Geology and Ground-Water Resources of Douglas County, Kansas

By

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Prepared by the United States Geological Survey and the State Geological Survey of Kansas with the co-operation 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.

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CONTENTS

ILLUSTRATIONS

TABLES

GEOLOGY AND GROUND-WATER RESOURCES OF DOUGLAS COUNTY, KANSAS

By Howard G. O'Connor

ABSTRACT

This report describes the geography, geology, and ground-water resources of Douglas County, Kansas, which has an area of about 474 square miles and in 1955 had a population of 32,067. The area lies within the Dissected Till Plain and the Osage Plain sections of the Central Lowlands physiographic province. Kansas River drains the northern three fourths, and tributaries of Marais des Cygnes River drain the southern fourth. The mean annual precipitation at Lawrence is 34.57 inches and the mean annual temperature 56.5° F. Farming, chemical manufacturing, and educational institutions employ many residents of the area. Oil and gas, sand, gravel, and limestone are mineral resources currently being produced.

In Douglas County the rocks above the Precambrian basement are 2,400 to 3,000 feet thick and are all of sedimentary origin. They include rocks of Quaternary, Pennsylvanian, Mississippian, Devonian, Ordovician, and Cambrian age. The exposed Pennsylvanian and Quaternary rocks are nearly 1,000 feet thick; their distribution is shown on a geologic map. The thickness, attitude, and sequence of the rock units are shown in cross sections.

The dominant regional structure is the Prairie Plains Monocline, which is chiefly post-Permian in age and which causes the outcropping Pennsylvanian rocks to dip northwestward about 20 feet per mile. Faulting and small sharp flexures in southern Douglas County affect the Pedee, Douglas, and lower Shawnee rocks. The faults and folds are believed to be chiefly nontectonic in origin. Extensive submarine slides and differential compaction suggest that the structures are penecontemporaneous and probably are restricted to the post-Stanton rocks.

Wisconsinan and Recent alluvial deposits 45 to 90 feet thick in the Kansas River valley yield large supplies of ground water and constitute the most important aquifer in the area, as more than four-fifths of the ground water pumped comes from an area of 6 square miles in the Kansas River valley. Illinoisan fluvial deposits and Kansan glacial and fluvial deposits locally yield small to moderate ground-water supplies. The Ireland Sandstone member of the Lawrence Shale and the Tonganoxie Sandstone member of the Stranger Formation are the most important bedrock aquifers; they provide water for domestic and stock requirements and small amounts for municipal water supplies.

Fresh ground water occurs locally to a depth of about 500 feet. Water from Quaternary deposits is generally good except for carbonate hardness and locally excessive iron content. The Ireland and Tonganoxie Sandstones yield calcium and magnesium bicarbonate water of good quality in water-table areas, and downdip or downgradient in the artesian areas they yield a sodium bicarbonate water, which is generally soft though high in dissolved solids.

Ground-water pumpage in 1955 was 2,266.4 million gallons, or 6,950 acre-feet, divided as follows: public supplies 1,610 acre-feet; industrial supplies 4,490 acre-feet; irrigation supplies 630 acre-feet; and other pumpage, 220 acre-feet. Industrial and irrigation use has greatly increased since 1950.

Field data upon which this report is based include records of 436 wells, test holes, and springs; logs of 196 wells and test holes; and chemical analyses of 113 water samples.

INTRODUCTION

Purpose and Scope of Investigation

A study of the geology and ground-water resources of Douglas County was begun in the spring of 1952 by the State Geological Survey of Kansas and the U. S. Geological Survey in co-operation with the Division of Sanitation of the Kansas State Board of Health and the Division of Water Resources of the Kansas State Board of Agriculture. As water from wells constitutes an important supply for municipal, industrial, irrigation, domestic, and stock needs, this investigation was made to determine the distribution, thickness, and lithologic and hydrologic properties of the rocks containing fresh water in the county.

Because rocks older than late Missourian (Pennsylvanian) age do not contain fresh water they are considered only briefly in this report. Other mineral resources and the structural geology of the area also are discussed briefly. Data regarding present and potential ground-water developments, together with the effects of pumping on discharge, recharge, and quality of the water, are summarized for the principal aquifers.

Location and Extent of Area

Douglas County is in central eastern Kansas and is bounded on the north by Jefferson and Leavenworth Counties, on the east by Johnson County, on the south by Franklin County, and on the west by Osage and Shawnee Counties (Fig. 1). It includes all or parts of 22 townships, constituting about 474 square miles.

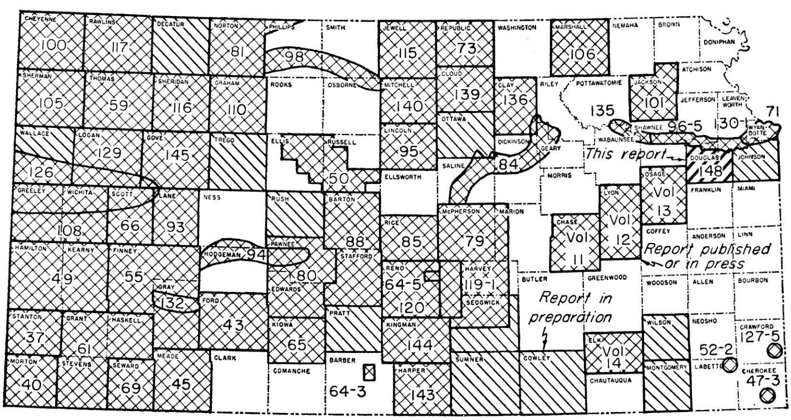

FIG. 1.—Map showing area discussed in this report, and other areas in Kansas for which ground-water reports have been published or are in preparation.

Previous Investigations

The sequence of rocks that crop out in Douglas and adjacent eastern Kansas counties has been studied and described by many geologists (Haworth, 1894, 1894a, 1895; Bennett, 1896; Beede, 1898; Todd, 1909, 1911, 1918, 1918a; Hinds and Greene, 1915; Wing, 1921; Schoewe, 1923, 1924, 1930, 1930a, 1930b, 1949; Moore, 1932, 1936, 1949; Rich, 1932, 1932a, 1933; Patterson, 1933; Moore, Elias, and Newell, 1934; Newell, 1935; Hoover, 1936; Moore and Landes, 1937; Moore, Frye, and Jewett, 1944; Frye and Walters, 1950; Lins, 1950; Moore and others, 1951; Frye and Leonard, 1952; O'Connor and others, 1955; Ball, 1957; Laughlin, 1957; and Sanders, 1957). Coal resources of the area have been studied by Haworth (1898), Whitla (1940), Bowsher and Jewett (1943), and Abernathy, Jewett, and Schoewe (1947).

Studies relating to the ground-water resources have been made by Bailey (1902), Haworth (1913), Moore and others (1940), Lohman (1941), Davis and Carlson (1952), Merriam (1954), Foley, Smrha, and Metzler (1955), Grimes (1957), and Dufford (1958).

The subsurface geology has been described by McClellan (1930), Ockerman (1935), Lee (1943), Lee and others (1946), Lee, Leatherock, and Botinelly (1948), and Lee and Merriam (1954). The geology pertaining to oil and gas has been discussed by Jewett and Abernathy (1945) and by Jewett (1949, 1954). Named structures that have geographic application to Douglas County have been listed by Jewett (1951). Recently Farquhar (1957) has summarized information on the geology of the Precambrian rocks in Kansas.

Methods of Investigation

The data upon which this report is based were obtained chiefly in the spring and summer of 1952 and 1953 during which time wells were inventoried, test holes were drilled, water samples were collected for chemical analysis, and most of the areal geology was mapped. About three months of additional field work between 1954 and March 1957 included the drilling of several more test holes, inventorying additional wells, collecting additional water samples for chemical analysis, conducting pumping tests, logging water wells, and completing the geologic mapping. Data submitted to March 1957 by co-operating water-well drillers are included in the report.

Geologic and ground-water data collected and given in reports by Lohman (1941), Davis and Carlson (1952), and Dufford (1958) were partly restudied, and some were modified before inclusion in this report. Test holes reported in Table 9 were drilled with a hydraulic-rotary drilling machine owned by the State Geological Survey and operated by W. T. Connor, K. L. Walters, and E. L. Reavis, and with a power auger operated by John Perry and William Gellinger. Drill cuttings were collected in the field and later examined microscopically in the laboratory. Altitudes of wells and test holes were determined by W. W. Wilson and the author by planetable and alidade surveys or by interpolation from 7½-minute topographic maps having 10-foot contour intervals.

The base map used in Plates 1 and 2 was compiled from aerial photographs obtained from the Production and Marketing Administration, U. S. Department of Agriculture, and from maps of the Soil Conservation Service, the State Highway Commission of Kansas, and the Kansas Turnpike Authority. Areal geology was mapped on aerial photographs (scale 1:20,000) and later transferred to a 1:40,000-scale base map.

Well-Numbering System

The well and test-hole numbers used in this report give the location of wells according to General Land Office surveys. The well number is composed of township, range, and section numbers, followed by lowercase letters that indicate the subdivision of the section in which the well is located. The first letter denotes the quarter section, the second letter denotes the quarter-quarter section, or 40-acre tract, and the third letter, when used, indicates the quarter-quarter-quarter section, or 10-acre tract. The 160-acre, 40-acre, and 10-acre tracts are designated a, b, c, or d in a counterclockwise direction, beginning in the northeast quarter. When two or more wells are located within a 10-acre tract, the wells are numbered serially according to the order in which they were inventoried. An example of the well-numbering system is given in Figure 2.

Acknowledgments

Appreciation is expressed to the many residents who supplied information concerning local geology, wells, and water supplies. Mr. N. J. Burris, of the State Board of Health, and water superintendents of the towns in the area provided information on municipal water supplies. The Westvaco Mineral Products Div. of Food Machinery & Chemical Corp., Kansas Power and Light Co., Na-

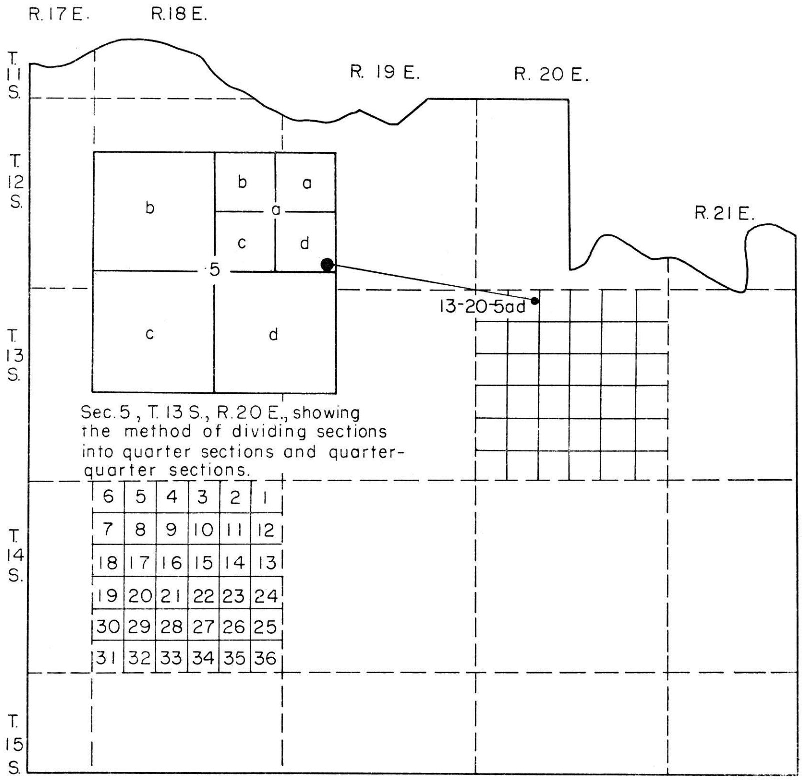

FIG. 2.—Map of Douglas County illustrating well-numbering system used in this report.

tional Alfalfa Dehydrating and Milling Co., and Cooperative Farm Chemical Association generously provided information concerning their ground-water developments.

Jungmann Bros., Messrs. E. V. Smith, Farrell Bryan, and W. D. and Homer Wilson, D. W. Brewer & Sons, Messrs. Lee Hendee, Jr., and Lon Dietrich, Carl Moore & Son, Mr. Harold Lutz, Baugher & King Drilling Co., Mr. H. R. Swank, Walter Fees Drilling Co., Messrs. J. S. Holmes and Raymond and Kenneth Schutz, Air Made Well Co., and Layne-Western Co., provided logs of wells that they had drilled in this area.

John D. McNeal and other geologists of the State Highway Commission of Kansas made available from their files much geologic information, including geologic profiles of several highway projects.

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

The manuscript for this report has been reviewed critically by several members of the Federal and State Geological Surveys; by Robert Smrha, Chief Engineer, and George S. Knapp, Engineer, Division of Water Resources, Kansas State Board of Agriculture; and by Dwight F. Metzler, Director, and Willard O. Hilton, Geologist, of the Division of Sanitation of the Kansas State Board of Health.

The illustrations were drafted by Barbara Daly and Nancy Chamney.

GEOGRAPHY

Topography and Drainage

Douglas County lies partly within the Dissected Till Plains and partly within the Osage Plains sections of the Central Lowlands physiographic province as defined by Fenneman (1931). Schoewe (1949) included the area partly in the Attenuated Drift Border division of the Dissected Till Plains and partly in the Osage Cuestas division of the Osage Plains. The major topographic features are the east-trending Kansas and Wakarusa River valleys and the upland cuestas formed by differential erosion of the limestone, shale, and sandstone beds. Locally, as in the Hesper area in the eastern part of the county, plains developed on glaciofluvial deposits are minor topographic features.

Kansas River and its tributaries drain the northern three fourths of the county and tributaries of Marais des Cygnes River drain the southern fourth. The highest point in the county is in the southwestern part and is about 1,200 feet above sea level; the lowest point is along Kansas River at the east edge of the county, about 778 feet above mean sea level. Kansas River has an average gradient of about 2 feet per mile.

Climate

Douglas County has a humid continental climate. Nearly three fourths of the annual precipitation falls during the growing season, which averages 196 days. The average date of the last killing frost in the spring is April 10 and the average date of the first killing frost in the fall is October 23.

The mean annual precipitation at Lawrence is 34.57 inches and the mean annual temperature, 56.5° F.

The mean monthly and annual precipitation and temperature are given in Table 1.

TABLE 1.—*Monthly and annual precipitation and temperature at Lawrence, 1931-55. From records of U. S. Weather Bureau*

Month	Mean precipitation, inches	Mean temeprature, ° F
January	1.22	31.5
February	1.07	35.8
March	2.16	44.4
April	3.43	56.4
May	4.83	65.3
June	4.75	75.4
July	3.48	80.6
August	4.67	78.8
September	3.31	70.7
October	2.33	59.8
November	1.91	44.7
December	1.41	34.9
Mean annual, 1931-55	34.57	56.5

POPULATION

Douglas County was organized in 1855. In 1955 it ranked 12th among the counties in the state, having a population of 32,067. Lawrence, the county seat and largest city, had a population of 20,928. Other important communities and their 1955 populations are Baldwin, 1,376; Eudora, 1,410; and Lecompton 279.

TRANSPORTATION

Douglas County is served by the main lines of the Atchison, Topeka & Santa Fe Railway system; the Chicago, Rock Island & Pacific Railroad; and the Union Pacific Railroad.

There are about 99 miles of improved state and federal highways and turnpikes in Douglas County. The principal highways are U. S. 40, crossing the county from east to west in the northern part, and U. S. 56, from east to west in the southern part. U. S. 24 crosses the northeast corner of the county, and Kansas Highway 10 extends eastward from Lawrence into Johnson County. The Kansas Turnpike nearly parallels U. S. 40. U. S. 50 and Kansas Highway 33 are hard-surfaced roads in the southeastern part of the county. U. S. 59 crosses the middle of the county from north to south. About 0.2 mile of Kansas Highway 32 extends eastward from its junction with U. S. 24 and 40 in the northeast corner of the county.

Agriculture and Industry

Agriculture is an important part of the economy of Douglas County. According to the 1954 Census of the State Board of Agriculture, there were then 1,435 farms. Crops produced in 1956 had a value of $6,834,410. Livestock and poultry having a value of $5,009,340 also were produced in 1956. The acreage of principal crops grown in 1956 is shown in Table 2.

Several chemical industries produce ammonia, urea, ammonium nitrate, phosphates, phosphoric acid, dry ice, and boron chemicals. The University of Kansas and Haskell Institute at Lawrence and Baker University at Baldwin have about 2,000 full-time employees and are an important segment of the economy.

Table 2.—*Acreage and value of principal crops grown in Douglas County in 1956. Kansas State Board of Agriculture, 1958*

Crop	Acreage	Value
Corn	29,400	$1,501,200
Wheat	32,700	2,286,400
Oats	15,300	356,300
Soybeans	8,600	252,880
Hay	31,200	1,252,000
Sorghums for forage	2,100	69,300
Sorghums for grain	9,500	380,260
Sorghums for silage	3,900	397,800
Other crops	....	338,270
Total	....	$6,834,410

Mineral Resources

Oil and gas.—In 1955, oil production from 20 wells in two fields amounted to 10,853 barrels. The Baldwin field has produced oil since 1919, and in 1955 there were 19 wells producing from the Squirrel sand in the upper part of the Cherokee Group at a depth of about 800 feet. One well in the Eudora South field is reported to have produced 72 barrels of oil from the Squirrel sand at a depth of about 700 feet (Goebel, Hornbaker, Atkinson, and Jewett, 1956).

Gas in commercial quantities has not been produced for several years, but gas for local farm consumption is obtained from some wells in the eastern half of the county, principally from the Squirrel sand, 700 to 800 feet deep, but also from sand in the Pleasanton Group at a depth of about 340 feet. Figure 3 shows the location of oil and gas fields and the dry holes that have been drilled outside the producing areas prior to January 1957.

Although no oil or gas has been found in rocks older than the

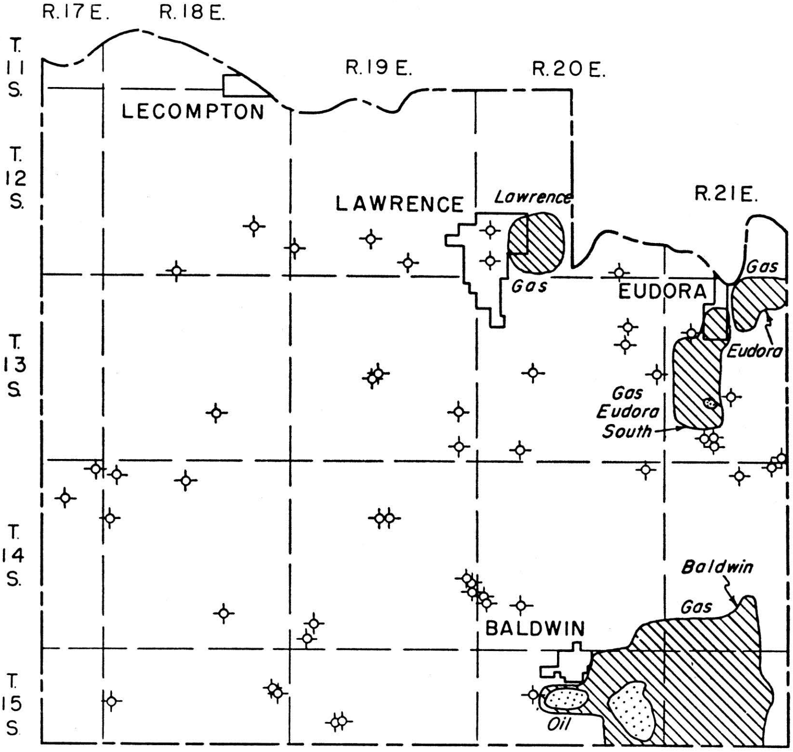

FIG. 3.—Map of Douglas County showing location of oil and gas fields and dry holes drilled outside of producing areas prior to January 1957.

Cherokee Group, known structural conditions suggest that stratigraphic traps may exist in Devonian or Viola (Kimmswick) rocks (Jewett, 1954).

Coal.—Bowsher and Jewett (1943) report that coal has been mined in 21 different operations in Douglas County, the first coal having been mined during settlement of the area in the 1860's. The principal coals mined in the past have been the Blue Mound coal in the Stranger Formation and the Lower Williamsburg coal in the Lawrence Shale. In addition, at least three other named coal beds have been recognized, namely the Upper Williamsburg coal near the top of the Lawrence Shale and the Upper and Lower Sibley coals in the Stranger Formation.

In the Blue Mound area (sec. 21, 22, 27, and 28, T. 13 S., R. 20 E.) three coals are present in the Tonganoxie Sandstone member of the Stranger Formation. According to Whitla (1940) the lowest of these, the Blue Mound coal, is 12 to 14 inches thick and lies approximately 55 feet below the top of the Tonganoxie Sandstone member. Two other coal beds, measuring 6.5 and 3 inches thick, respectively, lie approximately 37 feet and 55 feet above the Blue Mound coal; these are the Lower and Upper Sibley coals.

The Lower Williamsburg coal has been mined locally on several farms in T. 13 and 14 S., R. 18 E., and is reported to range in thickness from 8 to 14 inches.

The Upper Williamsburg coal, because of its thinness, has not been mined in Douglas County. In the vicinity of Lone Star Lake a coal bed 0.5 to 1 foot thick, believed to be the Upper Williamsburg, occurs about 10 feet below the top of the Lawrence Shale. The Williamsburg coals are chiefly in the southern part of the county.

The Douglas Group coals have not been mined for many years and most of the former workings are now obscure. Bowsher and Jewett (1943) gave the mine locations and history of production of the Douglas coals in detail.

Sand and gravel.—Arkosic sand and gravel is dredged from Kansas River just below the Bowersock mill and dam at Lawrence. This plant, operated by the Bowersock Mills & Power Co., is the only commercial producer of sand and gravel in the county. Several small sand and gravel pits in Kansan glaciofluvial deposits have been operated intermittently in other parts of the county, as at Shank Hill in sec. 26, T. 13 S., R. 19 E. Because these deposits are not well sorted and may contain large boulders and cemented zones, the pits are difficult to operate.

A large sand and gravel pit was operated at Lakeview during construction of the Kansas Turnpike. Dredging in the ancient meander of Kansas River that now forms Lakeview Lake removed several thousand yards of sand and gravel and created a deep hole in the former uniformly shallow lake.

The chief use of sand and gravel produced locally is for paving and construction. Bowdish and Runnels (1952) demonstrated that the Kansas River sand can be used to produce a nearly pure feldspar product of commercial grade and a high-quality silica sand having less than 0.03 percent Fe_2O_3, suitable for use in glass, glass fiber, and the ceramic industry.

Limestone.—The outcropping limestones have been quarried and used for concrete and other aggregate, crushed rock for road metal, agricultural limestone, riprap, subgrade and embankment material, and building stone.

Three limestones are currently being quarried and crushed for concrete aggregate, road metal, and agricultural lime. Of these the Plattsmouth Limestone member of the Oread Limestone is the most extensively quarried, chiefly because it is relatively thick (commonly about 18 feet), has desirable physical properties, and is found near the principal areas of use. Several quarries have produced limestone from the Toronto Limestone member of the Oread Limestone in the area north of Baldwin, where it locally is 9 to 12 feet thick. The Stoner Limestone member of the Stanton Limestone has been quarried 1 mile northeast of Eudora and along Little Wakarusa Creek about 2¼ miles south of Eudora, where it is 16 or 17 feet thick. Chemical analyses of rock samples from some of the important limestone ledges are given in Table 3.

No quarries are operated for the production of dimension stone, but several ledges have been quarried and the stone used locally for building. The Toronto Limestone member of the Oread Limestone was quarried along the outcrop where little or no overburden was present, at several places just west of the Kansas University campus and on the campus. It weathers brown and is durable, as is evident in the several University buildings constructed of the Toronto Limestone. It does not withstand weather quite as well as the more widely used Cottonwood Limestone member of the Beattie Limestone and the Fort Riley Limestone member of the Barneston Limestone used in buildings and bridges throughout eastern Kansas. Several structures in Baldwin utilize the Haskell Limestone as building stone. The gymnasium shows the pleasing gray color and weathering characteristics of this stone.

The Clay Creek Limestone member of the Kanwaka Shale, the Spring Branch and Avoca Limestone members of the Lecompton Limestone, and the Ozawkie Limestone member of the Deer Creek Limestone have been used in the construction of small bridges, rural schools, and numerous farm buildings in the area but have not been quarried extensively. The Westphalia Limestone, because of its thinness and smooth surfaces, has been quarried locally for flagstone. Projects requiring riprap for road, bridge, or railroad fill and embankment protection have utilized the nearest local limestone available in sufficient quantities and having the necessary physical properties.

Sandstone.—Massive beds of the Ireland Sandstone member of the Lawrence Shale and the Tonganoxie Sandstone member of the Stranger Formation were quarried locally for building stone in the late 19th and early part of the 20th centuries. Where used as build-

TABLE 3.—*Chemical analyses of selected outcropping limestones from Douglas County*

[Adapted from Runnels and Schleicher, 1956]

Limestone member	Thickness (feet)	Location[a] T–R–Sec.	Constituent, percent by weight													Laboratory no.
			[b]$CaCO_3$	[b]$MgCO_3$	[b]$CaCO_3$ equiv.	CaO	MgO	L.O.I.[c]	SiO_2	[d]Al_2O_3	[e]Fe_2O_3	SO_3	S	P_2O_5	Total	
Curzon	3	12–17–11	91.38	0.61	92.04	51.27	0.79	40.50	4.66	1.62	1.15	T	....	0.06	100.05	54369
Ervine Creek	8	11–18–32c	95.06	1.13	95.22	53.35	.54	41.90	2.70	.55	1.69	T	....	.07	100.80	49452
Rock Bluff	3	11–18–32c	82.87	7.62	91.98	46.48	3.64	40.47	3.49	1.25	5.06	0.15	....	T	100.54	49446
Ozawkie	....	11–17–36	95.07	....	95.18	53.27	....	41.88	2.11	.71	.89	0	0	T	99.02	50554
Spring Branch	6.8	11–17–36b	73.94	12.41	90.91	41.63	5.93	40.00	6.29	1.55	4.22	.10	0.01	.08	99.80	53216
Plattsmouth	14	12–19– 1a	81.55	1.53	84.95	45.69	.73	37.38	13.94	.92	1.83	T	....	T	100.49	51438
do	8	12–19–25c	88.40	1.05	90.02	49.58	.50	39.61	7.59	1.04	1.01	0	0	.04	99.37	52367
do	14.5	12–18–32a	90.97	.65	92.30	50.94	.31	40.61	5.86	.87	1.07	T	.04	.06	99.72	53217
do	11	13–19– 4c	87.83	1.59	90.52	49.39	.76	39.83	7.62	.93	1.01	.06	.08	.10	99.71	53212
do	10.3	14–18–22a	89.83	2.03	91.64	50.44	.97	40.32	6.41	1.44	.44	.13	....	.02	100.17	54370
Toronto	8	12–19–25c	78.78	7.03	87.84	44.19	3.36	38.65	8.26	1.32	3.97	0	0	.04	99.79	52358
do	3	12–19–36d	68.89	19.64	96.50	38.60	9.39	42.46	3.22	.61	5.10	T	....	0	99.58	4766
do	3.6	13–19–35b	93.38	1.15	93.75	52.34	.55	41.25	3.48	1.17	1.08	0	....	.02	99.89	54372
do	4.2	14–20–19d	94.77	1.13	95.16	53.11	.54	41.87	3.16	.82	.54	0	....	.01	100.05	54371
Stoner	14	13–21– 4a	93.93	1.71	96.59	52.79	.82	42.50	2.11	.52	.63	.08	.06	.04	99.49	5112
do	17	13–21–18d	95.09	1.86	96.09	53.29	.89	42.28	2.17	.73	.56	T	....	.01	99.93	52135
do	15.3	13–21–15d	93.70	1.51	94.07	52.51	.72	41.39	3.23	.97	.88	T	.05	.01	99.71	53170
do	13.2	13–21–20b	88.26	4.66	95.39	49.49	2.23	41.97	3.01	1.46	1.35	0	.07	.03	99.54	53215

a. Record of precise locality is on file in office of State Geological Survey of Kansas, Lawrence.
b. Calculated.
c. Net loss of weight on ignition from 105°C to 1000°C.
d. Includes MnO, ZrO_2, V_2O_5, and TiO_2 when present.
e. Total iron expressed as Fe_2O_3.

ing stone the rock, generally all six faces, has been sawed into rectangular blocks. Although relatively soft when cut, it commonly develops a hard crust on exposure to weathering, is durable, and has a pleasing tan or gray-tan color.

Friable deposits of the Ireland Sandstone member have been utilized recently as subgrade material in local road construction.

Zinc and lead.—Haworth (1904) reported that a mining company was formed in 1901 to mine lead and zinc ore in Douglas County, after farmers living south and west of Lawrence discovered fairly large crystals of both ores in several localities in the area, but no mining was done. Several farmers report that small amounts of ore recovered from streambeds and shale banks on their farms were smelted, and the metal sold at Lawrence. No reports of zinc or lead having been marketed commercially have been verified, however.

The mined ore was chiefly sphalerite containing small amounts of galena. It occurs with calcite in calcareous concretionary masses and septaria in some of the shale beds. During this investigation it was found to be most abundant in the Lawrence-Snyderville Shale where the Toronto Limestone member of the Oread is absent, in the southern part of Douglas County. Similar concretions are found in other Pennsylvanian shales in other areas also. Nowhere in eastern Kansas are these concretions of economic importance, however.

Ceramic materials.—Material suitable for the manufacture of brick and tile is abundant in eastern Kansas in the Pennsylvanian shales, chiefly illitic shales. Recent studies by Plummer and Hladik (1948, 1951) have indicated that both lightweight and dense constructional aggregates can be manufactured from Pennsylvanian shale and Pleistocene silt, which crop out in Douglas County. Both the Pennsylvanian and the Pleistocene materials produce ceramics that are red or dark in color.

The Lawrence Vitrified Brick & Tile Co. operated a plant at the north end of Mississippi Street in Lawrence (NE¼ sec. 25, T. 12 S., R. 19 E.) from 1899 to the 1920's. This plant manufactured building tile, silo blocks, face brick, paving brick, and common brick. Much of the paving brick in Lawrence streets was manufactured here. Silt, sand, and gravel from Kansan terrace deposits adjacent to the plant and shale from the lower part of the Lawrence Shale were combined in various proportions to produce the desired tile or brick.

Clayey parts of the Lawrence Shale excavated on the University of Kansas campus have been used with good results by the pottery classes in the Department of Design for modeling, throwing, and slip casting of pottery (Norman Plummer, personal communication).

Economic value of mineral resources.—Schoewe (1956) lists the minerals produced commercially in 1955 as sand, gravel, stone, and oil, and their total value as about $194,600. Oil was valued at about $30,600, and the sand, gravel, and stone were valued at about $164,000. Non-commercial production of gas was not included.

SUBSURFACE STRATIGRAPHY *

Sedimentary rocks of Paleozoic and Quaternary age underlie Douglas County. The Paleozoic rocks are of Pennsylvanian, Mississippian, Devonian, Ordovician, and Cambrian age and overlie the Precambrian basement. The thickness of the Paleozoic rocks ranges from about 2,400 feet in the southeast corner and the northeast corner along Kansas River to about 3,000 feet in the northwest corner of the county. The general thickness and character of the subsurface rocks are known through the study of logs and samples of drill cuttings from oil and gas wells in the area. The sequence and attitude of the major rock units are shown in a cross section on Plate 1.

An excellent discussion of the stratigraphy and structural development of the Forest City Basin, which includes the area of this report, was prepared by Lee (1943). More recently Lee and Merriam (1954) prepared north-south and east-west cross sections through Douglas County, which depict the Paleozoic structural movements that affected the area.

PRECAMBRIAN ROCKS

Quartzite, schist, slate, marble, porphyry, and granite have been reported from wells drilled into the Precambrian in Kansas. Lee (1943) identified as pink granite the Precambrian rock in the R. F. Duffens No. 1 Stanley well (NW¼ NE¼ NW¼ sec. 3, T. 14 S., R. 21 E.) and the C. J. Neuner et al No. 1 Emmett well (SE¼ NW¼ sec. 6, T. 14 S., R. 18 E.)

The Precambrian topography slopes to the northwest across Douglas County from about 1,400 feet below sea level in the southeast corner to approximately 2,000 feet below sea level in the northwest corner (Jewett, 1954, fig. 9).

CAMBRIAN ROCKS

The Lamotte Sandstone of Late Cambrian age underlies the Arbuckle Group and overlies Precambrian rocks. Throughout Douglas County it is believed to be generally less than 30 feet thick, and

* The stratigraphic nomenclature of this report is that of the Kansas Geological Survey and does not necessarily follow the nomenclature of the U. S. Geological Survey.

locally may be absent. It is reported to be 7 feet thick in the Duffens No. 1 Stanley well in central eastern Douglas County and 15 feet thick in the Neuner No. 1 Emmett well in central western Douglas County. The Lamotte is a fine- to coarse-grained sandstone composed chiefly of quartz or quartz and feldspar.

Cambrian and Ordovician Rocks

In Douglas County the Arbuckle Group, of Early Ordovician and Late Cambrian age, consists of five recognizable subdivisions. The upper three, of Ordovician age, and their thickness in east-central Douglas County (Duffens No. 1 Stanley well) are as follows: (1) undifferentiated Cotter and Jefferson City Dolomites, 106 feet; (2) Roubidoux Dolomite, 167 feet; and (3) undivided Gasconade Dolomite and Van Buren Formation [including a slight thickness of Gunter Sandstone in the basal part], 206 feet. The lower two subdivisions of the Arbuckle, of Late Cambrian age, and their reported thickness in this well are, (1) the Eminence Dolomite, 175 feet, and (2) the Bonneterre Dolomite, 19 feet (Lee, 1943, fig. 5). Except for the Roubidoux Dolomite, which thickens slightly to the northwest across the county, all the subdivisions of the Arbuckle thin to the north and west. The thickness of the Arbuckle ranges from about 750 or 800 feet in the southeast to about 500 feet in the northwest.

Ordovician Rocks

Late Ordovician rocks in eastern Kansas are represented by the Maquoketa Shale, and Middle Ordovician rocks by the Viola Limestone. Both Middle and Early Ordovician rocks are included in the Simpson Group.

The Maquoketa Shale is present only in the northwestern part of the county (Lee, 1943, fig. 11), where it ranges in thickness from a featheredge to nearly 50 feet and consists of greenish-gray silty dolomitic shale and silty dolomite. The Viola Limestone is present throughout the area and consists of slightly more than 100 feet of limestone.

The Simpson Group is distributed throughout the county and comprises the Platteville Formation and the underlying St. Peter Sandstone. The upper beds include gray lithographic limestone, gray shale, brown cherty dolomite, and green shale. Lower beds are chiefly medium- to coarse-grained, well-rounded white sandstone and some shale (Lee, 1943; Moore and others, 1951). The Simpson Group has a thickness of about 50 to 100 feet. According to Lee (1943, fig. 13), Silurian rocks are absent in Douglas County.

Devonian Rocks

In Douglas County the Devonian rocks are believed to be present directly below the Chattanooga Shale everywhere except in a small area in the east-central and southeastern parts (Lee and Merriam, 1954, fig. 2), where Viola Limestone directly underlies the Chattanooga Shale. A maximum of slightly less than 100 feet of Devonian limestone and dolomite is present in the northwest (Lee, 1943, fig. 12). Undifferentiated Silurian and Devonian rocks are commonly termed the "Hunton" Group in eastern Kansas.

Mississippian or Devonian Rocks

The Chattanooga Shale of Mississippian or Devonian age ranges in thickness from slightly less than 50 feet to about 100 feet and is thickest in the northwestern part of the county (Lee, 1943, fig. 14). It is greenish-gray, dark-gray, and black shale, and is silty and pyritiferous in part. Locally a thin sandy shale or sandstone in the lower part is correlated with the Misener Sandstone member in parts of eastern Kansas.

Mississippian Rocks

Lee (1943, fig. 16) indicated that the Mississippian rocks had a thickness range of about 250 to 400 feet, thinning in the southern part of Douglas County and in Franklin County (Lee, 1939, p. 36). The Spergen(?) and Warsaw Limestones of Meramecian age, the Burlington Limestone of Osagian age, and the Sedalia and Chouteau formations of Kinderhookian age are believed to be present in the county (Lee, 1940, pl. 6). The Mississippian rocks are chiefly limestone and dolomite.

Pennsylvanian Rocks

The Pennsylvanian rocks are represented by the Virgilian Series, the Missourian Series, and the Desmoinesian Series. The Wabaunsee, Shawnee, and Douglas Groups make up the Virgilian Series. The Missourian Series consists of the Pedee, Lansing, Kansas City, and Pleasanton Groups. The Marmaton and Cherokee Groups compose the Desmoinesian Series. Pennsylvanian rocks exposed in Douglas County are discussed in more detail in the following pages.

STRATIGRAPHY OF OUTCROPPING ROCKS

Pennsylvanian System—Missourian Series

Lansing Group

Plattsburg Limestone

The Plattsburg Limestone is the lowermost and oldest outcropping formation in Douglas County. It is poorly exposed in the bluff along Kansas River east of Eudora, and along the lower part of Captain Creek and parts of Little Wakarusa Creek. The formation comprises the following three members in ascending order: Merriam Limestone, Hickory Creek Shale, and Spring Hill Limestone. In the subsurface the formation ranges in thickness from about 12 to 32 feet.

Spring Hill Limestone member.—Only the Spring Hill Limestone member of the Plattsburg Limestone is exposed in Douglas County. It is light-gray to light-tan thin-bedded, wavy-bedded argillaceous limestone, and is about 13 to 22 feet thick in the Eudora area. *Composita,* echinoid, and crinoid fragments are common.

Vilas Shale

The Vilas Shale is poorly exposed east of Eudora along Kansas River and Captain Creek and locally south of Eudora along Little Wakarusa Creek. It is chiefly gray or greenish-gray silty shale in the upper part and sandy micaceous shale or silty sandstone in the middle and lower parts. Locally the lower middle part may be dark from disseminated carbonaceous material. The shale ranges from about 10 to 26 feet in thickness in the Eudora area, but may be much thinner in the subsurface. Except for carbonaceous plant fragments and sparse mollusks, the formation is not fossiliferous.

Stanton Limestone

The Stanton Limestone comprises three limestone and two shale members and is a resistant cuesta-forming formation. It commonly has a thickness of about 44 feet and is well exposed along stream bluffs in the vicinity of Eudora.

Captain Creek Limestone member.—The Captain Creek Limestone member, which was named for exposures east of Eudora along Captain Creek, is the lowermost member of the Stanton Limestone. The Captain Creek is gray or gray blue, dense, and fine grained, and when weathered its even, massive bedding is noticeable. In the middle or upper part a persistent zone of *Enteletes pugnoides* is observed and is characteristic. Fusulinids and small *Cryptozoon* are common in the upper part also. The Captain Creek has a thickness of 6 to 7 feet.

Eudora Shale member.—Shale beds about 7 feet thick compose the Eudora Shale member. The middle lower part is typically a black, carbonaceous fissile and thin-bedded shale. Commonly about half a foot of gray or buff shale separates the dark shale from the top of the Captain Creek Limestone member. The upper part of the member consists of gray or greenish-gray thin-bedded shale. Except for conodonts and macerated plant fragments in the black fissile beds, the shale is not fossiliferous.

Stoner Limestone member.—The Stoner Limestone member is the thickest and most persistent bench-forming member of the Stanton. It has a thickness of 15 to 17 feet in outcrops and quarries in the Eudora vicinity (Pl. 4A). It is light-bluish-gray, wavy-bedded limestone containing numerous thin shaly partings. The limestone is fine grained and contains much crystalline calcite. Although not so fossiliferous as cyclical equivalents in the Shawnee Group, such as the Plattsmouth and Beil Limestones, it contains numerous brachiopods, crinoid and echinoid fragments, bryozoans, and fusulinids. The upper surface of the member is hummocky and irregular.

Rock Lake Shale member.—Outcrops of the Rock Lake Shale member are chiefly marine sandstone in this area. The member commonly has a thickness of 10 to 15 feet, but locally is as thin as 4 feet. Where the member is thick the lower part consists of gray, blue, and green shale containing carbonized plants and, locally, a thin coal less than 1 inch thick. The middle and upper parts consist of gray, buff, or dark-brown thin-bedded to massive very fine grained micaceous sandstone. Marine fossils, chiefly the pelecypods *Myalina* and *Aviculopecten,* in the upper part serve to distinguish this sandstone from the younger nonmarine Tonganoxie Sandstone. Where the member is thin it comprises roughly equal parts of shale and sandstone. The contact of the marine sandstone with the underlying shale is distinct and uneven and suggests a disconformity. A complete section of the Rock Lake Shale is well exposed and has a thickness of about 15 feet in the Killough quarry in the NW¼ sec. 20, T. 13 S., R. 21 E. Here the overlying South Bend Limestone rests on massive sandstone of the Rock Lake Shale, and ground water has locally dissolved parts of the limestone and

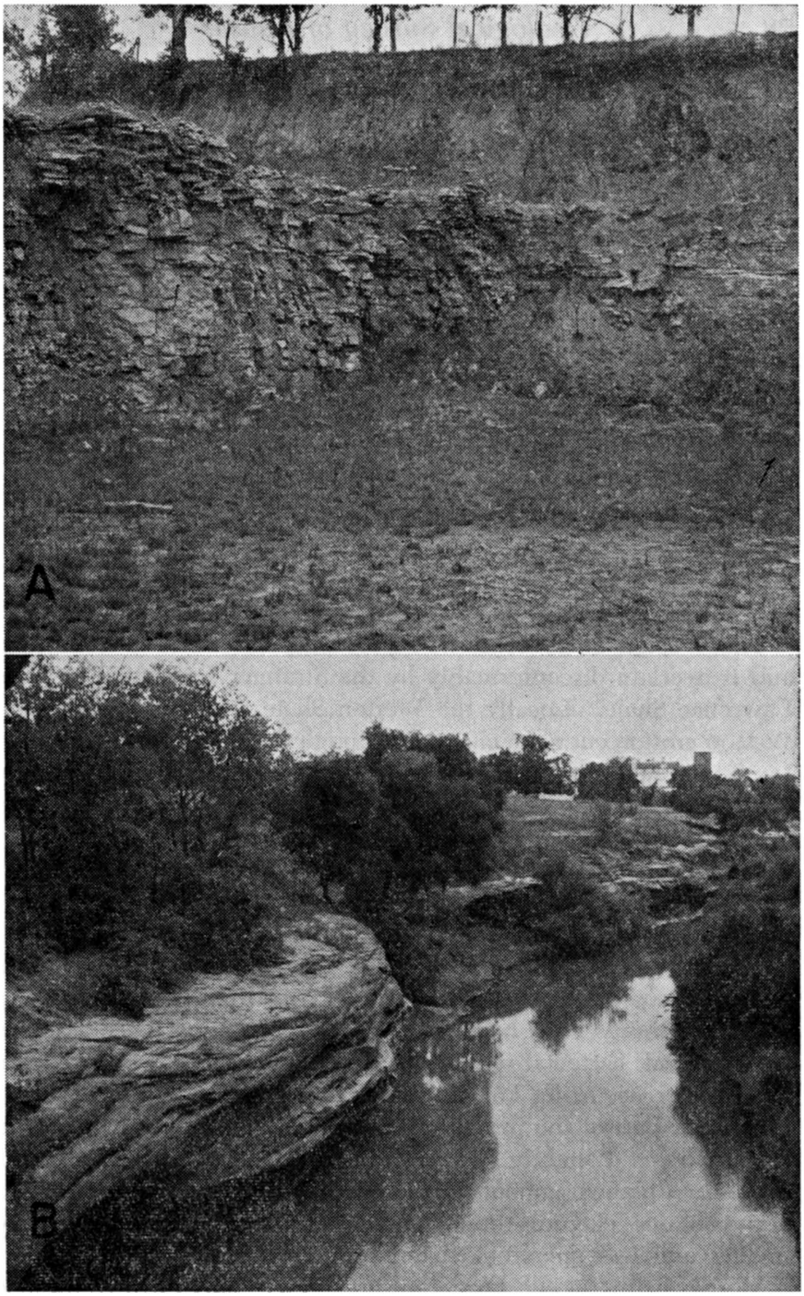

PLATE 4.—**A,** Stoner Limestone member of Stanton Limestone overlain by Kansan glaciofluvial deposits in quarry, NE cor. sec. 4, T. 13 S., R. 21 E.; **B,** Massive Tonganoxie Sandstone member of Stranger Formation at Dightman's Crossing, Wakarusa River, NE¼ NE¼ sec. 14, T. 13 S., R. 20 E.

reprecipitated it in the upper sandstone beds. This has resulted in the development of a gradational contact between these members and a hard calcite-cemented sandstone in the upper part of the Rock Lake Shale member.

South Bend Limestone member.—The uppermost member of the Stanton Limestone, the South Bend Limestone, has a thickness of about 1 to 4 feet. It is medium-bedded, blocky, fine-grained to sandy gray limestone. Although the upper contact is distinct, the lower contact may be gradational into sandstone of the underlying Rock Lake Shale member. The member is fossiliferous, containing abundant fusulinids and several species of brachiopods. Locally it is disconformably overlain by basal deposits of the Stranger Formation, or is absent, and the Stranger Formation rests on the Rock Lake Shale member.

Pedee Group

Weston Shale

The Weston Shale conformably overlies the Stanton Limestone and is overlain disconformably by the Stranger Formation and the Lawrence Shale. Locally the Weston Shale is absent where post-Weston erosion cut deep channels through the shale into the Stanton Limestone, and the younger rocks of the Douglas Group directly overlie the Stanton Limestone. The shale is thickest where the Stranger Formation is thin, and is best exposed in the Vinland and Clearfield areas.

The Weston Shale consists of slightly more than 100 feet of gray-blue and gray marine shale. The lower 50 to 60 feet is a hard medium-gray or bluish laminated and fissile clayey shale containing several zones of dense pinkish-gray clayey ironstone concretions, which weather yellowish brown or reddish brown. The concretions are elliptical, flattened parallel to the bedding, and 2 to 12 inches in diameter occurring both in layers and as scattered concretions. The upper part of the formation is commonly more bluish than the lower part, is a slightly silty clayey shale, and at least locally has carbonized plant fragments at the bedding planes. The upper part also contains clay-ironstone concretions, but they are generally smaller and less numerous than those in the lower part.

Marine fossils in the formation are sparse, but thin fossiliferous zones contain fragments of bryozoans, crinoids, and brachiopods. Weathered outcrops of the shale are mottled olive and gray, or tan, the color depending on the degree of oxidation of the beds.

Some exposures of the Weston Shale directly underlying the unconformity show evidence of a soil development, as represented by a more massive blocky claystone indicative of the B horizon of a soil enriched with clay, and lacking the fissile shaly texture typical of Weston Shale. A caliche zone is present also in some places.

PENNSYLVANIAN SYSTEM—VIRGILIAN SERIES

Douglas Group

Stranger Formation

The Stranger Formation is divided into five members designated, in ascending order, the Tonganoxie Sandstone, the Westphalia Limestone, the Vinland Shale, the Haskell Limestone, and the Robbins Shale. The formation rests unconformably on various parts of the Weston Shale and Stanton Limestone. Its maximum thickness is about 160 feet, but locally the Stranger Formation is absent and the Ireland Sandstone member of the Lawrence Shale directly overlies the Weston Shale.

Tonganoxie Sandstone member.—The Tonganoxie Sandstone member in this area is believed to be a nonmarine sandstone that occupies an erosional river valley cut into the Weston Shale and Stanton Limestone. Lins (1950) described the lithology, origin, and environment of the Tonganoxie Sandstone member in its outcrop area in Douglas, Leavenworth, and Wyandotte Counties. The erosional valley trends southwestward and is 14 to 20 miles wide. The city of Lawrence overlies about the middle of the valley. According to Lins, the Tonganoxie Sandstone member contains four distinct lithologic units, which, in ascending order are conglomerate, sandstone, shale, and coal. Sanders (1957), in a study of the sandstones of the Douglas and Pedee Groups in northeastern Kansas, concluded that the ancient Tonganoxie Valley of Lins continued in a southwesterly direction from the vicinity of Lawrence for at least 70 miles and had a width of 12 to 20 miles. The general location of the deeper part of the ancient Tonganoxie Valley is shown in Figure 4.

The basal conglomerate consists of fragments of concretions derived from the Weston Shale, fragments of limestone derived from the Stanton and Iatan Limestones, reworked invertebrate fossils, plant fragments, quartz sand and silt, and cementing material. The conglomerate is thickest and best developed where the Stranger Formation is in contact with parts of the Stanton Limestone. As would be expected, the conglomerate is not present everywhere,

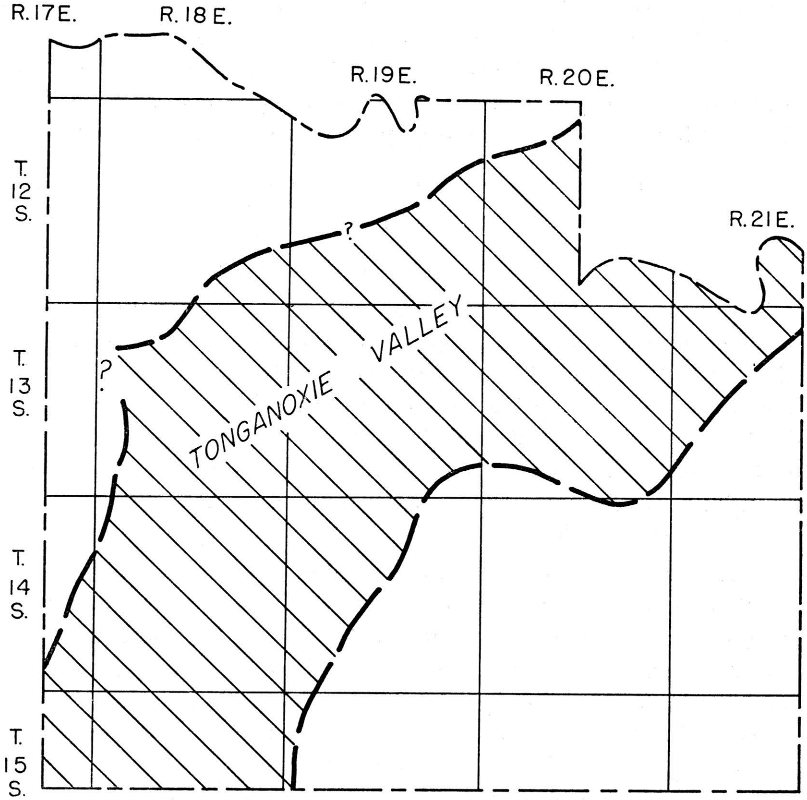

FIG. 4.—Generalized map of Douglas County showing location of ancient valley in which Tonganoxie Sandstone member of Stranger Formation was deposited.

sandstone or sandy shale being the basal deposit locally. In areas of thin Tonganoxie overlying pre-Tonganoxie hills of Weston Shale, the basal deposits of the Tonganoxie may be represented by a thin zone of subrounded to subangular shale and siltstone pebbles. A thin deposit of Tonganoxie Sandstone overlying thick Weston Shale, between which the disconformity can be recognized, is well exposed along the north side of a road cut in the SW¼ NE¼ sec. 26, T. 14 S., R. 20 E.

The Tonganoxie Sandstone member is chiefly fine to very fine (¼ to 1/16 mm) angular to subangular clear quartz, which is slightly cemented with calcite. Poorly sorted silty and shaly beds may contain as much as 20 percent of mica by volume. Festooned cross-bedded and massive sandstone (Pl. 4 *B*) is present in the lower part of the Tonganoxie Sandstone member at many places. The well-sorted channel-sandstone deposits grade laterally and vertically into thin-bedded argillaceous sandstone, siltstone, and shale, which are more micaceous and carbonaceous than the massive sandstone. The upper and middle parts of the member contain the fairly persistent Upper and Lower Sibley coals and, locally, other thin coals.

On fresh exposures the sandstone is very light gray to dark gray, the darker sand containing more carbonaceous material, the lighter sand being better sorted and cleaner. Small amounts of disseminated pyrite and iron-bearing clay minerals cause the sandstone to become stained with iron and to weather to tan or yellow brown on outcrops. The siltstone and shale beds of the Tonganoxie Sandstone member are gray to blue and weather tan to yellow brown. Ironstone and limonite concretions occur both in zones and scattered through the shaly parts of the member. Where the Westphalia Limestone member can not be recognized, the top of the Tonganoxie Sandstone member is placed at the top of the Upper Sibley coal. The thickness of the Tonganoxie ranges from 0 to about 120 feet.

