clay, noncalcareous, slightly sandy, gray and tan	8

Gravel and sand, predominantly colorless quartz and brown chert	5.5
PENNSYLVANIAN-Virgilian	
Howard limestone	
Limestone, hard	0.1
Total depth of test hole	43.6

19-13-31da Sample log of test hole in NE¼ SE¼ sec. 31, T. 19 S., R. 13 E., drilled December 1950. Surface altitude, 1,068.5 feet. Water level, 14.9 feet below land surface, December 16, 1950.

	Thickness, feet
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
PENNSYLVANIAN-Virgilian	
Howard limestone	
Shale, micaceous, gray	5
Total depth of test hole	40

19-13-32ba Sample log of test hole in NE¼ NW¼ sec. 32, T. 19 S., R. 13 E., drilled December 1950. Surface altitude, 1,083.7 feet. Water level, 19.8 feet below land surface, December 16, 1950.

	Thickness, feet
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
PENNSYLVANIAN-Virgilian	
Howard limestone	
Limestone, hard, gray	0.1
Total depth of test hole	26.6

20-13-6ab Sample log of test hole in NW¼ NE¼ sec. 6, T. 20 S., R. 13 E., drilled December 1950. Surface altitude, 1,066.7 feet. Water level, 5.0 feet below land surface, December 16, 1950.

	Thickness, feet
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 limestone detritus	2.5
PENNSYLVANIAN-Virgilian	
Howard limestone	
Shale, slightly sandy, pyritic, medium dark-gray	2
Total depth of test hole	21

20-13-6cd Sample log of test hole in SE¼ SW¼ sec. 6, T. 20 S., R. 13 E., drilled December 1950. Surface altitude, 1,079.2 feet. Water level, 8.0 feet below land surface, December 16, 1950.

	Thickness, feet
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
PENNSYLVANIAN-Virgilian	
Howard limestone	
Limestone, hard, gray	0.1
Total depth of test hole	30.1

20-13-7bb Sample log of test hole in NW¼ NW¼ sec. 7, T. 20 S., R. 13 E., drilled December 1950. Surface altitude, 1,085.4 feet. Water level, 9.2 feet below land surface, December 16, 1950.

	Thickness, feet
Road fill	4
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, friable, tan; contains mollusk shells	5
Silt and clay, very calcareous, sandy, pink-gray; contains mollusk shells	5
PENNSYLVANIAN-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

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