Westphalia Limestone member.—The Westphalia Limestone member is a medium-gray, carbonaceous laminated limestone as much as 1.5 feet thick, but it is not continuous and hence is not present at some of the outcrops of the section of rocks in which it normally occurs. A zone of calcareous shale above the Upper Sibley coal marks its probable position where limestone is not present, however. In addition to the carbonized plant fragments found in the bedding planes, it also contains the ostracode *Jonesina howardensis* and tiny gastropods. Its position directly over the Upper Sibley coal, its faunal assemblage, and its laminated appearance make this limestone unlike other underlying and overlying limestones and very easy to identify. The bed can be observed at several localities in the drainage area of Coal Creek and is well exposed in a road cut in the NE¼ NE¼ sec. 13, T. 14 S., R. 20 E.

Vinland Shale member.—Gray clayey to sandy shale and sandstone beds, chiefly marine, ranging from about 6 to 25 feet in thickness, compose the Vinland Shale member. A zone of the pelecypod *Myalina* persists nearly everywhere in the shale and sandstone at the top of the member. Beds of sandstone in the upper part locally attain a thickness of about 12 feet. The sand is fine to very fine, slightly micaceous, and on outcrops is commonly well cemented with calcite. Beds of calcite-cemented sandstone directly underlying the Haskell Limestone member are exposed in road and creek cuts near the center of the S½ sec. 8, T. 14 S., R. 20 E. At a small quarry along the east side of a creek in the NW¼ NE¼ sec. 4, T. 15 S., R. 21 E., the equivalent beds are 10 to 15 feet of thin, irregular beds of silty and sandy limestone interbedded with limy sandstone, all of which contain a molluscan fauna. In sec. 34 and 35, T. 14 S., R. 20 E., the Vinland Shale member contains a zone of red and green shale together with a thin coal above the sandstone in the upper part of the member. Most outcrops of the Vinland are gray, tan-weathering, silty to sandy shale. Septarian concretions occur locally in the upper part.

Haskell Limestone member.—Overlying the Vinland Shale member is the gray to bluish-gray, fine-grained Haskell Limestone member, which weathers brownish gray. The lower part of the Haskell Limestone member may be silty or very sandy locally where it overlies and is gradational into beds of sandstone in the Vinland Shale member. The lower, sandy part contains abundant mollusks. Fusulinids, brachiopods, crinoids, and calcareous "Cryptozoon"-type algae are common in the upper and middle parts, and locally the upper part is oölitic. The upper surface has numerous depressions containing small phosphatic nodules. The nodules contain a fauna (Twenhofel and Dunbar, 1914) including ganoid fish skulls and brain casts, nautiloids, ammonites, and orbiculoid brachiopods. Miller and Swineford (1957) discussed the paleoecology of the nodulose zone and concluded that the nodules are genetically related to and should be included with the Haskell Limestone rather than the Robbins Shale member.

The Haskell Limestone member is well exposed in and east of the city of Lawrence between Kansas and Wakarusa Rivers, and in the Coal Creek drainage area. It is the most widespread and distinctive marker bed between the Oread and Stanton Limestones in both the subsurface and outcrop areas of the Douglas and Pedee Groups. Its thickness ranges from about 1.3 to 5 feet. In the southern part of Douglas County post-Robbins pre-Ireland erosion locally removed the Haskell Limestone member and older beds.

Robbins Shale member.—The Robbins Shale member is a gray marine clayey shale 50 to 100 feet thick in the vicinity of its type locality near Yates Center in Woodson County. In southern Douglas County the Robbins Shale member ranges in thickness from 0 to about 12 feet and is directly overlain by massive beds of the Ireland Sandstone member, which are believed to be of nonmarine origin. In the northern two-thirds of the county, the Ireland Sandstone member is not recognized and the sequence from the base of the Oread Limestone to the top of the Haskell Limestone member is chiefly silty and sandy shale. Earlier workers (Patterson, 1933; Moore, 1936, 1949; Lins, 1950; Reynolds, 1957) studying these beds in the vicinity of Lawrence concluded that nearly all the clastic beds between the Oread Limestone and the Haskell Limestone member, except for a few inches of shale directly overlying the Haskell Limestone member, should arbitrarily be included in the Lawrence Shale. This provides a practical solution for mapping also, as the top of the Haskell and the base of the Oread are contacts that can be readily mapped in the field. The top of the Haskell Limestone was mapped throughout Douglas County as the boundary between the Lawrence Shale and the Stranger Formation, and the thin Robbins Shale member in the Baldwin area has been mapped with the Lawrence Shale. Where pre-Ireland erosion removed the Haskell Limestone the base of the Ireland Sandstone is mapped as the formation boundary.

It is to be noted that Patterson (1933) collected several species of foraminifera, chiefly arenaceous types, ostracodes, and holothurian plates and spicules from the "lower Lawrence" shale beds above the Haskell Limestone member. Detailed stratigraphic and paleontologic studies of the Lawrence-Robbins shale section may reveal the presence of a considerable thickness of the marine or brackish-water Robbins Shale.

The Robbins Shale member exposed in the Baldwin area is a marine gray to blue argillaceous very thin bedded shale that weathers yellow tan. A few inches above the base is an impure goethite bed about 2 or 3 inches thick containing a molluscan fauna. Sparse marine fossils also occur in the lower part of the shale. Miller and Swineford (1957) described in detail the lower part of the Robbins Shale.

Lawrence Shale

The Lawrence Shale includes strata between the Robbins Shale member and the Oread Limestone in the southern third of Douglas County, but in the northern two-thirds, because the contact between the Robbins Shale and Lawrence Shale is indeterminate, all deposits between the Oread Limestone and the Haskell Limestone arbitrarily have been included with the Lawrence Shale. The top of the Haskell Limestone is mapped on Plate 1 as the base of the

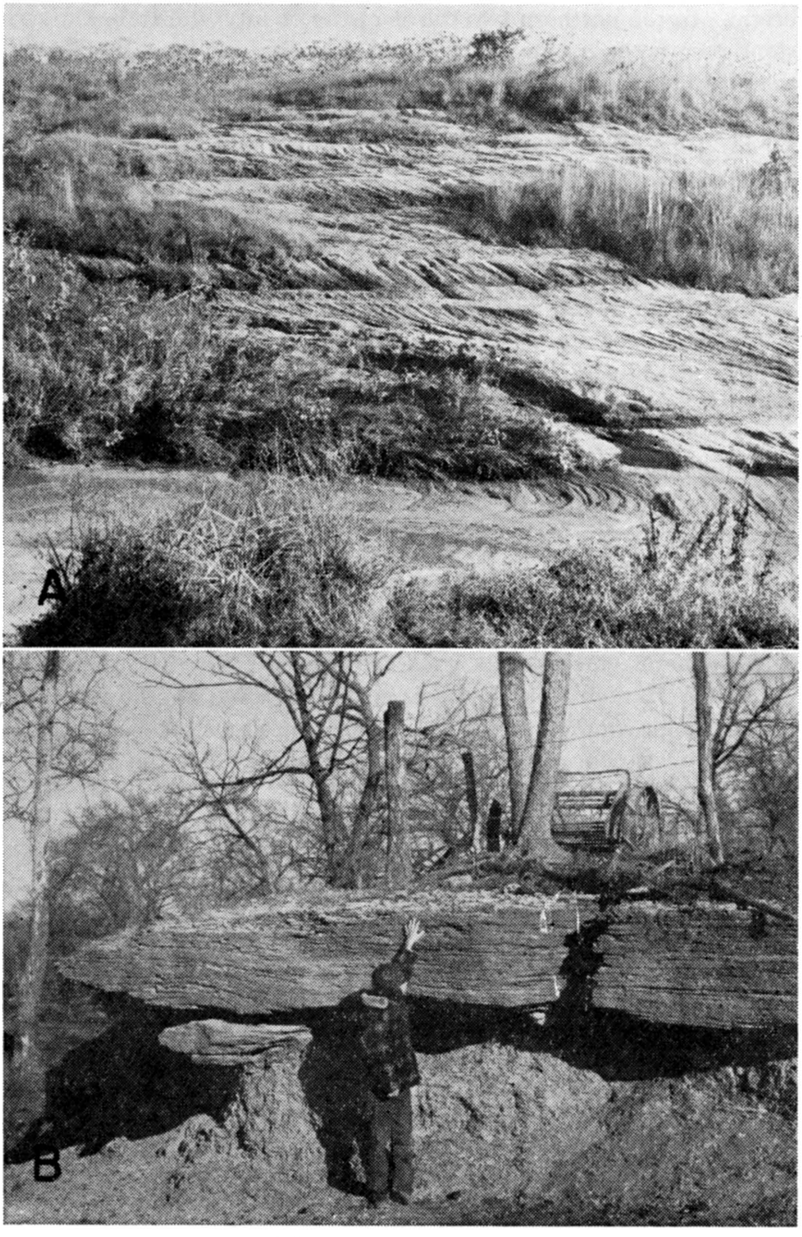

PLATE 5.—**A,** Westward-dipping foreset beds of thick Ireland Sandstone member of Lawrence Shale at "Hole in the Rock", NE¼ NW¼ sec. 2, T. 15 S., R. 19 E.; **B,** Detrital Amazonia(?) Limestone member in upper part of Lawrence Shale, center S½ SE¼ sec. 2, T. 14 S., R. 18 E.

Lawrence Shale, except where pre-Ireland erosion has cut through the Haskell, in which case the disconformity is mapped as the base of the Lawrence Shale. In areas south of the Worden fault in southern Douglas County where the Toronto Limestone member of the Oread Limestone is missing, the base of the Leavenworth Limestone is mapped as the upper boundary of the Lawrence Shale.

The Lawrence Shale contains two named members, the Ireland Sandstone and the Amazonia Limestone, and two unnamed shales. The formation commonly is 140 to 170 feet thick but locally in the area south of the Worden fault it is only 60 feet thick.

Ireland Sandstone member.—The name Ireland Sandstone member is applied to one or more beds of sandstone in the lower part of the Lawrence Shale below the Amazonia(?) Limestone. The sandstone is similar in lithology, color, composition, and texture to the Tonganoxie Sandstone except that it may be slightly coarser. In the subsurface the Ireland Sandstone is light gray where clean and well sorted, and medium or dark gray where carbonaceous material is more abundant. The direction of streamflow during deposition of the Ireland Sandstone member is indicated by the direction of inclination of foreset beds in some outcrops (Pl. 5A). The Ireland Sandstone is chiefly very fine to medium (1/16 to 1/2 mm), angular to subangular quartz containing a small percentage of mica, pyrite, and clay minerals and weathers tan or yellow brown. Thin-bedded and shaly parts of the Ireland may contain more clay and silt than sand.

The Ireland Sandstone, ranging in thickness from 0 to about 150 feet, fills a west-southwest-trending erosional valley cut into the Stranger Formation and Weston Shale in southern Douglas County (Fig. 5).

In the headwaters area of Captain Creek the relation of the Ireland Sandstone to the topography over which the sandstone was deposited can be clearly observed. In sec. 21 and 22, T. 14 S., R. 21 E., a deep channel filled with massive crossbedded sandstone and conglomerate trends nearly west along the northern part of each section. The base of the sandstone rises southward and is about 100 feet higher in the southwest corner of sec. 22 (Pl. 3, F-F′). Exposures along Captain Creek near the north side of sec. 21, T. 14 S., R. 21 E., show conglomerate at the base of the Ireland Sandstone in contact with the Weston Shale.

The Ireland Sandstone member was deposited in an ancient erosional valley about half a mile wide cut to a depth of about 100

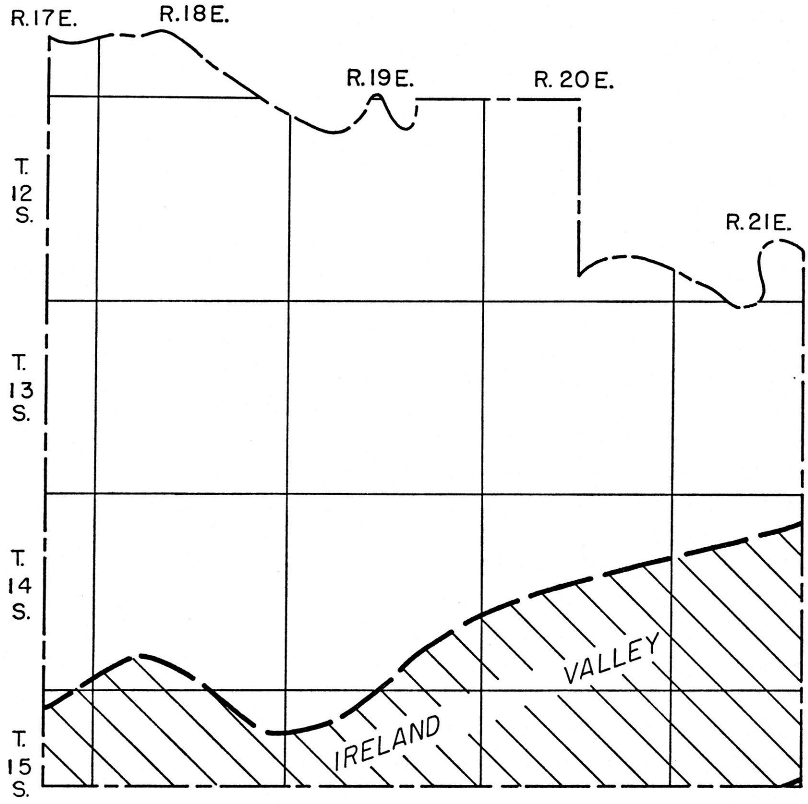

FIG. 5.—Generalized map of Douglas County showing location of ancient valley in which Ireland Sandstone member of Lawrence Shale was deposited.

feet below the Haskell Limestone in southeastern and south-central Douglas County. In an area 5 to 15 miles wide adjacent to the major channel, post-Stranger pre-Ireland erosion cut less deeply into the Stranger Formation and Weston Shale. In this wide area basal deposits of the Ireland Sandstone lie at various positions ranging from 50 feet or more below to about 12 feet above the Haskell, and in most of this area the sandstone adjacent to the principal sandstone-filled area shown in Figure 5 is about 40 feet thick. The Ireland Sandstone thins and becomes shaly in the central and northern parts of Douglas County and can not be differentiated.

Test hole 15-21-4bcc was drilled through 115 feet of Ireland Sandstone having an exceptionally thick conglomerate—nearly 46 feet—in the lower part. The base of the Ireland member is less than 30 feet above the Stanton Limestone, erosion having cut out all the Stranger Formation and most of the Weston Shale. Abundant fragments of detrital coal in the conglomerate and lower part of the sandstone must have been derived from coal beds in the Stranger Formation exposed locally as a result of post-Stranger pre-Ireland and early Ireland erosion. Rich (1932a, 1933) reported the occurrence of abundant coal fragments in the lower part of the Ireland Sandstone in Franklin County and suggested a similar source.

Amazonia(?) Limestone member.—The Amazonia(?) Limestone member is doubtfully recognized throughout most of the outcrop area. A few drillers logs indicate a thin limestone in the upper part of the Lawrence Shale, which may be the Amazonia(?) member. Locally the member may be present as an impure silty limestone or as detrital limestone. Such a detrital limestone, about 4 feet thick and containing considerable coal and shale fragments and having the appearance of a local channel filling, is well exposed near the center of the S½ SE¼ sec. 2, T. 14 S., R. 18 E. (Pl. 5B). A similar detrital limestone is present farther north in parts of adjacent Leavenworth County (Reynolds, 1957).

Where a limestone bed is not recognized the member may be represented by a zone of calichelike nodules of limestone about 20 to 45 feet below the top of the Lawrence Shale. Thickness of the member ranges from somewhat less than 1 foot to about 6 feet. Fragments of crinoids and brachiopods, small gastropods, and pelecypods are the common fossils.

Unnamed members.—Between the Ireland Sandstone and Amazonia(?) Limestone members there commonly is 5 to 20 feet of sandy and silty gray shale containing the Lower Williamsburg coal. That part of the formation between the Toronto and Amazonia(?) limestone members is chiefly shale and ranges from about 20 to 40 feet in thickness. It contains the thin Upper Williamsburg coal, best developed in the southern half of the county. This upper shale is olive, gray, and greenish gray and in many outcrops has a red or maroon zone, about 2 feet thick, 10 to 25 feet below the top. A bed of very fine grained sandstone several feet thick, partly cemented with calcite, or interbedded sandstone and siltstone occurs locally in the lower part and makes a subdued topographic bench on hillsides. The Upper Williamsburg coal, 0.5 to 1 foot thick, is present about 10 feet below the Toronto Limestone in the vicinity of Lone Star Lake.

Shawnee Group

Oread Limestone

The Oread Limestone is the lowest of the scarp-forming limestones of the Shawnee Group. Its average thickness, where all four limestone and three shale members are present, is about 60 feet. In part of southern Douglas County the Toronto Limestone member is absent, the beds between the base of the Lawrence Shale and the base of the Leavenworth Limestone are termed the Lawrence-Snyderville Shale, and the base of the Leavenworth Limestone member is mapped as the base of the Oread Limestone.

Toronto Limestone member.—The Toronto Limestone member typically is light yellow brown or light gray when fresh but on exposure becomes a deep yellow brown. Its average thickness is about 10 feet. The rock appears massive on fresh exposures, but breaks into slabby and irregular fragments upon weathering. Generally there are at least two thin partings consisting of shale or shaly limestone in the bed. Parts of the member contain abundant fossils, which weather white. Fusulinids and crinoid fragments are common, and bryozoans, horn corals, brachiopods, mollusks, and algae are locally abundant. Scattered chert nodules, weathering yellow brown, are common in the upper part in many outcrops.

Exposures of the Toronto Limestone in the area north of Baldwin, chiefly in T. 14 S., R. 20 E., are atypical and include light-gray-weathering, conglomeratic or brecciated semilithographic or thin-bedded argillaceous limestone in the lower part or locally throughout the member (Pl. 6B). Typical yellow-brown-weathering Toronto locally may be slightly sandy, whereas the light-gray semilithographic limestone appears pure but contains areas of light-greenish-gray clay and scattered pyrite nodules ½ to 1 inch in diameter.

In parts of T. 14 and 15 S., R. 20 E., the Toronto Limestone member grades from typical Toronto to brecciated and conglomeratic limestone. The Toronto Limestone member is absent as a result of nondeposition or post-depositional erosion in parts of southern Douglas County.

Snyderville Shale member.—The shale beds overlying the Toronto Limestone member are chiefly green and gray argillaceous and silty shale, claystone, and siltstone. Although the thickness of the shale averages about 10 or 15 feet, it ranges from about 0.1 foot to 45 feet. The lower and middle parts are chiefly a structureless claystone or

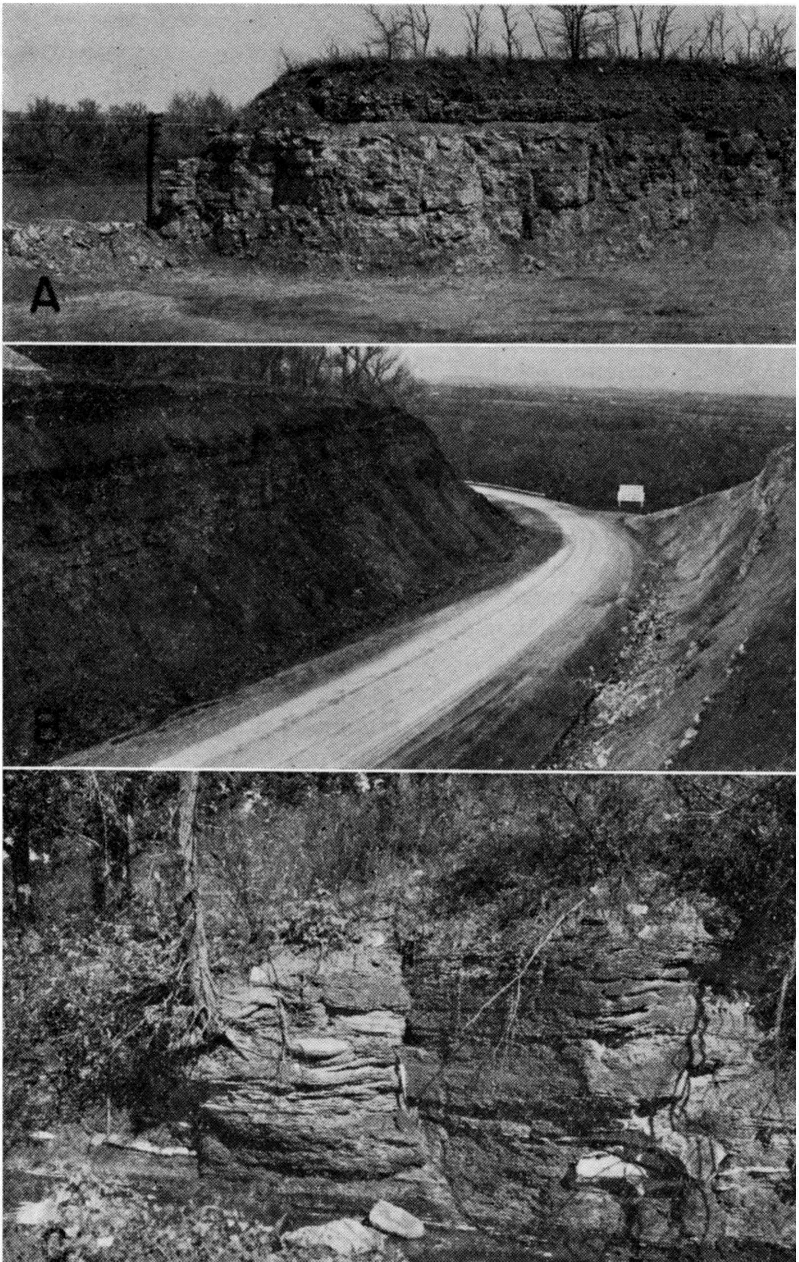

PLATE 6.—**A**, Plattsmouth Limestone, Heumader Shale, and Kereford Limestone members of Oread Limestone in quarry along Kansas river at east edge of Lecompton, NW¼ SW¼ sec. 35, T. 11 S., R. 18 E.; **B**, Lower and middle Oread Limestone showing unusually thin Snyderville Shale member and brecciated thin- to medium-bedded Toronto Limestone member below normal Heebner Shale and Leavenworth Limestone members. View north from SW¼ NW¼ sec. 27, T. 14 S., R. 20 E., Blue and Bald Mounds on horizon; **C**, Thick black fissile Heebner Shale member south of Worden fault, NW¼ NW¼ sec. 8, T. 15 S., R. 19 E. Note large calcareous concretions, which occur only in the abnormally thick black Heebner Shale. Compare with black Heebner Shale in 6B.

siltstone, which weathers into blocky irregular fragments and has the appearance of an old soil or underclay. In a small quarry in the SE¼ SW¼ sec. 20, T. 14 S., R. 20 E., this "soil" of the Snyderville seems to be particularly well developed, extending deep into the underlying Toronto. The Toronto seems to be partly leached and "rotted".

Above the structureless claystone or siltstone, in the top 2 or 3 feet of the member, locally a thin carbonaceous streak is overlain by gray calcareous and fossiliferous marine shale.

In the outlier of Oread Limestone at the northeast edge of Baldwin (sec. 34 and 35, T. 14 S., R. 20 E.) the Snyderville, about 45 feet thick, contains at its base nearly 10 feet of limestone conglomerate derived from the reworked Toronto Limestone member. In a new road cut in the SW¼ NW¼ sec. 27, T. 14 S., R. 20 E., the Snyderville is only about 1 foot thick (Pl. 6B).

To the west of Baldwin, south of the Worden fault, the base of the Snyderville cannot readily be identified, but the upper part of the Lawrence-Snyderville deposits is silty and sandy, contains 2 or 3 thin coal seams, and locally several thin molluscan limestones, which may be an expanded equivalent of the marine upper 2 or 3 feet of the Snyderville in the area north of the fault. At several exposures in the Worden area Lawrence-Snyderville beds show evidence of penecontemporaneous slumping and sliding.

Leavenworth Limestone member.—The Leavenworth Limestone member ranges in thickness from 0.8 foot to 2 feet except along and south of the Worden fault, where locally it is as much as 3.4 feet thick. It is composed of a single massive bed of hard gray-blue fine-grained limestone, which weathers light gray or creamy tan (Pl. 6B). It is brittle and breaks along closely spaced, nearly vertical joints, forming fragments having sharp edges. Many outcrops show a highly developed system of incipient vertical fractures, which cause the bed to break into sharp-edged angular fragments where it is exposed to active mechanical weathering processes.

Fossils are most abundant in the upper and lower parts and include fusulinids, crinoid and brachiopod fragments, and small cryptozoon-type algae. Small mollusks are generally abundant in the lower and upper 0.2 foot of the bed. The lower molluscan part locally weathers shaly and rusty brown.

Heebner Shale member.—The Heebner Shale is composed of about 5 to 8 feet of shale in central and northern Douglas County. The upper part is thin-bedded gray to olive shale generally containing few or no megafossils, although sparse brachiopods are present locally. The lower part consists of hard black, carbonaceous fissile shale containing conodonts and small elliptical gray-brown phosphatic concretions. The average thickness of the black fissile shale is 3 to 4 feet. In a few exposures the black shale does not lie directly on the Leavenworth Limestone but is separated from it by a few tenths of a foot of thin-bedded gray to olive shale.

In parts of south-central Douglas County south of the Worden fault the Heebner Shale is unusually thick, being about 14 to 18 feet. The sequence of lithologies is typical, except that large elliptical and elongate dense gray carbonaceous and pyritic limestone concretions are common in the black fissile shale (Pl. 6C), which may be as much as 12 feet thick compared with the average 3 or 4 feet elsewhere.

Plattsmouth Limestone member. — The Plattsmouth Limestone member, about 18 feet thick (Pl. 6A), is composed almost entirely of light-gray to nearly white wavy-bedded limestone, which weathers light gray to light tan. Scattered blue-gray chert nodules occur persistently near the middle of the bed. Thin gray shale partings between the wavy beds of limestone range in thickness from a featheredge to about 0.5 foot, but the aggregate thickness of shale beds in the member is small. The limestone, the chert, and the shale partings are fossiliferous; the fossils include fusulinids, crinoids, brachiopods, mollusks, corals, and algae. In many fossils the contained calcite is much more coarsely crystalline than that of the limestone matrix.

At several localities sinkholes have developed in and through the Plattsmouth Limestone member. These are associated with drainage changes (E½ sec. 15, T. 13 S., R. 18 E.) or with faulting or deformation of the beds (sec. 32, 33, and 36, T. 14 S., R. 19 E., and E½ sec. 12, T. 15 S., R. 18 E.).

Heumader Shale member.—In most outcrops, the Heumader Shale member is 2 to 4 feet thick (Pl. 6A), but locally it is slightly thicker. It is chiefly gray to green clayey and calcareous shale. Some exposures contain abundant fossils, chiefly brachiopods and mollusks, whereas others are seemingly unfossiliferous.

Kereford Limestone member.—The top member of the Oread Limestone consists of 2.5 to 9 feet of gray limestone and calcareous shale beds, which weather light gray to tan. In most exposures limestone composes two-thirds or more of the member, but calcareous shale beds may constitute half or slightly more of the deposits locally. Both limestone and shale beds contain abundant fossils, including fusulinids, brachiopods, horn corals, bryozoans, mollusks, crinoids, and algae. The lower limestone beds tend to be flaggy, and the upper limestone beds locally are oölitic.

Because the Kereford is relatively thin and nonresistant to weathering and is but a few feet above the escarpment-making Plattsmouth Limestone, natural exposures are not common. The Kereford is well exposed, however, in several quarries in the Plattsmouth Limestone.

Kanwaka Shale

Thickness of the Kanwaka Shale ranges from 56 to 87 feet but averages about 60 feet. The formation includes one limestone and two shale members.

Jackson Park Shale member.—The basal member of the Kanwaka consists of blue to gray silty to sandy micaceous shale, 33 to 52 feet thick, that weathers tan. Carbonized plant remains occur in the shale, and locally it contains a very thin coaly streak in the upper part. The member becomes more sandy toward the southwest and in places includes beds of very fine-grained sandstone in the lower part.

Clay Creek Limestone member.—The Clay Creek Limestone member is blue-gray, fine-grained to granular limestone, 3 to 6 feet thick, that weathers brownish gray. The lower and middle parts of the member are massive, vertically jointed limestone in fresh exposures but shelly where weathered. This part contains abundant fusulinids, brachiopods, and crinoid fragments.

The upper part consists of fossiliferous gray shale, as much as 1.2 feet thick, overlain by gray algal and molluscan fragmental limestone a few tenths of a foot thick.

Stull Shale member.—The Stull Shale member ranges from about 18 to 28 feet in thickness and comprises blue-gray clayey, silty, and sandy micaceous shale and gray very fine grained micaceous sandstone. Both shale and sandstone weather buff to tan. Sandstone in the middle and upper part of the member is as much as 11 feet thick in the north, but is much thinner or absent in the central and southern parts of the county. Carbonized plant remains are common in the shale beds and, locally, one or more very thin coals are present. The upper part of the member contains a sparse molluscan fauna in the Twin Mounds area, south of Wakarusa River.

Lecompton Limestone

The thickness of the Lecompton Limestone ranges from about 40 to 57 feet. The four limestone and three shale members that compose the formation closely resemble, in sequence and lithology, the members of the Oread Limestone.

Spring Branch Limestone member.—The Spring Branch Limestone member is the basal member of the Lecompton Limestone and is 8 to 14 feet thick. The lowest 5 feet is massive light-tan or light-gray-brown limestone in its unweathered state, but deep yellow brown where weathered, similar to the Toronto Limestone member of the Oread Limestone. This basal 5 feet is more resistant to weathering than the upper part and forms a prominent bench on hillsides. The massive bed contains chiefly crinoid and brachiopod remains in the lower 2 or 3 feet and a profusion of fusulinids in the upper part.

Overlying the resistant bench are beds of shaly limestone, shale, and limestone generally 3 to 8 feet thick. Fusulinids are plentiful in the lower 1 to 3 feet of these shaly beds. Interbedded unfossiliferous or sparsely fossiliferous beds of gray to tan shale and limestone overlain by a thin gray semilithographic, algal, or conglomeratic limestone constitute the upper part of the member.

Excellent exposures of the Spring Branch and other members of the Lecompton Limestone can be observed along the Kansas Turnpike in sec. 24, T. 12 S., R. 18 E., and in road and railroad cuts in the NW¼ sec. 36, T. 11 S., R. 17 E., just west of Grove.

Doniphan Shale member.—Dark-gray, weathering tan to brown, clayey shale 2 to 5 feet thick composes the Doniphan Shale member. Carbonized plant remains are present in the lower and middle parts and sparse mollusks in the upper part. The beds of the middle part locally contain a thin coal smut. The shale is partly thin bedded to subfissile, partly poorly bedded clay, which weathers blocky.

Big Springs Limestone member.—The Big Springs Limestone member is a dark, blue-gray dense to fine-grained limestone 2 to 3 feet thick, comparable to the Leavenworth and Rock Bluff Limestone members of other Shawnee formations. It weathers light tan, has prominent vertical joints, and locally may contain a thin shale break in the lower middle part. Fusulinids are abundant, especially in the lower part, but calcareous algae of the *Cryptozoon* and *Osagia* types, crinoids, bryozoans, brachiopods, and small mollusks also occur in the member.

Queen Hill Shale member.—The Queen Hill Shale member is 2 to 5 feet thick. The lower part is hard black fissile and subfissile shale, which is nonfossiliferous except for finely divided carbonaceous plant material and conodonts. The upper part is gray, tan-weathering, thin-bedded shale.

Beil Limestone member.—The Beil Limestone member is 9 to 10 feet thick. The lower half consists of relatively massive, somewhat irregularly bedded light-gray fossiliferous limestone. Thin irregular, featheredge shale partings also are included in this part of the member. The upper beds consist of interbedded thin nodular limestone, shaly limestone, and very calcareous shale. The entire member is abundantly fossiliferous, and the fossils weather free from the enclosing shaly matrix of the upper beds. Fusulinids, the corals *Caninia* and *Syringopora,* several species of brachiopods and bryozoans, crinoid fragments, and bellerophontid gastropods characterize the fauna. Weathered outcrops of the Beil Limestone are light gray, tan, and buff.

King Hill Shale member.—The King Hill Shale member averages 8 or 9 feet in thickness but locally may be as thin as 5 feet. It is chiefly gray, green, and yellow clayey and calcareous shale containing a persistent yellow impure "boxwork" limestone in the upper part and generally one or more thin impure limestones in the middle and lower parts. Sparse mollusks and brachiopods may occur in the top foot of the shale, but the member is almost devoid of megafossils.

Avoca Limestone member.—The uppermost member of the Lecompton Limestone is the Avoca Limestone member, which ranges in thickness from 3 to 4.5 feet. It is chiefly a dense, gray-blue massive limestone, which weathers blue gray to buff. The lower and middle part, a single massive bed, contains abundant fusulinids. Overlying this massive bed, in several exposures, is 0.1 to 0.5 foot of gray shale capped by a thin shaly, coquinoid, or algal limestone.

A fairly common feature of the upper part of the Avoca is the dark-gray somewhat fan-shaped areas containing irregular fine concentric markings, which are thought to be burrows of a worm. These worm markings are well exposed and abundant in the Avoca outcrop in the bed of Spring Creek near the center of the SE¼ SE¼ sec. 2, T. 12 S., R. 17 E.

Tecumseh Shale

Along Kansas River the Tecumseh Shale is about 65 feet thick but thins southward to about 58 feet. The lower 35 to 45 feet is chiefly gray micaceous sandy and silty shale and siltstone, which in several exposures consist of alternating light and dark varvelike laminae ranging in thickness from about 1 to 100 mm. The dark units are thinner and much more carbonaceous than the lighter colored units. Next higher is a very fine grained gray quartzose sandstone ranging in thickness from 0 to about 10 feet. Where sandstone is absent the upper beds are gray to olive sandy and silty shale. Although plant fossils are common in much of the member, marine fossils are found only in the upper few feet of shale and are rare or absent in most exposures. Locally, about 10 feet from the top of the formation the shale contains a few limy nodules or a thin irregular limestone. Weathered exposures of beds in the Tecumseh Shale range from light yellow gray to tan.

Deer Creek Limestone

The Deer Creek Limestone is divided into three limestone and two shale members having an aggregate thickness of about 34 feet. Generally the formation is slightly thinner in outcrops in Douglas County than in adjacent Osage, Shawnee, and Jefferson Counties.

Ozawkie Limestone member.—The basal member of the Deer Creek Limestone directly overlies the thick Tecumseh Shale and ranges from about 5 to 11 feet in thickness. The lower part typically is a massive, gray, brown-weathering limestone containing abundant fusulinids and *Osagia.* Upper beds are massive light-gray to buff earthy, impure molluscan limestone, which weathers to various shades of yellow or brown. Although the limestone is massive, it commonly weathers into irregular shelly chips. Locally, as along the Kansas Turnpike in the NW¼ sec. 22, T. 12 S., R. 18 E., the upper and lower beds are shaly unfossiliferous limestone and the middle beds are chiefly massive light-gray oölitic limestone.

Oskaloosa Shale member.—The thin Oskaloosa Shale member overlies the Ozawkie Limestone member and ranges from about 3 to 5 feet in thickness in outcrops. The member is thin-bedded shale and blocky clay. It is gray to greenish on fresh exposures but drab yellow when weathered. Fossils are rare or absent in most exposures.

Rock Bluff Limestone member.—The Rock Bluff Limestone member in the Deer Creek megacyclothem is analogous to the Big Springs and Leavenworth Limestone members of the Lecompton and Oread megacyclothems, respectively, and is a persistent and distinctive part of the formation. It is a single bed of hard, dense to fine-grained dark-blue-gray limestone, which is about 2 feet thick and has prominent vertical joints. It weathers light gray tan to gray brown. Fusulinids, brachiopods, crinoid fragments, and small mollusks are the common fossils found in it.

Larsh-Burroak Shale member.—Black, slaty, and fissile shale about 0.5 foot to 2.0 feet thick forms the basal part of the Larsh-Burroak Shale except in some places where it is separated from the underlying Rock Bluff Limestone by 0.1 foot or less of brown clayey shale. The upper beds are dark- to light-gray thin-bedded shale. Recognizable fossils are scarce but there are conodonts and fish remains in the black shale, and sparse specimens of the brachiopods *Crurithyris* and *Orbiculoidea* may be found in the dark-gray shale.

The Larsh-Burroak member ranges from about 2.5 to 5.0 feet in thickness and commonly is about 3 feet thick.

Ervine Creek Limestone member.—The Ervine Creek Limestone member ranges from about 13 to 17 feet and averages about 15 feet in thickness. The basal part, about 10 to 14 feet thick, is light-gray to white hard thin, wavy-bedded limestone containing several thin gray shale partings. The limestone is dense to finely crystalline, but contains irregularly distributed veinlets and fossil replacements of coarsely crystalline clear calcite. Fusulinids, brachiopods, crinoids, and echinoid and bryozoan fragments are common, and mollusks, corals, and sponges also may be found in the bed. Sparse chert nodules occur near the middle.

A thin, medium- to dark-gray shale about 1 foot thick overlies the wavy-bedded limestone locally and is overlain by about 3 feet of gray argillaceous and coquinoid limestone containing a molluscan fauna and the brachiopods *Derbyia* and *Linoproductus*. These upper few feet of shale and limestone tend to weather more rapidly and are not well exposed in most natural outcrops.

Calhoun Shale

In the vicinity of Big Springs the Calhoun Shale is about 60 to 68 feet thick. It is chiefly silty and sandy partly laminated carbonaceous gray shale containing a very thin carbonaceous bed or coal bed 1 to 2 feet from the top. An intraformational channel sandstone trending south and west through the town of Big Springs is well exposed in cuts on U. S. Highway 40 in the SW¼ sec. 11, T. 12 S., R. 17 E. About 30 feet of gray fine to very fine grained (¼ to 1/16 mm) crossbedded micaceous, quartzose sandstone can be observed in the upper and middle parts of the formation in cuts along Kansas Turnpike in the SE¼ sec. 11, T. 12 S., R. 17 E. Both the shale and the sandstone contain plant remains, and a few pelecypods were found at the top of the formation. The shale and sandstone weather yellow brown to tan.

Topeka Limestone

The Topeka Limestone is the youngest Pennsylvanian formation exposed in Douglas County and it is exposed only in the vicinity of Big Springs. Only the lower part of the formation is present in Douglas County.

Hartford Limestone member.—The Hartford Limestone member is 6 to 8 feet thick and consists of two limestone beds separated by a thin shale bed just below the middle of the member.

The limestones are light gray but readily weather to a deep yellow brown. The lower part is abundantly fossiliferous, containing fusulinids, crinoids, bryozoans, brachiopods, *Cryptozoon,* and gastropods. The upper part contains chiefly large gastropods, productid brachiopods, the brachiopod *Derbyia,* and algae. The upper part locally has a semioölitic texture, and the top surface may be very uneven. The thin middle shaly part is limy and fossiliferous.

Iowa Point Shale member.—Gray, tan-weathering thin-bedded calcareous shale averaging 2 to 3 feet in thickness is correlated with the Iowa Point Shale. Although not as fossiliferous as adjacent limestone beds, it commonly contains fusulinids, brachiopods, and bryozoans.

Curzon Limestone member.—Interbedded massive to thin-bedded limestone and thin-bedded calcareous shale having a thickness of about 12 feet compose the Curzon Limestone member. The limestone and shale beds are light to medium gray in unweathered exposures, but where weathered are yellow brown. Fossils are abundant and include crinoids, echinoids, horn corals, fusulinids, and several species of brachiopods and bryozoans.

Jones Point Shale member.—The youngest beds of the Topeka Limestone exposed are beds of gray shale that overlie the Curzon Limestone member and probably represent part of the Jones Point Shale member. The exposed thickness of this member is about 1 foot.

Quaternary System—Pleistocene Series

Pre-Kansan Deposits

Leached and oxidized gravel consisting chiefly of chert pebbles ¼-inch to 2 inches in diameter in a reddish sandy clay matrix is exposed at several places east and south of Lawrence and in the vicinity of Eudora. Although the gravel deposits consist chiefly of chert pebbles, all exposures examined contain erratics or rocks foreign to the pre-Pleistocene bedrock of the drainage system. Chert gravels are exposed in road cuts along Kansas Highway 10 in the SW¼ sec. 4, NE¼ sec. 9, and NW¼ sec. 10, in T. 13 S., R. 20 E.; in pasture land west of Haskell Institute in the NW¼ sec. 7, T. 13 S., R. 20 E.; and south of Wakarusa River along Haskell Avenue in the SE¼ sec. 19, T. 13 S., R. 20 E. These chert gravels rest on Pennsylvanian bedrock at altitudes of 880 to 900 feet. Erratics make up a significant part of the gravel, ranging from about 1 percent to perhaps 40 percent locally. The extensive distribution of chert gravel at this altitude indicates that these bodies are remnants of deposits of a stream that flowed at this level prior to invasion of the area by the Kansan glacier. Chert gravels containing more than a very small percentage of erratics are judged to have been reworked by the Kansan glacier and glacial melt water.

Chert gravel containing very sparse erratics and overlain by red Kansan water-laid silts rests on Pennsylvanian shale at an altitude of about 840 feet about 100 feet south of Kansas Highway 10, in the NE cor. sec. 7, T. 13 S., R. 21 E., near Eudora. Chert gravels containing numerous erratics overlie the Stanton Limestone at an altitude of about 850 feet and are overlain by Kansan silts and sands at the eastern boundary of the county along Kansas Highway 10.

The leached and oxidized condition of these gravels, their topographic position, and their position below Kansan drift indicate that they are probably early Pleistocene in age. Chert-gravel deposits containing few or no erratics and lying at altitudes of 930 to 950 feet along the north bluff of Kansas River in Leavenworth County in sec. 19, 20, and 29, T. 12 S., R. 21 E., may be of early Pleistocene or late Tertiary age.

As outwash from the Nebraskan glacier has not been conclusively demonstrated to have been discharged into the Kansas River drainage system (Frye and Walters, 1950; Frye and Leonard, 1952), the chert-gravel deposits containing only very small amounts of erratics probably represent late Tertiary stream deposits or early Kansan or

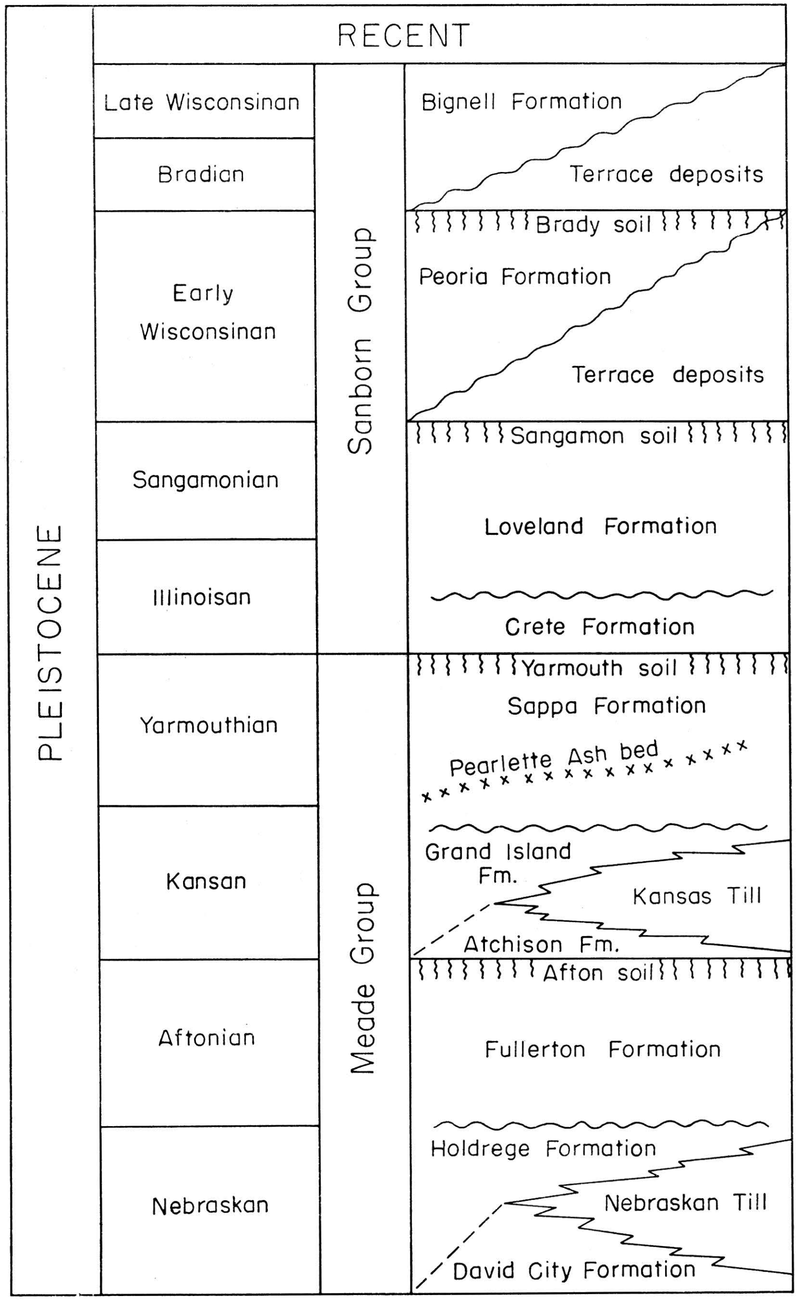

FIG. 6.—General classification of Kansas Pleistocene deposits.

Nebraskan deposits that were only slightly contaminated with northern erratics by Kansan proglacial streams. Chert-gravel deposits, previously cited, which are found south of Wakarusa River, containing more than very small amounts of erratics are judged to have been modified by outwash associated with the Kansan glacier or by glacial ice.

No uncontaminated chert-gravel deposits large enough to map and clearly older than Kansan were observed by the writer, and none are shown on Plate 1.

Kansan Stage

Deposits of Kansan age include lacustrine, fluvial, and glacial sediments. They are complex and have a greater vertical distribution in the topography than other Pleistocene deposits, chiefly because of the advance and retreat of a continental ice sheet into and from the area.

Drainage systems were disrupted and in particular the Kansas River system was greatly enlarged.

The general classification of Kansan and other Pleistocene deposits used in Kansas is shown in Figure 6.

Pro-Kansan outwash deposits are defined as the Atchison Formation, and where overlain by Kansas Till they can be readily identified. The Atchison Formation is not recognized outside the glaciated area. Retreatal-Kansan outwash deposits comprise the Grand Island and Sappa Formations. The Grand Island Formation consists chiefly of coarse gravel and sand, which locally interfinger with Kansas Till. The Sappa Formation, consisting chiefly of silt, conformably and gradationally overlies the Grand Island Formation and represents deposits formed during the later phase of glacial retreat. Outwash in this area is judged to be associated with the retreatal phase of glaciation, although locally, stratified Kansan deposits cannot clearly be identified as pro-Kansan or retreatal-Kansan in the terminal area.

Kansas Till

Areas mapped as Kansas Till (Qkt) on Plate 1 include sediments that were probably deposited directly from glacial ice. The till is dominantly unstratified and unsorted. Most of the till in the upland between Kansas River and Wakarusa River is clay and probably accumulated by lodgment from the base of the ice. Such deposits are well exposed along U. S. Highway 40 in the NE cor. sec. 26, T. 12 S., R. 18 E., and in pasture ditches in the SW¼ sec. 2, T. 13 S.,

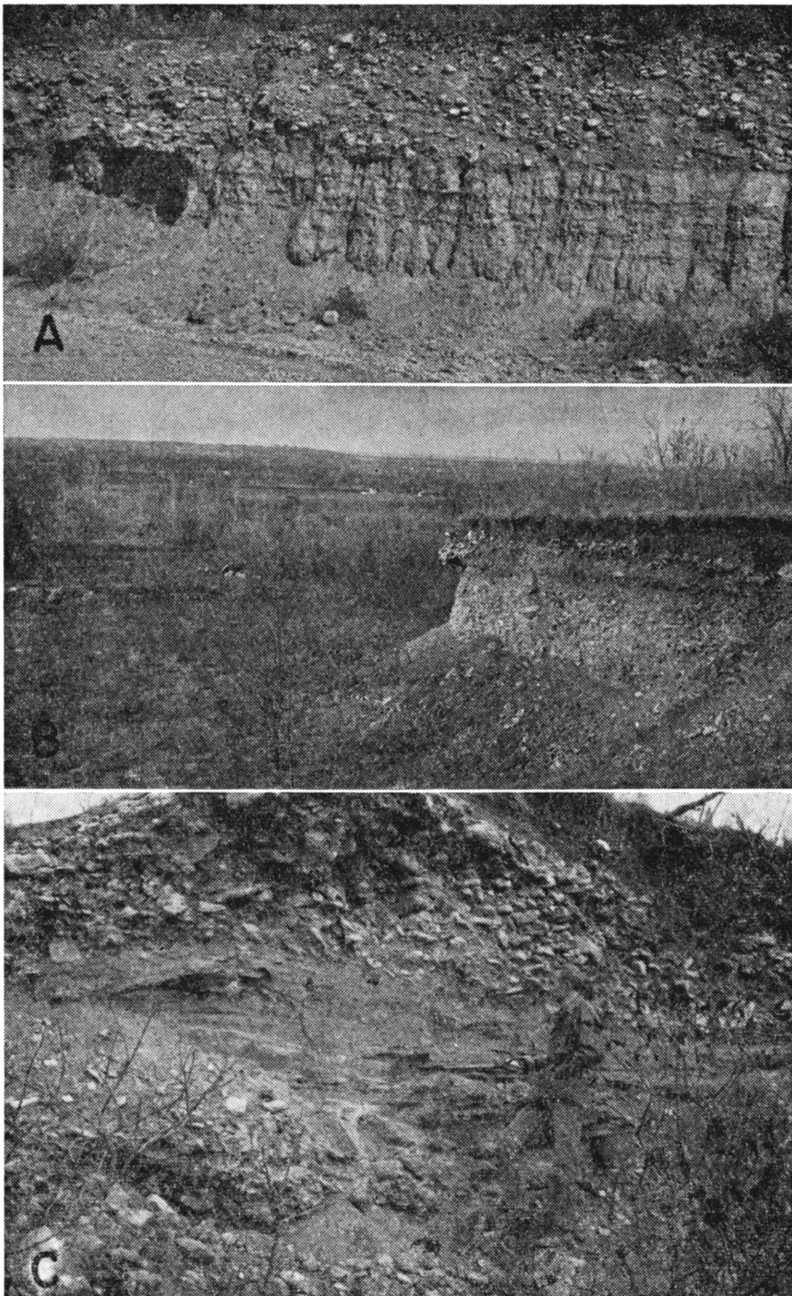

PLATE 7.—**A**, Kansas Till overlying varved lacustrine beds of Atchison Formation, SW¼ SW¼ sec. 2, T. 13 S., R. 19 E.; **B**, Coarse Kansan gravels capping Shank Hill in the Wakarusa River valley, NE¼ SE¼ sec. 26, T. 13 S., R. 19 E.; **C**, Closeup view of coarse, poorly sorted Kansan deposits capping Shank Hill.

R. 17 E. Other till deposits accumulated by dumping or being let down by slow wastage of the ice (superglacial ablation moraine). Such till is characterized by less clay and silt in proportion to gravel and sand, having been repeatedly washed by trickles of melt water during melting of the glacial ice. Southwest of Lawrence one such till deposit (Pl. 7A) overlying undisturbed lacustrine silt is well exposed in the SW cor. sec. 2, T. 13 S., R. 19 E. Locally, small bodies of stratified sand and gravel occur in the till in high upland positions, as in the NW¼ SE¼ sec. 24, T. 12 S., R. 18 E. All gradations between unstratified and unsorted till containing much clay to well-stratified and sorted glacial sands and gravels may be found in the area, and in many places where exposures are poor or lacking it is difficult to determine whether a deposit should be classed as till or as associated sorted and stratified glacial deposits (Atchison, Grand Island, and Sappa Formations).

Undoubtedly there are small areas of thin till that are not shown on Plate 1 because the deposits were too poorly exposed to be identified and delineated.

Kansan Glaciofluvial and Glaciolacustrine Deposits

Glaciofluvial and glaciolacustrine deposits (Atchison, Grand Island, and Sappa Formations) associated with the Kansan glacier are abundant and occur in high, intermediate, and low topographic positions in northern Douglas County. These deposits, mapped on Plate 1 as Qko, include the Atchison, Grand Island, and Sappa Formations and locally some till, but are mostly Grand Island and Sappa Formations. The predominance of stratified deposits rather than till in the terminal area of the glacier indicates that the Kansan glacier at its climax may have been a slowly flowing, rapidly melting ice mass. Much of the sediment carried by glacial ice, which originally may have been deposited as till or moraine, was subsequently modified by glacial melt water to produce stratified glacial deposits.

At its maximum extent the glacier probably occupied both the Kansas and the Wakarusa River valleys and the intervening divide, as indicated by scattered deposits of till on the divide between these rivers and by the presence of stratified gravels containing erratics at several high points in the topography south of Wakarusa River. Todd (1909) in discussing the history of Wakarusa River also noted and discussed the distribution and features of Kansan deposits in Douglas County. Schoewe (1930, fig. 1) depicted the maximum extent of the ice sheet in Douglas County. Where these stratified gravels are well exposed, as at Shank Hill in the SE¼ sec. 26, T. 13 S., R. 19 E., (Pl. 7B, C) and in several road cuts, they consist of poorly sorted sand and gravel ranging in thickness from about 2 feet to 30 feet. The thin deposits are leached and consist chiefly of chert, quartz, and igneous and metamorphic rocks from the north. The igneous and metamorphic rocks include pink and red Precambrian Sioux Quartzite derived from outcrops in southwestern Minnesota, northwestern Iowa, or southeastern South Dakota. Sioux Quartzite is the most distinctive of the northern rock types. Greenstone and gray granite from outcrops in northern Minnesota and western Ontario are common also. The thicker deposits are leached only in the upper part and contain chiefly limestone and other local rock types. A series of these deposits may be traced from the area southwest of Clinton eastward and southward across the county to a point near Clearfield, thence eastward into Johnson County, as follows: NW cor. sec. 33, T. 13 S., R. 18 E. (altitude 1,020 ft.), SE¼ sec. 34, T. 13 S., R. 18 E., and NE¼ sec. 3, T. 14 S., R. 18 E. (±1,070 ft.), N½ sec 30, T. 13 S., R. 19 E. (±1,030 ft.), SE¼ sec. 26, T. 13 S., R. 19 E. (1,007 ft.); a series of irregular, narrow linear and knob hills in sec. 29 and 30, T. 13 S., R. 20 E. (900 to 950 ft.); and a series of irregular, narrow linear and knob hills trending directly southeast from the SE¼ NE¼ sec. 33, T. 13 S., R. 20 E., to the center of the north side of sec. 17, T. 14 S., R. 21 E. (900 to 1,010 ft.). These gravels, judged from their areal distribution, topographic position, form, structure, size, and degree of sorting, are unquestionably ice-contact deposits laid down in and along the margin of the ice. Probably a series of streams locally flowed on Pennsylvanian bedrock along the glacier front. Streams also flowed in marginal crevasses on or within the ice to form stratified drift. Many short-lived marginal lakes were formed in blocked northward-flowing tributaries of Kansas River and Wakarusa River during the maximum advance of the glacier.

As the glacier became stagnant or nearly stagnant, marginal and superglacial streams were gradually replaced by englacial and subglacial streams flowing at lower altitudes. A glacial stream entered Douglas County along the west boundary in sec. 23, T. 17 S., R. 13 E., and flowed generally eastward for about 4 miles along the north side of the present Wakarusa River. The deposits of this stream now form a ridge of gravel, sand, and silt 30 to 40 feet thick locally and having a crest altitude of about 990 feet. Along parts of the stream course, erosion has reduced the ridge to a boulder belt only a few feet thick. To the east these deposits are found in a belt ½ to 1 mile wide trending eastward through Clinton at an altitude of ± 960 feet as a filled abandoned valley (B-B′, Pl. 3). South of Lawrence in sec. 11 and 12, T. 13 S., R. 19 E., these deposits form a prominent ridge having a crest altitude of slightly more than 900 feet (E-E′, Pl. 3). The lower and middle parts of the deposit forming this ridge are composed of boulders, gravel, and sand; the deposit becomes finer upward, as indicated by logs of test holes and water wells. Locally the gravels are chiefly chert, but abundant limestone boulders and erratics from the north are common also. Road cuts along U. S. Highway 59 have exposed unstratified bouldery and gravelly clay (till) at the top of the deposits. The distribution, topographic position, structure, and lithology of Kansan deposits probably result from the following sequence of events. During Nebraskan and early Kansan time prior to the advance of the Kansan glacier south of Kansas River, an east-flowing stream occupied the Wakarusa Valley and deposited chert and limestone gravels. During early Kansan time the stream probably entrenched itself, and for a short time proglacial melt water flowed down the valley, contributing small numbers of erratics to the chert and limestone gravel before being overridden by the glacier. As the glacier became nearly stagnant and the volume of melt water increased, a subglacial stream became re-established in much of the preglacial Wakarusa Valley. Much of the coarse rock material carried by the ice became stream load as the nearly stagnant ice melted, and the stream bed was alluviated. Subsequently, as the glacier continued to dissipate, a major glacial stream became established in the Kansas River valley, perhaps capturing much of the drainage system of Wakarusa River. Locally, till was deposited on glacial-stream gravel in parts of the Wakarusa Valley. The presence of till on outwash gravels may indicate minor readvances of the ice near its margin in the Wakarusa Valley. Till and fluvial deposits are recognized also southeast of Lawrence on the upland area along the divide between the Kansas and Wakarusa River valleys. Probably they have an interfingering and complex relationship similar to that of described deposits in sec. 11 and 12, T. 13 S., R. 19 E. Schoewe (1930b, p. 72), studying excavations in glacial deposits in the NW¼ NE¼ sec. 7, T. 13 S., R. 20 E., at Haskell Indian Institute, recognized two tills, the slightly different lithologies of which probably resulted from minor fluctuations of the Kansan glacier. Subsequent Pleistocene studies in northeastern Kansas indicate that only the Kansan glacier reached as far south as the Wakarusa Valley.

Lacustrine deposits of silt and sand deposited in temporary lakes resulted from derangement of early Kansan drainage by glacial ice and glacial deposits at the climax of Kansan glaciation. One such varved lacustrine deposit exposed on the west side of a small nob hill in the SW cor. sec. 2, T. 13 S., R. 19 E., (Pl. 7A) is at least 7 feet thick, and consists of 24 or more pairs of alternating thin dark-brown and thicker light-gray beds of silt and sand overlain by about 6 feet of unstratified and unsorted limestone gravel. The limestone gravel overlying the lake silt has many of the characteristics of superglacial till. Another varved lacustrine deposit is partly exposed at the base of a road cut 500 to 700 feet north of the SE cor. sec. 8, T. 14 S., R. 21 E. About 2 feet of alternating thin red-brown and thicker gray beds of silt and sand consisting of at least 8 varves is overlain by 1 to 2 feet of very fine red-brown sand and 3 to 10 feet of slightly bedded till. The till consists chiefly of sand, gravel, and cobble-size fragments of red-brown sandstone. Just north of the map area another pro-Kansas lacustrine deposit consisting of at least 22 feet of tan and gray laminated silt and sand overlain by Kansas Till is well exposed along Kansas Highway 32 in the SW¼ sec. 14 and NW¼ sec. 23, T. 12 S., R. 20 E., Leavenworth County.

Although temporary proglacial lakes must have been formed at many places as a result of blockage of Wakarusa and Kansas Rivers and their tributaries by the advancing Kansan glacier, exposures of lacustrine deposits are rare. The lacustrine deposits in general probably were thin and may have been incorporated in or destroyed by the advancing glacier. Where these lacustrine deposits were not capped by a protective cover of till or gravel, they probably were destroyed by erosion subsequent to the retreat of the ice.

The most extensive area of Kansan glaciofluvial and glaciolacustrine deposits in Douglas County is in the Hesper area south of Eudora and east of Little Wakarusa Creek and extends eastward to Kill Creek in Johnson County. This 50-square-mile area, south of Kansas River, is covered with glacial drift except where post-Kansan streams have cut through the deposits into underlying Pennsylvanian rocks. Schoewe (1930a) and Hoover (1936) regarded Kansan deposits in the Hesper area as reworked till. Dufford (1958), working in the area north of Hesper, classed the same deposits as part of the Menoken Terrace deposits, chiefly retreatal-Kansan outwash. In this study it was found that both outwash and till are included.

The early Kansan topography in the Eudora-Hesper area was a lowland, developed on the soft shales and sandstones of the Pedee and Douglas Groups, flanked by higher limestone cuestas both to the east and west. As the composition of till strongly reflects the character of the bedrock exposed upstream, it would be expected that sand, silt, and clay of local derivation would characterize any till or reworked till deposits in the area. The southernmost deposits of till in Douglas County are in this area (sec. 17, T. 14 S., R. 21 E.), indicating that the glacier must have overridden most of the area north of section 17 at its maximum extent. Many of these Kansan deposits are partly stratified. Basal deposits commonly are gravel or sand and locally are well sorted and clean but elsewhere are clayey and poorly sorted. Clayey and silty sand, or sandy clay, containing scattered gravel and cobbles, compose the upper part of these Kansan deposits in much of the area south of Eudora. Such a sequence is not everywhere present, because locally the deposits consist of unstratified sandy and gravelly silt and clay.

Kansas River has a surface altitude of about 780 feet and the surface of the Kansas River alluvium is at an altitude of about 800 feet in the vicinity of the north end of cross section F-F′ (Pl. 3) just east of Eudora. Kansan deposits along the south bluff have surface and base altitudes of about 885 and 855 feet, respectively. Southward, the surface and base of these Kansan deposits rise gently about 100 feet in a distance of about 7½ miles, forming a gently north sloping plain (Pl. 8A). This gently sloping plain is the principal geomorphic feature of the area, but locally there are smaller geomorphic features that are conspicuous. One such feature is a prominent northeastward-trending ridge 20 to 30 feet high and about 1½ miles long, which crosses the east county boundary into Johnson County (sec. 26, 27, and 34, T. 13 S., R. 21 E.). An auger hole along the crest of the ridge at an altitude of about 941 feet, and less than ¼ mile into Johnson County, penetrated 52 feet of sandy clay and sand. Adjacent to the ridge on the northwest is a series of small, obscure roughly symmetrical mounds. Although the origin of these features is uncertain, they may be depositional features associated with the wasting phase of the glacier.

Because of the various features of Kansan deposits south of Eudora, there seems to be no sharp dividing line between till and stratified drift; rather, one grades into and interfingers with the other. Most of the sediments are judged to have been deposited prior to the retreat of the Kansan glacier to a position north of Kansas River, and many of the stratified deposits are time equiv-

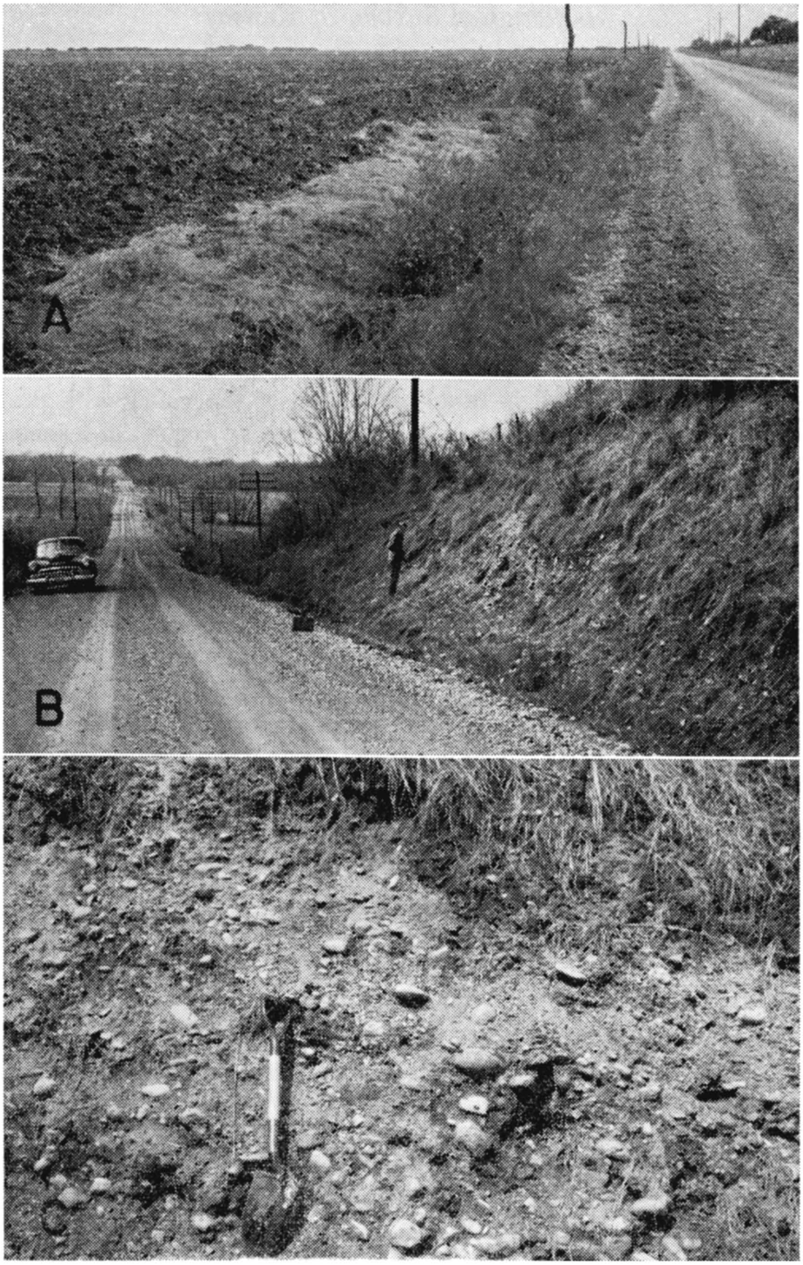

PLATE 8.—**A,** Part of extensive plain in Hesper area developed on Kansan glaciofluvial deposits. View south from near center W. side NE¼ sec. 27, T. 13 S., R. 21 E.; **B,** Toe of Menoken Terrace along north side of Kansas River valley, S. side SW¼ SW¼ sec. 9, T. 12 S., R. 20 E. Terrace-shale contact about at position of automobile. Newman Terrace surface in background; **C,** Poorly sorted Grand Island gravel and sand in basal Menoken Terrace deposits exposed just right of center in 8B.

alents of and related to the stratified deposits found in the Wakarusa River valley. The Grand Island and Sappa Formations compose the bulk of the deposits.

When the Kansan glacier retreated north of the Kansas River valley, large volumes of melt water discharged coarse, poorly sorted gravels (Pl. 8B, C) into the valley—the principal ice-marginal stream in the area—forming deposits 20 feet thick or more, which locally along the north side of the valley interfinger with Kansas Till (Davis and Carlson, 1952). The river gravels are nearly identical with gravel in the till. Dissipation and northward retreat of the glacier resulted in rapid alluviation of the valley with progressively finer sediments. At places, more than 60 feet of leached and oxidized reddish-brown sand, silt, and clay make up the upper part of this alluvial fill.

Most of the retreatal-Kansan deposits that filled the Kansas River valley have been removed by post-Kansan erosion, but remnants in the form of terrace deposits occupy an area of about 3 square miles along the south side of the Kansas River valley between Lawrence and Lakeview and a similar area on the north side of the valley. These Kansan terrace deposits are deeply dissected and have only approximately accordant summits ranging in altitude from about 890 to 930 feet. The combined areas have been named the Menoken Terrace (Davis and Carlson, 1952), and retreatal Kansan deposits (Grand Island and Sappa Formations) have been mapped as Menoken Terrace deposits in parts of the Kansas River valley (Davis and Carlson, 1952; Dufford, 1958; Beck, 1959). The name Menoken Terrace is used only as a geomorphic term in this report for a terrace on sediments of Kansan age in the Kansas River valley

Illinoisan Stage

During the Illinoisan Stage, continental glaciers were more remote from Kansas than during other Pleistocene stages. Indirect effects were the erosion of much of the previously deposited Kansan deposits in the Kansas River valley and its tributaries and the entrenchment of the river to a depth of 50 to 60 feet below basal Kansan deposits (E-E′, Pl. 3). Then followed aggradation of the valley to a depth locally of 70 feet or more. Minor amounts of loess were deposited on uplands adjacent to the Kansas River valley.

Deposits of Buck Creek Terrace

An alluvial fill deposited in late Illinoisan time and subsequently dissected has been named the Buck Creek Terrace deposits (Davis and Carlson, 1952) and is mapped as Qtbc on Plate 1. Crete and

Loveland Formations are names applied to the coarse basal deposits and the fine upper part, respectively. Crete sand and gravel is thin, generally less than 10 feet, although one test hole (13-20-20bc) penetrated 28 feet of silty and clayey sand. The Loveland Formation constitutes most of the terrace fill and is at least 62 feet thick locally (test hole 13-19-13bcc). The Loveland Formation is chiefly reddish or tan silt, sandy silt, and clay and is gradational into the underlying Crete.

In addition to water-laid deposits in the Buck Creek Terrace, the Loveland Formation contains thin eolian deposits (loess) locally. Loveland loess is generally less than 5 feet thick and is restricted to the bluffs bordering the Kansas River valley. This loess was not mapped.

The Sangamon soil, which is well developed on Buck Creek Terrace deposits, is characterized by its reddish color and thick clayey B horizon.

Wisconsinan and Recent Stages

The Newman Terrace deposits and alluvium were deposited in the valleys during Wisconsinan and Recent time, and thin loess of the Peoria Formation was deposited locally on the uplands. The Wisconsinan glaciers, although never nearer Kansas than southern Iowa, discharged large volumes of melt water into the Missouri River valley. Associated climatic changes indirectly resulted in a period of downcutting followed by aggradation of streams in this area.

Peoria Formation

The Peoria Formation, of early Wisconsinan age, is composed of thin, discontinuous light-gray to tan eolian silt deposits on the uplands in this area. The formation is thickest along bluffs of the Kansas River valley, where locally it is 5 to 10 feet thick, but elsewhere in the area it is generally less than 5 feet thick. Because of the small extent of areas in which loess of the Peoria Formation is more than 5 feet thick and because of the difficulty of identifying and delimiting these areas, owing to the vegetative cover, the loess is not shown on Plate 1. It is well exposed and has a thickness of 5 feet or more along the Kansas Turnpike in sec. 18, T. 12 S., R. 18 E., and in the west face of the quarry in the NE¼ sec. 4, T. 13 S., R. 21 E. It is 5 feet thick in test hole 13-20-5cb where it overlies thin Loveland Formation and Kansas Till.

Deposits of Newman Terrace

The cycle of erosion and alluviation initiated in early Wisconsinan time resulted in deepening the bedrock floor of the Kansas and Wakarusa River valleys 20 to 50 feet below the basal Illinoisan deposits. The terrace underlain by these early Wisconsinan deposits is the Newman Terrace, generally 30 to 40 feet below the Buck Creek Terrace in the Kansas and Wakarusa River valleys.

The basal Newman Terrace deposits in the Kansas River valley consist chiefly of gravel, which is much coarser than sediments now being carried by Kansas River (Wyman, 1935; Davis and Carlson, 1952). The sediments grade upward from cobbles through sand to a clayey silt at the surface. In the Kansas River valley, where the Newman Terrace deposits are thickest, coarse sediments 40 to 50 feet thick are overlain by a similar thickness of dark sandy, silty, and clayey sediments. In the Wakarusa River valley the coarse sediments generally are less than 10 feet thick and the valley fill is composed chiefly of silt and clay (E-E′, Pl. 3). The basal part of the Newman Terrace deposits is not exposed anywhere in the area and has not been dated on the basis of fossils. Its erosional position below Illinoisan Terrace deposits and its stratigraphic position below deposits of late Wisconsinan to Recent age that form the upper part of the alluvial fill indicate that its age is early Wisconsinan.

The Newman Terrace typically is a flat, poorly drained surface bordered by low natural levees. Unlike the topographically lower surface of the alluvium, it is not marked by old meander scars but is nearly featureless, and requires artificial drainage in many areas to allow cultivation. The upper 40 feet of deposits underlying the Newman Terrace are similar to sediments transported by Kansas River at the present time (Davis and Carlson, 1952, p. 229).

The Newman Terrace and alluvium together constitute the Kansas River flood plain. Slightly less than half the flood plain in the area from Eudora westward to Topeka, where the valley is wide, is the Newman Terrace. Eastward from Eudora to Kansas City the valley narrows where it is cut in rocks of the Lansing and Kansas City Groups, and the Newman Terrace, preserved only locally, forms less than 10 percent of the flood plain. In the Wakarusa River valley and many of the smaller tributaries to Kansas River, the Newman Terrace forms 90 percent or more of the flood plain. The Newman Terrace is about 20 feet above the average low-water stream level along Kansas River and much of Wakarusa River. The terrace surface is still being raised by slight vertical accretion each time it is covered by floodwaters. Studies by Davis and Carlson (1952) indicate that the 1951 flood added an average of about 5 mm of silt and silty clay to the Newman Terrace in the Kansas River valley. Ordinary floods cover the Newman Terrace in the Wakarusa River valley to depths of a few inches to a few feet, but only severe floods cover this terrace in the Kansas River valley and then may inundate only parts of the terrace, natural levees and high points on the terrace remaining above flood level.

Alluvial fills in tributaries to Marais des Cygnes River in southern Douglas County have not been firmly correlated with those of Kansas River. The alluvial fills forming the flood plains of these tributaries seem to correspond to the Newman Terrace and alluvium of Kansas River and its tributaries, however. Undifferentiated alluvial deposits, chiefly Wisconsinan and Recent in age but locally including Illinoisan deposits, in small tributaries to Marais des Cygnes and Kansas Rivers are shown on Plate 1 (Qtu).

Alluvium

Deposits mapped as Alluvium along Kansas River and its tributaries are late Wisconsinan and Recent in age and, together with the Newman Terrace, form the river flood plain. In the Kansas River valley, alluvium constitutes somewhat more than half the flood plain. In the valley of Wakarusa River and other tributaries to Kansas River, alluvium forms a very minor part of the flood plain. Along Wakarusa River above Coal Creek, alluvium, exclusive of the stream-channel deposits, ranges in width from 0 to about 150 feet, but because of its scattered and very limited distribution it is not shown separately on Plate 1.

In the Kansas River valley the alluvium is chiefly sand and silt similar to the sediments carried by the river at the present time. This alluvial surface is marked by meander scars and abandoned channels, and is irregular, commonly having a relief of 10 or 12 feet. Davis and Carlson (1952), McCrae (1954), Dufford (1958), and Beck (1959) have mapped, or considered mapping, during the course of field work in this and adjacent areas of the Kansas River valley, two or more surfaces within parts of the flood plain mapped as Alluvium in this report.

Davis and Carlson (1952, p. 215), in considering whether more than one surface (alluvium) could be mapped below the Newman Terrace, stated that "the point-bar accretion slopes in abandoned meanders are so gentle that they appear horizontal and unless carefully surveyed could easily be mistaken for terraces." Dufford

(1958) also recognized that these surfaces (below the Newman Terrace) are not horizontal and illustrated this with longitudinal and transverse profiles. He also stated (p. 28), ". . . unfortunately these [surface configuration, soil development, and elevation] contrasts are not everywhere conspicuous among the intermediate surfaces themselves, and no attempt has been made to differentiate them in mapping." Dufford recognized four surfaces lower than the Newman Terrace, one 3 feet below the Newman Terrace, one 4 feet below the Newman Terrace, a "youthful floodplain" surface, and a "modern active floodplain". The upper two of these four surfaces he named the "intermediate surface complex". All four exhibit an appreciable variation in altitude. Prominent scarps of these surfaces below the Newman Terrace may be as much as 10 feet high locally, but laterally they diminish and may become imperceptible.

The surface characteristics of the deposits below the Newman Terrace indicate that they are the result of gradual downcutting during progressive but nonuniform downstream migration of meanders. Moreover, the radii of curvature of the meander scars on the alluvial deposits below the Newman Terrace have increased during the later stages of development. The Alluvium and Newman Terrace, as mapped on Plate 1, can be readily differentiated in the field.

STRUCTURAL GEOLOGY

A detailed treatment of the structural geology is beyond the scope of this report. Certain aspects of the structural geology, however, both regional and local, are readily discernible in the outcropping and near-surface rocks and are summarized in the following paragraphs.

Regional Structure

The Prairie Plains Monocline is the dominant regional structure that affects Pennsylvanian rocks, which dip westward and northwestward about 20 feet per mile in eastern Kansas and parts of the neighboring states (Prosser and Beede, 1904). This structure is chiefly post-Permian in age. A structural map of Douglas County on which the top of the Haskell Limestone member of the Stranger Formation is used as a datum (Fig. 7) indicates a general dip to the northwest of slightly less than 20 feet per mile. The gentle northwest dip of the Pennsylvanian rocks is evident also on the geologic map (Pl. 1). Superimposed on the regional structure are many smaller synclinal and anticlinal structures. The amount

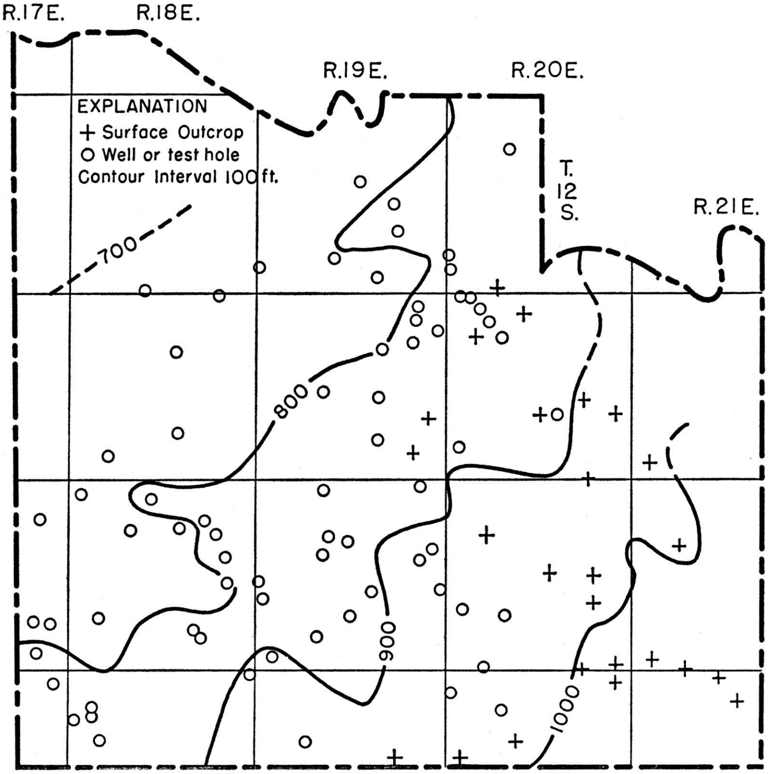

FIG. 7.—Structure contours on top of Haskell Limestone member of Stranger Formation.

of structural deformation shown generally increases appreciably with depth from the surface rocks into the older Pennsylvanian and Mississippian rocks. Thus a low anticline or structural nose in the surface rocks may reflect greater structural relief in the deeper Pennsylvanian rocks and at the top of the Mississippian.

Faulting and Folding

In southern Douglas County several faults and sharp structures have been observed in the Douglas Group and the Oread Limestone. Rich (1932a) first described these features as follows: South of a curved line marked by sharp flexing and faulting, which for several miles of its course closely follows the northern arc of a circle of about a 4-mile radius, the Toronto Limestone is missing; the Leavenworth Limestone is thicker than average and the Heebner Shale is abnormally thick, 16 feet instead of 6. The Plattsmouth Limestone at several places along the arc was faulted so that south of the fault it lies at the same level as the Toronto Limestone north of the break. These relations indicate (*a*) uplift of the area south of the curved line so that the Toronto either was not deposited or was eroded after deposition; (*b*) a renewal of movement, causing a relative sinking of the area south of the fault line while the Leavenworth Limestone and Heebner Shale were deposited; (*c*) deposition of Plattsmouth Limestone over all the area; and finally, (*d*) post-Plattsmouth faulting with downthrow to the south.

Patterson (1933) while studying the Douglas Group in the Baldwin area also made observations regarding the problem as follows: The Toronto Limestone has been removed by post-Toronto pre-Snyderville erosion in the Baldwin area and for at least 10 miles to the southwest of Baldwin. Post-Toronto pre-Snyderville erosion was deepest near Baldwin (SW cor. sec. 35, T. 14 S., R. 20 E.) where the upper 80 feet of the Lawrence Shale was eroded in addition to the Toronto Limestone. At the locality cited a limestone conglomerate overlain by 35 feet of Snyderville Shale rests on sandstone beds of the Ireland Sandstone. As mentioned by Rich (1932a) the Snyderville Shale, Leavenworth Limestone, and Heebner Shale are abnormally thick. Beds of Snyderville age deposited above the unconformity are predominantly shale near Baldwin, but to the southwest sand was deposited locally.

Laughlin (1957), who mapped adjacent areas of Franklin County to the south in T. 15 and 16 S., R. 17-19 E., indicated several areas in which the Toronto Limestone member is missing, but showed adjacent areas on each side in which the Toronto is present. Although faults are not indicated on the boundaries of these areas, except in one area northwest of Centropolis, a critical examination of the contacts might indicate post-Toronto pre-Leavenworth faulting and erosion of the Toronto member from these areas. Laughlin (personal communication) also noted an area (SW cor. sec. 29, T. 15 S., R. 18 E.) in which the Leavenworth Limestone member is missing but the overlying Plattsmouth and underlying Toronto limestones are present.

O'Connor and others (1955) noted three small faults in the Oread Limestone and slightly younger formations in Osage County and suggested the possibility of faults in other localities. Core drilling by the Corps of Engineers at the Pomona dam site in eastern Osage County in 1956 (sec. 17, 19, and 20, T. 16 S., R. 17 E.) revealed the presence of multiple low-angle faults in the lower Oread Limestone and the upper Lawrence Shale. The Toronto Limestone is absent in some of the cores and present in others.

Post-Stranger pre-Lawrence Faulting

Slump faulting that transects deposits of Weston Shale and the Stranger Formation was noted in southeastern Douglas County (sec. 33, T. 14 S., R. 21 E.). There, post-Stranger pre-Lawrence erosion cut through the Stranger Formation and deeply into the underlying Weston Shale creating a relatively steep walled valley about half a mile wide. Slump faulting caused large blocks of the valley wall to slide into the valley. This may or may not have been associated with small tectonic stresses in deeper rocks. The upper part of one such block, rotated so that the beds dip 35° to the east, may be observed (Pl. 9B) along the west bank of a creek near the center of sec. 33, T. 14 S., R. 21 E. Farther south along this creek near the south line of the section and adjacent parts of the NW¼ NW¼ sec. 4, T. 15 S., R. 21 E., the Haskell Limestone and Vinland Shale members have westward and northwestward dips of 5° to 12° perhaps representing secondary adjustments of the valley wall after slump faulting of the large blocks. The Ireland Sandstone member was then deposited in the post-Stranger pre-Lawrence erosional valley, filling it with conglomerate, sandstone, and shale. Essentially undisturbed beds of the Ireland overlie and abut the steeply dipping beds of the Weston and Stranger in these exposures. Minor slump structures resulting in dips of 5° to 12°, associated with post-Stranger pre-Lawrence erosion were noted also at several other outcrops in southeastern Douglas County.

Worden Fault

The principal fault affecting the surface rocks in southern Douglas County is of post-Toronto pre-Leavenworth age. From the vicinity of Baldwin a fault trends west in the lower tier of sections in T. 14 S., to a point just west of Worden, where it curves southward along the boundary between R. 18 and 19 E. to the Franklin County line. Mapping by Laughlin (1957) in northwestern Franklin County indicates that this fault may continue several miles farther south and west. The name Worden fault is proposed for this feature as the line of the fault is near the community of Worden. Although discussed and mapped as a single fault, it may be a series of en echelon faults of approximately the same age. The Worden fault

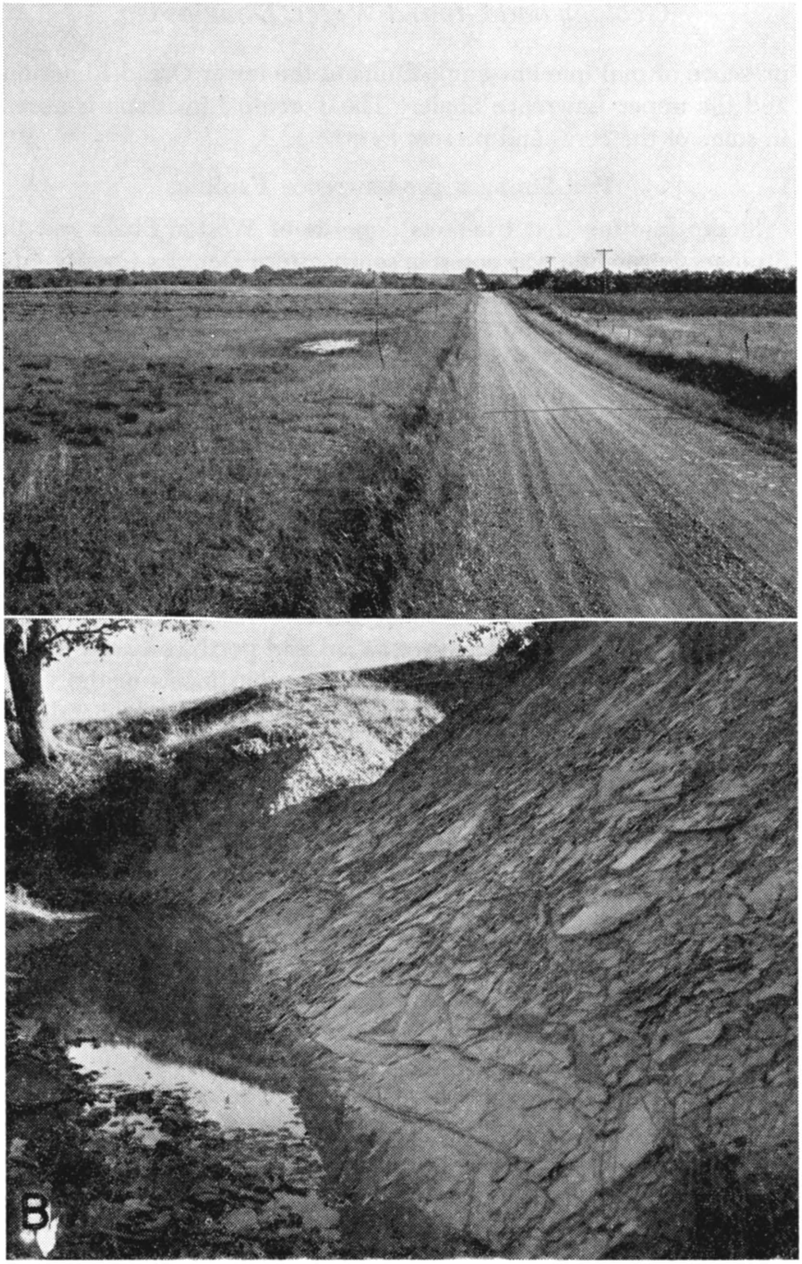

PLATE 9.—**A,** Nearly circular small water-filled sinkhole developed in Plattsmouth Limestone member of the Oread Limestone along Worden fault in the SE¼ NW¼ sec. 33, T. 14 S., R. 19 E., Plattsmouth member underlies surface in foreground and also hill 40 feet higher in background; **B,** Shale beds dipping 35° E. in post-Stranger pre-Ireland fault block adjacent to channel containing Ireland Sandstone member of Lawrence Shale. Normal dip of beds in this area is less than ½° NW. Tilted shale beds overlain by undisturbed beds of Ireland member. View south from NE cor. SW¼ sec. 33, T. 14 S., R. 21 E.

marks the northern boundary of an area in southern Douglas County in which the Toronto Limestone member of the Oread Limestone either was not deposited or was removed after deposition.

The next limestone above the Toronto, the Leavenworth Limestone member, is present both north and south of the Worden fault. The presence of the Leavenworth throughout the area dates the earliest movement on the Worden fault as post-Toronto pre-Leavenworth. At the east edge of Baldwin, in an outlier of Oread Limestone (Pl. 1), the basal part of that unit is represented by a conglomerate of reworked Toronto Limestone, which is further evidence of very late Toronto or Snyderville structural adjustments and modified sedimentation patterns. In the Baldwin vicinity the Worden fault may pass into a sharp flexure. An indication of the amount of post-Toronto pre-Snyderville uplift or erosion in the area is observable in the Baldwin area (NW¼ sec. 35, T. 14 S., R. 20 E.). Here the interval between the basal conglomerate of the Oread Limestone and the top of the Haskell Limestone is 60 to 65 feet, whereas in adjacent areas to the north the interval is the normal 140 to 170 feet. This suggests probable erosion of about 100 feet of Lawrence Shale in this area.

The evidence for the Worden fault throughout most of its mapped extent consists of the abrupt termination of the Toronto Limestone member. A clearly discernible fault surface in the underlying Lawrence Shale is nowhere well exposed in Douglas County, although shear zones in these beds have been observed in adjacent Franklin and Osage Counties. Locally sinkholes have developed in the Plattsmouth Limestone along this and associated faults (Pl. 9A).

As Rich indicated, there are several places along and near the Worden fault where the Plattsmouth Limestone member is faulted down to the south approximately to the position of the Toronto Limestone member north of the fault (Fig. 8A). There are also exposures of faulted Leavenworth Limestone member showing 5 to 10 feet of vertical displacement. Tilted beds of Lawrence Shale having dips of as much as 22° NE along the Worden fault-flexure zone are exposed in road cuts for a quarter of a mile east of the center of sec. 2, T. 15 S., R. 20 E.

Summary

Faulting and sharp flexing occur in rocks of the Douglas and Pedee Groups and the Oread Limestone in southern Douglas County and adjacent areas to the south and west. Reconnaissance

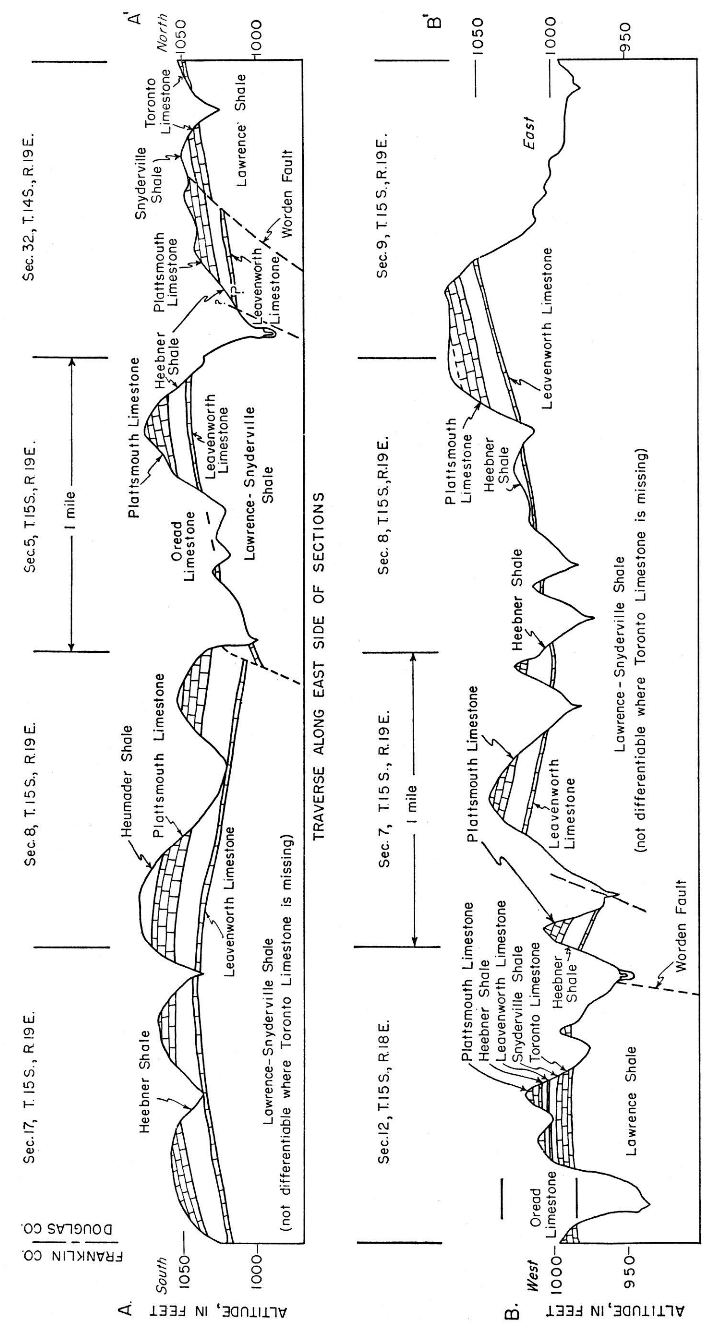

FIG. 8.—Geologic sections in vicinity of Worden fault, southern Douglas County.

structural mapping on the underlying Stanton Limestone indicates that the faults and sharp flexures shown in the rocks of the Douglas and Oread do not similarly affect the Stanton Limestone. Detailed structural mapping will be necessary to determine whether faults and flexures in the rocks of the Douglas and Oread are reflected locally in the deeper rocks also. The faulting and sharp flexures affecting the beds of the Douglas, Pedee, and Oread are judged, on the basis of data now available, to be chiefly nontectonic, and an explanation for the structural features must be found in the post-Stanton rocks.

The post-Stranger pre-Ireland topography observed in southeastern Douglas County indicates that there was as much as 100 feet of local relief and at least one deep channel approximately half a mile wide incised to within 30 feet of the Stanton Limestone locally. Evidence of slumping associated with the cutting and filling of one post-Stranger pre-Ireland channel has previously been cited, and sliding likely occurred at other places west and south along this channel also. The erosional valley was subsequently filled with the Ireland Sandstone, which formed a narrow wedge at the base and broadened irregularly upward to a thickness of 100 to 150 feet locally. Adjacent to this wedgelike sandstone body, the rocks above the Stanton Limestone were principally shale.

Irregularities in thickness and distribution of the sandstone and shale in the Lawrence Shale and the resulting differences in amount of compaction also resulted in flexures in the overlying Oread Limestone. The Worden fault, one of the most prominent and conspicuous of the postdepositional adjustments along the margins of the thick Ireland Sandstone member, resulted in the nondeposition or erosion of the Toronto Limestone member over parts of the area. Other beds of the Oread Limestone show thickness changes and less extensive faulting because of subsequent continuing adjustments in and adjacent to the area of thick Ireland Sandstone.

Although much new information regarding the structure and stratigraphy, beyond that described by Rich (1932a) and Patterson (1933), is known regarding this part of southern Douglas County, northwestern Franklin County, and eastern Osage County, many features are still poorly understood. Detailed surface and subsurface stratigraphic studies and structural mapping in the three counties will be necessary before the history of this area is clearly understood.

GROUND-WATER RESOURCES

Source, Occurrence, and Movement of Ground Water

The discussion of the occurrence of ground water in Douglas County is based partly on a detailed treatment by Meinzer (1923, 1923a). A general discussion of the principles of ground-water occurrence with special reference to Kansas has been given by Moore and others (1940).

Ground water is the part of the water below the surface of the land that is in the zone of saturation and supplies wells and springs. It is derived mainly from precipitation, falling as rain or snow, some of which reaches the zone of saturation by percolation downward through the soil and subsoil.

The rocks in the outer crust of the earth are not solid but contain many openings, or voids, that hold air, water, or other fluids. Generally, the rock formations below a certain level are saturated with water. The upper surface of the zone of saturation is not a level surface nor a static surface, but one that has many irregularities, which on a modified scale are generally similar to the irregularities of the surface topography. Under natural conditions, the small part of the precipitation that reaches the zone of saturation moves slowly toward the streams and discharges into them or is lost by transpiration and evaporation in the valley areas.

Water in the zone of saturation, available to wells, may be unconfined or confined. Unconfined or free ground water is water that does not have a confining or impermeable body restricting its upper surface. The upper surface of unconfined ground water is called the water table. Shallow wells constructed in the near-surface weathered limestone, sandstone, and shale, the alluvial deposits in stream valleys, and the colluvial slope deposits generally tap unconfined ground water. Ground water is said to be confined if it occurs in permeable zones between relatively impermeable beds that confine the water under pressure. Most of the wells constructed in the unweathered Pennsylvanian bedrock tap confined ground water.

Ground-Water Recharge and Discharge

The addition of water to the underground reservoir is called recharge and may be effected in several ways. The most important source of recharge is local precipitation; for shallow upland wells local precipitation is the only source of recharge. Lesser amounts are contributed elsewhere by influent seepage from streams and ponds and by subsurface inflow from adjacent areas. Locally, however, influent seepage from streams may contribute an important amount of recharge to adjacent alluvial deposits and to the bedrock where streams cut across permeable zones in bedrock.

Recharge is seasonal in the Midwest, including Douglas County. Generally the water levels of wells have been lowered by natural drainage into streams during the winter, when the soil is frozen and precipitation is slight. During the spring months precipitation is fairly abundant, temperature is moderately cool, and transpiration and evaporation demands are low, resulting in considerable recharge. Recharge may occur in other seasons, also, whenever precipitation is sufficient to overcome soil-moisture deficiency built up during a preceding dry period.

Ground water moves downward through the permeable rocks in accordance with the character and structure of the rocks, to points of lower elevation. It may discharge directly into a stream as a spring or seep or may discharge by evaporation or transpiration where the water table is near the surface. A part of the ground water is discharged from wells, but, with the exception of the municipal, industrial, and irrigation pumpage in the Kansas River valley in the vicinity of Lawrence, the amount discharged by wells in Douglas County is small compared with that discharged by other means.

Under natural conditions, over a long period of time, approximate equilibrium exists between the amount of water that it added annually to ground-water storage and the amount that is discharged annually.

Chemical Character of Ground Water

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

The analyses of 112 samples of water from wells, test holes, and springs in Douglas County are given in Table 4 in parts per million (ppm). Factors for converting parts per million of mineral constituents to equivalents per million are given in Table 5.

Table 4.—*Analyses of water from typical wells, test holes, and springs in Douglas County*

Analyst, H. A. Stoltenberg, except as noted. Dissolved constituents given in parts per million [a]

Well number	Depth, feet	Geologic source	Date of collection	Temperature (°F)	Dissolved solids	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na+K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Hardness as $CaCO_3$: Calcium, magnesium	Hardness as $CaCO_3$: Carbonate	Hardness as $CaCO_3$: Noncarbonate
11-18-34bd	30	Alluvium	10-27-55	...	442	31	0.31	121	18	16	456	19	11	0.2	1.8	376	374	2
12-17-14aa	70	Calhoun Shale	5-22-53	...	557	7.8	.28	87	42	60	454	109	19	.2	8.4	390	372	18
12-18-3aa	26.0	Kanwaka Shale	5-22-53	...	764	5.6	.18	210	12	23	303	191	119	.2	111	574	248	326
12-18-11cc	21.4	Lecompton Limestone	5-22-53	...	804	3.2	.14	195	7.6	48	209	65	125	.1	257	518	172	346
12-19-5dd	24	Alluvium	12- 2-50	...	424	27	4.0	113	19	17	425	14	22	.5	2.0	360	348	12
12-19-23ba	129.4	Kansan glaciofluvial deposits	12- 2-50	...	309	22	1.1	61	8.2	44	309	2.9	14	.2	4.9	186	186	0
12-19-23dc	182.9	do.	3-11-50	...	369	16	1.9	95	11	24	334	30	10	.2	18	282	274	8
12-19-24a	49	Alluvium	11-14-40[b]	...	...	...	17	...	...	...	549	...	28	.3	...	440	440	0
12-19-24ad1	47.5	do.	11-14-40[b]	...	...	...	6.6	98	21	...	437	...	59	.4	...	331[c]	331	0
12-19-24ad2	46	do.	11- 9-40[b]	...	...	...	16	...	...	...	527	...	21	.1	...	420	420	0
12-19-24dd	51.3	do.	2-28-47	...	592	22	10	140	18	25	454	75	19	.2	1.5	424	372	52
12-19-25aa1	51	do.	2-10-45	...	507	26	8.8	133	17	17	427	63	15	.3	1.3	402	350	52
12-19-25ad1	51	do.	11- 4-44	...	695	34	11	156	21	30	439	133	28	.4	2.6	476	360	116
12-19-25ad2	51	do.	4- 9-54	...	474	28	5.2	134	14	19	456	33	16	.2	1.7	392	374	18
12-19-26abb	61-235	Kansan glaciofluvial deposits and Stranger Formation	7-22-53[b]	...	...	...	...	...	...	...	...	...	5,550	...	...	...	...	...
12-19-26ab	134.5	Stranger Formation	3-11-50	...	21,400	15	20	615	257	7,340	237	279	12,800	.9	8.8	2,590	194	2,400
12-20-16bc	45	Alluvium	12- 2-40[b]	...	...	...	.6	106	14	...	368	...	2.5	.1	...	322[c]	302	20
12-20-17dd	67.5	do.	11-20-40[b]	...	...	...	1.5	113	14	...	425	...	6	.3	...	340[c]	340	0
12-20-17dd	73	Stranger Formation	11-20-40[b], [e]	...	...	...	2.0	...	...	...	420	...	32	.4	...	330	330	0
12-20-18ba1	35.8	Alluvium	12-19-40[b]	...	...	...	1.4	...	.6	...	386	...	3.0	.2	...	316	316	0
12-20-19ba1	...	do.	12- 9-40[b]	...	...	...	8.3	202	35	...	673	...	34	.2	...	648[c]	552	96
12-20-19ba4	22.9	do.	12- 7-40[b]	...	...	...	2.9	193	26	...	542	...	47	.2	...	589[c]	444	145
12-20-19bcc	49.0	do.	11- 8-40[b]	...	...	...	12	126	21	...	510	...	12	.2	...	401[c]	401	0
12-20-19bd1	50.0	do.	12- 5-40[b]	...	...	...	19	...	...	...	786	...	92	.1	...	640	640	0
12-20-19bd2	22.3	do.	12- 6-40[b]	...	...	...	.43	214	23	...	581	...	50	.4	...	629	476	153
12-20-19ca	45.0	do.	12- 4-40[b]	...	...	...	9.3	160	28	...	659	...	68	.2	...	515	515	0
12-20-19cc	50.0	do.	11- 7-40[b]	...	...	...	13	...	...	...	466	...	15	.3	...	350	350	0
12-20-19cd1	50.0	do.	12- 4-40[b]	...	...	...	30	221	45	...	874	...	89	.1	...	737[c]	716	21
12-20-19da	45.0	do.	11-25-40[b]	...	...	...	16	...	...	...	559	...	56	.2	...	448	448	0
12-20-20ab	31.0	Newman Terrace deposits	12- 2-40[b]	...	...	...	1.4	119	13	...	400	...	1.5	.2	...	351[c]	328	23

12-20-20baa	80.0	Alluvium	11-19-40[b]	...	...	...	1.6	...	...	...	422	...	16	.3	...	356	346	10
12-20-20bc	35.3	Newman Terrace deposits	12- 2-40[b]	...	...	...	3.9	118	13	...	387	...	6.0	.3	...	348[c]	317	31
12-20-30abb	50.0	Alluvium	11-18-40[b]	...	...	...	2.8	103	18	...	334	...	183	.5	...	331[c]	274	57
12-20-30ba1	50.0	do	11-18-40[b]	...	...	...	6.7	135	30	...	605	...	78	.3	...	461[c]	461	0
12-20-30ba2	45.0	do	12- 4-40[b]	...	...	...	14	...	...	...	666	...	38	.3	...	502	502	0
12-20-30ba3	45.0	do	11-26-40[b]	...	...	...	13	154	32	...	673	...	23	.1	...	516[c]	516	0
12-20-30bc1	50.0	do	11-26-40[b]	...	...	...	7	124	24	...	476	...	46	.4	...	408[c]	390	18
12-20-30bc2	50.0	do	11- 5-40[b]	...	...	...	6.6	...	...	...	456	...	26	.3	...	396	374	22
12-20-30bc3	50.0	do	11- 6-40[b]	...	...	...	6.6	...	...	...	395	...	23	.2	...	324	324	0
12-20-30bc4	50.0	do	11- 6-40[b]	...	...	...	8.3	125	24	...	416	...	37	.2	...	411[c]	341	70
12-20-30bc5	47.0	do	11- 6-40[b]	...	...	...	11	...	...	...	403	...	23	.2	...	380	330	50
12-20-30bc6	48.0	do	12- 3-40[b]	...	...	...	4.6	123	18	...	383	...	26	.2	...	381[c]	314	67
12-20-30bc7	55.0	do	11-27-40[b]	...	...	...	3.3	...	...	...	481	...	46	.1	...	400	394	6
12-20-30bd1	29.0	do	12- 2-40[b]	...	...	...	49	274	69	...	1,310	...	41	.1	...	968[c]	968	0
12-20-30bd2	27	do	12- 6-40[b]	...	...	...	22	...	...	...	780	...	38	.2	...	626	626	0
12-20-35db	27	do	12-29-52	...	639	24	.41	49	10	16	222	4.1	7	.1	2.8	163	163	0
12-21-27dc	22	do	12-29-52	...	569	22	.11	168	15	14	468	75	21	.2	23	480	384	96
12-21-31dc	18	do	12-29-52	...	504	34	.08	138	14	17	422	40	15	.3	38	402	346	56
13-17-24ca	SP	Kansan glaciofluvial deposits	5-22-53	...	226	12	.07	73	3.0	6.9	231	4.5	8.0	.1	4.4	194	190	4
13-18-2aa	300	Lawrence Shale	7-14-55[d]	...	...	...	...	...	...	...	...	...	9,310	...	...	...	...	...
13-18-22ba	33.7	Kansan glaciofluvial deposits	5-28-53	...	485	9.6	.18	116	9.2	36	290	25	40	.0	106	328	238	90
13-18-28ba	350	Stranger Formation	5-28-53	...	4,840	22	.86	212	90	1,480	466	565	2,210	1.2	29	899	382	517
13-18-32bc	192	Lawrence Shale	1-27-56[d,e]	...	8,070	...	...	...	...	...	...	...	4,380	...	...	...	...	...
13-19-1cc2	118	Stranger Formation	1- 8-55[d]	...	...	...	...	...	...	...	...	...	4,030	...	...	...	...	...
13-19-7dd	96-146	do	6- 6-55	...	1,720	9.5	.74	31	16	621	370	59	795	1.4	4.1	144	144	0
13-19-11da1	110	do	5-28-54[d]	...	...	...	...	...	...	...	...	...	1,410	...	...	...	...	...
13-19-12aad	78-127	do	6-21-54	...	2,980	9.6	.55	103	31	1,020	434	58	1,540	.3	4.9	384	356	28
13-19-12bbb	70	Kansan glaciofluvial deposits	6-10-55	...	340	20	.33	91	5.4	21	281	16	13	.1	35	249	230	19
13-19-12cbb	124.5	Kansan glaciofluvial deposits and Stranger Formation	6-11-54	...	580	4.6	.11	79	36	99	451	17	121	.4	1.3	345	345	0
13-19-13aa	70	Stranger Formation	6- 1-53	...	2,170	5.8	3.6	105	30	705	378	.0	1,140	.0	.4	386	310	76
13-19-18dd	37	Newman Terrace deposits	5-29-53	...	318	5.2	.17	71	10	27	205	67	13	.2	24	218	168	50
13-19-21bb	98.9	Stranger Formation	7-28-52	...	360	12	.89	81	13	41	386	11	10	.3	1.5	256	256	0
13-19-23da	140	do	5-28-53	59	1,620	23	1.3	38	15	571	577	127	555	3.6	.0	156	156	0
13-19-27dd	312	do	4-23-56[d]	...	...	...	...	...	...	...	...	...	670	...	...	...	...	...
13-19-28cb1	42	Buck Creek Terrace deposits	5-29-53	58	538	3.2	.06	125	20	44	453	11	28	.2	84	394	372	22
13-19-28cb2	107	Stranger Formation	10-18-54[d]	...	...	...	...	...	...	...	...	...	1,630	...	...	...	...	...
13-20-5caa	160	do	6-11-54	...	476	7.6	.25	90	26	44	333	129	14	.1	1.5	332	273	59
13-20-8ad	160	do	5-22-53	...	396	4.0	11	74	24	46	399	43	8.0	.2	.3	283	283	0
13-20-11bb	43	Newman Terrace deposits	12-29-52	...	516	20	.08	153	14	14	451	31	27	.1	35	439	370	69

TABLE 4.—*Analyses of water from typical wells, test holes, and springs in Douglas County—Continued*

WELL NUMBER	Depth, feet	Geologic source	Date of collection	Temperature (°F)	Dissolved solids	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na+K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Hardness as $CaCO_3$: Calcium, magnesium	Hardness as $CaCO_3$: Carbonate	Hardness as $CaCO_3$: Noncarbonate
13-20-13cc	63	Stranger Formation	5-25-53	...	222	7.8	.39	50	8.2	23	227	5.3	8.0	.2	7.1	158	158	0
13-20-35cd	140	Stranger Formation and Stanton Limestone	6-22-54	...	587	3.8	.18	106	28	68	378	156	38	.3	1.3	380	310	70
13-21-5db	61.1	Alluvium	7-15-55	...	548	27	.03	150	13	19	432	69	27	.1	6.2	428	354	74
13-21-10cc	27	Kansan glaciofluvial deposits	5-25-53	57	252	13	.10	35	7.8	48	226	14	7.0	.3	16	120	120	0
13-21-17dc	SP	do.	2-24-53	...	220	8.8	.06	34	7.0	35	176	14	7.0	.1	17	114	114	0
13-21-21dd	50	do.	5-30-53	57	469	6.4	4.9	89	12	61	309	49	33	.3	66	272	254	18
14-17-25ca	458	Stranger Formation	3- 9-56	...	...	...	...	...	...	...	...	...	168	...	...	...	...	...
14-17-26ad	405	do.	3-19-56[d]	...	2,060	...	...	...	...	...	...	...	822	...	...	...	...	...
14-17-36bd	296	Lawrence Shale	2——50	...	...	...	...	...	...	...	...	...	420	...	...	...	...	...
14-18-10bd	325	Stranger Formation	1-11-54[d,e]	...	...	...	...	...	...	...	...	...	1,130	...	...	...	...	...
14-18-11db	160	do.	6-21-54	...	3,390	12	.23	30	17	1,260	556	235	1,540	3.0	7.5	145	145	0
14-18-23aa1	377	do.	1- 5-48	...	...	...	...	...	...	...	...	...	655	3.6	...	50	...	...
14-18-24cc	335	do. (?)	6- 6-55	...	1,200	4.0	.31	5.5	1.3	434	486	285	130	3.2	93	19	19	0
14-18-30ad	276-289	Lawrence Shale	5-18-54	...	3,300	18	.17	15	10	1,220	678	540	1,130	3.1	22	78	78	0
14-18-30ad	428-475	Stranger Formation	10-10-54	...	1,540	6.0	.74	5.7	2.9	608	461	15	670	3.1	1.3	26	26	0
14-18-31ad	340	Lawrence Shale	5-26-53	...	2,690	22	.18	14	7.6	946	760	1,020	294	6.0	4.9	66	66	0
14-18-34cc	245	do.	5-26-53	...	1,710	13	1.2	7.0	4.4	621	734[f]	580	119	4.4	.4	36	36	0
14-19-3dd	121	Stranger Formation	5- 5-55[d]	...	...	...	...	...	...	...	...	...	361	...	...	...	...	...
14-19-4bb	142	do.	6-22-54	...	5,190	11	2.0	73	44	1,900	483	58	2,860	2.1	3.8	363	363	0
14-19-15db2	28.7	Oread Limestone	5-28-53	...	515	2.6	.09	63	36	80	417	32	43	.2	53	305	305	0
14-19-16bc	304	Stranger Formation	5-28-53	...	4,820	23	.37	52	26	1,800	550	151	2,500	3.0	.2	236	236	0
14-19-24da	385	Lawrence Shale	6-21-54	...	1,420	8.8	.78	4.1	3.0	554	847	246	186	4.5	1.8	22	22	0
14-19-28ad	160	do.	6- 6-55	...	770	8.5	.26	4.7	1.8	301	498	87	120	1.3	1.6	19	19	0
14-20-14dc	37	Stranger Formation	5-25-53	58	520	5.0	.22	130	18	40	460	84	12	.1	4.4	398	377	21
14-20-22ba	107	Stanton Limestone	3- 2-57	...	3,060	7.0	.31	29	17	1,160	361	1.2	1,670	1.4	.8	142	142	0
14-20-29da	92	Lawrence Shale	6-22-54	...	560	13	.18	95	23	86	495	83	17	.3	1.1	332	332	0
14-20-30aa	200	do.	12——55[d]	...	...	...	...	...	...	...	...	...	75	...	...	...	...	...
14-20-31aa	186	do.	6- 7-55	...	475	14	.11	22	24	129	395	53	36	.5	2.9	154	154	0
14-20-32cd	87-94	do.	6-22-54	...	820	12	.55	36	16	255	483	139	116	1.3	2.7	156	156	0
14-20-32cd	285-290	Vilas Shale	9-18-53[d,e]	...	...	...	...	...	...	...	...	...	5,220	...	...	...	...	...
14-21-9aa	50	Kansan glaciofluvial deposits	5-30-53	57	155	10	.63	20	3.8	31	128	1.0	8.0	.1	18	66	66	0
14-21-18ad	184	Stanton Limestone and Bonner Springs Shale	6-22-54	58	2,120	8.2	.14	5.3	3.6	847	647	.0	925	12	3.3	28	28	0

14-21-30ad	200	Colluvium, Stranger Formation, and Stanton Limestone	6- 6-55	....	354	23	.54	50	8.0	72	332	28	8.0	.3	1.7	158	158	0
15-17-1ac2	497	Stranger Formation	4- 1-53	....	604	9.0	.62	40	15	176	350	37	154	.8	.3	162	162	0
15-17-1ac2	497	do	12-12-55	....	565	....	.32	38	12	173	346	31	144	.7	.4	144	144	0
15-17-13dc	315	do	2——50	....	....	....	....	....	....	....	....	....	152	....	....	....	....	....
15-18-1aa	301	Lawrence(?) Shale	4-20-48	....	1,430	26	3.6	7.2	3.6	519	695	449	47	4.4	4.9	33	33	0
15-18-7ad	350	Stranger Formation	5-26-53	....	2,670	16	.08	14	7.6	970	720	688	590	4.8	29	66	66	0
15-18-15cd1	485	Lawrence(?) Shale or Stranger(?) Formation	5-26-53	57	2,230	20	1.1	16	8.6	829	637	313	720	3.8	6.2	76	76	0
15-19-1cd	104	Lawrence Shale	5-29-53	58	446	2.6	6.1	89	29	41	415	58	16	.4	6.2	341	340	1
15-19-17cd	170	do	6-21-54	....	649	9.2	.94	124	32	62	415	193	22	.3	2.7	441	340	101
15-20-15ada	26	Lawrence Shale and terrace deposits	7-19-54	....	158	20	.38	29	5.7	19	142	7.8	7.0	.3	2.0	96	96	0
15-21-5aa	....	Lawrence Shale	4-18-55	....	135	21	.60	21	5.2	14	98	9.1	6.0	.2	6.2	74	74	0
15-21-7ac	90	do	5-29-53	58	252	7.6	.12	34	12	33	129	8.2	27	.4	66	134	106	28

a. One part per million is equivalent to 1 pound of substance per million pounds of water or 8.33 pounds per million gallons of water.
b. Data from Table 4 of Lohman (1941). Table 4 also includes pH, free carbon dioxide, and manganese. Analyst, E. O. Holmes.
c. Calculated.
d. Analysts, John Schleicher and Russell Runnels, Kansas Geol. Survey.
e. May be diluted with fresher water from overlying beds.
f. Includes the equivalent of 67 ppm of CO_3^{--}.
g. Composite sample from city wells.

Quality in relation to use.—Ground water from properly constructed wells characteristically has good bacterial and sanitary quality, but the chemical character of the water is of importance also. Water to be used for drinking should not contain excessive amounts of iron, magnesium, chloride, sulfate, nitrate, and certain other constituents. Water used for cooking and washing has these and other limitations, chiefly of hardness and bicarbonate. Water used for irrigation should not contain excessive mineral matter nor excessive amounts of chloride or of sodium in relation to other cations.

Ground water used in industrial processes generally must meet certain standards. These standards for some processes may be

TABLE 5.—*Factors for converting parts per million of mineral constitutents to equivalents per million*

Cation	Conversion factor	Anion	Conversion factor
Ca^{++}	0.0499	HCO_3^-	0.0164
Mg^{++}	.0822	SO_4^{--}	.0208
Na^+	.0435	Cl^-	.0282
		NO_3^-	.0161
		F^-	.0526

much more critical than standards for drinking water. The total dissolved solids, hardness, hydrogen-ion concentration (pH), alkalinity, and iron are some of the more important factors. Temperature also is an important factor in many industrial uses of ground water.

Dissolved solids.—When water is evaporated the residue consists mainly of the mineral constituents listed in Table 4 and may include a small quantity of organic material and water of crystallization. Water containing less than 500 ppm of dissolved solids generally is satisfactory for domestic use, except for difficulties resulting from its hardness, or an excessive content of iron. Water containing more than 1,000 ppm of dissolved solids may include enough of certain constituents to produce a noticeable taste or to make it unsuitable in some other respect.

The amount of dissolved solids in 66 samples of ground water collected in Douglas County from wells, test holes, and springs is indicated in Table 4. The dissolved solids content ranged from 135 to 21,400 ppm. Twenty-two samples, all from Pennsylvanian sandstone and limestone aquifers, contained more than 1,000 ppm.

Hardness.—Hardness of water is commonly recognized by its effect when soap is used with the water. Calcium and magnesium cause nearly all the hardness of water and are the active agents in the formation of the greater part of scale in steam boilers and other vessels in which water is heated or evaporated.

In addition to the total hardness, the table of analyses gives the carbonate and noncarbonate hardness of water in Douglas County. Carbonate, or 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, therefore, is sometimes called permanent hardness. The two types of hardness have the same reaction when the water is used with soap.

Water having a hardness of less than 60 ppm is rated as soft and is seldom treated to remove hardness. Hardness of 60 to 120 ppm increases the consumption of soap but does not seriously interfere with the use of the water for most purposes. Hardness of more than 120 ppm can be noticed by anyone; if the amount is about 200 ppm or more the water is sometimes softened for household use, or cisterns may be installed to collect soft rainwater. Where municipal supplies are softened, the hardness is generally reduced to between 80 and 100 ppm.

The hardness of 97 samples of ground water collected in Douglas County ranged from 19 to 2,590 ppm (Table 4). The hardest and softest waters were from Pennsylvanian sandstones, but more than half of the samples collected from Pennsylvanian rocks had a hardness of less than 200 ppm. Almost all the water samples collected from Quaternary deposits have a hardness range from 200 to 800 ppm, and in general they are appreciably harder than water from the Pennsylvanian sandstones.

Iron.—Iron (Fe) generally is present in small quantities in most natural ground water. If water contains much more than 0.1 ppm, some of the iron may precipitate as a reddish sediment. Iron in excess of 0.3 ppm is undesirable, as it may stain cooking utensils, plumbing fixtures, and clothing being laundered, or give a disagreeable taste to the water.

The iron content of 96 samples of ground water collected in Douglas County ranged from 0.03 to 49 ppm (Table 4). Of the 96 samples, 69 contained 0.3 ppm or more of iron.

Fluoride.—Fluoride (F) in concentrations of about 1 ppm in drinking water used by children during the period of calcification of the teeth prevents or lessens the incidence of tooth decay; concentrations greater than 1.5 ppm may cause mottling of the enamel (Dean, 1936, 1938; U. S. Public Health Service, 1946).

The fluoride content of 97 samples of ground water collected in Douglas County ranged from 0.0 to 12 ppm. Fifteen samples, all from Pennsylvanian sandstone aquifers, contained fluoride in amounts greater than 1.5 ppm.

Nitrate.—A concentration of 90 ppm of nitrate (NO_3) in drinking water may cause cyanosis and hence is judged by the Kansas State Board of Health to be dangerous to infants (Metzler and Stoltenberg, 1950), and some authorities (Comly, 1945) recommend that water containing more than 45 ppm should not be used for preparation of infants' formulas. Concentrations of nitrate found in ground water generally do not cause cyanosis in older children or adults but may have other adverse effects.

Of the 64 samples analyzed for nitrate (NO_3), only 4 contained more than 90 ppm. Of these, 3 samples were from shallow dug wells, which as a rule are more susceptible to contamination from the surface than are deeper, drilled wells. The nitrate content of the 64 samples ranged from 0.0 to 257 ppm.

Sulfate.—Sulfate (SO_4) in ground water is derived chiefly from solution of gypsum and the oxidization of iron sulfides. Sulfate occurring in ground water as magnesium sulfate (Epsom salt) and sodium sulfate (Glauber's salt) in excess of about 500 ppm may have a laxative effect on persons not accustomed to drinking such water.

Chloride.—Chloride (Cl) in ground water may be derived from connate marine water in the sediments, from sewage, or, in small quantities, from solution of minerals containing chloride. Chloride has little effect on the suitability of water for ordinary use unless the quantity is enough to give the taste of salt. A chloride content of about 250 or 300 ppm can be detected by persons having a sensitive taste. Water strong in chloride is corrosive to many metal surfaces.

Sodium chloride is the chief dissolved constituent of the ground water in some of the deeper Pennsylvanian sandstone aquifers, which prevents use of otherwise adequate supplies of ground water in some parts of the county.

The chloride content of 112 samples analyzed ranged from 1.5 to 12,800 ppm.

Sanitary considerations.—The analyses of water (Table 4) show only the amount of dissolved minerals and do not indicate the sanitary quality of the water. Well water may contain mineral matter that gives the water an objectionable taste, but may be free from harmful bacteria and consequently may be safe for drinking. Other well water, good tasting and seemingly pure, may contain harmful bacteria. Excessive amounts of certain dissolved minerals, such as chloride or nitrate, may indicate pollution.

Recommended sanitary types of construction and suggestions for locations and pump installations for different types of wells can be obtained from the Kansas State Board of Health.

Changes in temperature and quality of water.—The temperature of ground water tapped by wells is uniformly about 57°F to 59°F in this area but may be a few degrees colder or warmer in very shallow or very deep aquifers. In most aquifers, except very shallow ones, the annual temperature fluctuation is small. The pumping of wells located near a stream may induce recharge from the stream, and thus cause an increase or decrease in the temperature of ground water being pumped. The temperature of Kansas River ranges from about 32°F to 80°F, and if a significant proportion of ground water being pumped from a well is indirect recharge of appreciably colder or warmer river water, the well-water temperature may be noticeably affected. According to temperature records kept by Westvaco Mineral Products Division of Food Machinery & Chemical Corp. at its Lawrence plant, ground water pumped from its well field, 0.6 to 0.7 mile from Kansas River, has a nearly constant temperature of 58°F throughout the year, the maximum variation reportedly being about half a degree. Wells therefore must be much closer to the river to be noticeably affected by fluctuations in the temperature of the river water.

The chemical quality of water in an aquifer may be modified by ground-water development and use. Return flow from irrigation, waste water from industry, or waste water from municipalities generally contains a greater proportion of dissolved matter than it had prior to use. If all or a part of this water is returned to the aquifer it may result in a ground-water supply of lower quality. If development of ground-water supplies results in additional recharge of better or poorer water to the aquifer, it may produce ground water of respectively better or poorer quality.

Aquifer Properties

An aquifer is a geologic formation, a part of a formation, or a group of formations that will yield water. The quantity of ground water that an aquifer will yield to wells depends partly on its thickness, extent, continuity, and homogeneity, and partly on its physical properties of permeability and porosity.

The field coefficient of permeability (P) is defined as the number of gallons of water that will move in 1 day, at the prevailing water temperature, through a vertical section of the aquifer 1 foot square under a hydraulic gradient of 100 percent or 1 foot per foot. Coefficients of permeability of less than 100 gallons a day per square foot are considered low, coefficients of 100 to 1,000 are medium, and those of more than 1,000 are considered high. The coefficient of transmissibility (T) is equal to the field coefficient of permeability multiplied by the thickness (m) of the aquifer.

The coefficient of storage (S) is defined as the volume of water, measured in cubic feet, released from storage in each column of the aquifer having a base 1 foot square and a height equal to the thickness of the aquifer, when the water table or other piezometric surface is lowered 1 foot. In water-table aquifers the coefficient of storage for long periods of pumping is approximately the specific yield and has a range from about 0.1 to 0.3. The specific yield is defined as the ratio of the volume of water a saturated material will yield by gravity to its own volume. For artesian aquifers the coefficient of storage generally is very small, ranging from about 10^{-5} to 10^{-3}.

The coefficients of transmissibility and of storage are used in making quantitative estimates of water available in an aquifer, and of the water-level decline that will result from pumping. Controlled aquifer (or pumping) tests can be made to obtain the data required to determine these coefficients.

Drawdown in a well is the lowering of the water table or piezometric surface caused by pumping or artesian flow. The specific capacity of a well is the discharge expressed as rate of yield per unit of drawdown, generally gallons per minute per foot of drawdown.

Hydrologic data on the principal aquifers, obtained by pumping and laboratory tests, and information supplied by well owners are summarized in Table 6.

Availability of Ground Water

In Douglas County fresh ground water is known to occur in unconsolidated rocks locally to a depth of about 90 feet and in consolidated rocks locally to a depth of about 500 feet.

Except for cemented and consolidated zones in the fluvial and glaciofluvial deposits of Kansan age, the Pleistocene aquifers are all unconsolidated. They have a wide range of geologic and hydrologic characteristics and occur on the uplands, the valley sides, and as valley fillings. The texture of these deposits ranges from well-sorted sand and gravel to unsorted boulder clay.

The consolidated rock aquifers consist chiefly of sedimentary limestones, shales, and sandstones, which have a regional dip averaging about 20 feet per mile to the northwest. There is a pronounced, though gradual, change in the permeability of the consolidated rocks with depth. The relatively impermeable clay shales and dense limestones are slightly permeable and will yield small amounts of water to wells in the zone of weathering. The sandstones constitute the most important consolidated rock aquifers.

Unconsolidated Rock Aquifers

Alluvium and Deposits of Newman Terrace

Kansas River valley.—Large quantities of ground water are available from alluvium and Newman Terrace deposits in the Kansas River valley, the extent of which is shown on Plate 1. Logs of wells and test holes (at the end of this report) indicate that these deposits have a minimum thickness of about 45 feet in much of the valley and as much as 90 feet in the bedrock channel shown in Figure 9. The thickness of saturated water-bearing material ranges from about 25 feet to 65 feet or possibly more.

The saturated alluvial deposits have a wide range of permeability (Table 6), but most values of the coefficient of permeability are greater than 1,000 gpd per ft.^{2}, and in parts of the aquifer they are greater than 12,000 (Lohman, 1941, p. 36). The largest coefficient of transmissibility determined by pumping test (well 12-19-1dd) was 354,000 gpd per ft. Specific capacities of wells reported in Table 6, which range from 14 to 175 gpm per ft. of drawdown, probably are representative. Yields of wells in the alluvium generally range from 500 to 1,000 gpm, but some yields are as low as 100 gpm.

TABLE 6.—*Summary of hydrologic data on principal aquifers in Douglas County*

Well or test hole number	Date of pumping test	Principal aquifer	Discharge (gpm)	Drawdown (feet)	Duration of test (min.)	Specific capacity (gpm)	Thickness of aquifer, m (feet)	Coefficient of permeability, P (gpd per ft.²)	Coefficient of transmissibility, T (gpd per ft.)	Coefficient of storage, S	Remarks
12-19-1db1	11-11-55	Newman Terrace deposits	780	8.5	150	92	59	6,000	354,000	1.1×10^{-3}	Unpublished open-file data.
12-19-4dd	2- 3-41	Alluvium	±700	4	+120	175	60				Data from Wesley Brune.
12-19-14bd	1938	do	300	20	480	15	37.5				Data from Layne-Western Co.
12-19-24a		do					36.6	1,594[a]			L 10[d].
12-19-24ad1		do					35.7	1,612[a]			L 9[d].
12-19-24ad2		do					36.8	999[a]			L 8[d].
12-19-24dac		do						1,403[a]			L 6[d]. Determined for materials 4-47.5 ft.
12-19-24dd	3- ?-47	do	300	4.1	240	73	38.8				Data from Layne-Western Co.
12-19-25aa1	1945	do	402	10.5	390	38	40				Do.
12-19-25aa2	1954	do	±355	8.4	270	±42	32.9				Do.
12-19-25aa3	1954	do	350	6	90	58	31.5				Do.
12-19-25ad1	1944	do	300	7	1,440	43					Do.
12-19-25ad2	1954	do	350	6.5	90	54	37				Do.
12-20-7adc	1940	Newman Terrace deposits	900	10	1,440	90	59				Data from W. H. Allison.
12-20-17add		do					57.6	2,490[a]			L 18[d].
12-20-17cd		do	±800	9	1,440	±89	43.4				Data from W. H. Hayden.
12-20-17dd		Alluvium					59.3	4,726[a]			L 17[d]. Determined for materials 14-70 ft.
12-20-19bcc		do						1,121[a]			L 7[d]. Determined for materials 10-43.5 ft.
12-20-19ca		do					36.6	1,003[a]			L 27[d]. Determined for materials 1.5-43.5 ft.
12-20-19cc		do						1,091[ab]			L 5[d]. Determined for materials 0-45.5 ft.
12-20-19cd1		do					30.1	1,090[ab]			L 26[d]. Determined for materials 13-45 ft.
12-20-19da		do					34.6	992[a]			L 20[d]. Determined for materials 12-41.5 ft.
12-20-20baa		do					58	3,433[ab]			L 16[d]. Determined for materials 8-72 ft.
12-20-20bcc		Newman Terrace deposits					55	1,560[a]			L 15[d]. Determined for materials 22-57 ft.
12-20-20da	1934	Alluvium	±400	13	600	±31	36				Data from G. E. Robinson.
12-20-28db	2- ?-54	do	800	12	150	67	37				Data from John Vogel.
12-20-29aad	1955	do	450	9	±120	50	37				Data from Dean Kloepper.
12-20-29ac1	1- ?-55	do	170	6	4,320	28	23				Data from Wm. Tornaden. Original specific capacity reported to be 35.
12-20-29ac2	1- ?-55	do	140	10	4,320	14	24				Do. Original specific capacity reported to be 28.
12-20-29ad1	1- ?-55	do	120	5	4,320	24	26				Data from Wm. Tornaden.

12-20-29ad2	1- ?-55	Alluvium..........	150	±7	4,320	21	26	....	....	....	Data from Wm. Tornaden. Original specific capacity reported to be 30.
12-20-30abb	....	do..........	....	....	....	....	32.7	1,634 [a]	....	....	L 14 [d]. Determined for materials 13-43.5 ft.
12-20-30ba1	....	do..........	....	....	....	....	35.2	2,110 [ab]	....	....	L 13 [d]. Determined for materials 10-48 ft.
12-20-30ba2	....	do..........	....	....	....	....	33	564 [a]	....	....	L 25 [d]. Determined for materials 8-41 ft.
12-20-30ba3	....	do..........	....	....	....	....	....	1,902 [a]	....	....	L 21 [d]. Determined for materials 8-42 ft.
12-20-30bc1	....	do..........	....	....	....	....	35.4	3,267 [a]	....	....	L 12 [d]. Determined for materials 14-48 ft.
12-20-30bc2	....	do..........	....	....	....	....	31.5	1,054 [a]	....	....	L 1 [d]. Determined for materials 13-45.5 ft.
12-20-30bc3	....	do..........	....	....	....	....	....	1,114 [a]	....	....	L 2 [d]. Determined for materials 21-44.5 ft.
12-20-30bc4	....	do..........	....	....	....	....	....	1,058 [a]	....	....	L 3 [d]. Determined for materials 14-45 ft.
12-20-30bc5	....	do..........	....	....	....	....	....	1,256 [a]	....	....	L 4 [d]. Determined for materials 13-27 and 29-44 ft.
12-20-30bc6	....	do..........	....	....	....	....	32.15	1,844 [a]	....	....	L 23 [d]. Determined for materials 10-46.5 ft.
12-20-30bc7	....	do..........	....	....	....	....	33.2	1,576 [a]	....	....	L 22 [d]. Determined for materials 11-28 and 38-52 ft.
12-20-30bc8	....	do..........	....	....	....	....	33.35	1,657 [a]	....	....	L 24 [d]. Determined for materials 10.5-50 ft.
15-17-1ac2	5-11-54	Tonganoxie Sandstone member.... (Stranger Formation)	35	40.63	258	1.18	90 [c]	18	1,620	5×10^{-5}	Unpublished open-file data.
15-20-15ad	5-16-56	Ireland Sandstone member......... (Lawrence Shale)	45.8	±6	950	±7.66	20	343	6,861	....	Do.
15-21-4bcc	5-14-56	do..........	....	....	....	....	....	....	4,258	....	Do.
15-21-5ad2	5-14-56	do..........	25	....	533	1	42	126	5,280	....	Do.

a. Weighted average coefficient of permeability determined by laboratory methods. (From Lohman, 1941, table 1.)
b. Excluding unsaturated part of top sample.
c. Modified from drillers log; samples from 485-495 ft. are limestone.
d. L1, L2, etc., refer to test-hole numbers used by Lohman (1941).

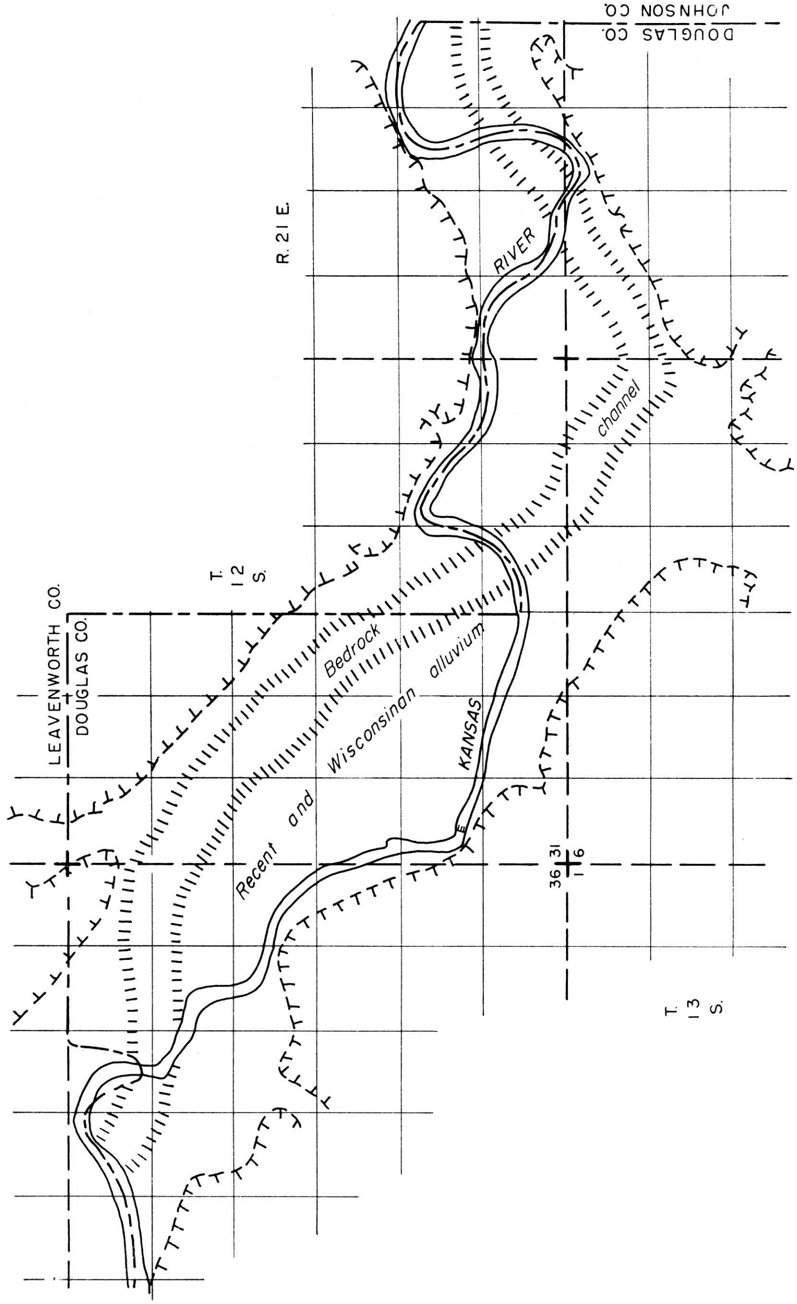

FIG. 9.—Approximate location of bedrock channel in Kansas River valley and present stream channel.

TABLE 7.—*Use of ground water in Douglas County, 1955*

	Daily use (gallons)			Total use, 1955		Principal aquifer
	Maximum	Minimum	Average	Millions of gallons	Acre-feet	
Public supplies[a]						
Baldwin	200,000	100,000	130,000	47	144	Ireland Sandstone
Eudora	150,000	50,000	80,000	29	89	Alluvium
Lecompton	...	...	10,000	3.6	11	do
Overbrook	40,000	10,000	20,000	7.3	22	Tonganoxie Sandstone
Wellsville	90,000	30,000	60,000	22	68	Ireland Sandstone
Lawrence	...	...	1,136,000	415[b]	1,274	Alluvium
Industrial supplies						
Cooperative Farm Chemicals Association	...	...	1,290,000	471[b]	1,445	Alluvium and Newman Terrace deposits
Kansas Power & Light Co.	2,160,000	1,440,000	1,584,000	578[b]	1,774	Alluvium
Westvaco Mineral Products Division	1,300,000	570,000	1,134,000	414[b]	1,271	do
National Alfalfa Dehydrating & Milling Co.	...	...	...	1.5	4.6	Alluvium and Newman Terrace deposits
Irrigation supplies[c]	...	...	...	205	629	do
Other pumpage						
Rural domestic and stock, and miscellaneous	...	...	200,000	73	224	
Total	...	...	...	2,266.4	6,955.6	

a. Data from State Board of Health and from water superintendents.
b. Metered.
c. Data from Division of Water Resources, Kansas State Board of Agriculture, and from well owners.

The average hydraulic gradient of the water table in this part of the Kansas River valley is about 2½ feet per mile (Davis and Carlson, 1952, pl. 2; Dufford, 1958, fig. 3), but locally, as in the vicinity of the Bowersock Mill & Power Co. dam, at Lawrence, the gradient may be as much as 20 feet per mile (Lohman, 1941, p. 42).

Lohman computed the underflow in the Kansas River valley at Lawrence to be about 1,500,000 gpd, which he stated was probably too low because of the assumed hydraulic gradient used in the south half of the valley. Recharge in the valley was estimated by Lohman to be about 10 percent of the annual precipitation or about 64 million gallons on each square mile annually.

Industrial and municipal pumpage in the Lawrence area in 1955 was more than 5 mgd (Table 7), all of which was from parts of the alluvium and Newman Terrace deposits having relatively unfavorable hydrologic characteristics compared with those of the aquifer in the deep bedrock-channel area (Fig. 9). During peak irrigation periods an additional 3 to 5 mgd is pumped for irrigation in the Kansas River valley.

Fluctuations of the water table in well 12-20-17ccb, near the middle of the valley, shown in Figure 10 for the period February 1952 to August 1958, are the result of recharge to and discharge from the aquifer by natural and artificial means. Records of wells and test holes in these deposits are given in Table 8.

The chemical character of ground water in the aquifer is indicated by the water analyses in Table 4. In general the ground water can be characterized as a very hard calcium bicarbonate water that contains much iron and has a pH range from 6.9 to 7.5.

Wakarusa River valley.—Moderate quantities of ground water occur in the alluvium and Newman Terrace deposits of the Wakarusa River valley. The geologic and hydrologic characteristics of this aquifer are quite different from those in Kansas River valley, as shown in Plate 3 and in logs of test holes at the end of this report. Sandy and clayey silt compose most of the aquifer, but a thin sand and gravel section lies at the base. Test holes indicate a thickness of about 50 to 70 feet of alluvial material. The average saturated thickness is 40 to 50 feet, but only 1 to 7 feet of silty sand and gravel is commonly available in which a well screen can be set and a well developed.

Yields of 50 to 100 gpm probably can be obtained, but in 1957 there were no wells of this capacity in operation. Drilled wells in this aquifer are difficult to screen and develop so that an objectionable quantity of very fine sand and silt is not pumped with the water. Many of the domestic wells are of large diameter and are dug just far enough below the water table to obtain a supply by slow infiltration to the well from the sandy and clayey silt in the upper and middle parts of the aquifer. The average hydraulic

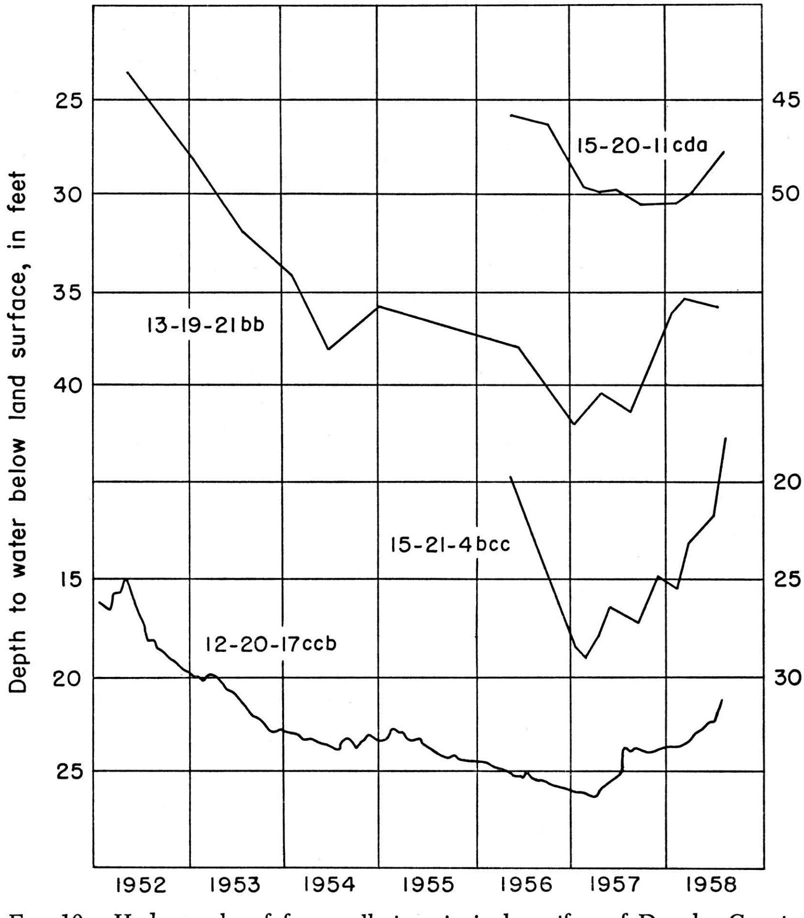

FIG. 10.—Hydrographs of four wells in principal aquifers of Douglas County.

gradient of the water table in the alluvium and Newman Terrace deposits in the Wakarusa River valley is about 4 feet per mile.

The chemical character of the ground water is indicated by the water analysis of well 13-19-18dd (Table 4). The water is generally satisfactory for domestic use except for hardness and iron. Wells screened at the base of the aquifer where it directly overlies and is hydraulically connected with the Tonganoxie Sandstone member may obtain water containing more dissolved solids and chloride than that elsewhere.

Other stream valleys.—Tributaries of Kansas and Wakarusa Rivers contain alluvium and Newman Terrace deposits but they are thin and generally do not yield large amounts of water to wells. The lower parts of Little Wakarusa and Captain Creeks have 30 feet or more of alluvial deposits, containing a sand and gravel deposit in the basal part, that probably are capable of yielding 10 to 50 gpm to wells. Other streams have chiefly silty and clayey deposits ranging from about 10 to 50 feet in thickness and yielding ground water commonly at rates of 1 to 10 gpm.

The quality of ground water from deposits in these smaller valleys is generally satisfactory except for excessive hardness and iron content.

Deposits of Buck Creek Terrace

Buck Creek Terrace deposits are chiefly sandy clay and silt. Although the lower 2 to 10 feet generally includes poorly sorted sand and gravel containing considerable silt and clay, the aquifer does not yield ground water readily to wells.

Test holes drilled through these deposits (Pl. 2, 3) indicate a maximum thickness of about 68 feet and a maximum saturated thickness of about 55 feet in the Wakarusa River valley, where the deposits are most extensive.

Although it is difficult to keep very fine sand and silt from entering drilled wells constructed in the Buck Creek Terrace deposits, the aquifer is the source of satisfactory water supplies for several farms, from both dug and drilled wells. No wells were inventoried that would pump more than about 20 gpm, but supplies of 25 to 50 gpm probably could be obtained locally from properly constructed and developed wells.

The quality of ground water from this aquifer is generally satisfactory for domestic use except for excessive hardness (Table 4) and locally high iron content.

Undifferentiated post-Kansan Alluvium and Terrace Deposits

Deposits younger than Kansan and which are equivalent in age to the alluvium and Newman Terrace and Buck Creek Terrace deposits in the larger valleys occur in many of the smaller tributary valleys but are not differentiated on Plate 1. These deposits range in thickness from about 10 to 40 feet. Because they are derived chiefly from the local rocks in the drainage area of the individual tributary and because of the predominance of shale in the area, most of the sediments are poorly sorted sandy clays and silts, although alluvium may be very sandy in tributaries draining areas of the Tonganoxie or Ireland Sandstone members or extensive Kansan deposits.

There is a wide range in the capacity of these deposits to store and transmit ground water, but small supplies of 1 to 10 gpm can generally be obtained from them for domestic and stock use. Because of the low yields, dug wells providing considerable storage in the well itself are more satisfactory than small-diameter drilled wells. Well 12-20-4bc (Table 8 and well log) is a representative well obtaining a domestic water supply from these deposits.

The chemical character of the ground water is similar to that obtained from other post-Kansan alluvial deposits in the larger valleys.

Kansan Deposits

Because of the wide range in thickness, extent, and character of the Kansan deposits, their ability to store and transmit water differs greatly from one locality to another. Deposits of clayey till, whether small dissected patches or extensive deposits, generally supply little or no water to wells. Fluvial outwash deposits, however, may be permeable and transmit water readily. Small dissected deposits generally are easily drained. This is illustrated by the Kansan outwash along Kansas River between Lawrence and Lakeview, where suburban development has resulted in many wells and test holes having been drilled for domestic water supplies. Some of these wells and test holes have been drilled through a very thin saturated zone of sand and gravel of the Grand Island Formation at the base of the deposits and yield satisfactory domestic supplies. Others may obtain small amounts of ground water from perched water bodies in the Sappa Formation or in post-Kansan alluvial and colluvial deposits. Still others penetrated the entire thickness of Kansan deposits without encountering any saturated material capable of yielding a domestic water supply and were drilled into the sandstone of the Stranger Formation, which underlies this area. As water in the Tonganoxie Sandstone member is salty in this area (test hole 12-19-26abb; Tables 4 and 8), such wells are failures unless at least a small amount of water is yielded by the Kansan deposits. If as much as 10 or 15 gallons of water per hour is obtained from the Kansan deposits in wells drilled into the

Tonganoxie Sandstone member, this small amount of fresh water will move into the well and down into storage in the Tonganoxie because of the lower head in the sandstone. Water supplies of 200 to 300 gpd have been obtained from such wells, but if pumped heavily they may yield brackish or salty water.

In other areas of extensive Kansan deposits, such as the Hesper area, wells completed in saturated sand and gravel may yield large domestic and stock water supplies. Yields of 50 gpm probably can be obtained locally. Other wells, however, encountering only clay and sandy clay, or in marginal areas where the water table is below the Kansan deposits, may yield little or no ground water. Several small streams in the Hesper area have perennial flows maintained by ground-water discharge from the Kansan deposits.

The quality of water in Kansan deposits is indicated by the analyses in Table 4.

Consolidated Rock Aquifers

Limestone and Shale Aquifers

Limestone and shale are widespread over the county at or near the surface, and individual stratigraphic units are uniform in thickness and composition and are laterally continuous. In their unweathered state the limestone and shale are relatively impermeable and generally will not yield enough water to constitute a reliable water supply. At or near the surface, however, weathering processes tend to increase or enlarge the open spaces within the rocks, especially along joints, fractures, and bedding planes, so that locally these rocks may yield small supplies of ground water to shallow wells.

The permeability of weathered limestone and shale differs greatly from place to place. Effectiveness of recharge to and discharge from these rocks is importantly influenced by such factors as type and thickness of soil, vegetative cover, slope and topographic position, and thickness and extent of the weathered zone.

Haworth (1897, p. 15; 1913, p. 51) described water supplies obtainable from these rocks in Douglas County and, in particular, a ground-water supply developed by the University of Kansas in 1896 on the south slope of Mount Oread. Haworth's investigation revealed weathered shale and colluvial deposits as much as 40 feet thick on the middle part of the hillslope. A large dug well 19 feet deep, with galleries extending east and west along the base of the weathered shale zone, produced about "5,000 gallons a day almost all the year, and 10,000 in wet weather." Generally, large-diameter dug wells are more successful than drilled wells in such material, because of their large storage capacity. Static water levels in such wells may be within a few feet of the land surface in wet years and decline greatly in dry years. Successive years of deficient precipitation may cause wells constructed in these shallow aquifers to go dry.

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

Sandstone Aquifers

Calhoun, Tecumseh, and Kanwaka Shales.—Each of these shale formations contains relatively thin intraformational channel sandstones, 5 to 30 feet thick locally, which yield small ground-water supplies to domestic wells. The sandstones have similar lithologic and hydrologic properties and are chiefly very fine to fine, micaceous, angular to subangular quartz sandstone. Although no permeability tests were made of these aquifers, their physical and lithologic similarity to sandstone of the Ireland and Tonganoxie Sandstone members suggests that their hydraulic properties might also be similar.

Wells 12-17-14aa and 12-18-3aa obtain water from sandstone in the Calhoun and Kanwaka Shales, respectively, which is representative of the quality and quantity of water generally obtainable from these aquifers (Tables 4 and 8). Yields of such wells, commonly 2 gpm or less, are satisfactory only for small domestic supplies.

Lawrence Shale.—The Lawrence Shale contains the Ireland Sandstone member, an important sandstone aquifer in southern Douglas County, which provides small to moderate quantities of ground water. Many wells yield 5 to 50 gpm, and in most favorable areas 100 gpm probably can be obtained.

Both Baldwin and Wellsville obtain municipal water supplies from the Ireland Sandstone member. Logs of wells and test holes (at the end of this report) indicate that locally the Ireland Sandstone member is more than 115 feet thick. Figure 5 shows the principal area of occurrence of the sandstone, and Plate 1 indicates the areal extent of Lawrence Shale in this area. In the area of outcrop of the Ireland Sandstone member, ground water occurs chiefly under water-table conditions, and as much as 100 feet of saturated water-bearing material may be present locally. In the southwestern part of the county the aquifer is overlain by confining beds and the water is artesian, but the aquifer is generally not as thick as in south-central and southeastern parts of the county.

The coefficient of permeability of the well-sorted, massive channel deposits ranges from about 100 to 350 gpd per ft.^{2}, but that of much of the aquifer is about 25 to 150 gpd per ft.^{2}

Well 15-20-15ad (Baldwin well 8) penetrates about 19 feet of saturated water-bearing sandstone, which has a coefficient of permeability of about 340 gpd per ft.^{2} Well 15-21-5ad (Wellsville well 3) penetrates 61 feet of Ireland Sandstone, which has a coefficient of permeability of about 125 gpd per ft.^{2} These wells are pumped at about 45 and 25 gpm and have specific capacities of about 7.6 and less than 1 gpm per ft., respectively (Table 6). They are representative of the water supplies available from this aquifer.

Conditions are very favorable for recharge to the aquifer, especially in areas having friable and leached sandstone at or near the surface in the headwater areas of Tauy, Coal, and Captain Creeks. A considerable amount of ground water is discharged to tributaries of these streams, giving rise to small perennial streamflows and local marshy areas. The amount of ground water pumped from wells in this area is small compared with the amount discharged naturally.

The chemical quality of ground water in the Ireland Sandstone member is excellent in the outcrop or water-table area. It is a calcium magnesium bicarbonate water that is moderately low in dissolved solids. The municipal and domestic supplies obtained from it generally are not treated before use except for chlorination. Downdip, in southwestern Douglas County, the aquifer is confined, and the water contains more total dissolved solids. Instead of being a calcium magnesium bicarbonate water it is a soft sodium bicarbonate water, owing to natural softening by base exchange. The fluoride content of the ground water generally is greater in this area, and in many wells exceeds the recommended maximum of 1.5 ppm. The amount of chloride in the water of some wells that tap the Ireland Sandstone member is enough to give a salty taste. Chemical analyses of samples of ground water from the Lawrence Shale, chiefly from the Ireland Sandstone member, are given in Table 4.

Stranger Formation.—The Stranger Formation contains the Tonganoxie Sandstone member, an important aquifer similar to the

Ireland Sandstone in thickness, areal extent, and origin, but the two sandstones generally do not occur in the same geographic area except in southwestern Douglas County. The Vinland Shale member of the Stranger Formation locally contains a thin sandstone, which yields small amounts of ground water to a few wells. The sandstone in the Vinland commonly is very calcareous, and locally the voids between sand grains are almost completely filled with calcite. No data are available regarding the permeability of the sandstone in the Vinland Shale member, but it is probably very low. In some wells the sandstone in the Stranger Formation is not readily identifiable with the one in the Vinland Shale member or with the upper part of the Tonganoxie Sandstone member.

The Tonganoxie Sandstone member yields supplies of 5 to 50 gpm to many wells, and locally where most permeable may yield 50 to 100 gpm. It is the principal source of domestic and stock supplies in a belt several miles wide trending southwest nearly along the strike of the rocks from the Lawrence area to the southwest corner of the county (Fig. 4). Logs of wells and test holes indicate 70 feet of sandstone in the basal part of the Tonganoxie Sandstone member locally. Plate 1 indicates the outcrop area of the Stranger Formation; where it is broad, the Stranger Formation generally includes at least a few feet of sandstone of the Tonganoxie member.

In the outcrop area of the Tonganoxie Sandstone in the lower part of the Wakarusa River valley east and southeast of Lawrence, ground water in that aquifer is chiefly unconfined, but west and southwest of Lawrence the aquifer is confined between relatively impermeable limestone and shale beds and the water is artesian.

The coefficient of permeability of the Tonganoxie Sandstone probably has about the same range as that of the Ireland Sandstone, about 15 to 150 gpd per $ft.^2$, but locally well-sorted massive deposits are probably much more permeable.

Overbrook municipal well 1 (15-17-12ac2) obtains water from the Tonganoxie Sandstone, and the results of a pumping test on this well are summarized in Table 6. The coefficient of transmissibility computed from this test was 1,620 gpd per ft. The thickness of the aquifer is about 90 feet; hence, the coefficient of permeability is about 18 gpd per $ft.^2$

The hydraulic gradient in the artesian part of the Tonganoxie Sandstone member is approximately 7 feet per mile between well 15-17-1ac2 and well 13-19-27dd. The ground water is moving from southwestern Douglas County northeastward toward the

Wakarusa River valley in the vicinity of Lawrence, where it discharges into alluvial deposits in the Wakarusa and Kansas River valleys.

Recharge to the nonartesian parts of the Tonganoxie Sandstone member south and east of Lawrence is chiefly from local precipitation in the outcrop area. Recharge to the artesian part of the aquifer in southwestern Douglas county is believed to result from hydraulic interconnection between Ireland Sandstone member and Tonganoxie Sandstone member in northwestern Franklin County. Ground water in the Tonganoxie in the artesian area of southwestern Douglas County generally is more mineralized downdip and also downgradient from southwestern Douglas County toward its discharge area in the vicinity of Lawrence.

The quality of water in the Tonganoxie Sandstone member ranges from good to bad. The water is salty in the lower, or downdip, part of the aquifer. In much of southwestern Douglas County the water is a soft to moderately hard sodium chloride water. It is of good quality in the southwestern corner of the county but is more brackish westward downdip and northeastward downgradient in the artesian area. In the water-table area southeast of Lawrence the water is generally a calcium bicarbonate water of good quality, although iron and fluoride may be present locally in objectionable amounts. Analyses of samples of ground water from Tonganoxie Sandstone and undifferentiated Stranger Formation are given in Table 4.

Rock Lake Shale.—The Rock Lake Shale member locally contains fine and very fine sandstone, ranging in thickness from a featheredge to about 13 feet, which yields water to a few wells in eastern Douglas County. Table 4 includes analyses of water from two wells (14-20-22ba and 14-21-18ad) that obtain all or part of their water supply from this sandstone. As indicated by these analyses, the water is brackish but usable for livestock. Although a few wells reportedly yield water of good quality from this aquifer, other wells are known to yield water that is brackish. Conclusive data are not available, but it is likely that water in the aquifer west of R. 20 E. is salty, and in parts of R. 20 and 21 E. is brackish. Yields of wells range from about 1 to 10 gpm.

Bonner Springs Shale.—The oldest sandstone known to yield water of usable quality in Douglas County is in the Bonner Springs Shale, which underlies the Plattsburg Limestone. Locally at well 14-20-22cc at least 16 feet of sandstone is present in the formation.

Areas in which fresh water, or brackish water that is usable for stock, can be obtained probably are limited to parts of R. 20 and 21 E. Only two wells (14-20-22ba and 14-21-18ad) that obtained water from this aquifer were inventoried. Yields of 1 to 10 gpm can be obtained locally from this aquifer.

Other Aquifers

The Wyandotte Limestone, which underlies the Bonner Springs Shale, is the oldest formation known to be yielding usable (fresh or brackish) water to a well (14-21-16cc) in Douglas County. Older Pennsylvanian rocks have not been systematically studied or exploited for sources of ground water, but information obtained from drilling for oil and gas indicates that the water in the deeper Pennsylvanian rocks probably becomes progressively more mineralized with depth and may contain dissolved solids ranging from about 5,000 to 50,000 ppm, or even more.

Some unconfirmed reports indicate that some of the water in the pre-Pennsylvanian rocks is of a better quality than the water in the deep Pennsylvanian rocks. The "Hunton" limestone of Silurian and Devonian age is known to contain water of usable quality in parts of Brown and Doniphan Counties in northeastern Kansas, and the Arbuckle Group, of Cambrian and Ordovician age, yields municipal water supplies in southeastern Kansas. Reliable analyses of ground water from pre-Wyandotte beds were not obtained during this investigation.

Utilization of Ground Water

Public Supplies

Five towns—Baldwin, Eudora, Lecompton, Overbrook (Osage County) and Wellsville (Franklin County)—have well fields in Douglas County that provide the entire supplies for those towns. Lawrence utilizes both surface water and ground water for its public supply. Available logs of municipal wells and test holes indicated on Plate 2 are included at the end of this report.

Baldwin

Two dug wells and six drilled wells (Table 8; Pl. 2) supply water for the town of Baldwin. Seven of the wells, ranging from 40 to 60 feet in depth and from 8 to 120 inches in diameter, tap the Ireland Sandstone member of the Lawrence Shale, and one well 26 feet deep and 240 inches in diameter taps both the

Ireland Sandstone and alluvial deposits along Spring Creek. Water is pumped from the well field to an elevated 200,000-gallon steel reservoir near the center of town.

Approximately 47 million gallons (144 acre-feet) of water was used in 1955 (Table 7). The water is of good quality, as shown by the analysis in Table 4. Chlorination is the only treatment given the water.

Eudora

The water supply of Eudora is obtained from two wells about 12 inches in diameter and 64 feet deep, which produce water from alluvium in the Kansas River valley. The average pumpage is about 80,000 gpd (Table 7); in 1955 approximately 29 million gallons (89 acre-feet) was pumped from the well field.

The newer of the two wells was not inventoried, but it is located in the same area and is of similar construction to the well inventoried (13-21-5db).

The water is of good quality except for more than 400 ppm of hardness (Table 4). Water is pumped from the well field to an elevated 50,000-gallon steel storage reservoir for distribution after being softened, treated for removal of iron, and chlorinated.

Lawrence

Both ground water and surface water are now used for the Lawrence municipal water supply, but originally only ground water and later only surface water was used (Lohman, 1938). Six wells ranging from 48.5 to 51.3 feet in depth are located north of the water plant in alluvium along Kansas River (Pl. 2). They are each equipped with 12-inch diameter screens, 18-inch casing, and 350 gpm capacity pumps. According to Robert Mounsey, city water superintendent (personal communication), in 1955 the well field supplied 414,817,600 gallons of water or about 34.6 percent of the total supply of 1,198,042,000 gallons. The quality of water in Kansas River changes with its stage and is affected by seasonal changes. Whenever the river water is excessively turbid or contains large quantities of taste- or odor-causing algae, the percentage of well water used is increased.

Normally the river water is somewhat softer than the ground water, but the ground water has a more nearly constant chemical quality and is free from turbidity, taste, and odor-causing organisms. The water is softened, chlorinated, and fluorinated at the treatment plant.

Lecompton

Lecompton obtains its water supply from a well (11-18-34bd) northwest of the town in the alluvium of the Kansas River valley. The well is 10 inches in diameter and 30 feet deep. Average pumpage is reported to be approximately 10,000 gallons a day (Table 6). In 1955 approximately 3.6 million gallons (11 acre-feet) was pumped.

The water is very hard and contains 0.31 ppm iron and manganese (Table 4) but otherwise is of good quality.

Overbrook

Two drilled wells in southwestern Douglas County supply water for Overbrook, which is in Osage County to the west. The wells tap the Tonganoxie Sandstone member of the Stranger Formation. Well 15-17-1ac1 (east well), is 507 feet deep and is cased with 412.5 feet of 6¼-inch iron casing. Well 15-17-1ac2 is 497 feet deep and is cased with 417 feet of 6¼-inch iron casing. Each well is equipped with a 35-gpm capacity submersible turbine pump. Water is pumped from the wells to an elevated 50,000-gallon steel reservoir at the east edge of town.

The water is of satisfactory quality as shown by the two analyses in Table 4, although it is hard and exceeds slightly the maximum values recommended by the U. S. Public Health Service for dissolved solids and iron. Analyses of water samples collected April 1, 1953, and December 12, 1955, indicate that the quality of water had improved slightly between those dates. Water treatment consists of chlorination.

The average daily usage is about 20,000 gallons, and in 1955 a total of about 7.3 million gallons (22 acre-feet) was pumped.

Wellsville

Prior to June 1956, two large dug wells, each 60 feet deep, and one 8¼-inch drilled well, 61 feet deep, provided the municipal water supply of the city of Wellsville, Franklin County (Pl. 2). In 1956 a fourth well (15-21-4bb), 100 feet deep, was drilled and added to the supply system. All the wells obtain water from the Ireland Sandstone member of the Lawrence Shale.

In 1955 an estimated 22 million gallons, or 68 acre-feet (Table 7), was pumped from the well field through a 50,000-gallon elevated steel storage reservoir near the center of town.

The water is of good quality as shown by the chemical analysis in Table 4. Chlorination is the only treatment given the water.

7—5329

Industrial Supplies

Cooperative Farm Chemicals Association

Ammonium nitrate, urea solutions, anhydrous ammonia, and ammonia solutions are produced by the Cooperative Farm Chemicals Association plant east of Lawrence. Ground water is pumped from nine wells (Pl. 2) in alluvial deposits of the Kansas River valley for use principally in cooling processes, boiler feed, and products manufacture. A total of 471 million gallons of water (Table 7) was pumped from the well field in 1955. Consumptive use amounts to approximately half a million gallons per day. During the last half of 1955 the plant also obtained 63 million gallons of water from the city of Lawrence.

Kansas Power and Light Co.

The Kansas Power and Light Co. generating plant between Lawrence and Lakeview is the largest single user of ground water in Douglas County. Six wells in the alluvium of the Kansas River valley provide 1,000 to 1,500 gpm continuously. In 1955 pumpage was approximately 578 million gallons, or 1,774 acre-feet (Table 7). The water is used chiefly for cooling.

National Alfalfa Dehydrating and Milling Co.

The National Alfalfa Dehydrating and Milling Co. has dehydrators at Lakeview and Midland, which operate during the growing season. The Midland plant has storage and processing facilities that operate throughout the year. Approximately 1.5 million gallons of water is used annually by the two dehydrators.

Westvaco Mineral Products Division Food Machinery & Chemical Corp.

Sodium phosphate, phosphoric acid, and dry ice are manufactured by the Westvaco Mineral Products Division in north Lawrence. Ground water, obtained from six wells in the alluvium of the Kansas River valley, is used for cooling. In 1955 the well field was pumped at a rate of 800 to 900 gpm about 80 percent of the year, and pumpage totaled 414 million gallons (1,271 acre-feet). About 10 to 15 percent of the water pumped is consumed.

Irrigation Supplies

The first irrigation of field crops in the Kansas River valley was probably in the middle 1930's. During the 1940's rainfall was generally above normal and interest in irrigation declined. The years 1952 to 1956, inclusive, were drought years and interest in irrigation was revived. In 1955 an estimated 629 acre-feet of water was pumped from wells and water-table pits in the Kansas River valley in Douglas County, to irrigate 656 acres of crops, principally corn and alfalfa. In 1957, 1,080 acres was irrigated from wells or water-table pits. Irrigation water is most commonly distributed by sprinkler systems, and the wells are pumped at rates of 350 to 1,000 gpm.

Water analyses available indicate that the ground water is satisfactory for crops most commonly irrigated. Ground water in the Kansas River valley generally has a low sodium (alkali) hazard and a medium or high salinity hazard. Crops of moderate salt tolerance, such as corn, alfalfa, wheat, oats, and potatoes, can be irrigated without special practices, but high-salinity water cannot be used on soils having restricted drainage. For a more thorough discussion of the suitability of water for irrigation the interested reader is referred to Agriculture Handbook 60 of the U. S. Department of Agriculture.

No ground-water irrigation is practiced outside the Kansas River valley, as sufficiently high yields generally are not obtainable elsewhere in the county.

Domestic and Stock Supplies

Several hundred water supplies for domestic and stock needs are obtained from wells and springs in Douglas County. During 1955, a drought year, many farm, domestic, and stock supplies were inadequate, and much water was hauled from municipal supplies and from Kansas Emergency Relief Committee wells. It is estimated that, exclusive of water from municipal sources, about 200,000 gpd of water was obtained from wells and springs. The total 1955 use is estimated at 73 million gallons or 224 acre-feet (Table 7).

Summary

Pumpage of ground water increased more than 400 percent between 1950 and 1956, chiefly as a result of industrial and irrigation developments. Additional large increases for industry and agriculture are likely to result in the next few years; most of the ground water will be obtained from alluvium and Newman Terrace deposits in the Kansas River valley.

RECORDS OF WELLS, TEST HOLES, AND SPRINGS

Information pertaining to 436 water wells, test holes, and springs in Douglas County is given in Table 8. Measured depths to water are given to the nearest 0.01 foot, whereas depths reported by the owner, tenant, or driller are given only to the nearest foot. Similarly, measured depths of wells are given to the nearest 0.1 foot, whereas reported depths are given only to the nearest foot.

TABLE 8.—*Records of wells, test holes, and springs in Douglas County*

Well Number (1)	Location	Owner or tenant	Type of well (2)	Depth of well, feet (3)	Diameter of well, inches	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)	Altitude of land surface, feet (7)	Depth to water level below land surface, feet (8)	Date of measurement	REMARKS (Yield given in gallons a minute; drawdown in feet) (9)
	T. 11 S., R. 18 E.													
11-18-28cd	SE SW sec. 28		Dr	55.0	4	N	Sand, gravel	Alluvium	N	N	843.3	2.78	8-19-50	TH by KGS.
*11-18-34bd	SE NW sec. 34	City of Lecompton	Dr	30	10	S	do	do	T, E	P			1956	Reported to have 25 gpm pump.
11-18-34cd	SE SW sec. 34	Fred Smith	Du	44.5	30	R	Sandstone	Kanwaka Shale	B, H	D		26.10	6-22-50	
	T. 12 S., R. 17 E.													
12-17-1da	NE SE sec. 1	Myron Nelson	Du	9.0	72	R	Limestone, shale	Topeka Limestone	Cy, H	S	±1,065	4	8-24-50	
12-17-2cc	SW SW sec. 2	R. C. Traxler	Du	40	60	R	Shale, limestone	Calhoun Shale and Topeka Limestone	B, H	D	±1,110	12.42	8-11-50	
*12-17-14aa	NE NE sec. 14	R. T. Cree	Dr	70	6¼	GI	Sandstone	Calhoun Shale	Cy, H	D		41	7——52	20 ft. of 6¼-inch steel surface casing, 5½-inch GI top to bottom. Yield 1.
12-17-14dc	SW SE sec. 14	R. L. Wulfkuhle	Du	11.4	60	R, C	Clay, silt, gravel	Colluvium and alluvium†	Cy, E	D, S		2.52	5-18-53	Goes dry in dry years. Dry in part of 1952.
12-17-26db	NW SE sec. 26	Chas Worthington	Du	33	48	R	Limestone, shale	Deer Creek Limestone and Tecumseh Shale	J, E	D		18	5-18-53	Do.
	T. 12 S., R. 18 E.													
12-18-2bd	SE NW sec. 2	M. J. Coleman	Du	14.9	36	C, B	do	Lecompton Limestone	Cy, H	D		14.40	10-28-47	Small yield; goes dry in dry years.
*12-18-3aa	NE NE sec. 3	J. M. Taylor	Du	26.0	60	C, B	Sandstone	Kanwaka Shale	Cy, H	D		20.45	5-19-53	Approximate yield 1 to 2.
12-18-3ba	NE NW sec. 3	Joe Smith	Du	21.3	42	R	Shale	do	B, H	D		19.35	10-28-47	
12-18-4bb	NW NW sec. 4		Du	20.2	36	R	Limestone, shale, silt	Lecompton Limestone and colluvium	Cy, H	S		8.05	10-28-47	
*12-18-11cc	SW SW sec. 11	George McCarty	Du	21.4	32	R	Limestone shale	Lecompton Limestone	B, H	D		18.78	5-19-53	
12-18-12ba	NE NW sec. 12		Du	18.9		R	Shale	Kanwaka Shale	B, H	D		11.90	10-28-47	

12-18-13cd	SE SW sec. 13	School District	Du	17.9	48	R	Limestone, shale	Lecompton Limestone	Cy, H	N	......	11.76	4-25-55	
12-18-19dd	SE SE sec. 19	Howard Hildenbrand	Du	27	60-90	R	Shale, limestone	Tecumseh Shale and Lecompton Limestone	Cy, H	D, S	......	8	5——52	Goes dry in dry years.
12-18-22dc	SW SE sec. 22	......	Du	14.3	42	R	Limestone, silt, gravel	Lecompton Limestone and colluvium	Cy, W	S	......	13.14	8-23-53	Not adequate in dry years.
12-18-34db	NW SE sec. 34	George Steele	Du	25	54	R, C	Silt, gravel	Terrace deposits	Cy, E	D, S	......	17	5-22-53	Do.
	T. 12 S., R. 19 E.													
12-19-1db1	NW SE sec. 1	B. L. Anderson Construction Co.	Dr	82	12	S	Sand	Newman Terrace deposits	T, E	In	±835	23	11-11-55	Drawdown 8.5 ft. after 2.5 hours while pumping at +780.
12-19-1db2	NW SE sec. 1	do	Dr	81	12	S	do	do	T, E	In	±835	23	2——56	
12-19-4dd	SE SE sec. 4	W. Brune and brothers	Dr	82	15	C	Gravel, sand	Alluvium	T, G	I	±831	22	2——41	Drawdown 4 after pumping 700 for several hrs.
*12-19-5dd	SE SE sec. 5	Jack V. Grimes	Dr	24	......	GP	Sand	do	......	D	......	......	12- 2-50	
12-19-7ac	SW NE sec. 7	......	Du	18.6	48	R	Limestone	Oread Limestone	Cy, H	D, S	±950	4.00	6-23-50	
12-19-7dc	SW SE sec 7	......	Du	15.4	±36	R	Limestone, shale	do	Cy, H	D, S	......	14.30	10-28-47	
12-19-8ac	SW NE sec. 8	......	Du	8.1	±48	R	Limestone	do	B, H	S	......	6.30	10-28-47	
12-19-8bd	SE NW sec. 8	School District 69	Du	11.5	......	GI	Shale, limestone	Kanwaka Shale	E, H	D	±990	8.40	6-22-50	
12-19-9ad	SE NE sec. 9	......	Dr	70.0	4	N	Gravel, sand	Alluvium	N	N	828.4	7.2	8-14-50	TH by KGS.
12-19-10cc	SW SW sec. 10	National Alfalfa Dehydrating and Milling Co.	Dr	52	8	S	do	do	C, E	In	832.5	12.70	6-22-50	Yield 300.
12-19-10dc	SW SE sec. 10	Lakeview School	Du	23.2	2	GP	do	do	Cy, H	D	832.2	13.30	6-16-50	
12-19-14bb1	NW NW sec. 14	Kansas Power & Light Co.	Dr	52	18	S	do	do	C, E	In	......	......	1-14-55	Well 6.
12-19-14bb2	NW NW sec. 14	do	Dr	52	18	S	do	do	C, E	In	......	......	1-14-55	Well 4.
12-19-14bb3	NW NW sec. 14	do	Dr	52	18	S	do	do	C, E	In	......	......	1-14-55	Well 5.
12-19-14bc1	SW NW sec. 14	do	Dr	52	18	S	do	do	C, E	In	......	......	1-14-55	Well 3
12-19-14bc2	SW NW sec. 14	do	Dr	53	18	S	do	do	C, E	In	......	14	11- 2-37	Well 2.
12-19-14bd	SE NW sec. 14	do	Dr	52	18	S	do	do	C, E	In	......	14.5	11- 2-37	Well 1. Drawdown 20 after pumping 300 for 8 hrs.; water level reported.
12-19-14cb	NW SW sec. 14	Charlton Bartz	Dr	50	......	N	......	......	......	......	......	......	1- 7-55	Dry hole.
12-19-15bc	SW NW sec. 15	Lakeview Fishing & Shooting Assoc.	Dr	210	......	N	Sandy shale, dark shale	Stranger Formation and Stanton Limestone	N	N	±840	......	9-10-51	Filled with 75 ft. of salt water overnight. Hole abandoned.
12-19-15cd	SE SW sec. 15	......	Dr	54.0	4	N	......	......	N	N	860.0	......	8-14-50	TH by KGS.
12-19-16cc	SW SW sec. 16	Barker School	Du	20.8	36	R	Limestone	Oread Limestone	B, H	D	±987	15.80	6-24-50	
12-19-17ac	SW NE sec. 17	C. Allen	Du	15.6	24	R	do	do	Cy, H	S	±950	4.00	6-19-50	
12-19-22ab	NW NE sec. 22	S. O. Gentry	Dr	90	6	S	Gravel	Terrace deposits	Cy, E	D, S	±860	35	6-27-50	
12-19-22dd	SE SE sec. 22	......	Du	10.2	48	R	Sandy silt	do	Cy, H	S	±900	3.80	6-27-50	
12-19-23aa	NE NE sec. 23	Leonard Hills	Dr	51.7	6	......	Gravel	do	Cy?, E	D, S	±880	49.70	6-26-50	

Table 8.—*Records of wells, test holes, and springs in Douglas County—Continued*

Well Number (1)	Location	Owner or tenant	Type of well (2)	Depth of well, feet (3)	Diameter of well, inches	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)	Altitude of land surface, feet (7)	Depth to water level below land surface, feet (8)	Date of measurement	REMARKS (Yield given in gallons a minute; drawdown in feet) (9)
	T. 12 S., R. 19 E.													
12-19-23ab	NW NE sec. 23	Leonard Hills	Dr	131.5	6	......	Sandstone	Stranger Formation	Cy, H	N	±890	73.00	6-26-50	Water reported too salty to use for domestic or stock needs.
12-19-23add	SE SE NE sec. 23	Riverside School	Dr	141	......	......	Gravel	Kansan glaciofluvial deposits	....	D	±880	80	11-22-54	Chloride +4,800 ppm at depth of 147 ft; well plugged back to 141 ft., chloride reported 240 ppm.
*12-19-23ba	NE NW sec. 23	N. W. Goff	Dr	129.4	6	S	Sandy clay	do	—, E	D	±904	59.40	6-27-50	Well also penetrated water-bearing sandstone at 121-129 ft.
12-19-23cd	SE SW sec. 23	— Oatman	DD	170	30 to 6	B, S?	Clayey sand	do	Cy, E	D	±890	41.19	3-16-50	
*12-19-23dc	SW SE sec. 23	A. C. Edwards	Dr	182.9	6	GI	Clayey sand, gravel	do	Cy, E	D, S	±890	59.60	3-11-50	Well also penetrated water-bearing sandstone in lower part of hole.
12-19-23dd	SE SE sec. 23	....	Du	19.0	48	R	Silt, sand	do	Cy, H	S	±890	15.20	6-26-50	
*12-19-24a	Cen. NE sec. 24	....	Dr	50.0	4	N	Sand, gravel	Alluvium	N	N	821.4	12.4	....	‡(L-10).
12-19-24ac	SW NE sec. 24	....	Dr	30.0	4	N	do	Kansan glaciofluvial deposits	N	N	856.1	....	....	‡(L-11).
*12-19-24ad1	SE NE sec. 24	....	Dr	50.0	4	N	do	Alluvium	N	N	821.6	11.8	....	‡(L-9).
*12-19-24ad2	SE NE sec. 24	....	Dr	50.0	4	N	do	do	N	N	819.2	9.2	....	‡(L-8).
12-19-24bb	NW NW sec. 24	J. A. Wingert	Du	31.3	36	R	Silt, sand	Terrace deposits	B, H	D	±865	28.80	6-27-50	
12-19-24ca	NE SW sec. 24	B. W. Bales	Du	50	36	C	do?	do?	Cy, H	D	±870	48	6-23-50	Reportedly poor well; water discolored.
12-19-24dac	SW NE SE sec. 24	....	Dr	50.0	4	N	Sand, gravel	Alluvium	N	N	817.7	....	....	‡(L-6).
*12-19-24dd	SE SE sec. 24	City of Lawrence	Dr	51.3	18	S	do	do	T, E	P	±823	12.5	3- 8-47	Water level reported. Drawdown 4.1 after 4 hrs. pumping at 300. City well 3.

*12-19-25aa1	NE NE sec. 25	do	Dr	51	18	S	do	do	T, E	P	±822	11	2-10-45	Drawdown 10.5 after 6½ hrs. pumping at 402. City well 2.
12-19-25aa2	NE NE sec. 25	do	Dr	50.5	18	S	do	do	T, E	P	±822	17.6	4- 1-54	City well 4. Depth and water level reported.
12-19-25aa3	NE NE sec. 25	do	Dr	48.5	18	S	do	do	T, E	P	±822	17	4- 8-54	City well 6. Depth reported.
*12-19-25ad1	SE NE sec. 25	do	Dr	51	18	S	do	do	T, E	P	±819	....	1944	City well 1.
*12-19-25ad2	SE NE sec. 25	do	Dr	51	18	S	do	do	T, E	P	±820	14	4-15-54	City well 5.
12-19-25ddb	NW SE SE sec. 25	....	B	44.0	4	N	Silt, sand	Kansan glaciofluvial deposits	N	N	±852	....	7- 8-54	TH by KGS.
*12-19-26abb	NW NW NE sec. 26	....	Dr	237.0	4	N	Gravel and sand; sandstone	do and Stranger Formation	N	N	±890	....	7-22-53	Do.
*12-19-26ab	NW NE sec. 26	Earl Farris	Dr	134.5	5½	GI	Sandstone	Stranger Formation	Cy, E	N	±892	86.54	3-24-50	Water too salty to use.
12-19-27cc	SW SW sec. 27	....	B	10.0	4	N	....	....	N	N	±1,027	....	10-10-55	TH by KGS.
12-19-28ba	NE NW sec. 28	— Higgens	Dr	200	8	S	....	....	N	N	±961	....	5-19-53	Dry hole.
12-19-28cc	SW SW sec. 28	J. D. Phillips	Du	25	±60	R	Shale, sandstone	Kanwaka Shale	Cy, H	D	....	18	5-19-53	Not adequate in dry years.
12-19-34dd	SE SE sec. 34	J. G. Votaw	Dr	105	8	N	....	....	N	N	±980	....	5-22-53	Dry hole.
12-19-35cd	SE SW sec. 35	— Smith	Dr	120	6	....	Sandstone, sandy shale	Lawrence Shale	....	....	±967	....	3——52	Reported yield, ⅓.
	T. 12 S., R. 20 E.													
12-20-4bc	SW NW sec. 4	University of Kansas	Du	27.0	72 to 36	C-B	Gravel, silt	Terrace deposits	Cy, E	D	±920	20.54	11-11-55	
12-20-7adc	SW SE NE sec. 7	C. B. Young	Dr	85.8	42 to 24	S-GI	Sand, gravel	Newman Terrace deposits	C, G	I	±830	23.15	12- 6-40	Drawdown 10 after 24 hrs. at 900. Depth reported.
12-20-7bbb	NW NW NW sec. 7	National Alfalfa Dehydrating & Milling Co.	Dr	42.4	7	S	do	do	....	In	826.8	11.53	10- 7-48	
12-20-8aa1	NE NE sec. 8	J. F. Morgan	Du	26	±60	S-R	Sand, gravel	Terrace deposits	Cy, E	D, S	....	....	2-28-55	Not adequate in drought years. Dry when measured.
12-20-8aa2	NE NE sec. 8	do	Dr	+150	....	....	....	....	N	N	....	....	....	Reported dry hole.
12-20-8da	NE SE sec. 8	....	Dr	63.0	4	N	....	....	N	N	894.0	....	10- 7-49	TH by KGS.
12-20-9cdd	SE SE SW sec. 9	....	Dr	50.0	4	N	Sand, gravel	Kansan glaciofluvial deposits	N	N	883.0	....	....	‡(L-19)
*12-20-16bc	SW NW sec. 16	W. J. Gilmore Estate	Dn	45	1¼	GP	do	Newman Terrace deposits	Cy, W	D, S	830.7	21.60	11-30-40	
12-20-16da	NE SE sec. 16	Rays Truck Stop Cafe	Dr	42	6	S	do	Terrace deposits	J, E	D	±827	....	1952	
12-20-17add	SE SE NE sec. 17	....	Dr	80.0	4	N	Gravel, sand	Newman Terrace deposits	N	N	829.4	21.4	....	‡(L-18).
12-20-17ccb	NW SW SW sec. 17	....	Dr, Dn	50.0	10, 1¼	GI, GP	Sand, gravel	do	N	O	±831	16.05	2- 1-52	Observation well installed by KGS.
12-20-17cd	SE SW sec. 17	University of Kansas	Dr	54	19	GI	do	do	C, T	I	818.6	10.40	11-30-40	Drawdown reported 9 after 24 hrs. at 800.

TABLE 8.—*Records of wells, test holes, and springs in Douglas County—Continued*

WELL NUMBER (1)	Location	Owner or tenant	Type of well (2)	Depth of well, feet (3)	Diameter of well, inches	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)	Altitude of land surface, feet (7)	Depth to water level below land surface, feet (8)	Date of measurement	REMARKS (Yield given in gallons a minute; drawdown in feet) (9)
	T. 12 S., R. 20 E.													
*12-20-17dd	SE SE sec. 17		Dr	80.0	4	N	Gravel, sand	Alluvium	N	N	815.7	8.2		‡(L-17).
*12-20-18ba1	NE NW sec. 18	Fred Laptad	Dn	35.8	1¼	GP	Sand, gravel	do	Cy, H	S	827.1	14.75	12- 7-40	
12-20-18ba2	NE NW sec. 18	do	Dn	50	1¼	GP	do	do	Cy, W	S	827.9	±16	12- 7-40	
12-20-19aa	NE NE sec. 19	Raymond Pine	Dr	59	18	GI	do	Newman Terrace deposits	T, T	I	±831	21	3—56	
*12-20-19ba1	NE NW sec. 19	Lester McGee	Dn		1¼	GP	do	Alluvium	Cy, H	D			12- 7-40	
12-20-19ba2	NE NW sec. 19	do	Dn	19.2	1¼	GP	do	do	Cy, H	S	821.1	10.50	12- 7-40	
12-20-19ba3	NE NW sec. 19	W. L. Moore	Dn	24.4	1¼	GP	do	do	N	N	823.1	12.93	12- 5-40	
*12-20-19ba4	NE NW sec. 19	Harold Brown	Dn	22.9	1¼	GP	do	do	Cy, E	D	825.2	15.46	12- 6-40	
12-20-19ba5	NE NW sec. 19		Dr	49.0	4	N	do	do	N	N	817.5	7.5		‡(L-29).
*12-20-19bcc	SW SW NW sec. 19		Dr	49.0	4	N	do	do	N	N	817.2			‡(L-7).
*12-20-19bd1	SE NW sec. 19		Dr	50.0	4	N	do	do	N	N	822.5	12.9		‡(L-28).
*12-20-19bd2	SE NW sec. 19	Frank Fox	Dn	22.3	1¼	GP	do	do	Cy, H	S	822.6	13.62	12- 6-40	
*12-20-19ca	NE SW sec. 19		Dr	45.0	4	N	do	do	N	N	815.9	6.9		‡(L-27).
*12-20-19cc	SW SW sec. 19		Dr	50.0	4	N	do	do	N	N	818.0			‡(L-5).
*12-20-19cd1	SE SW sec. 19		Dr	50.0	4	N	do	do	N	N	820.0	14.9		‡(L-26).
12-20-19cd2	SE SW sec. 19	I. R. Iles	Dn		1¼	GP		do	N	N	819.5	12.30	11-29-40	
*12-20-19da	NE SE sec. 19		Dr	45.0	4	N	Gravel, sand	do	N	N	813.1	6.9		‡(L-20).
*12-20-20ab	NW NE sec. 20	E. B. Pine	Dn	31.0	1¼	GP		Newman Terrace deposits	Cy, H	D, S	827.6	19.46	11-30-40	
*12-20-20baa	NE NE NW sec. 20		Dr	80.0	4	N	Gravel, sand	Alluvium	N	N	821.5			‡(L-16).
12-20-20bcc	SW SW NW sec. 20		Dr	60.0	4	N	Sand, gravel	Newman Terrace deposits	N	N	829.4	22		‡(L-15).
*12-20-20bc	SW NW sec. 20	Clarence Pine	Dn	35.3	1¼	GP		do	Cy, H	D	828.8	21.45	11-30-40	
12-20-20da	NE SE sec. 20	W. H. Pendleton	DD	50	19		Sand, gravel	Alluvium	C, T	I	±820	14	12- 6-40	Drawdown 12 or 13 after 10 hrs. pumping at 400.
12-20-28db	NW SE sec. 28	John Vogle	Dr	60	18	GI	do	do	T, G	I	±815	23	2—54	Drawdown 12 after 2½ hrs. at 800.
12-20-29aad	SE NE NE sec. 29	Westvaco Min. Prod. Div.	Dr	56	12	S	do	do	T, E	In	±817	19	6—55	Well 7. Drawdown 9 pumping at 450.

12-20-29ac1	SW NE sec. 29	do	Dr	47	10	S	do	do	T, E	In	±819	24	1-21-55	Well 5. Drawdown 6 after 72 hrs. pumping at 170.
12-20-29ac2	SW NE sec. 29	do	Dr	50	12	S	do	do	T, E	In	±820	26	1-21-55	Well 4A.
12-20-29ac3	SW NE sec. 29	do	Dr	52	12	S	do	do	T, E	In	±818	24	1-21-55	Well 6.
12-20-29ad1	SE NE sec. 29	do	Dr	50	10	S	do	do	T, E	In	±818	24	1-21-55	Well 1.
12-20-29ad2	SE NE sec. 29	do	Dr	50	12	S	do	do	T, E	In	±818	24	1-21-55	Well 2A.
12-20-29ad3	SE NE sec. 29	do	Dr	190	6	N	do	do	N	N	±817		1954	Chloride in 48-75 ft. depth reported +2,000 ppm. Drilled as bedrock test hole.
*12-20-30abb	NW NW NE sec. 30		Dr	50.0	4	N	do	do	N	N	816.6	10.8		‡(L-14).
*12-20-30ba1	NE NW sec. 30		Dr	50.0	4	N	do	do	N	N	816.9	12.8		‡(L-13).
*12-20-30ba2	NE NW sec. 30		Dr	45.0	4	N	do	do	N	N	814.8	8		‡(L-25).
*12-20-30ba3	NE NW sec. 30		Dr	45.0	4	N	do	do	N	N	811.0			‡(L-21).
*12-20-30bc1	SW NW sec. 30		Dr	50.0	4	N	do	do	N	N	816.2	12.6		‡(L-12).
*12-20-30bc2	SW NW sec. 30		Dr	50.0	4	N	do	do	N	N	815.5	13		‡(L-1).
*12-20-30bc3	SW NW sec. 30		Dr	50.0	4	N	do	do	N	N	815.8			‡(L-2).
*12-20-30bc4	SW NW sec. 30		Dr	50.0	4	N	do	do	N	N	814.9			‡(L-3).
*12-20-30bc5	SW NW sec. 30		Dr	47.0	4	N	do	do	N	N	814.4			‡(L-4).
*12-20-30bc6	SW NW sec. 30		Dr	48.0	4	N	do	do	N	N	814.8	14.35		‡(L-23).
*12-20-30bc7	SW NW sec. 30		Dr	55.0	4	N	do	do	N	N	821.7	19.3		‡(L-22).
12-20-30bc8	SW NW sec. 30		Dr	52.0	4	N	do	do	N	N	818.2	16.15		‡(L-24).
*12-20-30bd1	SE NW sec. 30	Carl Graber	Dn	29.0	1¼	GP		do	N	N	823.3	21.33	11-30-40	
*12-20-30bd2	SE NW sec. 30	do	Dn	27	1¼	GP		do	Cy, E	S			11-30-40	
12-20-30cca	NE SW SW sec. 30	Lawrence Sanitary Milk & Ice Cream Co.	Dr	222			Sandstone	Stranger Formation	C, E	N	±845		1940	Reported yield 40 salty water. Abandoned 1950.
12-20-31ba	NE NW sec. 31	Wren Building	Dr	160	5½	S	do	do		N	±860		1-21-55	Salty water; originally used to supply swimming pool.
12-20-31caa	NE NE SW sec. 31		B	19.0	4	N			N	N	±860		7- 6-54	TH by KGS.
12-20-33aa	NE NE sec. 33	John Vogel	D	49	18	GI	Sand, gravel	Alluvium	T, G	I		24	2——54	
12-20-33ca1	NE SW sec. 33	Cooperative Farm Chemicals Assoc.	D	51	18	S	do	do	T, E	In			10——55	Well G. Altitude of water level reported 781 ft. Oct. 1955.
12-20-33ca2	NE SW sec. 33	do	D	53	18	S	do	do	T, E	In			10——55	Well H. Altitude of water level reported 778 ft. Oct. 1955.
12-20-33ca3	NE SW sec. 33	do	D	43	18	S	do	do	T, E	In			10——55	Well I. Altitude of water level reported 790 ft. Oct. 1955.
*12-20-35db	NW SE sec. 35	H. C. Altenbernd	Dn	27	1¼	GP		do	Cy, H	N	812	18.17	11- 1-52	
12-20-36ddd	SE SE SE sec. 36		Dr	56.0	4	N	do	do	N	N	810	14.8	4-19-52	TH by KGS.
	T. 12 S., R. 21 E.													
12-21-27cd	SE SW sec. 27	C. Westerhams	Dn	31.3	1¼	GP	Sand	do	Cy, —	N	799.5	17.92	1- 6-53	
12-21-27da	NE SE sec. 27	C. Broers	Dn	26	1¼	GP	Sand, gravel	do		N	797.5	19	12- 6-52	
*12-21-27dc	SW SE sec. 27			22			do	do					12-29-52	

TABLE 8.—*Records of wells, test holes, and springs in Douglas County—Continued*

Well Number (1)	Location	Owner or tenant	Type of well (2)	Depth of well, feet (3)	Diameter of well, inches	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)	Altitude of land surface, feet (7)	Depth to water level below land surface, feet (8)	Date of measurement	REMARKS (Yield given in gallons a minute; drawdown in feet) (9)
	T. 12 S., R. 21 E.													
12-21-31bcc	SW SW NW sec. 31		Dr	48.0	4	N	Sand, gravel	Alluvium	N	N	808	13.7	4-18-52	TH by KGS.
*12-21-31dc	SW SE sec. 31			18			do	do					12-29-52	
12-21-34cbb	NW NW SW sec. 34		Dr	48.0	4	N	do	do	N	N	801		6-22-53	TH by KGS.
12-21-34da	NE SE sec. 34	W. Spitzli	Du	33.7	36	R	Sand	do		D, S	810	27.44	11- 4-52	
	T. 13 S., R. 17 E.													
13-17-1cc	SW SW sec. 1	Elmer Nichols	Du	16.4	96	R	Silt, clay, sand	Colluvium and alluvium†	Cy, H	D, S		3.10	5-21-53	
13-17-12cc	SW SW sec. 12		B	49.0	4	N	Clayey sand	Kansas Till	N	N	±1,073		10-18-55	TH by KGS.
13-17-24bd	SE NW sec. 24		Du	15.6	32-36	R	Gravel, sand	Kansan glaciofluvial deposits	N	N	±955	12.51	5-21-53	
*13-17-24ca	NE SW sec. 24	Sam Kennedy	Sp				do	do	N	D, S			5-21-53	Estimated yield 8.
	T. 13 S., R. 18 E.													
*13-18-2aa	NE NE sec. 2	Robert Kay	Dr	300	5½	GI	Sandy shale	Lawrence Shale	N	N	±1,010		7- 8-55	Salty water.
13-18-5ba	NE NW sec. 5		Du	33.3		R	Sand, gravel	Terrace deposits	Cy, N	D, S	±876	13.24	5-22-53	KERC well.
13-18-7cd	SE SW sec. 7	J. M. Clough	Dr	250	5½	GI	Sandstone	Lawrence Shale	T, E	S	±1,031	108	12-20-56	Water below 200 ft. reported very salty.
13-18-8cd	SE SW sec. 8	Robert Kampshrader	Dr	220			do	do		N	±910		1955	Water at 180-200 ft. reported very salty. Hole abandoned.
13-18-10bd	SE NW sec. 10		Dr	70.0	4	N	Silt, sand, gravel	Newman Terrace deposits	N	N	±864		7-13-53	TH by KGS.
13-18-10dc	SW SE sec. 10		Dr	122.5	4	N	Sandy clay, sand, gravel	do	N	N	±861		7-13-53	Do.
13-18-15ca	NE SW sec. 15		Dr	16.0	4	N			N	N	±967		7-10-53	Do.
13-18-17ad	SE NE sec. 17	Marvin Houk	Du	30	120	R		Kansan glaciofluvial deposits	Cy, W	D, S	±910	8	5-20-53	
13-18-17bd	SE NW sec. 17	J. C. Riepen	Du	14.1	60	R	Silt, clay	Colluvium and alluvium†	Cy, W	D, S		5.68	5-20-53	
13-18-17ca	NE SW sec. 17	E. M. Casey	Du	12	48	R	do	do	Cy, E	D, S		6	9—52	

13-18-17da	NE SE sec. 17	Belvoir School	Dr	186	6	S	Sandstone	Stranger Formation	Cy, H	N	±898	....	5-20-53	Used casing reported to impart taste to water. Not used.
13-18-22aa	NE NE sec. 22	....	Du	22.4	......	R	Gravel, sand	Kansan glaciofluvial deposits	Cy, H	D, S	±920	4.60	5-20-53	KERC well.
13-18-22ab	NW NE sec. 22	....	Dr	28.0	4	N	do	do	N	N	±964	....	7-10-53	TH by KGS.
*13-18-22ba	NE NW sec. 22	Charles Oldfather	Du	33.7	36	R	do	do	J, E	D, S	±969	32.20	5-20-53	
13-18-23aa1	NE NE sec. 23	Charles Nemec	Du	32	48	R	Shale?	Lawrence (?) Shale	Cy, W	S	±908	8	5-20-53	
13-18-23aa2	NE NE sec. 23	do	Du	70	48	R	Shale	do	Cy, W	D	....	62	5-20-52	
13-18-23ba	NE NW sec. 23	W. H. Barton	Dr	326	5½	GI	Sandstone	Stranger Formation	Cy, E	D, S	±944	125	....	Water-bearing sandstone reported at 286-326 ft.
13-18-28ab	NW NE sec. 28	Dwight Henry	Dr	340	6?	......	do	do	Cy, E	S	....	155	5-28-53	Top of water-bearing sandstone reported at 300 ft. Reported brackish.
*13-18-28ba	NE NW sec. 28	Otis Heinie	Dr	350	6	GI	do	do	Cy, E	S	±975	150	9- 4-52	Top of water-bearing sandstone reported at 300 ft. Brackish water.
*13-18-32bc	SW NW sec. 32	Arthur Gaines	Dr	192	5½	GI	do	Lawrence Shale	....	S	±965	....	1-27-56	Brackish water. Reported 200 gal./day fresh water from 17 to 34 ft.
13-18-33ad	SE NE sec. 33	Clarence Anders	Dr	150	6?	GI	do	Stranger? Formation	Cy, E	D, S	±880	....	9- 4-52	Reported yield 1, brackish water.
	T. 13 S., R. 19 E.													
13-19-1acc	SW SW NE sec. 1	....	B	18.5	4	N	....	....	N	N	±881	....	7- 5-54	TH by KGS. Dry hole.
13-19-1ac	SW NE sec. 1	University of Kansas	Du	17.7	24	R	Silt, clay	Colluvium and alluvium†	Cy, H	N	±883	9.07	5- 3-52	NE cor. 18th and Michigan St.
13-19-1bc	SW NW sec. 1	....	Dr	300.0	4	N	....	....	N	N	±998	....	1-12-47	TH by KGS.
13-19-1ca1	NE SW sec. 1	Norman Plummer	Dr	50	6	GI	Sandy silt	Terrace deposits	Cy, E	D	±890	19.08	5- 3-52	
13-19-1ca2	NE SW sec. 1	Norman Plummer	B	62.0	4	N	do	do	N	N	±890	....	7- 5-54	TH by KGS.
13-19-1ca3	NE SW sec. 1	Clarence Edmonds	Du	27.2	72	B, R	do	do	N	N	....	4.21	5- 3-52	
13-19-1cb	NW SW sec. 1	George Kapfer	Dr	153	10	GI	Shale?	Lawrence Shale	Cy, E	D	....	30	5- 3-52	Reported yield 8-9 gal./hr.
13-19-1cc1	SW SW sec. 1	M. E. Hodges	Dr	154	6	S	Sandstone?	Stranger? Formation	Cy, H	D	....	....	6-30-50	Water reported to have "soda" taste.
*13-19-1cc2	SW SW sec. 1	Tom Akin	Dr	118	6?	N	Sandstone	Stranger Formation	N	N	±885	....	1- 8-55	High chlorides. Well plugged and abandoned.
13-19-1cc3	SW SW sec. 1	Keith Cloepfil	Du	19.4	36	R	Shale?	Lawrence Shale	Cy, H	D	±898	5.31	5- 5-52	Goes dry in dry weather.
13-19-1cd	SE SW sec. 1	G. W. Ousdahl	Dr	33.3	5	GI	Silty sand	Terrace deposits	Cy, E	D	±870	9.47	5- 3-52	
13-19-1dbc	SW NW SE sec. 1	....	B	46.0	4	N	Sandy silt	do	N	N	±873	10.9	7- 6-54	TH by KGS.
13-19-5bb	NW NW sec. 5	....	Du	18.8	......	R	Silt, gravel	Colluvium and alluvium†	Cy, H	D, S	±910	4.71	5-19-53	KERC well.
13-19-7ad	SE NE sec. 7	Jim Sanders	Du	28	48	R	Silt, sand	do	Cy, E	D, S	±885	20	5-19-53	
*13-19-7dd	SE SE sec. 7	Ed. Steele	Dr	146	6¼?	S	Sandstone	Stranger Formation	Cy, E	D, S	±846	35	6- 6-55	
13-19-8bd	SE NW sec. 8	School District	Du	37.0	36	R	Sandy silt	Terrace deposits	Cy, H	D	±886	23.33	5-19-53	
13-19-8dbb	NW NW SE sec. 8	....	B	52.0	4	N	do	do	N	N	±881	43.8	10-26-55	TH by KGS.

TABLE 8.—*Records of wells, test holes, and springs in Douglas County—Continued*

Well Number (1)	Location	Owner or tenant	Type of well (2)	Depth of well, feet (3)	Diameter of well, inches	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)	Altitude of land surface, feet (7)	Depth to water level below land surface, feet (8)	Date of measurement	REMARKS (Yield given in gallons a minute; drawdown in feet) (9)
	T. 13 S., R. 19 E.													
13-19-10dd	SE SE sec. 10	Norman Aldrich	Dr	110	6¼	S	Gravel, sand, sandstone	Terrace deposits, Stranger Formation	T, E	D, S	±836	29	4-21-55	Fresh water in terrace deposits. Brackish water in sandstone.
13-19-11aa1	NE NE sec. 11	A. A. Wilson	Du	60	......	R	Gravel, sand	Kansan glaciofluvial deposits	Cy, E	D, S	±912	....	5- 5-52	
13-19-11aa2	NE NE sec. 11	....	Dr	30.0	4	N	do	do	N	N	±907	....	7- 9-53	TH by KGS.
13-19-11bd	SE NW sec. 11	Merle Ward	Du	27.8	24	R	do	do	N	N	±894	23.44	5- 5-52	
13-19-11cd	SE SW sec. 11	Bert Jewett	Dr	90	......	GI?	do?	do?	Cy, W	D, S	±864	....	1-30-53	
*13-19-11da1	NE SE sec. 11	C. V. Bryan	Dr	110	6	S	Sandstone	Stranger Formation	Cy, E	D, S	±881	....	5- 5-52	Brackish water.
13-19-11da2	NE SE sec. 11	....	Dr	32.0	4	N	Sandy, gravely clay	Kansan glaciofluvial deposits	N	N	±876	....	7- 9-53	TH by KGS.
13-19-11da3	NE SE sec. 11	Richard Oehlert	Dr	150	5½	GI	Clayey sand, sandstone	do and Stranger Formation	....	......	±870	40	2-24-56	
13-19-11dd	SE SE sec. 11	Radio Station KLWN	Dr	101	6	GI	Sandy clay, sandstone	Terrace deposits, Stranger Formation	J, E	D	±850	....	1- 7-55	Gravel packed well.
13-19-11ddd	SE SE SE sec. 11	....	Dr	60.0	4	N	Gravel, sand	Terrace deposits	N	N	±849	....	7- 9-53	TH by KGS.
13-19-12aaa	NE NE NE sec. 12	....	B	23.0	4	N	....	....	N	N	±881	....	7- 7-54	TH by KGS.
13-19-12aab	NW NE NE sec. 12	Ralph Puckett	Dr	163.5	6¼	S	Sandstone	Stranger Formation	T, E	D	±883	70.12	6-11-54	Good water.
*13-19-12aad	SE NE NE sec. 12	Gene Puckett	Dr	127	6¼	S	do	do	T, E	D	±866	60	6-26-53	Brackish water.
13-19-12ac	SW NE sec. 12	Fern Stevenson	Du	29.2	30	R	Gravel, sand	Kansan glaciofluvial deposits	Cy, E	D	±901	19.11	5- 5-52	Not adequate in drought years.
13-19-12ad	SE NE sec. 12	....	B	24.0	4	N	do	do	N	N	±903	....	7- 7-54	TH by KGS. Dry hole.
13-19-12ba	NE NW sec. 12	Park Hetzel	Dr	70	6¼	S	do	Terrace deposits	—, E	D	±868	20	8-27-53	Drilled to 111 ft., plugged back to 70. Salty or brackish water at 105 ft.
*13-19-12bbb	NW NW NW sec. 12	Big Buy Drive-In	Dr	60	6	GI	do	Kansan glaciofluvial deposits	J, E	D	±890	....	6-10-55	Drilled to 200 ft., plugged back to 60 ft. Gravel-packed well. Reported yield 2.
13-19-12cb	NW SW sec. 12	Fred A. Bremer	Dr	109	6?	......	Sandstone?	Stranger? Formation	Cy, E	D	±874	....	5- 5-52	Yield 1.

*13-19-12cbb	NW NW SW sec. 12	Albert Hayden	Dr	124.5	6	GI	Clay?, sandstone	Kansan glaciofluvial deposits, Stranger Formation	T, E	D	±873	60	4-29-54	
13-19-12cbc	SW NW SW sec. 12	Orville Flory	Dr	50	6	GI	Sand, gravel	Kansan glaciofluvial deposits	....	D	±864	20	6-15-52	Gravel-packed well. Reported yield +20.
*13-19-13aa	NE NE sec. 13	S. R. Reynolds	Dr	70	6	S	Sandstone	Stranger Formation	J, E	D, S	±830	20	6-24-52	Brackish water.
13-19-13bcc	SW SW NW sec. 13	....	Dr	81.5	4	N	Gravel, sand	Terrace deposits	N	N	±850	13.97	7-10-53	TH by KGS.
13-19-14aa	NE NE sec. 14	Paul Snyder	Dr	111	6	GI	do and sandstone	do and Stranger Formation	T, E	D	±852	32	4- 8-54	Reported drawdown 20 after 1 hr. at 10. Gravel-packed well.
13-19-14ad	SE NE sec. 14	C. E. Dunigan	DD	42	48 and 6	R	Sandy silt	Terrace deposits	Cy, E	D, S	±853	....	1-30-53	
13-19-14ba	NE NW sec. 14	Walt Neider	Du	24.6	48	R	Silt, sand	do	Cy, W	S	±845	12.14	1-30-53	
13-19-14dd	SE SE sec. 14	....	Dr	60.0	4	N	Gravel, sand	do	N	N	±825	8.7	7-10-53	TH by KGS.
13-19-15cc	SW SW sec. 15	C. E. Shelley	Dr	70	6¼	S	do	do	Cy, E	D, S	±838	25	1-28-54	
*13-19-18dd	SE SE sec. 18	Leslie Demeritt	DD	37	24 and 6	R	Sand, silt	Newman Terrace deposits	Cy, E	D	±843	5.29	5-29-53	
13-19-19bb1	NW NW sec. 19	C. W. Collins	Du	28	48	R	do	do	Cy, H	D	±862	18	5-19-53	
13-19-19bb2	NW NW sec. 19	do	Du	27.7	96	R	do	do	Cy, W	S	±862	18.09	5-19-53	
*13-19-21bb	NW NW sec. 21	Robert Mason	Dr	98.9	5¼	S	Sandstone	Stranger Formation	J, E	D, S	±861	23.48	5-20-52	Observation well.
13-19-22ad	SE NE sec. 22	Charles Oldfather	Dr	169	8	S	do	do	N	N	±886	85	7- 2-56	Chloride reported 2,400 ppm. Estimated yield 50.
13-19-23aa	NE NE sec. 23	....	Dr	64.0	4	N	Sand, gravel	Terrace deposits	N	N	±827	14.1	7-10-53	TH by KGS.
13-19-23ad	SE NE sec. 23	....	Dr	65.0	4	N	do	do	N	N	±830	13.3	7-10-53	Do.
*13-19-23da	NE SE sec. 23	Walter Kollmorgen	Dr	140	5½	GI	Sandstone	Stranger Formation	Cy, E	D	±856	....	5-28-53	Reported yield 10.
13-19-24aa	NE NE sec. 24	William Mears	Dr	165	8	GI	do	do	Cy, E	D, S	±844	....	6- 1-53	
*13-19-27dd	SE SE sec. 27	George Luckan	Dr	312	6¼	S	do	do	Cy, —	D, S	±1,005	205	4-23-56	Reported yield 25 to 50.
*13-19-28cb1	NW SW sec. 28	Walter Thome	Du	42	36-42	R	Silt, sand, gravel	Buck Creek Terrace deposits	J, E	D	±867	20	5-29-53	
*13-19-28cb2	NW SW sec. 28	do	Dr	107	6	GI	Sandstone	Stranger Formation	Cy, E	S	±865	20	5-29-53	
13-19-31cc	SW SW sec. 31	R. A. Brandt	Du	16.1	30-36	R	Sand, gravel	Terrace deposits	Cy, H	D	....	15.48	8-12-53	
13-19-36ab	NW NE sec. 36	Harold Skinner	Dr	95	5½	GI	Sandstone	Stranger Formation	....	D, S	....	64	6——56	
13-19-36bb	NW NW sec. 36	Charles Iles	Dr	118	......	......	do	do	....	D, S	±893	....	1948	
	T. 13 S., R. 20 E.													
13-20-1add	SE SE NE sec. 1	....	Dr	66.5	4	N	Sand, gravel	Alluvium	N	N	809	11.5	4-19-50	TH by KGS.
13-20-1dd	SE SE sec. 1	C. A. Spray	Du	24.5	48	R	do	do	....	D, S	812.6	18.50	11- 1-52	
13-20-3ca	NE SW sec. 3	D. W. Brunk	Du	24	30	R	do	do	....	D, S	813.0	14.58	11- 1-52	
13-20-4ab1	NW NE sec. 4	Cooperative Farm Chemicals Assoc.	Dr	56	18	S	do	Terrace deposits	T, E	In	....	....	10——55	Well B. Drilled to 59 ft., cased and screened to 56 ft. Altitude of water level reported 778 ft. Oct. 1955.
13-20-4ab2	NW NE sec. 4	do	Dr	62	18	S	do	do	T, E	In	....	....	10——55	Well A. Altitude of water level reported 780 ft. Oct. 1955.

TABLE 8.—*Records of wells, test holes, and springs in Douglas County—Continued*

WELL NUMBER (1)	Location	Owner or tenant	Type of well (2)	Depth of well, feet (3)	Diameter of well, inches	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)	Altitude of land surface, feet (7)	Depth to water level below land surface, feet (8)	Date of measurement	REMARKS (Yield given in gallons a minute; drawdown in feet) (9)
	T. 13 S., R. 20 E.													
13-20-4ab3	NW NE sec. 4	Cooperative Farm Chemicals Assoc.	Dr	57	18	S	Sand, gravel	Terrace deposits	T, E	In	....	....	10—55	Well C. Altitude of water level reported 776 ft. Oct. 1955.
13-20-4ba1	NE NW sec. 4	do	Dr	52	18	S	do	Alluvium	T, E	In	....	....	10—55	Well D. Altitude of water level reported 778 ft. Oct. 1955.
13-20-4ba2	NE NW sec. 4	do	Dr	53	18	S	do	do	T, E	In	....	....	10—55	Well E. Altitude of water level reported 780 ft. Oct. 1955.
13-20-4bb	NW NW sec. 4	do	Dr	52	18	S	do	do	T, E	In	....	....	10—55	Well F. Altitude of water level reported 780 ft. Oct. 1955.
13-20-5bd	SE NW sec. 5	George Zillner	Du	19.9	36-48	R	Clay, gravel	Kansan glaciofluvial deposits	Cy, E	D	±891	7.17	6-12-52	
*13-20-5caa	NE NE SW sec. 5	Ralph Kerns	Dr	160	8	S	Sandstone	Stranger Formation	J, E	D	±890	88	8- 5-54	
13-20-5cb	NW SW sec. 5	....	B	9.8	4	N	....	....	N	N	....	....	1950	TH by KGS.
13-20-5dc1	SW SE sec. 5	Douglas County (4-H grounds)	Dr	185	6	GI	Sandstone	Stranger Formation	Cy, E	D, S	±921	109	6-26-52	
13-20-5dc2	SW SE sec. 5	Oliver Peters	Dr	174	6	GI	do	do	T, E	D	±916	110.54	3-13-56	Reported yield 15.
13-20-6aa	NE NE sec. 6	Paul Boyer	Dr	66	6	S	Clay	Kansan glaciofluvial deposits	....	D	±861	14	5-28-52	
13-20-6aba	NE NW NE sec. 6	....	B	25.0	4	N	Silty clay	Colluvium and alluvium†	N	N	±855	....	7- 6-54	TH by KGS.
13-20-6cd	SE SW sec. 6	....	B	19.0	4	N	do	do	N	N	±872	....	8-16-54	Do.
13-20-7ad	SE NE sec. 7	Paul Clawson	Dr	143	6	GI	Sandstone	Stranger Formation	Cy, E	D	....	74	7—53	
13-20-8ab1	NW NE sec. 8	....	B	23.5	4	N	....	....	N	N	±910	....	7- 8-54	TH by KGS.
13-20-8ab2	NW NE sec. 8	P. A. Diehl	Dr	184	6¼	....	Sandstone	Stranger Formation	....	D	±912	104	7-30-53	
*13-20-8ad	SE NE sec. 8	Nellie Harris	Dr	160	4⅞	S	do	do	Cy, E	D, S	±880	40	3-21-53	Gravel-packed well. Reported yield 1.
13-20-8bb	NW NW sec. 8	Delbert Richardson	Dr	130	....	....	do	do	Cy, E	D, S	....	....	6-23-52	

13-20-9ab	NW NE sec. 9	R. L. Thomas	Dr	186	6	GI	do	do	T, E	D, S	±905	....	6-24-52	Water at 176 ft.
13-20-9bb	NW NW sec. 9	W. K. Eisele	DD	140	±36-6?	R-GI	do	do	Cy, E	D, S	±884	....	6-24-52	Well penetrates intermittent water-bearing zone in upper part of well also.
13-20-9dad	SE NE SE sec. 9	....	B	35.0	4	N	Sand, gravel	Kansan glaciofluvial deposits	N	N	±861	23.5	8-27-54	TH by KGS.
13-20-10ac	SW NE sec. 10	Ed. Martin	Du	40	......	R	Sandstone?	Stranger? Formation	J, E	D, S	±842	....	6-23-52	
13-20-10cb	NW SW sec. 10	Lloyd Webster	Du	33	42	R	Sand, gravel	Kansan glaciofluvial deposits	Cy, E	D, S	±864	25.4	6-23-52	Reported very good well.
*13-20-11bb	NW NW sec. 11	J. D. Martin	Dr	43	8¼	S	do	Newman Terrace deposits	....	N	815.7	13.67	11- 1-52	
13-20-13ab	NE NE sec. 13	Carl Clifton	Du	35	48	R	Sandstone	Stranger Formation	Cy, H	N	....	25.05	7-22-54	
*13-20-13cc	SW SW sec. 13	Robert E. Stark	Dr	63	6	GI	do	do	Cy, H	D	±848	20	1——53	
13-20-15ba	NE NW sec. 15	H. Eisele	Du	36	36	R	Sand?, silt?	Terrace deposits	....	D, S	836.0	17	10- 1-52	
13-20-15db	NW SE sec. 15	E. K. Patterson	Du	24.7	32	R	Sand, gravel	Newman Terrace deposits	....	N	813.8	17.70	11- 1-52	
13-20-16aa	NE NE sec. 16	H. C. Stewart	Dr	112	8¼	S	Sandstone	Stranger Formation	....	D, S	±851	....	5——56	Reported yield ¾.
13-20-16ab	NW NE sec. 16	Frank Topping	Dr	147	6	GI	do	do	N	N	....	80	6-23-52	Reported yield 250 gal./day.
13-20-16bb	NW NW sec. 16	William Lemon	Dr	90	6¼	S	do	do	....	D, S	±833	50	1955	Reported yield 2½.
13-20-16cc	SW SW sec. 16	James Nitchals	Du	32.2	36	R	Sand, silt?	Newman Terrace deposits	Cy, E	D, S	±818	12.50	6-23-52	
13-20-17aa	NE NE sec. 17	Charles L. Shirar	Du	25.4	84	B	Sandstone	Stranger Formation	T, E	D, S	....	15.47	6-23-52	
13-20-19cd	SE SW sec. 19	Carl Clifton	Dr	130	6	GI	do	do	N	N	±984	75.00	11- 1-55	Reported yield 40. Gravel-packed well.
13-20-20bb	NW NW sec. 20	McCue Estate	Du	22.1	72	R	Sand, silt?	Terrace deposits	Cy, W	S	±841	10.00	6-24-52	
13-20-20bc	SW NW sec. 20	....	B	68.5	4	N	Sand	do	N	N	±850	....	8-27-54	TH by KGS.
13-20-21cc	SW SW sec. 21	Jess Carson	Dr	50	6	S	Sandstone?	Stranger Formation	Cy, E	D, S	±818	20	6-24-52	
13-20-22dc	SW SE sec. 22	Harold Lutz	Dr	148	6¼	S	Sandstone	do	N	N	±900	82.30	12- 8-55	
13-20-23dc	SW SE sec. 23	Tom Akin	Dr	108	6¼	S	do	do	N	N	±898	....	12- 8-55	
13-20-25bb	NW NW sec. 25	Winston Keyee	Dr	112	6¼	S	do	do	Cy, —	S	±894	....	12- 8-55	
13-20-25cc	SW SW sec. 25	Wayne Strong	Dr	102	6¼	S	do	do	J, E	D, S	±905	42	12- 8-55	
13-20-30ad	SE NE sec. 30	Fairplain School	Dr	94	6	S	do	do	N	N	±900	82.50	6- 1-53	Observation well.
13-20-30cd	SE SW sec. 30	Robert Niesly	Dr	132	6¼	S	do	do	....	.....	±898	60	4——56	
13-20-31ad1	SE NE sec. 31	Don Alford	Du	25	36-48	R	Shale?, sandstone	do	Cy, E	D, S	±921	20	6- 1-53	Not adequate in droughts.
13-20-31ad2	SE NE sec. 31	do	DD	160	36-6	R-?	do	do	Cy, H	S	±920	20	6- 1-53	Reported yield 10 gal./hour.
13-20-31cb	NW SW sec. 31	Elsie Hunsinger	Du	40	72	R	Shale?	Lawrence Shale	Cy, H	D, S	....	....	6- 2-53	
13-20-31cd	SE SW sec. 31	do	Du	15.0	72	R	Silt?, shale?	Colluvium and Lawrence Shale	Cy, W	D, S	....	4.58	6- 2-53	Reported yield 3.
13-20-32cc	SW SW sec. 32	Walter George	Dr	127	6	S	Sandstone?	Stranger Formation or Stanton Limestone	Cy, E	D, S	....	....	6- 2-53	Reported slightly brackish.
13-20-34dc	SW SE sec. 34	Jennie Eckman	Dr	185	......	S	Sandstone	Stranger Formation	Cy, E	D, S	±951	....	12-27-54	Reported yield 7½. Chloride reported 38 ppm.

TABLE 8.—*Records of wells, test holes, and springs in Douglas County—Continued*

WELL NUMBER (1)	Location	Owner or tenant	Type of well (2)	Depth of well, feet (3)	Diameter of well, inches	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)	Altitude of land surface, feet (7)	Depth to water level below land surface, feet (8)	Date of measurement	REMARKS (Yield given in gallons a minute; drawdown in feet) (9)
	T. 13 S., R. 20 E.													
*13-20-35cd	SE SW sec. 35	Roy Cramer	Dr	140	6¼	S	Sandstone	Stranger Formation and Stanton Limestone	Cy, E	D, S	±927	80	8- 3-53	Reported yield 6.
	T. 13 S., R. 21 E.													
13-21-3ccb	NW SW SW sec. 3		Dr	26.0	4	N	Gravel, sand	Kansan glaciofluvial deposits	N	N	882.5	19.2	6-27-53	TH by KGS.
*13-21-5db	NW SE sec. 5	City of Eudora	Dr	61.1	12	S	do	Alluvium	T, E	P		30.75	2-14-53	
13-21-7bbb	NW NW NW sec. 7		Dr	76.5	4	N	do	Newman Terrace deposits	N	N	812		4-19-52	TH by KGS.
13-21-7ddc	SW SE SE sec. 7		B	13.5	4	N			N	N	±899		8-27-54	TH by KGS. No water table.
*13-21-10cc	SW SW sec. 10	Clarence Neis	Dn	27	1¼	GI	Sand, gravel	Kansan glaciofluvial deposits	C, E	D, S			5-25-53	
13-21-10db	NW SE sec. 10	Herbert Meuffel	Dr	85		N			N	N			12——52	Dry hole.
13-21-15cb	NW SW sec. 15		Dr	35.0	4	N	Sand	Kansan glaciofluvial deposits	N	N	898.7	23.5	6-27-53	TH by KGS.
13-21-16aaa	NE NE NE sec. 16		Dr	30.0	4	N	do	do	N	N	885.2	12.6	6-27-53	Do.
*13-21-17dc	SW SE sec. 17	H. Giertz	Sp				do	do	N	S	±870		2-24-53	
13-21-17dc	SW SE sec. 17	do	Du	8.3	60	R	do	do		N	888.2	2.70	2-24-53	
*13-21-21dd	SE SE sec. 21	Hesper Community Building	Dr	50	6	GI	Sand, gravel?	do	Cy, H	D			5-30-53	
13-21-22ddd	SE SE SE sec. 22		Dr	13.0	4	N	Clay, sand	do	N	N	900.1	2.6	6-27-53	TH by KGS.
13-21-27ba	NE NW sec. 27		Dr	54.0	4	N	Sand	do	N	N	918.5		6-27-53	Do.
13-21-27bcc	SW SW NW sec. 27		Dr	65.5	4	N	Gravel, sand	do	N	N	929		6-30-53	Do.
13-21-28aa	NE NE sec. 28		Dr	55.5	4	N	do	do	N	N	912.4	±8	7- 2-53	Do.
13-21-28bb1	NW NW sec. 28	Louie L. Kindred	Du	33.0	30	R	do	do	Cy, H	D		18.08	7-30-52	
13-21-28bb2	NW NW sec. 28		Dr	34.0	4	N	do	do	N	N	892.8	±18	6-29-53	TH by KGS.
13-21-29ab	NW NE sec. 29		Dr	26.0	4	N	do	do	N	N	869.3	±9	7- 2-53	Do.
13-21-30ca1	NE SW sec. 30	George F. Trefz	Dr	110		N			N	N			11-19-55	Reported dry hole.
13-21-30ca2	NE SW sec. 30	do	Dr	60	8	S	Sandstone	Stranger Formation	Cy, E	S			11-19-55	Reported yield 1.
13-21-30cc	SW SW sec. 30	Elmer W. Reeves	Du	80	72-80	R	do	do	J, E	D		42	1955	Reported very low yield.

13-21-31ddc	SW SE SE sec. 31		B	30.0	4	N	Sand	Kansan glaciofluvial deposits	N	N	±920	18.7	8-26-54	TH by KGS.
13-21-34aa	NE NE sec. 34	Herbert Knabe	Du-Dn	40	48-1¼	R-GP	Sand, gravel	do	J, E	D, S	±934	27.27	5-25-53	
13-21-34bcc	SW SW NW sec. 34		Dr	49.0	4	N	do	do	N	N	930.7	±15	7- 2-53	TH by KGS.
	T. 14 S., R. 17 E.													
14-17-14aa	NE NE sec. 14	Hyluard Maichel	Du	25	42	R	Shale?, limestone?	Kanwaka Shale or Oread Limestone	N	N	±967	....	9- 3-52	
14-17-24dd	SE SE sec. 24	Joe Maichel	Dr	420	5½	GI	Sandstone	Stranger Formation	....	....	....	200	2-28-56	
*14-17-25ca	NE SW sec. 25	H. Maichel	Dr	458	6¼	S	do	do	Cy, E	D, S	±1,090	....	12-27-54	KERC well.
*14-17-26ad	SE NE sec. 26	Ralph Fuqua	Dr	405	5½	GI	do	do	....	D, S	±1,084	186	3-19-56	Reported yield 20.
14-17-35ad	SE NE sec. 35	Joseph Baldwin	Dr	410	5½	GI	do	do	Cy, E	D, S	±1,105	180	8-24-56	Reported good water.
*14-17-36bd	SE NW sec. 36	Clifford Desque	Dr	296	6?	GI?	do	Lawrence Shale	Cy, W	S	±1,110	197.1	9- 3-52	
14-17-36dd	SE SE sec. 36	Ivan Hoover	Dr	30	±96	R	Limestone?, shale?	Lecompton Limestone or Kanwaka Shale	C, E	D, S	±1,137	....	9- 2-52	
	T. 14 S., R. 18 E.													
14-18-3cd	SE SW sec. 3	Ed. Golladay	Du	11.9	72	R	Clay, silt, sand	Colluvium and alluvium†	Cy, T	D, S	±1,005	5.98	9- 9-52	
14-18-6ad	SE NE sec. 6	Stuart Thurber	Dr	300	6	S	Sandstone	Stranger Formation	Cy, W	S	±1,001	150	9- 4-52	Reported brackish? sodium bicarbonate water, low yield.
14-18-8ad	SE NE sec. 8	William Owens	Dr	239	6	GI	do	do	Cy, E	D, S	±984	164	1-14-55	
*14-18-10bd	SE NW sec. 10	Wayne Culley	Dr	325	5½	GI	do	do	Cy, E	D, S	±1,078	125	1- 8-54	
14-18-11bb	NW NW sec. 11	.... Powell	Dr	349	6	GI?	do	do	....	....	±1,004	....	1-14-55	Drilled to 355 ft., cemented back to 349 ft.
*14-18-11db	NW SE sec. 11	Raymond Flory	Dr	160	5½	GI	do	do	Cy, E	D, S	±915	70	7-25-52	Gravel-packed well. Reported yield 2½.
14-18-14aac	SW NE NE sec. 14	Douglas County (Lone Star Lake)	Dr	368	6	S	do	do	N	N	1,027.9	181.06	10-19-47	KERC well. Chloride reported 2,300 ppm.
14-18-18cb	NW SW sec. 18	Charles Simon	Dr	370	6	GI	do	Stranger Formation or Lawrence Shale	Cy, W	D, S	±1,080	....	9- 3-52	Reported yield 10. Sodium bicarbonate water.
*14-18-23aa1	NE NE sec. 23	N. T. Veatch	Dr	377	......	N	do	Stranger Formation	N	N	±1,040	....	11-27-47	Reported yield, 100 gal./day, abandoned as dry hole.
14-18-23aa2	NE NE sec. 23	do	Dr	341	......	N		....	N	N	....	....	1- 7-55	Abandoned as dry hole.
14-18-24aa	NE NE sec. 24	do	Dr	406	6¼	S	Sandstone	Stranger Formation	Cy, —	S	....	....	11-27-47	Reported brackish, yield +15.
*14-18-24cc	SW SW sec. 24	Roy W. Scribner	Dr	335	6¼	GI	do	do?	T, E	D, S	±1,042	....	6- 6-55	Reported low yield, brackish water.
14-18-25cc	SW SW sec. 25	Harley Lyon	Du	34.8	48	R	Shale, sandstone	Kanwaka Shale	Cy, E	S	±1,112	15.41	9- 9-52	
*14-18-30ad	SE NE sec. 30	Jeff A. Robertson	Dr	489	7	S	Sandstone	Stranger Formation	T, E	D, S	±1,112	250	5-19-54	Reported yield 10, from 428-475 ft. Set 412 ft. casing.
*14-18-31ad	SE NE sec. 31	George F. Fawl	Dr	340	6	GI	do	Lawrence Shale	Cy, E	D, S	±1,135	280	9- 2-52	Brackish water.

TABLE 8.—*Records of wells, test holes, and springs in Douglas County*—*Continued*

WELL NUMBER (1)	Location	Owner or tenant	Type of well (2)	Depth of well, feet (3)	Diameter of well, inches	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)	Altitude of land surface, feet (7)	Depth to water level below land surface, feet (8)	Date of measurement	REMARKS (Yield given in gallons a minute; drawdown in feet) (9)
	T. 14 S., R. 18 E.													
14-18-31cd	SE SW sec. 31	George Raible	Du	32	96-30	R	Limestone, shale	Lecompton Limestone	Cy, H	D	±1,134	±12	9- 3-52	
14-18-32cb	NW SW sec. 32	Ralph Maichel	Dr	350	6	GI?	Sandstone	Lawrence Shale	Cy, W	S	±1,145	....	9- 2-52	Reported sodium bicarbonate water.
14-18-33cc	SW SW sec. 33	E. C. Rappard	Du	33.2	54	R	Limestone	Lecompton Limestone	J, E	D	±1,154	17.08	9- 2-52	
*14-18-34cc	SW SW sec. 34	Albert Turner	Dr	245	6¼	S	Sandstone	Lawrence Shale	T, E	S	±1,082	145	5-26-53	Reported yield 4, drawdown 35. Cased to 180 ft. Brackish water.
14-18-35bb	NW NW sec. 35	H. W. Rappard	Dr	450	6¼	S	do	Stranger Formation	Cy, —	D, S	±1,138	....	12-22-54	KERC well.
14-18-35dc	SW SE sec. 35	E. Schreiber	Dr	225	6	S	do	Lawrence Shale	Cy, W	S	±1,085	....	1-14-50	Reported yield 1.
	T. 14 S., R. 19 E.													
14-19-1bb	NW NW sec. 1	W. A. Schaal	Dr	270	10	S	Limestone	Haskell Limestone	....	.....	±901	....	9-30-55	Reported yield ¼.
*14-19-3dd	SE SE sec. 3	Tom Cotton	Dr	121	6¼	S	Sandstone	Stranger Formation	B, H	D	....	96	4- 5-55	Reported sodium bicarbonate water, very low yield.
*14-19-4bb	NW NW sec. 4	Jess Markley	Dr	142	6	GI	do	do	Cy, E	S	±900	....	6-22-54	Reported yield 14. Brackish water.
14-19-4bba	NE NW NW sec. 4	Solen J. Markley	Du	21	60	C	Sand	Terrace deposits	Cy, E	S	±870	8	6-20-54	Not adequate in drought.
14-19-9cc	SW SW sec. 9	Alva Flory	Dr	228	5½	GI	Sandstone	Stranger Formation	Cy, E	S	....	....	1- 7-55	
14-19-13ab	NW NE sec. 13	Frank Cadwell	Dr	189	......	N	....	....	N	N	±1,010	....	4-26-56	Abandoned as dry hole.
14-19-13ca	NE SW sec. 13	M. R. Gill	Du	48.8	......	R	Limestone, shale	Oread Limestone	Cy, W	S	....	48.3	3-26-47	Well had been pumped just prior to measurement.
14-19-13cb	NW SW sec. 13	do	Dr	407	......	N	....	....	N	N	±1,127	....	10-27-47	Abandoned as dry hole.
14-19-15db1	NW SE sec. 15	D. F. Beeghley	Dr	±400	6¼	S	Sandstone	Stranger? Formation	Cy, W	S	±1,096	....	5-28-53	Reported sodium bicarbonate water.
*14-19-15db2	NW SE sec. 15	do	Du	28.7	72-120	R-N	Shale, limestone	Oread Limestone	Cy, H	D	±1,096	25.02	5-28-53	
14-19-16bb	NW NW sec. 16	W. H. Postma	Du	30	72-184	R	Shale	do	Cy, E	D	....	0.0	5-28-53	Well flowing. Flows most of year.

*14-19-16bc	SW NW sec. 16	do	Dr	304	5½	GI	Sandstone	Stranger Formation	Cy, E	S	±1,070	224	10-20-52	Brackish water.
14-19-19bb	NW NW sec. 19	— Powell	Dr	356	5½	GI	do	do	Cy, E	D, S	....	....	1- 7-55	
14-19-19cb	NW SW sec. 19	Otto Hack	Dr	300	5½	GI	do	do	Cy, E	D, S	±1,100	....	1- 7-55	Reported brackish.
14-19-22ac	SW NE sec. 22	Wayne Flory	Dr	383	8	N	....	....	N	N	±1,084	....	11- 3-55	Abandoned as dry hole.
*14-19-24da	NE SE sec. 24	O. R. Williams	Dr	385	6¼	S	Sandstone	Lawrence Shale	Cy, E	D, S	±1,119	....	6-21-54	Drilled to 422 ft., plugged back to 385 ft. Set 340 ft. casing. Shot hole at 208. Yield 1½.
*14-19-28ad	SE NE sec. 28	Ray Knaus	Dr	160	6¼	S	do	do	Cy, W	D, S	±1,102	....	6- 6-55	
14-19-35cd	SE SW sec. 35	....	Dr	130	6¼	S	do	do	Cy, E	D, S	±1,010	....	12-27-54	Reported yield 15. KERC well.
	T. 14 S., R. 20 E.													
14-20-2dc	SW SE sec. 2	Delbert Chamey	Dr	140	5½	GI	do	Stanton Limestone	....	D, S	±940	95	2- 6-57	Reported brackish water.
14-20-3ac	SW NE sec. 3	A. G. Hammond	Dr	114	6¼	S	do	Stranger Formation	....	D, S	....	50	10-27-53	Reported yield 7½.
14-20-5cc	SW SW sec. 5	F. W. Pratt	Dr	148	....	....	do	do	....	....	....	....	10——47	Reported very low yield.
14-20-5da	NE SE sec. 5	Edward Eckman	Du	30	60	R	do	do	Cy, E	D, S	....	5	6- 2-53	
14-20-7db	NW SE sec. 7	Elmer Christin	Du	18	36	R	do	do?	Cy, H	D	....	5	6- 2-53	
14-20-8cc	SW SW sec. 8	Wesley Jackson	Dr	100	....	....	....	....	....	....	....	....	12-27-55	Reported yield ½.
14-20-8dd	SE SE sec. 8	Charles Mitchel	Du	17.2	54	R	Silt, clay, sand	Colluvium and alluvium†	Cy, H	S	....	4.03	6- 2-53	Reported to go dry in droughts.
14-20-9ac	SW NE sec. 9	Aub Hagerman	Dr	90	8	GI	Sandstone?	Stanton Limestone	....	S	....	....	10-13-52	Reported low yield, brackish water.
14-20-12cb	NW SE sec. 12	Dale Crade	Dr	100	....	....	do	do	J, E	D	±895	....	5-25-53	Reported sodium bicarbonate water, low yield.
14-20-14ad	SE NE sec.14	W. E. Hoskins	Du	10	72	R	Silt, clay, sand	Colluvium and alluvium†	Cy, W	D, S	....	0.0	5-25-53	Well flowing, dug in ravine.
*14-20-14dc	SW SE sec. 14	S. C. Hemphill	Dr	37	6	GI	Sandstone	Stranger Formation	Cy, H	D	....	17	10-31-51	Gravel-packed well.
14-20-16aa	NE NE sec. 16	Clarence Hagerman	Du	48	36	R	Shale, clay	Weston Shale and colluvium	J, E	D	±892	....	6- 2-53	Reported not adequate in droughts.
14-20-16cc1	SW SW sec. 16	....	Du	19.3	120	R	Sand, gravel	Terrace deposits	Cy —	D, S	±888	6.59	6- 2-53	KERC well.
14-20-16cc2	SW SW sec. 16	Paul Clawson	Dr	85	....	N	....	....	N	N	±895	....	6-16-56	Abandoned as dry hole.
14-20-21bc	SW NW sec. 21	Paul Gibler	Dr	127	5½	GI	Sandstone	Stranger Formation	....	D	....	20	6-10-56	Reported very low yield.
*14-20-22ba	NE NW sec. 22	Webb Fenton	Dr	107	6¼	S	do	Stanton Limestone	—, E	D, S	±907	45.25	3- 2-57	Reported yield 12. Water above 39 ft. cased out. Brackish water.
14-20-22cc	SW SW sec. 22	George Rockhold	Dr	204	....	....	do	Bonner Springs Shale and Stanton Limestone	....	S	....	80	11-30-55	Water reported brackish 120-160 ft., reported salty at 188-204 ft.
14-20-28bc	SW NW sec. 28	Melvin Holmes	Dr	140	....	....	Shale	Lawrence Shale	....	....	....	58	3-22-56	Reported yield 1½.
*14-20-29da	NE SE sec. 29	William Vaughn	Dr	92	8	S	Sandstone	do	Cy, E	D, S	±1,065	40	9-28-53	Reported yield 3.
*14-20-30aa	NE NE sec. 30	Max Moore	Dr	200	....	....	Sandy shale	do	....	D, S	±1,126	....	12——55	Reported yield 1½.
14-20-30cb	NW SW sec. 30	Maurice Frye	Dr	162	6¼	S	Sandstone	do	....	D, S	±1,130	....	6-10-56	Reported yield 3.
*14-20-31aa	NE NE sec. 31	R. C. Mitchell	Dr	186	6¼	GI	do	do	Cy, E	D, S	±1,115	75	1934	
*14-20-32cd	SE SW sec. 32	Earl Black	Dr	130	8	S	do	do	J, E	D, S	±1,041	30	10-30-53	Reported yield 1. Drilled to 303 ft., plugged back to 130 ft.

TABLE 8.—*Records of wells, test holes, and springs in Douglas County—Continued*

WELL NUMBER (1)	Location	Owner or tenant	Type of well (2)	Depth of well, feet (3)	Diameter of well, inches	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)	Altitude of land surface, feet (7)	Depth to water level below land surface, feet (8)	Date of measurement	REMARKS (Yield given in gallons a minute; drawdown in feet) (9)
	T. 14 S., R. 21 E.													
14-21-3bc	SW NW sec. 3		Dr	48.5	4	N	Gravel, sand	Kansan glaciofluvial deposits	N	N	943.8	19.8	7- 2-53	TH by KGS.
14-21-3ccc	SW SW SW sec. 3		Dr	50.5	4	N	Sand	do	N	N	971.3	....	7- 2-53	Do.
*14-21-9aa	NE NE sec. 9	J. E. Brazil	Du	50	48	R	Sand, gravel	do	Cy, W	D, S	±982	47	5-30-53	
14-21-9add	SE SE NE sec. 9		Dr	81.0	4	N	do	do	N	N	977.5	26.4	7- 2-53	TH by KGS.
14-21-15abb	NW NW NE sec. 15		B	23.0	4	N	Sand	Terrace deposits	N	N	±927	6.2	8-26-54	TH by KGS.
14-21-15cbb	NW NW SW sec. 15		B	27.0	4	N	do	do	N	N	±932	19.2	10-26-55	Do.
14-21-16cc	SW SW sec. 16	Mary Rodewald	Dr	250	6¼	S	Limestone	Wyandotte Limestone	....	S	±970	....	3-20-56	Reported yield ⅙, brackish water at 190–202 ft.
14-21-17abb	NW NW NE sec. 17		B	22.0	4	N			N	N	±1,008	....	10-26-55	TH by KGS. Dry hole.
*14-21-18ad	SE NE sec. 18	Blondie Mathews	Dr	184	6¼	S	Sandstone	Stanton Limestone and Bonner Springs Shale	Cy, E	S	±955	60	7-15-53	Reported yield 4, brackish water.
14-21-18bb	NW NW sec. 18	Romie Deay	Du	30	48	R	do	Lawrence Shale	Cy, W	D, S	±1,028	18	5-25-53	
14-21-19dd1	SE SE sec. 19	W. A. Olmstead	Du	50	......	R	do	do	Cy?, D	D	±1,024	....	2-22-56	
14-21-19dd2	SE SE sec. 19	do	Dr	103	6¼	S	do	do	....	S	±1,024	25	4- 2-56	Reported yield 2.
14-21-27bb	NW NW sec. 27		Dr	127.5	4	N			N	N	±1,027	....	5- 1-56	TH by KGS.
*14-21-30ad	SE NE sec. 30	Russell Rohe	Dr	200	6¼	S	Sandy clay, sandstone	Colluvium, Stranger Formation, and Stanton Limestone	T, E	D, S	±1,003	31.90	6- 6-55	Reported yield ½.
	T. 15 S., R. 17 E.													
15-17-1aa	NE NE sec. 1	City of Overbrook	Dr	327	6¼	S	Sandstone	Lawrence Shale	N	N	±1,133	....	1——53	Reported yield 12, fresh water at 250–318 ft., not used because of high fluoride. City TH 2.
15-17-1ac1	SW NE sec. 1	do	Dr	507	6¼	S, N	do	Stranger Formation	T, E	P	±1,144	210	4- 1-53	Reported yield 45 from Tonganoxie Sandstone at 420–490 ft., drawdown 100. Well 1.
*15-17-1ac2	SW NE sec. 1	do	Dr	497	6¼	S, N	do	do	T, E	P	±1,141	210	4- 1-53	Reported yield 45 from Tonganoxie Sandstone at 395–485 ft., drawdown 100. Well 2.

15-17-2ab	NW NE sec. 2	do	Dr	290		N	do	Lawrence Shale	N	N	±1,146		1—53	City TH 1. Chloride reported 5,200, fluoride reported high.
15-17-2dd	SE SE sec. 2	Emil Mesentine	Du	30.7	48	R	Limestone, shale	Lecompton Limestone	C, E	D, S	±1,143	16.95	1-14-50	
15-17-11ba1	NE NW sec. 11	McCarty	Dr	380	6	S?	Sandstone	Lawrence Shale	Cy, W	S	±1,155		1-14-50	Reported very brackish.
15-17-11ba2	NE NE sec. 11	do	Dr	382			do	do					8—55	Do.
*15-17-13dc	SW SE sec. 13	R. E. Tutcher	Dr	315	6¼	S	do	Stranger Formation	Cy, —	D, S			12-27-54	KERC well.
	T. 15 S., R. 18 E.													
*15-18-1aa	NE NE sec. 1	— Briedhaupt	Dr	301			do	Lawrence? Shale		D, S	±1,085		4-20-48	Reported yield 2½.
15-18-4cc	SW SW sec. 4	Harry Prim	Dr	254	6	GI?	do	Lawrence Shale	Cy, H	D, S	±1,115		9- 4-52	Reported sodium bicarbonate water.
15-18-5aa	NE NE sec. 5	E. C. Rappard	Dr	300	6	GI	do	do	Cy, W	D, S	±1,125		9- 2-52	Do.
15-18-7aa	NE NE sec. 7	R. C. Price	Dr	434	6¼	S	do	Lawrence Shale and Stranger Formation		D, S	±1,035		8—34	KERC well. Reported yield, 3½, chloride 440 ppm.
*15-18-7ad	SE NE sec. 7	Chris Straub	Dr	350	6	GI	Sandy shale	Stranger Formation	Cy, E	D, S	±1,156	225	9- 2-52	Reported yield 10 from 318-350 ft. Gravel-packed well. Brackish water.
15-18-8ba	NE NW sec. 8	George Maichel	Dr	403			do	do		D, S		190	3—56	Reported brackish, yield 4.
15-18-8dd	SE SE sec. 8	Alva Miller	Du	17.7	48	R	Shale	Kanwaka Shale	Cy, H	D, S	±1,075	8.19	9- 4-52	
15-18-10db	NW SE sec. 10	Maurice Fishburn	Dr	348	5¾	GI	Sandstone	Lawrence? Shale or Stranger? Formation	Cy, W	D, S	±1,054	80	9- 4-52	Reported yield 18, sodium bicarbonate water.
15-18-12aa	NE NE sec. 12	A. L. Hornberger	Dr	220	5½	GI	do	do	Cy, W	D, S	±1,056	40	1923	
*15-18-15cd1	SE SW sec. 15	Wayne Owens	Dr	485	6	S	do	do	Cy, W	D, S		75	9- 4-52	Reported yield 30. Brackish water.
15-18-15cd2	SE SW sec. 15	do	Du	30	216	R	Limestone	Oread Limestone	Cy, H	S			9- 4-52	
15-18-17bb	NW NW sec. 17	J. B. Price	Dr	440	5½	GI	Sandy shale	Stranger Formation			±1,144		1- 7-56	Reported yield 1.
	T. 15 S., R. 19 E.													
*15-19-1cd	SE SW sec. 1	F. G. Ford	Dr	104	6	GI	Sandstone	Lawrence Shale	Cy, E	D, S	±1,023	50.43	5-29-53	Reported yield 6.
15-19-14bb	NW NW sec. 14	Leonard Newland	Dr	50			do	do		D		12	1955	Reported yield 32.
15-19-16cb	NW SW sec. 16	Verna Cobb	Dr	170	4⅞	S	do	do	J, E	S		135	6- 6-55	Reported yield 10.
*15-19-17cd	SE SW sec. 17	John Bulson	Dr	170	6¼	S	do	do	Cy, E	D, S		130	7—53	
	T. 15 S., R. 20 E.													
15-20-8aa	NE NE sec. 8	Jack Randell	Dr	101			do	do		D, S	±1,066	76	9—55	Reported yield 5.
15-20-11cda	NE SE SW sec. 11		Dr	182.0	1¼	GP	do	do	N	O	±1,056	45.95	5-15-56	TH by KGS.
15-20-11cd1	SE SW sec. 11	City of Baldwin	Du	42	196	B, N	do	do	T, E	P			3-15-56	Well 2. Wells 3, 4, 5, 6, 7, 9, 10, 11 pump into 2.
15-20-11cd2	SE SW sec. 11	do	Dr	50	8	S	do	do	J, E	P			3-15-56	Well 4. Reported yield 10.
15-20-11cd3	SE SW sec. 11	do	Dr	60	8	S	do	do	J, E	P			3-15-56	Well 7.
15-20-11cd4	SE SW sec. 11	do	Dr	55	8	S	do	do	T, E	P			3-15-56	Well 3.

TABLE 8.—*Records of wells, test holes, and springs in Douglas County—Concluded*

Well Number (1)	Location	Owner or tenant	Type of well (2)	Depth of well, feet (3)	Diameter of well, inches	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)	Altitude of land surface, feet (7)	Depth to water level below land surface, feet (8)	Date of measurement	REMARKS (Yield given in gallons a minute; drawdown in feet) (9)
	T. 15 S., R. 20 E.													
15-20-11cd5	SE SW sec. 11	City of Baldwin	Dr	64.2	8¼	S	Sandstone	Lawrence Shale	J, E	P	±1,046	33.01	9-28-56	Well 9.
15-20-11cd6	SE SW sec. 11	do.	Dr	68.6	8¼	S	do.	do.	J, E	P	±1,039	32.43	9-28-56	Well 10.
15-20-11cd7	SE SW sec. 11	do.	Dr	66	8¼	S	do.	do.	J, E	P	±1,030	....	9-31-56	Well 11.
15-20-11db	NW SE sec. 11	do.	Dr	50	8	S	do.	do.	J, E	P	....	....	3-15-56	Well 6.
15-20-11dc	SW SE sec. 11	do.	Dr	55	8	S	do.	do.	J, E	P	....	....	3-15-56	Well 5.
*15-20-15ada	NE SE NE sec. 15	do.	Du	26	240	B, C	Sandstone and sand	Lawrence Shale and terrace deposits	C, E	P	....	....	3-15-56	Well 1. Three Springs flow continuously into well.
15-20-15ad	SE NE sec. 15	do.	Dr	41	8	S, N	Sandstone	Lawrence Shale	T, E	P	....	22.14	5-16-56	Well 8. Measured water level 280 min. after pump shut off.
15-20-16cb	NW SW sec. 16	Harold Hutton	Du	38.9	60	R	do.	do.	Cy, E	D, S	±1,017	38	8- 4-53	Reported not adequate in dry years.
	T. 15 S., R. 21 E.													
15-21-3bbb	NW NW NW sec. 3	....	Dr	157.0	4	N	do.	do.	N	N	±1,091	....	5- 3-56	TH by KGS.
15-21-4bb	NW NW sec. 4	City of Wellsville	Dr	96	10	S	do.	do.	—, E	P	....	....	3-15-56	Well 4.
15-21-4bcc	SW SW NW sec. 4	....	Dr	144.2	5½	GI	do.	do.	N	O	±1,070	22.40	5-14-56	TH by KGS.
*15-21-5aa	NE NE sec. 5	City of Wellsville	Du	60	168	C	do.	do.	T, E	P	±1,050	22	4-30-55	Well 2.
15-21-5ad1	SE NE sec. 5	do.	Du	60	168	C	do.	do.	T, E	P	±1,050	18	4-30-55	Well 1.
15-21-5ad2	SE NE sec. 5	do.	Dr	61	8¼	S	do.	do.	T, E	P	±1,063	19.20	5-14-56	Well 3.
*15-21-7ac	SW NE sec. 7	Ralph Kalb	Du	90	48	R, N	do.	do.	Cy, W	D, S	±1,115	80	5-29-53	Reported yield 4.
15-21-10dc	SW SE sec. 10	Emery Mignot	Du	34.1	60	R	do.	do.	Cy, E	D, S	±1,084	23.08	2-29-56	
15-21-15aa	NE NE sec. 15	Carl Hughes	Du	50	48	R, N	do.	do.	Cy, W	D, S	±1,078	42	8-24-54	
15-21-16dc	SW SE sec. 16	Densil Cox	Dr	205	....	N	....	....	N	N	±1,145	....	1954	Reported as dry hole.
15-21-17cd	SE SW sec. 17	Richard Kramer	Du	52.5	42	R	Sandstone	Lawrence Shale	Cy, W	D, S	....	38.86	2-29-56	

1. Well-numbering system described in text.
2. B, bored well; DD, dug and drilled well; Dn, driven well; Dr, drilled well; Du, dug well; Du Dn, dug and driven well; Sp, spring.
3. Reported depths of wells given in feet below land surface; measured depths given in feet and tenths.
4. B, brick; C, concrete; GI, galvanized sheet iron; GP, galvanized-iron pipe; N, none; R, rock; S, heavy steel or iron; W, wood.
5. Method of lift: B, bucket; C, centrifugal; Cy, cylinder; E, endless chain with buckets; F, natural flow; J, jet; N, none; P, pitcher; T, turbine. Type of power: E, electric; G, gas engine; H, hand operated; T, tractor; W, windmill.
6. D, domestic; I, irrigation; In, industrial; N, none; O, observation; P, public supply; S, stock.
7. Altitude of land surface determined by planetable and alidade survey or spirit leveling given in feet or feet and tenths: ± altitudes are approximate, determined from 10-foot contour interval on modern 7½ minute topographic maps.
8. Measured depths to water in wells given in feet, tenths, and hundredths; reported depths given in feet. Depths to water in uncased test holes given in feet or feet and tenths.
9. TH, test hole; KGS, Kansas Geological Survey; KERC well, Kansas Emergency Relief Committee well maintained and operated by Douglas County.

* Chemical analysis given in Table 5.

† Thin deposits of colluvium, alluvium, or both in valleys of intermittent streams and on upland slopes, which are not mapped on Plate 1.

‡ Test hole by KGS. Data from Lohman (1941). L- number indicates original test hole number of Lohman.

LOGS OF WELLS AND TEST HOLES

Given on the following pages are logs of 88 test holes in Douglas County drilled by the State Geological Survey and logs of 108 wells and test holes obtained from drillers and other sources. Logs of test holes originally published by Lohman (1941) are indicated as T-1, T-2, etc.

11-18-28cd.—Sample log of test hole in SE SW sec. 28, T. 11 S., R. 18 E., about 300 feet north of railroad tracks; drilled August 18, 1950; depth to water, 2.78 feet. Altitude of land surface, 843.3 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Alluvium		
Clay, silty, dark	3	3
Silt, clayey, brown	2	5
Sand, medium to coarse, feldspar and quartz	6	11
Clay, silty, dark brown	1	12
Sand, medium, quartz and feldspar	11	23
Granules, coarse, and limestone boulder	1	24
Gravel, coarse, and granules	6	30
Gravel, coarse, granules and cobbles	7	37
Sand, coarse, and boulders	11	48
PENNSYLVANIAN—Virgilian		
Lawrence(?) Shale		
Shale, yellow brown to light blue gray	2	50
Shale, soft, blue; thin layer of brown siltstone	5	55

12-19-1db1.—Drillers log of well drilled by Jungmann Bros. Drilling Co. for B. L. Anderson Construction Co. in NW SE sec. 1, T. 12 S., R. 19 E., in 1955. Altitude of land surface, ±835 feet.

	Thickness, feet	Depth, feet
Soil	2	2
Soil, black	10	12
Clay	14	26
Sand, medium	24	50
Sand, coarse	20	70
Sand, coarse	12	82
Limestone	..	82

12-19-1db2.—Drillers log of well drilled by Jungmann Bros. Drilling Co. for B. L. Anderson Construction Co. in NW SE sec. 1, T. 12 S., R. 19 E., in 1955. Altitude of land surface, ±835 feet.

	Thickness, feet	Depth, feet
Soil	2	2
Soil, black	8	10
Clay	14	24
Sand, medium	16	40
Sand, coarse	20	60

	Thickness, feet	Depth, feet
Sand, medium	15	75
Sand, coarse	6	81
Limestone	..	81

12-19-9ad.—Sample log of test hole in SE NE sec. 9, T. 12 S., R. 19 E., 50 feet north of intersection on west road shoulder, drilled August 14, 1950; depth to water, 7.2 feet. Altitude of land surface, 828.4 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Alluvium		
Sand, fine to coarse, quartz and feldspar	8	8
Sand, medium to coarse; contains snail shells	12	20
Sand, coarse, quartzose	10	30
Sand, coarse, and granules of feldspar	18	48
Sand, coarse, and gravel containing limestone fragments	12	60
Gravel, coarse, and granules of quartz and feldspar; some weathered shale	8	68
PENNSYLVANIAN—Virgilian		
Shale, blue gray	2	70

12-19-14bc1.—(Lohman, 1941, p. 64) Drillers log of well drilled by Layne-Western Co. for Kansas Power & Light Co. in SW NW sec. 14, T. 12 S., R. 19 E., in 1938.

	Thickness, feet	Depth, feet
Soil	3	3
Clay	11	14
Sand, fine	4	18
Sand, coarse, some gravel	12	30
Clay	5	35
Sand, coarse, some gravel	10	45
Gravel and sand	8	53
Rock	..	53

12-19-14bd.—(Lohman, 1941, p. 64) Drillers log of well drilled by Layne-Western Co. for Kansas Power & Light Co. in SE NW sec. 14, T. 12 S., R. 19 E., in 1938.

	Thickness, feet	Depth, feet
Soil	3	3
Clay, sandy	8	11
Sand, fine	4	15
Sand, medium coarse	5	20
Sand, fine	3	23
Sand, medium coarse	7	30
Clay	1	31
Sand and gravel	14	45
Sand, gravel, and a few boulders	7	52
Rock	..	52

12-19-15bc.—Drillers log of well drilled by W. D. Wilson for Lakeview Fishing and Shooting Assoc. in SW NW sec. 15, T. 12 S., R. 19 E., in September 1951. Altitude of land surface, ± 840 feet.

	Thickness, feet	Depth, feet
Clay, yellow	46	46
Shale, blue	16	62
Limestone, blue	6	68
Shale, blue	38	106
Limestone, brown	3	109
Shale, gray, sandy	71	180
Limestone, brown	2	182
Shale, gray, sandy	6	188
Limestone, light gray	16	204
Shale, gray	4	208
Shale, black	2	210

12-19-15cd.—Sample log of test hole in SE SW sec. 15, T. 12 S., R. 19 E., drilled August 14, 1950. Altitude of land surface, 860.0 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Buck Creek Terrace deposits		
Soil, clayey, black	3	3
Silt and clay, brown	4	7
Silt, clayey, red	33	40
Silt, clayey, red; some fine sand	12	52
Sand, medium, to gravel	1	53
PENNSYLVANIAN—Virgilian		
Shale, blue gray	1	54

12-19-23ba.—Drillers log of well drilled by Holmes & Hammel Drilling Co. for N. W. Goff in NE NW sec. 23, T. 12 S., R. 19 E., in 1948. Altitude of land surface, ±904 feet.

	Thickness, feet	Depth, feet
Soil and clay	20	20
Clay, red, sandy	25	45
Shale, blue, sandy	24	69
Sandstone, soft	6	75
Limestone	5	80
Shale	1	81
Sandstone, hard	12	93
Shale	28	121
Sandstone, water	8	129
Shale	2	131

12-19-24a.—(Lohman, 1941, T-10) Sample log of test hole in cen. NE sec. 24, T. 12 S., R. 19 E., drilled 1940; depth to water, 12.4 feet. Altitude of land surface, 821.4 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Alluvium		
Soil, silty, dark	11	11
Sand, coarse to fine, and fine gravel	9	20
Sand, coarse, and fine gravel	2	22
Sand, coarse to fine, and fine gravel	8	30
Sand, coarse to medium	10	40
Sand, coarse	9	49
PENNSYLVANIAN—Virgilian		
Stranger Formation		
Shale, sandy, light gray, and sandstone	1	50

12-19-24ac.—(Lohman, 1941, T-11) Sample log of test hole in SW NE sec. 24, T. 12 S., R. 19 E., drilled 1940. Altitude of land surface, 856.1 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Kansan glaciofluvial deposits		
Soil, clay, silty, dark	3	3
Clay, silty, yellow brown	6	9
Clay, silty, light gray	3	12
Sand, fine to coarse, dirty	4.5	16.5
Sand and gravel, poorly sorted, orange brown	3.5	20
PENNSYLVANIAN—Virgilian		
Lawrence Shale		
Shale and sandstone, yellow green to gray	5.5	25.5
Shale, dark blue gray	4.5	30

12-19-24ad1.—(Lohman, 1941, T-9) Sample log of test hole in SE NE sec. 24, T. 12 S., R. 19 E., drilled 1940; depth to water, 9.2 feet. Altitude of land surface, 819.2 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Alluvium		
Sand, fine, earthy	10	10
Sand, coarse, and fine gravel	13	23
Sand, coarse	7	30
Sand, coarse to medium	10	40
Sand, medium	7.5	47.5
PENNSYLVANIAN—Virgilian		
Stranger Formation		
Shale, sandy, light gray, and sandstone	2.5	50

12-19-24ad2.—(Lohman, 1941, T-8) Sample log of test hole in SE NE sec. 24, T. 12 S., R. 19 E., drilled 1940; depth to water, 9.2 feet. Altitude of land surface, 819.2 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Alluvium		
Soil, sandy, brown	1	1
Soil, black	7	8
Sand, medium to fine, brown	2	10
Sand, medium to fine	9	19
Sand, medium to coarse, gray	11	30
Gravel, coarse to fine, and coarse to medium sand	10	40
Gravel, fine, and coarse sand	6	46
PENNSYLVANIAN—Virgilian		
Stranger Formation		
Shale, sandy, light gray	4	50

12-19-24dac.—(Lohman, 1941, T-6) Sample log of test hole in SW NE SE sec. 24, T. 12 S., R. 19 E., drilled 1940. Altitude of land surface, 817.7 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Alluvium		
Soil, sandy, dark	4	4
Sand, medium, brown	16	20
Sand, medium to coarse	4	24
Sand, medium, to fine gravel	6	30
Sand, coarse	10	40
Gravel, medium and coarse, some fine	7.5	47.5
PENNSYLVANIAN—Virgilian		
Stranger Formation		
Shale, sandy, gray, and sandstone	2.5	50

12-19-24dd.—Drillers log of well drilled by Layne-Western Co. for city of Lawrence in SE SE sec. 24, T. 12 S., R. 19 E., in 1947. Altitude of land surface, ±823 feet.

	Thickness, feet	Depth, feet
Top soil	1	1
Rock ballast and chat	4	5
Clay, sandy	10	15
Sand, medium	8	23
Sand, muddy	4	27
Sand, coarse	16	43
Clay	1.5	44.5
Sand, coarse, and clay balls	9.9	54.4

12-19-25aa1.—Drillers log of well drilled by Layne-Western Co. for city of Lawrence in NE NE sec. 25, T. 12 S., R. 19 E., in 1945. Altitude of land surface, ±822 feet.

	Thickness, feet	Depth, feet
Fill	10	10
Clay, sandy	10	20
Sand, fine to medium	12	32

	Thickness, feet	Depth, feet
Sand, fine, well packed	4	36
Sand, coarse	9	45
Sand, coarse, and gravel	6	51

12-19-25ad1.—Drillers log of well drilled by Layne-Western Co. for city of Lawrence in SE NE sec. 25, T. 12 S., R. 19 E., in 1944. Altitude of land surface, ±819 feet.

	Thickness, feet	Depth, feet
Sandy soil	1	1
River fill	4	5
Clay, soft, blue	13	18
Sand, fine, blue	7	25
Sand, medium to coarse	9	34
Sand, fine	3	37
Clay, blue, and rotten wood	0.5	37.5
Sand, fine	1.5	39
Sand, medium to coarse	3	42
Sand, coarse, and gravel; small rock	5	47

12-19-25ddb.—Sample log of test hole in NW SE SE sec. 25, T. 12 S., R. 19 E., about 120 feet north of center line of 6th Street and 100 feet east of center line of Alabama Street, drilled July 7, 1954. Altitude of land surface, ±852 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Kansan glaciofluvial deposits		
Soil, gray black	2	2
Silt and clay, gray to yellow brown	3	5
Silt and clay, yellow brown; fragments of ironstone and limonite concretions	20.5	25.5
Sand, medium, silty, yellow brown	3.5	29
PENNSYLVANIAN—Virgilian		
Lawrence(?) Shale		
Shale, gray blue, thin hard streaks in lower part	15	44

12-19-26abb.—Sample log of test hole in NW NW NE sec. 26, T. 12 S., R. 19 E., about 12 feet east and 200 feet south of N. quarter corner, drilled July 1953. Altitude of land surface, ±890 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Peoria Formation		
Soil, gray black	2	2
Silt, clayey, tan	2	4
Kansan glaciofluvial deposits		
Silt, clayey, gray	4	8
Silt, clayey, brown	19	27
Silt, clayey, tan gray; contains scattered gravel	10	37
Silt, clayey, tan gray	3	40
Silt, sandy, tan	11	51

	Thickness, feet	Depth, feet
Silt, sandy, tan; contains scattered gravel	10	61
Gravel and sand	5	66
PENNSYLVANIAN—Virgilian		
Lawrence Shale		
Shale, yellow gray	3	69
Stranger Formation—Haskell Limestone member		
Limestone, gray, sandy in upper part; contains thin shale break in lower part	4.2	73.2
Stranger Formation—Vinland Shale member		
Shale, gray	0.8	74
Sandstone, gray, silty, very fine, partly cemented with calcite	27	101
Shale, sandy, gray, and gray sandstone	11	112
Stranger Formation—Westphalia(?) Limestone member		
Limestone, soft, light gray	0.5	112.5
Stranger Formation—Tonganoxie Sandstone member		
Sandstone and sandy shale, gray; contains thin coal bed	9.5	122
Sandstone, gray, fine to very fine	21	143
Shale, blue gray; contains thin coal(?)	6	149
Sandstone, blue gray, fine to very fine; contains thin sandy shale	86	235
PENNSYLVANIAN—Missourian		
Weston(?) Shale		
Shale, gray	1.9	236.9
Stanton Limestone		
Limestone, light gray, hard	0.1	237

12-19-27cc.—Sample log of test hole in SW SW sec. 27, T. 12 S., R. 19 E., drilled October 1955. Altitude of land surface, ±1,027 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Peoria Formation		
Silt, gray black	2	2
Silt, tan	2	4
Kansas Till		
Clay, red brown	1	5
Clay, yellow brown; contains chert and quartzite	3	8
PENNSYLVANIAN—Virgilian		
Kanwaka Shale		
Shale, tan gray	2	10

12-19-28ba.—Drillers log of well drilled by W. D. Wilson for Mr. Higgens in NE NW sec. 28, T. 12 S., R. 19 E., in 1952. Altitude of land surface, ±961 feet.

	Thickness, feet	Depth, feet
Soil	3	3
Limestone, broken	17	20

	Thickness, feet	Depth, feet
Shale, blue	5	25
Limestone, yellow	20	45
Shale, hard, gray	25	70
Shale, sandy	35	105
Shale, gray, muddy	95	200

12-19-34dd.—Drillers log of well drilled by W. D. Wilson for J. G. Votaw in SE SE sec. 34, T. 12 S., R. 19 E., in May 1953. Altitude of land surface, ±980 feet.

	Thickness, feet	Depth, feet
Soil	2	2
Clay, red	6	8
Limestone, broken	4	12
Shale, black	8	20
Limestone, blue	2	22
Shale, light gray	13	35
Limestone	10	45
Shale, light	15	60
Shale, gray, sandy	45	105

12-19-35cd.—Drillers log of well drilled by Jungmann Bros. Drilling Co. for Vernon Smith in SE SW sec. 35, T. 12 S., R. 19 E., in March 1952. Altitude of land surface, ±967 feet.

	Thickness, feet	Depth, feet
Clay	5	5
Limestone	9	14
Shale	11	25
Redbed	9	34
Shale	10	44
Shale, sandy	39	83
Sandstone	5	88
Shale, sandy	22	110
Shale	10	120

12-20-4bc.—Drillers log of well dug by Tom Gibson for University of Kansas in SW NW sec. 4, T. 12 S., R. 20 E., in October 1955. Altitude of land surface, ±920 feet.

	Thickness, feet	Depth, feet
Black soil and gray-black silty clay	2.8	2.8
Gravel	0.2	3
Silty clay, gray black	3.5	6.5
Gravel	0.2	6.7
Silty clay, gray brown	5.3	12
Silty clay, brownish tan; contains scattered gravel	12.5	24.5
Silty clay, brownish tan; contains abundant limestone and chert gravel, cobbles, and sand	2.5	27
Shale, weathered, blue gray	..	27

12-20-7adc.—(Lohman, 1941, p. 63) Drillers log of well drilled by Ed Feyh for C. B. Young in SW cor. SE NE sec. 7, T. 12 S., R. 20 E., in May 1940. Altitude of land surface, ±830 feet

	Thickness, feet	Depth, feet
Sand, fine to medium, gray	40	40
Sand, coarse, and fine gravel; brown	10	50
Sand, medium, and coarse gravel; brown	5	55
Gravel, coarse, and some sand; brown	8	63
Sand, medium, and coarse gravel	4	67
Gravel, coarse, and brown sand	3	70
Sand, medium, and coarse gravel	4	74
Gravel, medium, and fine sand	3	77
Gravel, coarse, and medium sand	3	80
Gravel, coarse, and fine sand; iron-stained and contains limonite concretions	3	83
Shale, silty	1	84

12-20-8da.—Sample log of test hole in NE SE sec. 8, T. 12 S., R. 20 E., drilled October 7, 1948. Altitude of land surface, 894.0 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Kansan glaciofluvial deposits		
Clay, slightly sandy, red brown	1.5	1.5
Clay, sandy, buff tan and brown	5.5	7
Clay, sandy, dark tan	5	12
Clay, tan to buff; thin hard ferruginous bands	4	16
Clay, sandy, soft, tan	7	23
Clay and very fine sand, tan	9.5	32.5
Clay and very fine sand, tan; thin ferruginous sandstonelike beds	19.5	52
Sand, coarse, and fine gravel; mostly igneous material and chert	6	58
Gravel, fine to medium; igneous material and chert	4.5	62.5
PENNSYLVANIAN—Virgilian		
Stranger Formation		
Limestone, hard, gray; contains shell fragments	0.5	63

12-20-9cdd.—(Lohman, 1941, T-19) Sample log of test hole in SE cor. SW sec. 9, T. 12 S., R. 20 E., drilled 1940. Altitude of land surface, 883.0 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Kansan glaciofluvial deposits		
Clay, silty, reddish	3	3
Clay, silty, light gray and brown	4	7
Clay, silty, yellow	2	9
Clay, silty, orange yellow and light gray	5.5	14.5
Sand, fine to coarse, yellow brown	6.5	21
Clay, silty; contains concretions of limonite	4	25
Clay, silty, orange yellow and light gray	2	27
Gravel, poorly sorted, orange brown; contains concretions of limonite	6.5	33.5
Sand and gravel, brown, and some cobbles	10	43.5

PENNSYLVANIAN—Virgilian	Thickness, feet	Depth, feet
Lawrence(?) Shale		
Shale, gray	6.5	50

12-20-16da.—Drillers log of well drilled by W. D. Wilson for Rays Truck Stop Cafe in NE SE sec. 16, T. 12 S., R. 20 E. Altitude of land surface, ±827 feet.

	Thickness, feet	Depth, feet
Soil	3	3
Clay, yellow	7	10
Clay, sandy	10	20
Quicksand	10	30
Sand and gravel	12	42

12-20-17add.—(Lohman, 1941, T-18) Sample log of test hole in SE SE NE sec. 17, T. 12 S., R. 20 E., drilled 1940. Altitude of land surface, 829.4 feet.

QUATERNARY—Pleistocene	Thickness, feet	Depth, feet
Newman Terrace deposits		
Soil, silty, dark brown	3	3
Soil, silty, clayey, dark	5	8
Clay, silty, dark	4	12
Clay, silty, light brown	8	20
Clay, silty, light yellow	6	26
Clay, silty, dark	3.5	29.5
Sand, medium, and some coarse sand	5.5	35
Sand, medium to coarse	4	39
Gravel, coarse to fine	11	50
Gravel, fine to coarse, and some coarse sand	12	62
Gravel, coarse to fine, and some coarse sand	8	70
Gravel, coarse to fine	9	79

12-20-17cd.—(Lohman, 1941, p. 63) Drillers log of well drilled by W. H. Hayden for University of Kansas in SE SW sec. 17, T. 12 S., R. 20 E., in February 1939. Altitude of land surface, 818.6 feet.

	Thickness, feet	Depth, feet
Clay, brownish yellow	13.5	13.5
Sand, fine, white	0.5	14
Clay, yellow brown	12	26
Sand, coarse, and fine gravel	12	38
Clay, black	1	39
Gravel, coarse; contains boulders	3.5	42.5
Clay, black	4.5	47
Gravel, coarse, gray	7	54

12-20-17dd.—(Lohman, 1941, T-17) Sample log of test hole in NW cor. SE SE sec. 17, T. 12 S., R. 20 E., drilled 1940. Altitude of land surface, 815.7 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Alluvium		
Soil, silty, sandy, dark	8	8
Soil, silty; contains abundant shell fragments	1	9
Sand, fine, brown	5	14
Sand, coarse to medium, and some fine gravel	7	21
Sand, coarse to medium, brown to green	5	26
Gravel, coarse, to medium sand	4	30
Gravel, coarse to fine	30	60
Gravel, coarse to medium	7.5	67.5
PENNSYLVANIAN—Virgilian		
Stranger Formation		
Sandstone, light gray and brown	2.5	70
Sandstone, fine grained, light gray	10	80

12-20-19ba5.—(Lohman, 1941, T-29) Sample log of test hole in NE NW sec. 19, T. 12 S., R. 20 E., drilled 1940; depth to water, 7.5 feet. Altitude of land surface, 817.5 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Alluvium		
Soil, silty, dark (gumbo at top)	7	7
Sand, fine to coarse, interbedded with silty clay	4	11
Sand, coarse to medium, and fine to coarse gravel	10	21
Gravel, fine to coarse, and coarse to medium sand	9	30
Sand, coarse, and fine to coarse gravel	10	40
Gravel, fine to coarse, and fine to medium sand	5	45
PENNSYLVANIAN—Virgilian		
Stranger Formation		
Sandstone, hard, light gray	4	49

12-20-19bcc.—(Lohman, 1941, T-7) Sample log of test hole in SW cor. NW sec. 19, T. 12 S., R. 20 E., drilled 1940. Altitude of land surface, 817.2 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Alluvium		
Soil, sandy, dark	10	10
Sand, medium to coarse	10	20
Gravel, fine, and coarse sand	10	30
Sand, coarse, and fine gravel	10	40
Sand, coarse	3.5	43.5
PENNSYLVANIAN—Virgilian		
Stranger Formation		
Sandstone, hard, light gray	5.5	49

12-20-19bd1.—(Lohman, 1941, T-28) Sample log of test hole in SE NW sec. 19, T. 12 S., R. 20 E., drilled 1940; depth to water, 12.86 feet. Altitude of land surface, 822.5 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Alluvium		
Soil, dark	1	1
Sand, fine, light tan, and medium sand	15	16
Sand, coarse, gray, to medium gravel	14	30
Gravel, fine to coarse, and coarse sand	10	40
Gravel, coarse to fine, and some coarse sand	9.5	49.5
PENNSYLVANIAN—Virgilian		
Stranger Formation		
Clay, silty, light gray, and sandy shale	0.5	50

12-20-19ca.—(Lohman, 1941, T-27) Sample log of test hole in NE SW sec. 19, T. 12 S., R. 20 E., drilled 1940; depth to water, 6.95 feet. Altitude of land surface, 815.9 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Alluvium		
Soil, dark	1.5	1.5
Sand, medium, brown	9.5	11
Gravel, fine, and coarse sand	9	20
Gravel, fine to coarse, and coarse sand	10	30
Sand, coarse, and fine to coarse gravel	13.5	43.5
PENNSYLVANIAN—Virgilian		
Stranger Formation		
Clay, silty, light gray, and shale	1.5	45

12-20-19cc.—(Lohman, 1941, T-5) Sample log of test hole in SW SW sec. 19, T. 12 S., R. 20 E., drilled 1940. Altitude of land surface, 818.0 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Alluvium		
Sand, medium, brown	11	11
Sand, medium to coarse, brown	4	15
Sand, medium	5	20
Gravel, fine, to medium sand	10	30
Gravel, fine to coarse	10	40
Sand, coarse to medium	5.5	45.5
PENNSYLVANIAN—Virgilian		
Stranger Formation		
Shale, sandy, gray, and sandstone	4.5	50

12-20-19cd1.—(Lohman, 1941, T-26) Sample log of test hole in SE SW sec. 19, T. 12 S., R. 20 E., drilled 1940; depth to water, 14.9 feet. Altitude of land surface, 820.0 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Alluvium		
Soil; contains some sand and cinders	8	8
Clay soil, silty, gray	5	13
Sand, coarse to medium, and some fine gravel	17	30
Gravel, coarse to fine, and some coarse sand	10	40
Gravel, coarse to fine, and coarse sand	5	45
PENNSYLVANIAN—Virgilian		
Stranger Formation		
Sandstone, light gray, and sandy shale	5	50

12-20-19da.—(Lohman, 1941, T-20) Sample log of test hole in NE SE sec. 19, T. 12 S., R. 20 E., drilled 1940; depth to water, 6.9 feet. Altitude of land surface, 813.1 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Alluvium		
Soil, sandy, dark	3	3
Soil, clayey, silty, muddy gray	9	12
Gravel, fine to coarse, and coarse sand	9	21
Gravel, fine to coarse, and coarse sand	20.5	41.5
PENNSYLVANIAN—Virgilian		
Stranger Formation		
Sandstone, medium grained, light gray	3.5	45

12-20-20baa.—(Lohman, 1941, T-16) Sample log of test hole in NE cor. NW sec. 20, T. 12 S., R. 20 E., drilled 1940; depth to water, 14 feet. Altitude of land surface, 821.5 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Alluvium		
Soil, silty, dark	6	6
Soil, silty, brown	2	8
Sand, coarse, brown, and some medium sand	2	10
Sand, medium to coarse	10	20
Sand, coarse to medium, and some fine gravel	5	25
Sand, coarse, to coarse gravel	5	30
Sand, coarse to medium, and some fine gravel	9	39
Sand, coarse, to coarse gravel	4	43
Gravel, fine, and coarse sand	7	50
Gravel, fine to coarse, and coarse sand	10	60
Sand, coarse; contains boulders	12	72
PENNSYLVANIAN—Virgilian		
Stranger Formation		
Shale, sandy, gray, and sandstone	8	80

12-20-20bcc.—(Lohman, 1941, T-15) Sample log of test hole in SW cor. NW sec. 20, T. 12 S., R. 20 E., drilled 1940; depth to water, 22 feet. Altitude of land surface, 829.4 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Newman Terrace deposits		
Soil, black	3	3
Clay, silty, light brown	8	11
Sand, very fine to medium, tan	11	22
Sand, coarse, and some fine gravel	8	30
Sand, coarse, and fine to medium gravel	10	40
Sand, medium to coarse, and fine gravel	10	50
Sand, coarse to medium, and fine gravel	7	57
PENNSYLVANIAN—Virgilian		
Stranger Formation		
Shale, sandy, light gray, and some hard brown sandstone	3	60

12-20-20da.—(Lohman, 1941, p. 64) Drillers log of well drilled by G. E. Robinson for W. H. Pendleton in NE SE sec. 20, T. 12 S., R. 20 E., in August 1934. Altitude of land surface, ±820 feet.

	Thickness, feet	Depth, feet
Soil	6	6
Sand, fine, white	8	14
Sand and gravel, brown	3	17
Sand, fine, white	4	21
Gravel and sand, coarse, brown	14	35
Clay, black	1	36
Gravel, coarse, and brown sand	14	50

12-20-29ad1.—Drillers log of well drilled by Air Made Well Co. for Westvaco Chemical Co. in SE NE sec. 29, T. 12 S., R. 20 E., in 1951. Altitude of land surface, ±818 feet.

	Thickness, feet	Depth, feet
Surface silt and loam	3	3
Sand, silty, fine, brown	15	18
Sand, fine to medium, brown	6	24
Sand, coarse, brown, some silt streaks	4	28
Sand, medium to coarse, gray	6	34
Sand, coarse, gray, streaks of heavy thick silt and lenses of gravel	10	44
Gravel, gray, streaks of blue-gray silt and fine to coarse sand	7	51
Clay and silt, blue, grading into sandstone	3	54

12-20-29ad3.—Drillers log of test hole drilled by Jungmann Bros. Drilling Co. for Westvaco Chemical Co. in SE NE sec. 29, T. 12 S., R. 20 E., in July 1954. Altitude of land surface, ±817 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Alluvium		
Clay, sandy	18	18
Sand, some gravel	28	46

	Thickness, feet	Depth, feet
PENNSYLVANIAN—Virgilian		
Stranger Formation		
Shale	2	48
Sandstone	27	75
Shale, sandy	3	78
PENNSYLVANIAN—Missourian		
Stanton Limestone		
Limestone	19	97
Shale, dark	4	101
Limestone	15	116
Vilas Shale		
Shale	7	123
Plattsburg Limestone		
Limestone	20	143
Bonner Springs Shale		
Shale	10	153
Shale, sandy	7	160
Shale	10	170
Wyandotte Limestone		
Limestone	12	182
Shale	1	183
Limestone	7	190

12-20-30abb.—(Lohman, 1941, T-14) Sample log of test hole in NW cor. NE sec. 30, T. 12 S., R. 20 E., drilled 1940; depth to water, 10.8 feet. Altitude of land surface, 816.6 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Alluvium		
Soil, silty, sandy, brown	13	13
Sand, coarse to medium, and some fine gravel	7	20
Gravel, coarse to fine, and coarse to medium sand	10	30
Gravel, fine to coarse, and coarse sand	13.5	43.5
PENNSYLVANIAN—Virgilian		
Stranger Formation		
Sandstone, light gray, a hard boulder bed just above it,	6.5	50

12-20-30ba1.—(Lohman, 1941, T-13) Sample log of test hole in NE NW sec. 30, T. 12 S., R. 20 E., drilled 1940; depth to water, 12.8 feet. Altitude of land surface, 816.9 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Alluvium		
Road fill, soil, and rock	6	6
Soil, silty, dark brown	4	10
Sand, coarse and medium, and some fine gravel	10	20
Sand, coarse, and fine gravel	10	30
Sand, medium, to coarse gravel	10	40
Sand, medium, some coarse	8	48
PENNSYLVANIAN—Virgilian		
Stranger Formation		
Coal, black, and sandy light-gray shale	2	50

12-20-30ba2.—(Lohman, 1941, T-25) Sample log of test hole in NE NW sec. 30, T. 12 S., R. 20 E., drilled 1940; depth to water, 8 feet. Altitude of land surface, 814.8 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Alluvium		
Soil, dark	1.5	1.5
Silt, brown, and fine sand	6.5	8
Gravel, fine to coarse, and coarse to medium sand	6	14
Sand, coarse to medium, and fine to coarse gravel	6	20
Gravel, coarse to fine, and coarse sand	21	41
PENNSYLVANIAN—Virgilian		
Stranger Formation		
Sandstone, light gray	4	45

12-20-30ba3.—(Lohman, 1941, T-21) Sample log of test hole in NE NW sec. 30, T. 12 S., R. 20 E., drilled 1940. Altitude of land surface, 811.0 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Alluvium		
Soil, sandy, dark	8	8
Sand, medium to coarse, brown	4	12
Gravel, coarse to medium, and coarse to medium sand,	8	20
Gravel, coarse to fine, and some coarse sand	10	30
Gravel, fine to coarse, and coarse sand	10	40
Sand, coarse, and fine to coarse gravel	2	42
PENNSYLVANIAN—Virgilian		
Stranger Formation		
Shale, sandy, light gray	3	45

12-20-30bc1.—(Lohman, 1941, T-12) Sample log of test hole in SW NW sec. 30, T. 12 S., R. 20 E, drilled 1940; depth to water, 12.6 feet. Altitude of land surface, 816.2 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Alluvium		
Soil, sandy, dark brown	14	14
Sand, coarse to medium	6	20
Gravel, medium and coarse, and coarse and medium sand	10	30
Sand, coarse, and fine to coarse gravel	10	40
Gravel, fine, and coarse sand	8	48
PENNSYLVANIAN—Virgilian		
Stranger Formation		
Shale, sandy, light gray, and sandstone	2	50

12-20-30bc2.—(Lohman, 1941, T-1) Sample log of test hole in SW NW sec. 30, T. 12 S., R. 20 E., drilled 1940; depth to water, 13 feet. Altitude of land surface, 815.5 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Alluvium		
Soil, silty, dark; contains some sand and gravel	2.5	2.5
Soil, silty, dark	3.5	6
Soil, silty clay, dark brown	7	13
Sand, coarse, and fine gravel	7	20
Gravel, medium, and coarse sand	10	30
Gravel, medium and fine	10	40
Gravel, coarse to fine	5.5	45.5
PENNSYLVANIAN—Virgilian		
Stranger Formation		
Shale, sandy, light gray, and sandstone	4.5	50

12-20-30bc3.—(Lohman, 1941, T-2) Sample log of test hole in SW NW sec. 30, T. 12 S., R. 20 E., drilled 1940. Altitude of land surface, 815.8 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Alluvium		
Soil, earthy, black	10.5	10.5
Clay, dark blue to gray	10.5	21
Gravel, fine, and coarse sand	9	30
Gravel, medium to fine	14.5	44.5
PENNSYLVANIAN—Virgilian		
Stranger Formation		
Shale, sandy, gray, and sandstone	5.5	50

12-20-30bc4.—(Lohman, 1941, T-3) Sample log of test hole in SW NW sec. 30, T. 12 S., R. 20 E., drilled 1940. Altitude of land surface, 814.9 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Alluvium		
Soil, dark	1	1
Sand, fine, light tan	2	3
Clay, soft, dark	11	14
Gravel, fine to coarse, and coarse sand	6	20
Gravel, fine, and coarse sand	10	30
Sand, coarse, and fine gravel	10	40
Gravel, fine, and coarse sand	5	45
PENNSYLVANIAN—Virgilian		
Stranger Formation		
Shale, sandy, light gray	5	50

12-20-30bc5.—(Lohman, 1941, T-4) Sample log of test hole in SW NW sec. 30, T. 12 S., R. 20 E., drilled 1940. Altitude of land surface, 814.4 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Alluvium		
Soil, earthy, black	5	5
Clay, dark blue to gray	8	13
Sand, coarse to medium	7	20
Gravel, fine, and coarse to medium sand	7	27
Clay or sand (sample contains too much drilling mud to determine)	2	29
Sand, medium	5	34
Gravel, fine, and coarse sand	6	40
Sand, coarse, and fine gravel	4	44
PENNSYLVANIAN—Virgilian		
Stranger Formation		
Shale, sandy, light gray	3	47

12-20-30bc6.—(Lohman, 1941, T-23) Sample log of test hole in SW NW sec. 30, T. 12 S., R. 20 E., 150 feet west and 20 feet north of intersection of First and Maple Streets, drilled 1940; depth to water, 14.35 feet. Altitude of land surface, 814.8 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Alluvium		
Soil, sandy, brown	5	5
Sand, fine, brown	2	7
Clay, silty, dark	3	10
Sand, coarse, and fine gravel	10	20
Sand, coarse to medium, and some fine gravel	2.5	22.5
Clay, silty, dark blue gray	13.5	36
Sand, coarse, and fine gravel	4	40
Sand, coarse to medium	6.5	46.5
PENNSYLVANIAN—Virgilian		
Stranger Formation		
Shale, sandy, light gray, and sandstone	1.5	48

12-20-30bc7.—(Lohman, 1941, T-22) Sample log of test hole in SW NW sec. 30, T. 12 S., R. 20 E., drilled 1940; depth to water, 19.3 feet. Altitude of land surface, 821.7 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Alluvium		
Sand, fine, brown	9	9
Silt, soft, plastic, brown	2	11
Sand, coarse to medium	9	20
Sand, coarse to medium, and fine gravel	8	28
Clay, silty, dark gray	10	38
Gravel, fine to coarse, and coarse to medium sand	12	50
Sand, coarse to medium, and some fine gravel	2.5	52.5
PENNSYLVANIAN—Virgilian		
Stranger Formation		
Sandstone, light gray, and sandy shale	2.5	55

12-20-30bc8.—(Lohman, 1941, T-24) Sample log of test hole in SW NW sec. 30, T. 12 S., R. 20 E., 312 feet north of intersection of First and Lincoln Streets, drilled 1940; depth to water, 16.15 feet. Altitude of land surface, 818.2 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Alluvium		
Soil, sandy, brown	10.5	10.5
Sand, coarse to medium, brown	6.5	17
Sand, coarse, and fine gravel	3	20
Sand, coarse to medium, and fine gravel	10	30
Sand, coarse to medium, and fine to coarse gravel	10	40
Gravel, fine to coarse, some coarse sand	9.5	49.5
PENNSYLVANIAN—Virgilian		
Stranger Formation		
Shale, sandy, light gray, and sandstone	2.5	52

12-20-30cca.—Drillers log of well drilled by Holmes & Hammel Drilling Co. for Lawrence Sanitary Dairy in NE SW SW sec. 30, T. 12 S., R. 20 E., in 1940. Altitude of land surface, ±845 feet.

	Thickness, feet	Depth, feet
Soil and clay	10	10
Shale	15	25
Sandstone	5	30
Shale	12	42
Limestone	4	46
Shale, sandy	62	108
Sandstone, white (salt water)	50	158
Shale, sandy	6	164
Sandstone, white (salt water)	24	188
Limestone	6	194
Shale, black	6	200
Limestone	8	208
Shale	14	222

12-20-31ba.—Drillers log of well drilled by J. E. Goble for R. C. Jackman (WREN Building) in NE NW sec. 31, T. 12 S., R. 20 E., in June 1933. Altitude of land surface, ±860 feet.

	Thickness, feet	Depth, feet
Clay, yellow, soft	20	20
Sand, yellow, soft	10	30
Sand, yellow, soft, quicksand (some water)	20	50
Limestone, gray, hard	8	58
Shale, soft	17	75
Coal	1	76
Shale, light, calcareous	1	77
Shale, gray, soft	48	125
Sandstone, gray	35	160

12-20-31caa.—Sample log of test hole in NE NE SW sec. 31, T. 12 S., R. 20 E., about 80 feet west and 150 feet south of curbing at NE corner of South Park, east of Massachusetts Street, drilled August 19, 1954. Altitude of land surface, ±860 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Undifferentiated alluvium and colluvium		
Soil, gray black	3	3
Clay, silty, yellow to gray tan	4.5	7.5
Clay, silty, gray tan; contains fragments of sandstone, and ironstone concretions	9.5	17
PENNSYLVANIAN—Virgilian		
Lawrence Shale		
Shale, clayey, light gray and light tan	1.9	18.9
Stranger Formation		
Limestone	0.1	19

12-20-36ddd.—Sample log of test hole in SE SE SE sec. 36, T. 12 S., R. 20 E., 31 feet NW of SE corner, drilled April 18, 1952; depth to water, 15 feet. Altitude of land surface, 810 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Alluvium		
Soil, silty, gray	6	6
Silt, argillaceous, gray	10	16
Sand, fine to medium, quartz and feldspar	4	20
Sand, medium, quartz and feldspar	9	29
Sand, coarse, well sorted, quartz and feldspar	26.5	55.5
PENNSYLVANIAN—Missourian		
Stanton Limestone		
Limestone, gray	0.5	56

12-21-31bcc.—Sample log of test hole in SW SW NW sec. 31, T. 12 S., R. 21 E., drilled April 1952; depth to water, 13.7 feet. Altitude of land surface, 808 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Upper Pleistocene to Recent		
Alluvium		
Soil, silty, gray; many fine sand grains	12	12
Sand, medium, fairly well sorted; grains are quartz, feldspar, and some sandstone and basalt	8	20
Sand, coarse, fairly well sorted; grains are quartz, feldspar, and some basalt and limonite	8	28
Sand, medium, blue gray, well sorted	16.5	44.5
Sand, medium, fairly well sorted	2	46.5
PENNSYLVANIAN—Missourian		
Stanton(?) Limestone		
Limestone, gray, weathered	1.5	48

12-21-34cbb.—Sample log of test hole in NW NW SW sec. 34, T. 12 S., R. 21 E., drilled June 22, 1953. Altitude of land surface, 801 feet.

	Thickness, feet	Depth, feet
Road Fill	4	4
QUATERNARY—Pleistocene		
Alluvium		
Sand, silty, fine	15	19
Clay, silty	2	21
Sand and gravel, blue gray	26.8	47.8
PENNSYLVANIAN—Missourian		
Wyandotte(?) Limestone		
Limestone, hard, light gray	0.2	48

13-17-12cc.—Sample log of test hole in SW SW sec. 12, T. 13 S., R. 17 E., drilled October 1955. Altitude of land surface, ±1,073 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Kansas Till		
Clay, red brown; contains sand and fragments of gravel	3	3
Clay, sandy, yellow brown	3	6
Sand, very fine, silty and clayey, yellow	1	7
Clay, gravelly and sandy, yellow	17	24
Sand, very fine, very clayey, tan	12	36
Sand, very fine, very clayey, gray	12	48
PENNSYLVANIAN—Virgilian		
Kanwaka Shale		
Shale, clayey, gray	1	49

13-18-2aa.—Drillers log of well drilled by W. D. Wilson for Robert Kay in NE NE sec. 2, T. 13 S., R. 18 E., in April 1955. Altitude of land surface, ±1,010 feet.

	Thickness, feet	Depth, feet
Soil	3	3
Clay, yellow	6	9
Limestone, yellow	1	10
Shale, light gray	10	20
Shale, sandy, gray	25	45
Limestone, brown	5	50
Shale, muddy, gray	10	60
Limestone, soft, white	10	70
Slate, black	5	75
Limestone	1	76
Shale, dark	14	90
Limestone	16	106
Shale, light gray	24	130
Shale, sandy, gray	40	170
Shale, muddy, gray	87	257
Limestone, dark gray	4	261
Sandstone, dark gray	14	275
Shale, muddy, gray	25	300

13-18-7cd.—Drillers log of well drilled by Homer Wilson for J. M. Clough in SE SW sec. 7, T. 13 S., R. 18 E., in December 1956. Altitude of land surface, ±1,031 feet.

	Thickness, feet	Depth, feet
Soil	2	2
Clay, yellow	2	4
Limestone, shell	2	6
Clay, red	1	7
Limestone	1	8
Shale, dark	4	12
Limestone	4	16
Shale, light	7	23
Limestone, dark gray	7	30
Shale, sandy, light	25	55
Sandstone, dark gray	15	70
Shale, sandy, light	10	80
Sandstone, gray	20	100
Limestone, brown	6	106
Sandstone, gray	12	118
Limestone, hard, gray	4	122
Limestone, sandy, light	5	127
Limestone, white	3	130
Slate, black	14	144
Limestone, light, sandy	2	146
Limestone, sandy, gray	4	150
Limestone, sandy, white	7	157
Shale and sandstone, white	11	168
Shale, sandy, dark	2	170
Shale, sandy, light	7	177
Shale, muddy, gray	3	180
Shale, sandy, light	7	187
Coal and shale	7	194
Shale, sandy	8	202
Shale, light gray	7	209
Shale, sandy, light gray	5	214
Sandstone and shale	36	250

13-18-10bd.—Sample log of test hole in SE NW sec. 10, T. 13 S., R. 18 E., drilled July 1953. Altitude of land surface, ±864 feet.

QUATERNARY—Pleistocene

Newman Terrace deposits	Thickness, feet	Depth, feet
Soil, black	3	3
Clay, dark gray	6	9
Clay, silty, gray	3	12
Clay, silty, fossiliferous, light tan	7	19
Clay, silty, gray to blue gray	8	27
Clay, sandy, blue gray	24	51
Clay, green	6	57
Silt and very fine sand, fossiliferous, gray green	7	64
Sand, medium, to very coarse gravel, mostly chert, limestone, sandstone, and quartz; fossiliferous	1.5	65.5

	Thickness, feet	Depth, feet
PENNSYLVANIAN—Virgilian		
Lawrence Shale		
Shale, gray	4.5	70

13-18-10dc.—Sample log of test hole in SW SE sec. 10, T. 13 S., R. 18 E., drilled July 1953. Altitude of land surface, ±861 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Newman Terrace deposits		
Topsoil, dark	6	6
Clay, heavy, gray	5	11
Clay, silty, gray brown	10	21
Clay, sandy, brown	13	34
Clay, sandy, blue	30.5	64.5
Sand and gravel, chiefly quartz and chert; contains some limestone, sandstone, and quartzite pebbles	2.5	67
PENNSYLVANIAN—Virgilian		
Lawrence Shale		
Shale, sandy, blue gray	13	80
Shale, silty, blue gray	20	100
Shale, silty, blue gray and blue green	21.5	121.5
Stranger Formation—Haskell Limestone member		
Limestone, fossiliferous, hard, gray	1	122.5

13-18-15ca.—Sample log of test hole in NE SW sec. 15, T. 13 S., R. 18 E., about 20 feet south and 10 feet west of center of section, drilled July 1953. Altitude of land surface, ±967 feet.

	Thickness, feet	Depth, feet
Undifferentiated deposits		
Soil, gray black	2	2
Clay, red	3	5
PENNSYLVANIAN—Virgilian		
Oread Limestone—Kereford Limestone member		
Limestone, buff	2	7
Oread Limestone—Heumader Shale member		
Shale, clayey, light tan gray	7.5	14.5
Oread Limestone—Plattsmouth Limestone member		
Limestone, hard, light gray	1.5	16

13-18-22ab.—Sample log of test hole in NW NE sec. 22, T. 13 S., R. 18 E., about 20 feet south and 10 feet east of center of road intersection, drilled July 10, 1953. Altitude of land surface, ±964 feet.

	Thickness, feet	Depth, feet
Undifferentiated deposits		
Soil, black, and road fill	2	2
QUATERNARY—Pleistocene		
Kansan glaciofluvial deposits		
Clay, sandy and gravelly, red and tan	6	8
Clay, sandy, red	1.5	9.5
Clay, very sandy, light tan	7.5	17
Sand and gravel, chiefly quartz, chert, and quartzite	11	28
PENNSYLVANIAN—Virgilian		
Oread Limestone		
Limestone	..	28

13-18-32bc.—Drillers log of well drilled by Charles Jungmann for Arthur Gaines in SW NW sec. 32, T. 13 S., R. 18 E., in January 1956. Altitude of land surface, ±965 feet.

	Thickness, feet	Depth, feet
Soil	2	2
Clay, red	10	12
Limestone	1	13
Shale, light	4	17
Limestone (seep of fresh water)	17	34
Slate, black	2	36
Shale, gray	6	42
Limestone, very hard	23	65
Shale (trace of red shale at 90 ft.)	70	135
Shale, sandy	35	170
Sandstone	15	185
Shale	7	192

13-19-1acc.—Sample log of test hole in SW SW NE sec. 1, T. 13 S., R. 19 E., west side of alley at 1820 Michigan Street, drilled July 1954. Altitude of land surface, ±881 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Colluvium		
Soil, dark gray black	3	3
Silt and clay, brown tan	7	10
Silt and clay, yellow tan	5	15
PENNSYLVANIAN—Virgilian		
Lawrence Shale		
Shale, weathered, clayey, yellow tan	3.5	18.5

13-19-1bc.—Sample log of test hole in SW NW sec. 1, T. 13 S., R. 19 E., drilled January 1947. Altitude of land surface, ±998 feet.

	Thickness, feet	Depth, feet
Soil and fill	10	10
PENNSYLVANIAN—Virgilian		
Oread Limestone—Toronto Limestone member		
Limestone, white to yellow	3.5	13.5
Lawrence Shale		
Shale, argillaceous, gray to blue green	14.5	28
Shale, purple red	1	29
Shale, gray to blue gray	9	38
Siltstone, cemented, hard, dark gray	1.5	39.5
Shale, light blue gray	7.5	47
Shale, clayey to sandy, blue gray; contains a thin coal,	30	77
Shale, sandy and micaceous, blue gray to gray	104.5	181.5
Stranger Formation—Haskell Limestone member		
Limestone, fossiliferous, hard, light gray	3	184.5

	Thickness, feet	Depth, feet
Stranger Formation—Vinland Shale member		
Shale, very sandy, and cemented sandstone, blue gray,	15.5	200
Shale, argillaceous to sandy, blue gray; contains a thin coal	27	227
Stranger Formation—Westphalia(?) Limestone member		
Limestone, brittle, light gray	0.3	227.3
Stranger Formation—Tonganoxie Sandstone member		
Sandstone, fine to very fine, gray, and gray sandy shale; contains carbonized plant fragments	21.2	248.5
Sandstone, shaly, light gray	21.5	270
Sandstone, very fine to fine, micaceous, light gray	30	300

13-19-1ca2.—Sample log of test hole in NE SW sec. 1, T. 13 S., R. 19 E., about 40 feet north of Norman Plummer residence, 1400 West 19th Street, drilled July 5, 1954. Altitude of land surface, ±890 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Buck Creek Terrace deposits		
Soil, silty, gray black	2	2
Silt, light gray	2	4
Silt, clayey, yellow tan	2	6
Silt, clayey, red tan	4	10
Silt and clay, yellow tan; contains fragments of ironstone and sandstone	13	23
Silt and clay, sandy, yellow tan	28	51
PENNSYLVANIAN—Virgilian		
Lawrence Shale		
Shale, gray	11	62

13-19-1cc2.—Drillers log of well drilled by W. D. Wilson for Tom Akin in SW SW sec. 1, T. 13 S., R. 19 E., at service station at NE corner Twenty-third and Iowa Streets, in 1953. Altitude of land surface, ±885 feet.

	Thickness, feet	Depth, feet
Soapstone, yellow	20	20
Shale, light	22	42
Limestone	4	46
Shale, clayey, gray	18	64
Shale, sandy, gray	48	112
Sandstone, (brackish water)	6	118

13-19-1dbc.—Sample log of test hole in SW NW SE sec. 1, T. 13 S., R. 19 E., at rear of lot at 2005 Mitchell Road, drilled July 6, 1954; depth to water, 10.9 feet. Altitude of land surface, ±873 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Buck Creek Terrace deposits		
Soil, gray black	2.5	2.5
Silt, clayey, yellow tan	17.5	20
Silt, clayey, slightly sandy, yellow tan	18	38
PENNSYLVANIAN—Virgilian		
Lawrence Shale		
Shale, blue gray	8	46

13-19-8dbb.—Sample log of test hole in NW NW SE sec. 8, T. 13 S., R. 19 E., about 20 feet south and 5 feet east of center of section, drilled October 26, 1955; depth to water, 43.85 feet. Altitude of land surface, ±881 feet.

	Thickness, feet	Depth, feet
Road fill	1	1
QUATERNARY—Pleistocene		
Buck Creek Terrace deposits		
Silt, clayey, slightly sandy, tan brown	13	14
Silt, clayey, slightly sandy, red brown	8	22
Silt, clayey, light gray tan	2	24
Silt, clayey, sandy, red brown	7	31
Silt, sandy, brown and light gray	3	34
Silt, clayey, sandy, brown	16	50
PENNSYLVANIAN—Virgilian		
Lawrence(?) Shale		
Shale, light gray	2	52

13-19-10dd.—Drillers log of well drilled by Charles Jungmann for Norman Aldrich in SE SE sec. 10, T. 13 S., R. 19 E., in April 1956. Altitude of land surface, ±836 feet.

	Thickness, feet	Depth, feet
Soil	1	1
Clay, sandy	29	30
Gravel and sand, clayey	8	38
Limestone	4	42
Shale, sandy	38	80
Sandstone	20	100
Shale	10	110

13-19-11aa2.—Sample log of test hole in NE NE sec. 11, T. 13 S., R. 19 E., about 1,100 feet south and 45 feet west of NE corner, drilled July 9, 1953. Altitude of land surface, ±907 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Kansan glaciofluvial deposits		
Soil, gray black	2	2
Clay, red orange	1	3
Clay, red; contains gravel and sand	5	8
Clay, sandy and gravelly, yellow orange	3	11
Clay, very sandy, yellow tan	7	18
Sand, fine to coarse, yellow tan	4	22
Gravel and sand, predominantly chert, quartz, and limestone	4.5	26.5
PENNSYLVANIAN—Virgilian		
Lawrence Shale		
Shale, gray	3.5	30

13-19-11da2.—Sample log of test hole in NE SE sec. 11, T. 13 S., R. 19 E., about 0.6 mile south of corner on road shoulder, drilled July 1953. Altitude of land surface, ±876 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Kansan glaciofluvial deposits		
Soil, gray black	2	2
Clay, red tan	2	4
Clay, sandy and gravelly, yellow tan	3	7
Clay, sandy and gravelly, blue gray	2	9
Clay, very sandy, brown	12	21
Clay, blue gray	3	24
PENNSYLVANIAN—Virgilian		
Lawrence Shale		
Shale, partly weathered, tan	4	28
Shale, gray	4	32

13-19-11da3.—Drillers log of well drilled by Charles Jungmann for Richard Oehlert in NE SE sec. 11, T. 13 S., R. 19 E., in February 1956. Altitude of land surface, ±870 feet.

	Thickness, feet	Depth, feet
Soil	2	2
Clay, sandy	33	35
Sand, clayey	3	38
Limestone	4	42
Shale	31	73
Shale, sandy	41	114
Sandstone	16	130
Shale	4	134
Sandstone, thin shale streaks	16	150

13-19-11dd.—Drillers log of well drilled by W. D. Wilson for radio station KLWN in SE SE sec. 11, T. 13 S., R. 19 E., in July 1953. Altitude of land surface, ±850 feet.

	Thickness, feet	Depth, feet
Soil	5	5
Clay, yellow (show of water)	30	35
Shale, sandy, gray	45	80
Sandstone, gray (show of water)	15	95
Sandstone, white (lots of water)	6	101

13-19-11ddd.—Sample log of test hole in SE SE SE sec. 11, T. 13 S., R. 19 E., about 75 feet west and 10 feet north of SE corner, drilled July 7, 1953. Altitude of land surface, ±849 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Buck Creek Terrace deposits		
Soil, gray black	2	2
Clay, gray	3	5
Clay and silt, brown	4	9
Clay and silt, red brown	10	19
Silt and clay, light red brown	12	31
Silt and clay, sandy, light tan	15	46
Sand, very fine, silty, tan	6	52
Gravel, sandy and silty, tan	2	54
PENNSYLVANIAN—Virgilian		
Stranger Formation		
Sandstone, very fine	1	55
Shale, hard, gray	5	60

13-19-12aaa.—Sample log of test hole in NE NE NE sec. 12, T. 13 S., R. 19 E., drilled July 1954. Altitude of land surface, ±881 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Peoria(?) Formation		
Soil, gray black	2.5	2.5
Silt, gray tan	3	5.5
PENNSYLVANIAN—Virgilian		
Lawrence Shale		
Shale, clayey, yellow tan	17.5	23

13-19-12aab.—Drillers log of well drilled by Eugene Smith for Ralph Puckett in NW NE NE sec. 12, T. 13 S., R. 19 E., in 1953. Altitude of land surface, ±883 feet.

	Thickness, feet	Depth, feet
Soil	5	5
Shale, clayey, yellow	20	25
Limestone	5	30
Shale, blue	15	45
Shale, white	20	65
Shale, sandy	10	75
Shale	10	85
Shale, white	25	110
Shale, sandy	5	115
Sandstone, white	50	165

13-19-12ad.—Sample log of test hole in SE NE sec. 12, T. 13 S., R. 19 E., drilled July 1954. Altitude of land surface, ±903 feet.

	Thickness, feet	Depth, feet
Road fill	3	3
QUATERNARY—Pleistocene		
Kansan glaciofluvial deposits		
Clay, brown red; contains abundant gravel	2	5
Clay, silty, red brown	5	10
Clay and silt, brown red; contains abundant sand and gravel	7	17
Gravel, sandy and clayey, red brown	7	24

13-19-12ba.—Drillers log of well drilled by Eugene Smith for Park Hetzel in NE NW sec. 12, T. 13 S., R. 19 E., in August 1953. Altitude of land surface, ±868 feet.

	Thickness, feet	Depth, feet
Soil	3	3
Clay, yellow	24	27
Sand	10	37
Gravel	4	41
Shale, blue	20	61
Shale, white	50	111
Plugged well back to 70 feet		

13-19-12cbb.—Drillers log of well drilled by W. D. Wilson for Albert Hayden in NW NW SW sec. 12, T. 13 S., R. 19 E., in April 1954. Altitude of land surface, ±873 feet.

	Thickness, feet	Depth, feet
Soil	2	2
Clay, yellow (little water)	26	28
Shale, gray	10	38
Limestone	5	43
Shale, gray	10	53
Shale, sandy, gray	52	105
Sandstone, gray	5	110
Shale, sandy, gray	10	120
Sandstone, white (lots of water)	4.5	124.5

13-19-12cbc.—Drillers log of well drilled by W. D. Wilson for Orville Flory in SW NW SW sec. 12, T. 13 S., R. 19 E., in June 1952. Altitude of land surface, ±864 feet.

	Thickness, feet	Depth, feet
Soil	2	2
Clay, yellow	18	20
Clay, sandy	5	25
Sand and gravel, loose	10	35
Shale, gray	15	50

13-19-13bcc.—Sample log of test hole in SW SW NW sec. 13, T. 13 S., R. 19 E., about 100 feet east of center line of U. S. Highway 59 on north road shoulder of township road, drilled July 7, 1953; depth to water, 13.97 feet. Altitude of land surface, ±850 feet.

	Thickness, feet	Depth, feet
Road fill	2	2
QUATERNARY—Pleistocene		
Buck Creek Terrace deposits		
Silt, clayey, red and gray brown	4	6
Silt, clayey, tan	12	18
Clay, sandy, tan brown	12	30
Silt, sandy and clayey, tan	7.5	37.5
Silt, sandy and clayey, gray	26.5	64
Gravel and sand, silty, gray	3.5	67.5
PENNSYLVANIAN—Virgilian		
Stranger Formation		
Shale, sandy, hard, gray; contains thin beds of sandstone	12.5	80
Sandstone, cemented with calcite, very hard, gray brown	1.5	81.5

13-19-14aa.—Drillers log of well drilled by W. D. Wilson for Paul Snyder in NE NE sec. 14, T. 13 S., R. 19 E., in April 1954. Altitude of land surface, ±852 feet.

	Thickness, feet	Depth, feet
Soil	3	3
Clay, yellow	22	25
Quicksand, clayey (200 gal. fresh water per hour)	30	55
Shale, sandy, gray	25	80
Sandstone, gray	16	96
Sandstone, white (lots of water)	15	111

13-19-14dd.—Sample log of test hole in SE SE sec. 14, T. 13 S., R. 19 E., about 25 feet west of highway right of way and 710 feet north of SE corner, drilled July 5, 1953; depth to water, 8.70 feet. Altitude of land surface, ±825 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Newman Terrace deposits		
Silt and clay, gray black	2	2
Clay, gray	3	5
Clay, silty, brown	10	15
Clay, silty, blue gray to blue green	17	32
Clay, silty, brown	2	34
Clay, silty and sandy, blue	12	46
Gravel and sand, silty	7.5	53.5
PENNSYLVANIAN—Virgilian		
Stranger(?) Formation		
Shale, gray	6.5	60

13-19-21bb.—Drillers log of well drilled by W. D. Wilson for Robert Mason in NW NW sec. 21, T. 13 S., R. 19 E., in May 1952. Altitude of land surface, ±861 feet.

	Thickness, feet	Depth, feet
Soil	2	2
Soil, yellow	3	5
Clay, yellow	20	25
Clay, yellow, and sand	10	35
Limestone, shaly, dark	2	37
Shale, gray	13	50
Shale, sandy, gray	10	60
Sandstone, broken (water)	30	90
Shale, gray	10	100

13-19-22ad.—Drillers log of well drilled by Charles Jungmann for Charles Oldfather in SE NE sec. 22, T. 13 S., R. 19 E., on July 2, 1956. Altitude of land surface, ±886 feet.

	Thickness, feet	Depth, feet
Soil	2	2
Clay, brown	16	18
Shale, blue	9	27
Limestone	5	32
Shale, gray	12	44
Shale, sandy, contains dark streaks of shale	3	47
Sand, broken, and shale	15	62
Shale, sandy	13	75
Shale, gray	18	93
Sandstone, partly shaly	17	110
Sandstone, very shaly	4	114
Sandstone	52	166
Limestone	3	169

13-19-23aa.—Sample log of test hole in NE NE sec. 23, T. 13 S., R. 19 E., about 125 feet north and 60 feet west of north end of Wakarusa River bridge, drilled July 9, 1953; depth to water, 14.06 feet. Altitude of land surface, ±827 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Newman Terrace deposits		
Soil, silty, gray black	4	4
Clay, sandy and silty, gray tan	19	23
Clay, fossiliferous, blue	4	27
Clay, sandy, blue	8	35
Clay, sandy, blue green	8	43
Clay, sandy, gray	12	55
Sand and gravel, silty	4	59
PENNSYLVANIAN—Virgilian		
Stranger Formation		
Shale, gray	5	64

13-19-23ad.—Sample log of test hole in SE NE sec. 23, T. 13 S., R. 19 E., on shoulder southwest of intersection of U. S. Highway 59 and Clinton Road, drilled July 9, 1953; depth to water, 13.3 feet. Altitude of land surface, ±830 feet.

	Thickness, feet	Depth, feet
Road fill and soil	10	10
QUATERNARY—Pleistocene		
Newman Terrace deposits		
Clay, silty, dark gray	5	15
Clay, gray tan	6	21
Clay, silty and sandy, gray	33.5	54.5
Sand and gravel, silty, fossiliferous	7	61.5
PENNSYLVANIAN—Virgilian		
Stranger Formation		
Shale, hard, gray	3.5	65

13-19-23da.—Drillers log of well drilled by Jungmann Bros. for Walter Kollmorgen in NE SE sec. 23, T. 13 S., R. 19 E., in March 1953. Altitude of land surface, ±856 feet.

	Thickness, feet	Depth, feet
Soil	2	2
Clay	6	8
Boulders	1	9
Shale	66	75
Sandstone	10	85
Shale, sandy	3	88
Sandstone, broken	12	100
Sandstone (with hard cap)	38	138
Limestone	2	140

13-19-27dd.—Drillers log of well drilled by Homer Wilson for George Luckan in SE SE sec. 27, T. 13 S., R. 19 E., in April 1956. Altitude of land surface, ±1,005 feet.

	Thickness, feet	Depth, feet
Soil	2	2
Clay, red	6	8
Limestone, yellow	12	20
Shale, light	20	40
Shale, dark	140	180
Limestone	6	186
Shale, sandy, light	68	254
Sandstone	58	312

13-19-36ab.—Drillers log of well drilled by Raymond Schutz for Harold Skinner in NW NE sec. 36, T. 13 S., R. 19 E., in June 1956.

	Thickness, feet	Depth, feet
Topsoil	3	3
Sand rock	19	22
Clay, sandy, brown	8	30
Soapstone, sandy, gray	8	38
Soapstone	9	47
Lime rock	3	50
Soapstone, gray	8	58
Soapstone, brown	9	67
Sandstone, white (1 gpm water)	6	73
Soapstone, sandy	15	88
Sandstone, white	7	95
Lime rock	..	95

13-19-36bb.—Drillers log of well drilled by W. D. Wilson for Charles Iles in NW NW sec. 36, T. 13 S., R. 19 E., in 1948. Altitude of land surface, ±893 feet.

	Thickness, feet	Depth, feet
Soil	1	1
Shale, yellow	4	5
Limestone, hard	2	7
Clay, yellow	23	30
Shale, sandy, yellow	10	40
Shale, sandy, gray	35	75
Sandstone (water)	20	95
Shale, sandy, blue	10	105
Sandstone (water)	10	115
Shale, blue	3	118

13-20-1add.—Sample log of test hole in SE SE NE sec. 1, T. 13 S., R. 20 E., about 120 feet north of railroad track, drilled April 19, 1952; depth to water, 11.5 feet. Altitude of land surface, 809 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Alluvium		
Soil, silty, gray	3	3
Sand, coarse to very fine, brown	7	10
Sand, medium, brown	15	25
Sand, coarse, blue gray	5	30
Sand and fine gravel, blue gray	10	40
Sand, medium, blue gray	16	56
Gravel, fine, blue gray	9.5	65.5
PENNSYLVANIAN—Missourian		
Stanton(?) Limestone		
Limestone	1	66.5

13-20-4ab1.—Drillers log of well drilled by Layne-Western Co. for Cooperative Farm Chemicals Assoc. in NW NE sec. 4, T. 13 S., R. 20 E., in 1952.

	Thickness, feet	Depth, feet
Dirt, black	3	3
Clay, gray	25	28
Clay, blue	5	33
Clay, sandy, blue	4	37
Sand, fine; contains some clay	6	43
Sand, medium fine	2	45
Sand, medium coarse	3	48
Sand, medium coarse, and gravel	5	53
Sand, coarse, and big gravel	3	56
Shale, blue	3	59

13-20-5cb.—Sample log of test hole in NW SW sec. 5, T. 13 S., R. 20 E., drilled 1950.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Peoria Formation		
Silt, clayey, leached, dark brown	1	1
Silt, leached, mottled gray and brown	2	3
Silt, leached, mottled gray and brown; contains small caliche nodules	0.5	3.5
Silt, leached, mottled reddish brown and gray	1.5	5
Loveland Formation		
Silt, leached, yellow brown, contains 2-mm caliche nodules	1	6
Silt, clayey, slightly mottled, leached, yellow brown	0.5	6.5
Kansas Till		
Clay, leached, brown to reddish brown; contains MnO_2 stains, chert granules, and limonite nodules	1.5	8
Clay, silty, light reddish brown; contains some chert and feldspar grains	1.8	9.8

13-20-5dc1.—Drillers log of well drilled by W. D. Wilson for Douglas County in SW SE sec. 5, T. 13 S., R. 20 E., in June 1952. Altitude of land surface, ±921 feet.

	Thickness, feet	Depth, feet
Soil, gray black	2	2
Clay, yellow brown; contains chert gravel	12	14
Clay, mottled gray and brown; contains chert, pink quartzite, and greenstone gravel	20	34
Clay, greenish gray; contains much gravel (little water)	6	40
Shale, gray	20	60
Limestone	5	65
Shale, muddy	10	75
Shale, sandy, blue gray	60	135
Sandstone, gray	50	185

13-20-5dc2.—Drillers log of well drilled by Homer Wilson for Oliver Peters in SW SE sec. 5, T. 13 S., R. 20 E., in March 1956. Altitude of land surface, ±916 feet.

	Thickness, feet	Depth, feet
Soil	2	2
Clay, yellow	23	25
Sand and gravel, yellow	10	35
Shale, light gray	17	52
Limestone	5	57
Shale, sandy, gray	26	83
Shale, light	74	157
Sand, white (water)	17	174

13-20-6aa.—Drillers log of well drilled by H. R. Swank for Paul Boyer in NE NE sec. 6, T. 13 S., R. 20 E., in May 1952. Altitude of land surface, ±861 feet.

	Thickness, feet	Depth, feet
Soil	3	3
Joint clay, blue	14	17
Limestone, hard, blue	3	20
Shale, blue	3	23
Shale, sandy, blue	12	35
Shale, black	3	38
Shale, sandy, blue	10	48
Shale, clayey, gray	18	66

13-20-6aba.—Sample log of test hole in NE NW NE sec. 6, T. 13 S., R. 20 E., in SE corner Lot 1, Block A, Brookdale Addition, 16th and Learnard Ave., drilled July 6, 1954. Altitude of land surface, ±855 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Undifferentiated colluvium and alluvium		
Silt, gray black	2	2
Clay, silty, yellow tan	2	4
Clay, silty and sandy, yellow tan; contains fragments of sandstone and limonite concretions	21	25
PENNSYLVANIAN—Virgilian		
Stranger Formation—Haskell Limestone member		
Limestone	..	25

13-20-6cd.—Sample log of test hole in SE SW sec. 6, T. 13 S., R. 20 E., approximately 50 feet east of center line of Vermont Street at 2208 Vermont, drilled August 1954. Altitude of land surface, ±872 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Undifferentiated colluvium and alluvium		
Soil, gray black	2	2
Clay, silty, gray	2	4
Clay, silty, yellow; contains fragments of limonite concretions	15	19
PENNSYLVANIAN—Virgilian		
Stranger Formation—Haskell Limestone member		
Limestone, hard	..	19

13-20-7ad.—Drillers log of well drilled by W. D. Wilson for Paul Clawson in SE NE sec. 7, T. 13 S., R. 20 E., in July 1953.

	Thickness, feet	Depth, feet
Soil	2	2
Shale, sandy	8	10
Clay, yellow	10	20
Limestone	3	23
Shale, light gray	72	95
Sandstone, gray	48	143

13-20-8ab1.—Sample log of test hole in NW NE sec. 8, T. 13 S., R. 20 E., about 130 feet NE of NE corner of India School, drilled July 8, 1954. Altitude of land surface, ±910 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Peoria Formation		
Silt, gray black	2	2
Silt, gray tan	3	5
Kansas Till		
Clay, silty and sandy, gray tan	5	10
Clay, very sandy, yellow tan; contains abundant chert and quartz gravel	9	19
PENNSYLVANIAN—Virgilian		
Lawrence Shale		
Shale, silty, tan	4.5	23.5

13-20-8ab2.—Drillers log of well drilled by Eugene Smith for P. A. Diehl in NW NE sec. 8, T. 13 S., R. 20 E., in July 1953. Altitude of land surface, ±912 feet.

	Thickness, feet	Depth, feet
Soil	4	4
Clay, yellow	20	24
Gravel (water)	4	28
Shale, dark blue	11	39
Shale, light blue	12	51
Limestone	5	56
Shale, blue	14	70
Sandstone, coarse	10	80
Shale, sandy	20	100
Sandstone, coarse	32	132
Sandstone, fine to very fine (water)	52	184

13-20-8ad.—Drillers log of well drilled by Lee Hendee, Jr., for Nellie Harris in SE NE sec. 8, T. 13 S., R. 20 E., in March 1953. Altitude of land surface, ±880 feet.

	Thickness, feet	Depth, feet
Soil	2	2
Clay, yellow	9	11
Clay, sandy, yellow	3	14
Clay, buff to olive	18	32
Limestone	4	36
Shale, gray	12	48

	Thickness, feet	Depth, feet
Limestone	2	50
Sandstone, shaly	37	87
Shale, sandy	6	93
Sandstone	2	95
Shale	10	105
Sandstone, shaly	33	138
Sandstone	22	160

13-20-9dad.—Sample log of test hole in SE NE SE sec. 9, T. 13 S., R. 20 E., about 950 feet south of E quarter corner on west road shoulder, drilled August 27, 1954; depth to water, 23.5 feet. Altitude of land surface, ±861 feet.

	Thickness, feet	Depth, feet
Road fill	1	1
QUATERNARY—Pleistocene		
Peoria Formation		
Silt, gray black	0.5	1.5
Silt, tan	3.5	5
Kansan glaciofluvial deposits		
Clay, mottled yellow tan and light gray	1	6
Clay, brown red; contains gravel and sand	3	9
Clay, brown to tan; contains gravel and sand	11	20
Sand and gravel, clayey, tan	12.5	32.5
PENNSYLVANIAN—Virgilian		
Stranger Formation		
Shale, gray	2.5	35

13-20-13cc.—Drillers log of well drilled by W. D. Wilson for Robert Stark in SW SW sec. 13, T. 13 S., R. 20 E., in January 1953. Altitude of land surface, ±848 feet.

	Thickness, feet	Depth, feet
Soil and surface	10	10
Sandstone	52	62
Shale, clayey, blue	1	63

13-20-16aa.—Drillers log of well drilled by Harold Lutz for H. C. Stewart in NE NE sec. 16, T. 13 S., R. 20 E., in May 1956. Altitude of land surface, ±851 feet.

	Thickness, feet	Depth, feet
Soil	4	4
Gravel and boulders	16	20
Sandstone, and yellow shaly sandstone	20	40
Shale, blue; contains thin coal bed at depth of 64 feet,	50	90
Sandstone, cemented	12	102
Shale	10	112

13-20-16bb.—Drillers log of well drilled by Harold Lutz for William Lemon in NW NW sec. 16, T. 13 S., R. 20 E., in 1955. Altitude of land surface, ±833 feet.

	Thickness, feet	Depth, feet
Topsoil	2	2
Silt, sandy, red	18	20
Sandstone, yellow	12	32
Sandstone, brown	8	40
Shale, gray	10	50
Sandstone	0.5	50.5
Shale, gray	19.5	70
Sandstone (show of water)	1	71
Shale, gray	9	80
Sandstone (water)	4	84
Shale	1	85
Sandstone	3	88
Limestone	2	90

13-20-19cd.—Drillers log of well drilled by W. D. Wilson for Carl Clifton in SE SW sec. 19, T. 13 S., R. 20 E., in October 1955. Altitude of land surface, ±984 feet.

	Thickness, feet	Depth, feet
Gravel	3	3
Clay, red	7	10
Sandstone, broken	15	25
Clay, yellow	15	40
Shale, sandy, gray	52	92
Sandstone, dark gray	5	97
Shale, muddy, blue	5	102
Sandstone (lots of water)	28	130

13-20-20bc.—Sample log of test hole in SW NW sec. 20, T. 13 S., R. 20 E., drilled August 27, 1954. Altitude of land surface, ±850 feet.

	Thickness, feet	Depth, feet
Road fill	2.5	2.5
QUATERNARY—Pleistocene		
Peoria Formation		
Silt, clayey, gray black	2.5	5
Silt, clayey, tan	1.5	6.5
Buck Creek Terrace deposits		
Clay, light gray	1	7.5
Clay, tan brown	6.5	14
Silt, clayey, yellow tan to yellow brown	11	25
Silt, micaceous, sandy, yellow tan	7	32
Sand, very fine to fine, silty and clayey	28	60
PENNSYLVANIAN—Missourian		
Weston(?) Shale		
Shale, argillaceous, gray	8.5	68.5

13-20-22dc.—Drillers log of well drilled by Harold Lutz for Harold Lutz in SW SE sec. 22, T. 13 S., R. 20 E., in 1953. Altitude of land surface, ±900 feet.

	Thickness, feet	Depth, feet
Clay	30	30
Limestone	4	34
Shale	66	100
Sandstone	48	148

13-20-23dc.—Drillers log of well drilled by Harold Lutz for Tom Akin in SW SE sec. 23, T. 13 S., R. 20 E., in 1954. Altitude of land surface, ±898 feet.

	Thickness, feet	Depth, feet
Soil	8	8
Clay, sandstone, and coal	25	33
Shale	40	73
Sandstone	35	108

13-20-25bb.—Drillers log of well drilled by Harold Lutz for Winston Keyee in NW NW sec. 25, T. 13 S., R. 20 E., in 1954. Altitude of land surface, ±894 feet.

	Thickness, feet	Depth, feet
Soil and sandstone	12	12
Shale, clay, and coal	65	77
Sandstone (water)	33	110
Limestone	2	112

13-20-25cc.—Drillers log of well drilled by Harold Lutz for Wayne Strong in SW SW sec. 25, T. 13 S., R. 20 E., in December 1955. Altitude of land surface, ±905 feet.

	Thickness, feet	Depth, feet
Soil	30	30
Shale	20	50
Sandstone (lower 25 feet yields water)	52	102

13-20-30cd.—Drillers log of well drilled by Harold Lutz for Robert Niesly in SE SW sec. 30, T. 13 S., R. 20 E., in April 1956. Altitude of land surface, ±898 feet.

	Thickness, feet	Depth, feet
Soil	3	3
Clay, yellow	2	5
Limestone	1	6
Clay, gray	24	30
Shale, blue	22	52
Coal	1	53
Clay, sticky	1	54
Shale, gray	58	112
Sandstone (water)	20	132

13-20-34dc.—Drillers log of well drilled by Commerce Drilling Co. for Jennie Eckman in SW SE sec. 34, T. 13 S., R. 20 E., in 1934. Altitude of land surface, ±951 feet.

	Thickness, feet	Depth, feet
Soil	3	3
Gravel and clay	8	11
Clay, yellow	4	15
Shale, sandy	50	65
Shale, gray	37	102
Shale, dark	3	105
Shale, light	9	114
Sandstone (water)	50	164
Limestone	3	167
Shale	2	169
Limestone	16	185

13-21-3ccb.—Sample log of test hole in NW SW SW sec. 3, T. 13 S., R. 21 E., along east road shoulder 20 feet south of intersection, drilled June 26, 1953; depth to water, 19.2 feet. Altitude of land surface, 882.5 feet.

	Thickness, feet	Depth, feet
Road fill	3	3
QUATERNARY—Pleistocene		
Peoria(?) Formation		
Silt, light gray tan	4.5	7.5
Kansan glaciofluvial deposits		
Clay, very sandy, brown red	8.5	16
Sand and fine gravel, red brown	7	23
Gravel and sand, chiefly chert and quartz	3	26
PENNSYLVANIAN—Missourian		
Stanton Limestone		
Limestone, hard	..	26

13-21-7bbb.—Sample log of test hole in NW NW NW sec. 7, T. 13 S., R. 21 E., in ditch along east side of road 346 feet south of center line of Kansas Highway 10, drilled April 19, 1952. Altitude of land surface, 812 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Newman Terrace deposits		
Soil, sandy, argillaceous, black	2	2
Clay, silty, gray	3	5
Clay, silty, light brown	23	28
Clay, silty, blue gray	9.5	37.5
Clay, silty, black	3.5	41
Gravel, medium to fine, arkosic	35	76
PENNSYLVANIAN—Missourian		
Stanton(?) Limestone		
Limestone, gray	0.5	76.5

13-21-7ddc.—Sample log of test hole in SW SE SE sec. 7, T. 13 S., R. 21 E., about 8 feet north of center line of road at crest of hill, drilled August 27, 1954. Altitude of land surface, ±899 feet.

	Thickness, feet	Depth, feet
Road fill	1	1
QUATERNARY—Pleistocene		
Peoria(?) and Loveland(?) Formations		
Silt, black	1	2
Silt, clayey, red brown to tan brown	3	5
Kansas Till		
Clay, sandy and gravelly, red	5	10
PENNSYLVANIAN—Virgilian		
Stranger Formation		
Sandstone, shaly, yellow tan	1	11
Shale, silty, micaceous, olive tan; contains thin coal streak	2.5	13.5

13-21-10db.—Drillers log of well drilled by W. L. Hendee, Jr., for Herbert Meuffel in NW SE sec. 10, T. 13 S., R. 21 E., in December 1952.

	Thickness, feet	Depth, feet
Topsoil and clay	3	3
Sandstone	5	8
Sandstone, shaly	3	11
Sandstone, hard	2	13
Shale, gray	3	16
Limestone	15	31
Shale, black	7	38
Limestone	8	46
Shale, gray blue	6	52
Sandstone	3	55
Shale, gray blue	5	60
Limestone	14	74
Shale	1	75
Limestone	3	78
Shale, gray	7	85

13-21-15cb.—Sample log of test hole in NW SW sec. 15, T. 13 S., R. 21 E., about 0.35 mile north of corner, drilled June 27, 1953; depth to water, 23.5 feet. Altitude of land surface, 898.7 feet.

	Thickness, feet	Depth, feet
Road fill	3	3
QUATERNARY—Pleistocene		
Kansan glaciofluvial deposits		
Clay and silt, sandy, tan	6	9
Clay and silt, sandy, gray tan	11	20
Sand, clayey, gray tan	11	31
PENNSYLVANIAN—Missourian		
Weston Shale		
Shale, blue gray	4	35

13-21-16aaa.—Sample log of test hole in NE NE NE sec. 16, T. 13 S., R. 21 E., about 75 feet west of intersection on south road shoulder, drilled June 26, 1953; depth to water, 12.6 feet. Altitude of land surface, 885.2 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Kansan glaciofluvial deposits		
Silt and clay, sandy, dark gray	3	3
Clay and silt, very sandy, tan	3	6
Sand and gravel, very clayey, tan brown	3	9
Sand, chiefly medium to coarse, tan brown	3	12
Gravel, fine to coarse, and sand	15	27
PENNSYLVANIAN—Missourian		
Weston Shale		
Shale, argillaceous, blue gray	3	30

13-21-22ddd.—Sample log of test hole in SE SE SE sec. 22, T. 13 S., R. 21 E., about 50 feet west of intersection on north road shoulder, drilled June 27, 1953; depth to water, 2.6 feet. Altitude of land surface, 901.1 feet.

	Thickness, feet	Depth, feet
Road fill	2	2
QUATERNARY—Pleistocene		
Kansan glaciofluvial deposits		
Clay and silt, very sandy, tan gray	2	4
Clay and silt, very sandy, brown tan; contains abundant gravel	4	8
Gravel and sand, very argillaceous	4	12
Silt and clay, tan brown; contains sparse sand and gravel	1	13
PENNSYLVANIAN—Missourian		
Stanton Limestone		
Limestone	..	13

13-21-27ba.—Sample log of test hole in NE NW sec. 27, T. 13 S., R. 21 E., about 2,000 feet east of corner, drilled June 27, 1953. Altitude of land surface, 918.5 feet.

	Thickness, feet	Depth, feet
Road fill	3	3
QUATERNARY—Pleistocene		
Kansan glaciofluvial deposits		
Clay, sandy, tan gray	14	17
Sand, very fine to medium, tan	5	22
Sand, fine to coarse, tan brown	18	40
Gravel and sand, tan brown	9	49
PENNSYLVANIAN—Missourian		
Stanton Limestone		
Limestone, gray	5	54

13-21-27bcc.—Sample log of test hole in SW SW NW sec. 27, T. 13 S., R. 21 E., drilled June 30, 1953. Altitude of land surface, 929 feet.

	Thickness, feet	Depth, feet
Road fill	2	2
QUATERNARY—Pleistocene		
Peoria(?) Formation		
Silt, gray tan; contains a few sand grains	3	5
Kansan glaciofluvial deposits		
Clay and silt, very sandy, gray tan	10	15
Clay and silt, very sandy, tan	2	17
Clay and silt, tan; contains abundant gravel and sand,	3	20
Sand, medium, brown tan	13.5	33.5
Gravel and sand, clayey, brown tan	1	34.5
Clay and silt, green tan; contains much sand	5	39.5
Gravel and sand, clayey, brown tan	1.5	41
Clay and silt, green tan; contains abundant gravel and sand	2	43
Gravel and sand, clayey, gray	4	47
PENNSYLVANIAN—Missourian		
Weston Shale		
Shale, blue gray	10	57
Shale, gray blue	4	61
Stanton Limestone—South Bend Limestone member		
Limestone, hard, gray	3.5	64.5
Stanton Limestone—Rock Lake Shale member		
Sandstone, fine, hard, gray	1	65.5

13-21-28aa.—Sample log of test hole in NE NE sec. 28, T. 13 S., R. 21 E., about 0.3 mile west of Hesper intersection, drilled June 29, 1953; depth to water ±8 feet. Altitude of land surface, 912.4 feet.

	Thickness, feet	Depth, feet
Road fill	2	2
QUATERNARY—Pleistocene		
Peoria(?) Formation		
Clay, silty, mottled gray and tan	3	5
Kansan glaciofluvial deposits		
Clay, sandy, gray tan	5	10
Clay, sandy, tan	4	14
Clay, sandy and gravelly, tan	2	16
Sand and clay, tan	2	18
Sand and gravel	1.5	19.5

	Thickness, feet	Depth, feet
PENNSYLVANIAN—Missourian		
Weston Shale		
Shale, hard, clayey, gray tan	1	20.5
Shale, blue gray	9.5	30
Concretion, clay ironstone, hard, pink gray	0.3	30.3
Shale, silty, blue gray	9.7	40
Shale, clayey, gray	9.7	49.7
Concretion, clay ironstone, hard, pink gray	0.3	50
Shale, clayey, gray	5	55
Stanton Limestone		
Limestone	0.5	55.5

13-21-28bb2.—Sample log of test hole in NW NW sec. 28, T. 13 S., R. 21 E., about 600 feet east of corner on road shoulder, drilled June 29, 1953; depth to water ±18 feet. Altitude of land surface, 892.8 feet.

	Thickness, feet	Depth, feet
Road fill	2	2
QUATERNARY—Pleistocene		
Peoria(?) Formation		
Silt and clay, light gray	2	4
Kansan glaciofluvial deposits		
Clay, silty, tan	8	12
Clay, sandy, tan	8	20
Clay, sandy and gravelly, tan	7	27
Sand, very fine, clayey, tan	5	32
Gravel and sand, chiefly fragments of chert, sandstone, and quartz	0.5	32.5
PENNSYLVANIAN—Missourian		
Stanton Limestone—Rock Lake Shale member		
Sandstone, calcite cemented, hard, yellow brown	1.5	34

13-21-29ab.—Sample log of test hole in NW NE sec. 29, T. 13 S., R. 21 E., about 35 feet south of center line of road, drilled June 30, 1953; depth to water, ±9 feet. Altitude of land surface, 869.3 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Peoria(?) Formation		
Silt, gray black	2.5	2.5
Kansan glaciofluvial deposits		
Clay, gray	1.5	4
Clay, mottled brown and gray	4	8
Clay, mottled blue and gray	5	13
Clay, sandy and gravelly, gray	2.5	15.5
Sand and gravel, clayey	3.5	19
PENNSYLVANIAN—Missourian		
Stanton Limestone—Rock Lake Shale member		
Sandstone, ferruginous, yellow brown	3	22
Shale, blue gray	2	24
Stanton Limestone—Stoner Limestone member		
Limestone, gray	2	26

13-21-31ddc.—Sample log of test hole in SW SE SE sec. 31, T. 13 S., R. 21 E., about 6 feet east of center of south side of SE quarter section, drilled August 26, 1954; depth to water, 18.7 feet. Altitude of land surface, ±920 feet.

	Thickness, feet	Depth, feet
Road fill	1.5	1.5
QUATERNARY—Pleistocene		
Peoria(?) Formation		
Silt, clayey, medium gray	0.5	2
Silt, clayey, brown tan	2	4
Kansan glaciofluvial deposits		
Clay, yellow tan; contains some gravel and sand	7	11
Clay, gray tan; contains some gravel and sand	1.5	12.5
Clay, stiff, compact, light gray mottled with brown	0.5	13
Clay, sandy, light gray; contains fragments of limonite concretions	5	18
Clay, very sandy, yellow tan	5	23
Sand, very fine to medium, clayey, yellow tan	4	27
PENNSYLVANIAN—Missourian		
Weston(?) Shale		
Shale, gray	3	30

13-21-34bcc.—Sample log of test hole in SW SW NW sec. 34, T. 13 S., R. 21 E., about 10 feet north of W quarter corner on road shoulder, drilled July 1, 1953; depth to water, ±15 feet. Altitude of land surface, 930.7 feet.

	Thickness, feet	Depth, feet
Road fill	2	2
QUATERNARY—Pleistocene		
Peoria Formation		
Silt, gray tan	2	4
Kansan glaciofluvial deposits		
Clay, sandy, slightly calcareous, mottled tan gray and red brown	1.5	5.5
Clay, sandy, mottled tan red and light gray	2.5	8
Clay and silt, very sandy, light tan and light gray	2	10
Sand, clayey, tan brown	6	16
Gravel and sand, silty, tan brown	8	24
PENNSYLVANIAN—Missourian		
Weston Shale		
Shale, argillaceous, blue gray	24.5	48.5
Stanton Limestone		
Limestone, hard, gray	0.5	49

14-17-24dd.—Drillers log of well drilled by Charles Jungmann for Joe Maichel in SE SE sec. 24, T. 14 S., R. 17 E., in February 1956.

	Thickness, feet	Depth, feet
Soil	2	2
Clay, sandy	9	11
Limestone, broken	4	15
Shale	7	22
Limestone	4	26
Shale	54	80
Limestone	50	130
Slate	2	132
Shale	5	137
Limestone	9	146
Shale	79	225
Shale, sandy	80	305
Limestone	5	310
Shale, sandy	40	350
Sandstone	70	420

14-17-25ca.—Drillers log of well drilled by Commerce Drilling Co. for H. Maichel in NE SW sec. 25, T. 14 S., R. 17 E., in December 1934. Altitude of land surface, ±1,090 feet.

	Thickness, feet	Depth, feet
Soil and clay	9	9
Sand rock	5	14
Shale, dark	5	19
Limestone	8	27
Shale, gray	22	49
Limestone	5	54
Shale, dark	41	95
Limestone	7	102
Shale, dark	3	105
Limestone	20	125
Shale, black	2	127
Limestone	4	131
Shale, gray	6	137
Limestone	12	149
Shale, gray	100	249
Shale, light	51	300
Shale, sandy	14	314
Limestone	6	320
Sandstone	138	458

14-17-26ad.—Drillers log of well drilled by Charles Jungmann for Ralph Fuqua in SE NE sec. 26, T. 14 S., R. 17 E., in March 1956. Altitude of land surface, ±1,084 feet.

	Thickness, feet	Depth, feet
Soil	2	2
Limestone, broken	14	16
Shale	17	33
Limestone	4	37
Shale	4	41
Limestone	5	46
Shale	41	87
Limestone, broken	18	105
Limestone	12	117
Limestone, broken	31	148
Shale	67	215
Limestone	3	218
Shale	90	308
Limestone	4	312
Shale	42	354
Sandstone (water)	44	398
Shale	7	405

14-17-35ad.—Drillers log of well drilled by Charles Jungmann for Joseph Baldwin in SE NE sec. 35, T. 14 S., R. 17 E., in August 1956. Altitude of land surface, ±1,105 feet.

	Thickness, feet	Depth, feet
Soil	3	3
Clay	4	7
Limestone	4	11
Shale, gray	14	25
Limestone	5	30
Shale, dark	4	34
Limestone	3	37
Shale	2	39
Limestone	2	41
Limestone, soft	6	47
Shale	23	70
Limestone, broken	15	85
Shale, sandy, gray	29	114
Limestone	4	118
Shale	12	130
Limestone	15	145
Shale, dark	2	147
Limestone	3	150
Shale	9	159
Limestone	4	163
Limestone, broken	8	171
Shale	48	219
Limestone	2	221
Shale, sandy	75	296

	Thickness, feet	Depth, feet
Limestone	5	301
Shale	44	345
Sandstone	17	362
Limestone	3	365
Sandstone	45	410

14-18-8ad.—Drillers log of well drilled by W. D. Wilson for William Owens in SE NE sec. 8, T. 14 S., R. 18 E., in 1951. Altitude of land surface, ±984 feet.

	Thickness, feet	Depth, feet
Soil	1	1
Clay	4	5
Shell limestone	2	7
Shale, gray	5	12
Limestone, brown	8	20
Limestone, gray	10	30
Shale, dark	4	34
Shale, gray	6	40
Limestone, brown	4	44
Shale, gray	6	50
Limestone, gray	13	63
Shale, gray	10	73
Limestone	1	74
Shale, sandy, gray	76	150
Shale, muddy, gray	55	205
Limestone	3	208
Shale, sandy, dark	17	225
Sandstone (water)	14	239

14-18-10bd.—Drillers log of well drilled by W. D. Wilson for Wayne Culley in SE NW sec. 10, T. 14 S., R. 18 E., in January 1954. Altitude of land surface, ±1,078 feet.

	Thickness, feet	Depth, feet
Soil	2	2
Limestone, shelly	2	4
Clay, yellow	16	20
Shale, gray	52	72
Limestone, shelly	5	77
Shale, gray	8	85
Limestone, gray (water)	18	103
Shale, dark	5	108
Limestone	2	110
Shale, muddy, gray	14	124
Limestone, white	11	135
Shale, light	65	200
Shale, sandy, gray	84	284
Limestone, brown	4	288
Shale, gray	17	305
Sandstone, white (water)	20	325

14-18-11bb.—Drillers log of well drilled by W. D. Wilson for Mr. Powell in NW NW sec. 11, T. 14 S., R. 18 E., in 1951. Altitude of land surface ±1,004 feet.

	Thickness, feet	Depth, feet
Soil	4	4
Limestone, shelly	2	6
Limestone	10	16
Shale, dark	4	20
Limestone	3	23
Shale, gray	7	30
Limestone	15	45
Shale, gray	15	60
Limestone	1	61
Shale, sandy, gray	141	202
Limestone	4	206
Sandstone, hard, dead	4	210
Shale, dark	3	213
Shale, sandy, gray	7	220
Sandstone (water)	50	270
Shale, sandy, gray	82	352
Limestone	3	355

14-18-11db.—Drillers log of well drilled by W. D. Wilson for Raymond Flory in NW SE sec. 11, T. 14 S., R. 18 E., in July 1952. Altitude of land surface, ±915 feet.

	Thickness, feet	Depth, feet
Soil and sandy yellow clay	15	15
Shale, dark gray	86	101
Limestone	3	104
Shale, sandy, dark gray	31	135
Sandstone (water)	18	153
Sandstone, dead	7	160

14-18-14aac.—Drillers log of Douglas County well at Lone Star Lake in SW NE NE sec. 14, T. 14 S., R. 18 E., drilled in 1934. Altitude of land surface, 1,027.9 feet.

	Thickness, feet	Depth, feet
Soil and clay	6	6
Limestone	12	18
Shale, gray	5	23
Limestone	4	27
Shale, light	1	28
Limestone	17	45
Shale, gray	153	198
Limestone	5	203
Shale, gray	7	210
Limestone	3	213
Shale, gray	7	220
Shale, sandy	20	240
Sandstone (just enough water to drill with)	19	259

	Thickness, feet	Depth, feet
Sandstone, broken	10	269
Shale, sandy	31	300
Sandstone (water)	10	310
Sandstone, broken	15	325
Sandstone	33	358
Limestone	9	367
Shale, gray	1	368

14-18-23aa1.—Drillers log of well drilled by W. D. Wilson for N. T. Veatch in NE NE sec. 23, T. 14 S., R. 18 E., in November 1947. Altitude of land surface, ±1,040 feet.

	Thickness, feet	Depth, feet
Soil and yellow clay	4	4
Limestone, broken	3	7
Shale	2	9
Limestone	10	19
Shale, dark	4	23
Limestone	2	25
Shale, gray	14	39
Limestone, white	12	51
Shale, gray	39	90
Shale, sandy	40	130
Shale, gray	94	224
Limestone, hard	3	227
Shale, sandy	100	327
Sandstone, hard, gray (little water)	8	335
Shale, sandy	5	340
Shale, dark	1	341
Limestone, white, soft	13	354
Shale, gray and black	5	359
Limestone	10	369
Shale, sandy and clayey, gray	8	377

14-18-24aa.—Drillers log of well drilled by W. D. Wilson for N. T. Veatch in NE NE sec. 24, T. 14 S., R. 18 E., in November 1949.

	Thickness, feet	Depth, feet
Soil and yellow clay	18	18
Limestone (little water)	4	22
Shale, gray	32	54
Limestone	5	59
Shale	12	71
Limestone	19	90
Shale, black	3	93
Limestone	2	95
Shale, gray	5	100
Limestone, white	15	115
Shale, light	25	140
Shale, sandy	50	190

	Thickness, feet	Depth, feet
Shale, gray	90	280
Limestone	3	283
Shale	7	290
Sandstone	10	300
Shale, white	5	305
Sandstone, hard, gray (fresh water, 1.2 gpm)	20	325
Shale, dark gray	10	335
Shale, sandy	40	375
Sandstone (brackish water)	31	406

14-18-30ad.—Drillers log of well drilled by Walter Fees Drilling Co. for Jeff A. Robertson in SE NE sec. 30, T. 14 S., R. 18 E., in May 1954. Altitude of land surface, ±1,112 feet.

	Thickness, feet	Depth, feet
Soil	2	2
Clay and gravel	13	15
Limestone, shells	6	21
Shale	83	104
Limestone, shells	5	109
Shale	8	117
Limestone	18	135
Shale	5	140
Limestone	2	142
Shale	12	154
Limestone	14	168
Shale	79	247
Shale, sandy	29	276
Sandstone (water)	13	289
Shale	46	335
Limestone	5	340
Shale	15	355
Sandstone	7	362
Sandstone, broken	8	370
Shale	58	428
Sandstone (water)	47	475
Limestone	13	488
Shale, black	1	489

14-18-35bb.—Drillers log of well drilled by Commerce Drilling Co. for H. W. Rappard in NW NW sec. 35, T. 14 S., R. 18 E., in August 1934. Altitude of land surface, ±1,138 feet.

	Thickness, feet	Depth, feet
Soil and clay	5	5
Loose limestone	3	8
Clay	8	16
Shale, gray	24	40
Limestone	3	43
Shale, gray	34	77
Limestone	4	81

	Thickness, feet	Depth, feet
Shale, gray	12	93
Limestone	18	111
Shale, dark	4	115
Limestone	2	117
Shale, dark	12	129
Limestone	12	141
Shale, gray	44	185
Shale, sandy	42	227
Shale, gray	26	253
Shale, sandy	19	272
Sandstone	13	285
Shale, gray	11	296
Shale, green	4	300
Shale, gray	8	308
Limestone	6	314
Shale, gray	24	338
Shale, sandy	8	346
Sandstone	17	363
Shale, sandy	27	390
Sand (water)	52	442
Limestone	1	443
Shale, dark	2	445
Limestone, blue	5	450
Limestone, white	..	450

14-19-1bb.—Drillers log of well drilled by Baugher and King Drilling Co. for W. A. Schaal in NW NW sec. 1, T. 14 S., R. 19 E., in September 1955. Altitude of land surface, ±901 feet.

	Thickness, feet	Depth, feet
Soil	4	4
Clay, yellow	8	12
Sandstone	12	24
Limestone	2	26
Shale	64	90
Limestone	1	91
Shale, blue	65	156
Limestone, soft, sandy	10	166
Shale, blue	2	168
Limestone	13	181
Shale, dark and black	10	191
Shale, dark blue	3	194
Limestone	6	200
Shale	5	205
Limestone	19	224
Shale, red	4	228
Shale, green	2	230
Shale, blue; lower part sandy	26	256
Limestone, fossiliferous, white	14	270

14-19-4bb.—Drillers log of well drilled by W. D. Wilson for Jess Markley in NW NW sec. 4, T. 14 S., R. 19 E., in February 1953. Altitude of land surface, ±900 feet.

	Thickness, feet	Depth, feet
Soil	2	2
Clay, yellow	26	28
Shale, gray	35	63
Limestone	3	66
Shale, gray	54	120
Sandstone	22	142

14-19-9cc.—Drillers log of well drilled by W. D. Wilson for Alva Flory in SW SW sec. 9, T. 14 S., R. 19 E., in February 1953.

	Thickness, feet	Depth, feet
Soil and clay	9	9
Limestone	2	11
Shale, dark	7	18
Limestone	2	20
Shale, white	10	30
Limestone	9	39
Shale, light	149	188
Limestone	3	191
Shale, light gray	5	196
Sandstone, gray	54	250
Sandstone, white (lots of water)	38	288

14-19-13ab.—Drillers log of well drilled by Raymond Schutz for Frank Cadwell in NW NE sec. 13, T. 14 S., R. 19 E., in April 1956. Altitude of land surface, ±1,010 feet.

	Thickness, feet	Depth, feet
Topsoil	4	4
Clay, red	4	8
Limestone	8	16
Shale, black	5	21
Limestone	2	23
Soapstone	9	32
Limestone	8	40
Soapstone, green and red	37	77
Limestone	1	78
Soapstone, sandy	87	165
Soapstone	22	187
Limestone	2	189

14-19-13cb.—Drillers log of well drilled by Lon Dietrich for M. R. Gill in NW SW sec. 13, T. 14 S., R. 19 E., in October 1947. Altitude of land surface, ±1,127 feet.

	Thickness, feet	Depth, feet
Soil and clay	27	27
Limestone	15	42
Shale, blue	2	44
Shale, black	4	48

	Thickness, feet	Depth, feet
Limestone	3	51
Shale	7	58
Limestone	9	67
Shale	4	71
Limestone	3	74
Shale	6	80
Shale, red	4	84
Shale	134	218
Limestone, shelly	2	220
Shale	144	364
Limestone, gray	21	385
Shale, black	9	394
Limestone	6	400
Shale	7	407

14-19-16bc.—Drillers log of well drilled by W. D. Wilson for W. H. Postma in SW NW sec. 16, T. 14 S., R. 19 E., in October 1952. Altitude of land surface, ±1,070 feet.

	Thickness, feet	Depth, feet
Soil	6	6
Limestone, broken	8	14
Shale, dark	4	18
Limestone	4	22
Shale, light	8	30
Limestone	12	42
Shale, light gray	143	185
Limestone	3	188
Shale, dark	12	200
Sandstone, dark (water)	70	270
Shale, sandy	10	280
Sandstone (lots of water)	24	304

14-19-19bb.—Drillers log of well drilled by W. D. Wilson for Mr. Powell in NW NW sec. 19, T. 14 S., R. 19 E., in 1951.

	Thickness, feet	Depth, feet
Soil	3	3
Clay, yellow	5	8
Limestone, shelly	3	11
Limestone, brown	3	14
Shale, gray	12	26
Limestone	15	41
Shale, dark	4	45
Limestone	1	46
Shale, gray	9	55
Limestone	1	56
Shale, light	4	60
Limestone	8	68
Shale, light	162	230
Limestone, brown	4	234
Sandstone, gray (water)	102	336
Sandstone (more water)	20	356

14-19-22ac.—Drillers log of well drilled by W. D. Wilson for Wayne Flory in SW NE sec. 22, T. 14 S., R. 19 E., in December 1955. Altitude of land surface, ±1,084 feet.

	Thickness, feet	Depth, feet
Soil	2	2
Clay, red	5	7
Limestone, shelly	3	10
Limestone, yellow	5	15
Shale, dark	8	23
Shale, light	3	26
Limestone, hard	1	27
Shale, light	171	198
Limestone	3	201
Shale, sandy	20	221
Shale, muddy, dark gray	110	331
Limestone	1	332
Sandstone, gray	7	339
Shale, muddy	2	341
Limestone	15	356
Slate, black	10	366
Limestone	7	373
Shale, sandy, dark	9	382
Limestone	1	383

14-19-24da.—Drillers log of well drilled by Eugene Smith for O. R. Williams in NE SE sec. 24, T. 14 S., R. 19 E., in 1953. Altitude of land surface, ±1,119 feet.

	Thickness, feet	Depth, feet
Soil	3	3
Clay	5	8
Limestone	3	11
Shale, blue	7	18
Limestone	3	21
Shale, blue	8	29
Limestone	16	45
Shale, gray	40	85
Shale, sandy	25	110
Limestone	10	120
Shale, sandy	65	185
Sandstone (1 gpm fresh water)	23	208
Limestone	4	212
Shale, blue	123	335
Limestone	4	339
Sandstone (very little water)	6	345
Limestone	15	360
Shale, black	7	367
Limestone	8	375
Shale, blue	10	385
Sandstone (small amount of gas)	5	390
Limestone, blue and white	32	422
(Plugged back to 385 feet)		

14-20-5cc.—Drillers log of well drilled by Holmes & Hammel Drilling Co. for F. W. Pratt in SW SW sec. 5, T. 14 S., R. 20 E., in October 1947.

	Thickness, feet	Depth, feet
Soil and clay	2	2
Sandstone	12	14
Shale, sandy, light	52	66
Sandstone (little water)	4	70
Shale, sandy	40	110
Limestone	6	116
Sandstone	5	121
Limestone	16	137
Shale, black	7	144
Limestone	4	148

14-20-16cc2.—Drillers log of well drilled by Raymond Schutz for Paul Clawson in SW SW sec. 16, T. 14 S., R. 20 E., in June 1956. Altitude of land surface, ±895 feet.

	Thickness, feet	Depth, feet
Topsoil	2	2
Clay, yellow; contains much gravel	28	30
Clay, soapstone	55	85
Limestone	..	85

14-20-22ba.—Drillers log of well drilled by Carl Moore for Webb Fenton in NE NW sec. 22, T. 14 S., R. 20 E., in March 1957. Altitude of land surface, ±907 feet.

	Thickness, feet	Depth, feet
Soil	2	2
Clay	13	15
Clay and sand (fresh water, static level ±10 ft.)	20	35
Shale	27	62
Limestone	8	70
Sandstone (brackish water)	8	78
Shale	2	80
Limestone	18	98
Shale, black (brackish water)	8	106
Limestone	1	107

14-20-22cc.—Drillers log of well drilled by Raymond Schutz for George Rockhold in SW SW sec. 22, T. 14 S., R. 20 E., in November 1955.

	Thickness, feet	Depth, feet
Dirt	1.5	1.5
Flag rock	2.5	4
Clay, brown and gray	60	64
Soapstone, gray	51	115
Limestone, hard	4	119
Sandstone, white (brackish water)	4	123
Rock, hard	3	126

	Thickness, feet	Depth, feet
Sandstone (brackish water)	6	132
Limestone, soft, white	17	149
Soapstone, gray	3	152
Shale, black	4	156
Limestone, white	8	164
Soapstone, soft	4	168
Limestone, hard and soft	20	188
Sandstone, white (salty water)	16	204

14-20-29da.—Drillers log of well drilled by Eugene Smith for William Vaughn in NE SE sec. 29, T. 14 S., R. 20 E., in September 1953. Altitude of land surface, ±1,065 feet.

	Thickness, feet	Depth, feet
Soil	3	3
Clay	13	16
Sandstone, gray	15	31
Shale, sandy	37	68
Sandstone	24	92

14-20-30aa.—Drillers log of well drilled by Raymond Schutz for Max Moore in NE NE sec. 30, T. 14 S., R. 20 E., in December 1955. Altitude of land surface, ±1,126 feet.

	Thickness, feet	Depth, feet
Topsoil	4	4
Limestone	15	19
Soapstone, black	2	21
Limestone	1	22
Soapstone	8	30
Limestone	15	45
Soapstone	35	80
Limestone, soft	2	82
Sandstone	4	86
Soapstone	11	97
Rock, flaky, brown	8	105
Soapstone, sandy	89	194
Rock, brown	5	199
Limestone	1	200

14-20-30cb.—Drillers log of well drilled by Carl Moore for Maurice Frye in NW SW sec. 30, T. 14 S., R. 20 E., in 1955. Altitude of land surface, ±1,130 feet.

	Thickness, feet	Depth, feet
Topsoil	2	2
Clay	2	4
Limestone	4	8
Shale	57	65
Sandstone	4	69
Sandstone, broken	56	125
Sandstone	10	135
Sandstone, broken	27	162

14-20-32cd.—Drillers log of well drilled by Eugene Smith for Earl Black in SE SW sec. 32, T. 14 S., R. 20 E., in September 1953. Altitude of land surface, ±1,041 feet.

	Thickness, feet	Depth, feet
Clay	12	12
Sandstone, brown	13	25
Shale, white	30	55
Shale, blue	32	87
Sandstone (1 gpm, fresh water)	7	94
Shale, blue	4	98
Limestone	3	101
Shale, blue	132	233
Sandstone (little gas)	7	240
Limestone	15	255
Shale, black	10	265
Limestone	5	270
Shale, black	3	273
Sandstone, gray (no water)	12	285
Sandstone (water, brackish)	5	290
Limestone	10	300
Limestone, sandy	3	303
(Plugged back to 130 feet)		

14-21-3bc.—Sample log of test hole in SW NW sec. 3, T. 14 S., R. 21 E., drilled July 1, 1953; depth to water, 19.8 feet. Altitude of land surface, 943.8 feet.

	Thickness, feet	Depth, feet
Road fill	1.5	1.5
QUATERNARY—Pleistocene		
Kansan glaciofluvial deposits		
Clay and silt, slightly sandy, tan gray	2.5	4
Clay and silt, very sandy, tan and red brown	3	7
Clay and silt, very sandy, light gray and tan	9	16
Sand, fine to coarse, tan	6	22
Gravel and sand, tan	4.5	26.5
PENNSYLVANIAN—Missourian		
Weston Shale		
Shale, olive to yellow	2	28.5
Shale, clayey, gray blue	11.5	40
Shale, clayey, hard, gray blue	7.5	47.5
Stanton Limestone		
Limestone, hard, gray	1	48.5

14-21-3ccc.—Sample log of test hole in SW SW SW sec. 3, T. 14 S., R. 21 E., about 100 feet north of corner on road shoulder, drilled July 1, 1953. Altitude of land surface, 971.3 feet.

	Thickness, feet	Depth, feet
Road fill	1	1

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Kansan glaciofluvial deposits		
Silt and clay, sandy, tan	3	4
Clay, very sandy, noncalcareous, leached and oxidized, red	4	8
Sand, medium to coarse, clayey, red	10	18
Sand, medium to coarse, red brown	5	23
Sand, medium to coarse, tan brown	23.5	46.5
PENNSYLVANIAN—Missourian		
Weston Shale		
Shale, clayey, yellow tan and blue gray	3.5	50

14-21-9add.—Sample log of test hole in SE SE NE sec. 9, T. 14 S., R. 21 E., on road shoulder about 75 feet north of E quarter corner, drilled July 1, 1953; depth to water, 26.4 feet. Altitude of land surface, 977.5 feet.

	Thickness, feet	Depth, feet
Road fill	1.5	1.5
QUATERNARY—Pleistocene		
Peoria(?) Formation		
Clay and silt, light brown gray	2	3.5
Clay and silt, mottled light gray and tan	2.5	6
Kansan glaciofluvial deposits		
Sand, very clayey, mottled tan and gray	3	9
Sand, clayey, mottled light gray and brown red	1	10
Sand, medium, clayey, brown red	2	12
Sand, medium, tan	12	24
Gravel and sand, silty, tan	4	28
PENNSYLVANIAN—Missourian		
Weston Shale		
Shale, clayey, yellow tan	3.5	31.5
Shale, clayey, gray; contains clay ironstone concretions,	49	80.5
Stanton Limestone—South Bend Limestone member		
Limestone, very hard, gray	0.5	81

14-21-15abb.—Sample log of test hole in NW NW NE sec. 15, T. 14 S., R. 21 E., about 315 feet east of bridge on road shoulder, drilled August 26, 1954; depth to water, 6.2 feet. Altitude of land surface, ±927 feet.

	Thickness, feet	Depth, feet
Road fill	1	1
QUATERNARY—Pleistocene		
Undifferentiated post-Kansan alluvium and terrace deposits		
Soil, sandy and silty, black	4	5
Clay, silty and sandy, tan gray	2	7
Sand, very fine, clayey, tan	2	9
Sand, very fine to medium, clayey, light tan brown	11.5	20.5
PENNSYLVANIAN—Missourian		
Weston Shale		
Shale, clayey, gray	2.5	23

14-21-15cbb.—Sample log of test hole in NW NW SW sec. 15, T. 14 S., R. 21 E., drilled October 1955. Altitude of land surface, ±932 feet.

	Thickness, feet	Depth, feet
Road fill	1	1
QUATERNARY—Pleistocene		
Undifferentiated post-Kansan alluvium and terrace deposits		
Silt, sandy and clayey, dark gray	4	5
Clay, silty, gray brown	5	10
Clay and very fine sand, dark gray brown	8	18
Sand, very fine, clayey, gray green	7	25
PENNSYLVANIAN—Missourian		
Weston Shale		
Shale, clayey, blue gray	2	27

14-21-16cc.—Drillers log of well drilled by Carl Moore for Mary Rodewald in SW SW sec. 16, T. 14 S., R. 21 E., in May 1956. Altitude of land surface, ±970 feet.

	Thickness, feet	Depth, feet
Soil	2	2
Clay	30	32
Shale	64	96
Limestone	28	124
Shale, dark	8	132
Limestone	8	140
Shale	8	148
Limestone	32	180
Shale	4	184
Limestone	18	202
Shale	4	206
Sandstone	8	214
Shale, sandy	28	242
Limestone	8	250

14-21-17abb.—Sample log of test hole in NW NW NE sec. 17, T. 14 S., R. 21 E., drilled October 1955. Altitude of land surface, ±1,008 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Peoria Formation		
Silt, gray and gray tan	2.5	2.5
Kansas Till		
Clay, slightly sandy, compact, mottled light gray and light tan	1.5	4
Clay, compact, stiff, light gray tan; contains gravel and sand	9	13
Clay, gravelly and sandy, tan brown	4	17
Gravel, very clayey, tan brown	2	19
PENNSYLVANIAN—Virgilian		
Lawrence(?) Shale		
Shale, hard, tan	3	22

14-21-18ad.—Drillers log of well drilled by Eugene Smith for Blondie Mathews in SE NE sec. 18, T. 14 S., R. 21 E., in July 1953. Altitude of land surface, ±955 feet.

	Thickness, feet	Depth, feet
Soil and shale	90	90
Sandstone (1.5 gpm water)	15	105
No log	55	160
Sandstone (2.5 gpm water)	24	184

14-21-19dd2.—Drillers log of well drilled by Raymond Schutz for Wilber Olmstead in SE SE sec. 19, T. 14 S., R. 21 E., in April 1956. Altitude of land surface, ±1,024 feet.

	Thickness, feet	Depth, feet
Topsoil	6	6
Sandstone	64	70
Sandstone, white	13	83
Limestone	0.5	83.5
Soapstone, clay	19.5	103

14-21-27bb.—Sample log of test hole in NW NW sec. 27, T. 14 S., R. 21 E., drilled May 1956. Altitude of land surface, ±1,027 feet.

	Thickness, feet	Depth, feet
Road fill	3	3
QUATERNARY—Pleistocene		
Colluvium		
Clay, sandy, light tan gray	9	12
PENNSYLVANIAN—Missourian		
Weston Shale		
Shale, thin bedded, clayey, oxidized, light gray tan	8	20
Shale, silty, very thin even bedding, gray blue	20	40
Shale, silty, slightly micaceous, thin bedded, gray blue; contains plant fragments and several thin hard clay-ironstone-concretion zones	10	50
Shale, hard, fissile, clayey, gray blue	40	90
Shale, fissile, clayey, blue gray	10	100
Shale, fissile, clayey, gray; contains zones of hard clay-ironstone concretions	17	117
Stanton Limestone—South Bend Limestone member		
Limestone, hard, fossiliferous, light brown gray; contains thin shale break near base	3.5	120.5
Stanton Limestone—Rock Lake Shale member		
Shale, gray	0.3	120.8
Sandstone, fine grained, ferruginous, quartzose, dark gray brown	1.7	122.5
Shale, gray	0.5	123
Stanton Limestone—Stoner Limestone member		
Limestone, soft, light gray white; contains blue-green shaly inclusions	4.5	127.5

14-21-30ad.—Drillers log of well drilled by Carl Moore for Russell Rohe in SE NE sec. 30, T. 14 S., R. 21 E., in 1954. Altitude of land surface, ±1,003 feet.

	Thickness, feet	Depth, feet
Soil and clay	15	15
Clay, sandy (water)	25	40
Shale	86	126
Limestone	6	132
Sandstone (water)	3	135
Shale	5	140
Limestone	13	153
Shale	8	161
Limestone	9	170
Shale	6	176
Limestone	24	200

15-17-1aa.—Drillers log of test hole drilled by Jungmann Bros. Drilling Co. for city of Overbrook in NE NE sec. 1, T. 15 S., R. 17 E., in January 1953. Altitude of land surface, ±1,133 feet.

	Thickness, feet	Depth, feet
Soil	2	2
Clay	11	13
Limestone	7	20
Shale	2	22
Limestone	3	25
Shale	2	27
Limestone	15	42
Shale	1	43
Limestone	14	57
Shale	18	75
Limestone	7	82
Shale, sandy	33	115
Limestone	7	122
Shale	13	135
Limestone	15	150
Shale, black	3	153
Limestone	3	156
Shale	12	168
Limestone	12	180
Shale	40	220
Shale, sandy	30	250
Sandstone (water 12 gpm)	68	318
Shale	9	327

15-17-1ac1.—Drillers log of well drilled by Jungmann Bros. Drilling Co. for city of Overbrook in SW NE sec. 1, T. 15 S., R. 17 E., in February 1953. Altitude of land surface, ±1,144 feet.

	Thickness, feet	Depth, feet
Soil	2	2
Clay and gravel	11	13
Limestone	7	20
Shale, black	2	22
Limestone	3	25
Shale	2	27
Limestone	13	40
Shale	13	53
Limestone	7	60
Shale	11	71
Sandstone	20	91
Shale	2	93
Shale, sandy	3	96
Limestone	14	110
Shale	6	116
Limestone	17	133
Shale, black	4	137
Limestone	2	139
Shale	7	146
Limestone	16	162
Shale	16	178
Limestone	1	179
Shale	16	195
Sandstone (6 gpm water)	60	255
Sandstone	40	295
Shale, sandy	10	305
Shale	20	325
Sandstone, very hard	6	331
Shale, sandy	19	350
Shale	10	360
Shale, sandy	60	420
Sandstone (fresh water)	87	507
Shale, black	..	507

15-17-1ac2.—Drillers log of well drilled by Jungmann Bros. Drilling Co. for city of Overbrook in SW NE sec. 1, T. 15 S., R. 17 E., in March 1953. Altitude of land surface, ±1,141 feet.

	Thickness, feet	Depth, feet
No log	58	58
Limestone	4	62
Shale	40	102
Limestone	5	107
Shale	5	112

	Thickness, feet	Depth, feet
Limestone	18	130
Shale	5	135
Limestone	2	137
Shale	7	144
Limestone	21	165
Shale	30	195
Shale, sandy	48	243
Sandstone (water)	76	319
Shale, sandy	11	330
Sandstone	5	335
Shale, green	5	340
Sandstone	15	355
Shale	35	390
Shale, sandy	5	395
Sandstone (fresh water)	100	495
Shale, dark	2	497

15-17-2ab.—Drillers log of test hole drilled by Jungmann Bros. Drilling Co. for city of Overbrook in NW NE sec. 2, T. 15 S., R. 17 E., in January 1953. Altitude of land surface, ±1,146 feet.

	Thickness, feet	Depth, feet
Soil	2	2
Clay	23	25
Shale	10	35
Limestone	6	41
Shale	2	43
Limestone	17	60
Shale	4	64
Limestone	12	76
Shale	25	101
Sandstone	32	133
Shale	2	135
Limestone	6	141
Shale	2	143
Limestone	25	168
Slate	2	170
Limestone	3	173
Shale	4	177
Limestone	16	193
Shale	17	210
Shale, red	5	215
Shale	15	230
Shale, sandy	50	280
Sandstone (water)	10	290

15-17-11ba2.—Drillers log of well drilled by Charles Jungmann for Mr. McCarty in NE NW sec. 11, T. 15 S., R. 17 E., in August 1955.

	Thickness, feet	Depth, feet
Soil	2	2
Shale	42	44
Limestone	35	79
Shale, sandy	39	118
Limestone	6	124
Shale	16	140
Limestone	13	153
Shale	5	158
Limestone	20	178
Shale	2	180
Limestone	5	185
Shale	10	195
Limestone	12	207
Shale	53	260
Shale, sandy	15	275
Sandstone (limy break at ±314 ?)	85	360
Sandstone, broken, and shale	22	382

15-17-13dc.—Drillers log of well drilled by Commerce Drilling Co. for R. E. Tutcher in SW SE sec. 13, T. 15 S., R. 17 E., in 1934 (?).

	Thickness, feet	Depth, feet
Soil and clay	9	9
Limestone	18	27
Shale, black	3	30
Limestone	3	33
Shale, gray	10	43
Limestone	12	55
Shale, blue	20	75
Shale, light	15	90
Shale, sandy	72	162
Shale, gray	13	175
Shale, dark	27	202
Limestone	7	209
Shale, gray	11	220
Sandstone (water)	75	295
Sandstone, broken	20	315

15-18-1aa.—Drillers log of well drilled by W. D. Wilson for Mr. Briedhaupt in NE NE sec. 1, T. 15 S., R. 18 E., in April 1948. Altitude of land surface, ±1,085 feet.

	Thickness, feet	Depth, feet
Soil	1	1
Clay, yellow	4	5
Limestone	10	15
Shale, dark	3	18
Limestone	2	20
Shale, light	60	80
Sandstone, gray	15	95
Shale, sandy, gray	85	180
Sandstone (water)	45	225
Shale, sandy	55	280
Sandstone	20	300
Shale	1	301

15-18-7aa.—Drillers log of well drilled by Commerce Drilling Co. for R. C. Price in NE NE sec. 7, T. 15 S., R. 18 E., in August 1934. Altitude of land surface, ±1,035 feet.

	Thickness, feet	Depth, feet
Soil	5	5
Limestone	3	8
Shale, gray	3	11
Limestone	3	14
Shale, gray	5	19
Limestone	10	29
Shale, gray	25	54
Limestone	3	57
Shale, gray	13	70
Limestone	3	73
Shale, gray	22	95
Limestone	10	105
Shale, gray	3	108
Limestone	18	126
Shale, dark	5	131
Limestone	2	133
Shale, dark	5	138
Shale, gray	5	143
Limestone	8	151
Shale, gray	2	153
Limestone	4	157
Shale, gray	38	195

	Thickness, feet	Depth, feet
Shale, dark	12	207
Shale, sandy	9	216
Sandstone	54	270
Shale, gray	55	325
Limestone	5	330
Shale, sandy	5	335
Sandstone, broken	7	342
Shale, sandy	5	347
Sandstone	54	401
Shale, light	4	405
Shale, dark	9	414
Shale, light	3	417
Sandstone	10	427
Shale	7	434

15-18-7ad.—Drillers log of well drilled by W. D. Wilson for Chris Straub in SE NE sec. 7, T. 15 S., R. 18 E., in 1952. Altitude of land surface, ±1,156 feet.

	Thickness, feet	Depth, feet
Soil	2	2
Clay, yellow	5	7
Limestone, shell	6	13
Shale, black	3	16
Limestone	2	18
Shale, light	7	25
Limestone	8	33
Shale, light gray	22	55
Limestone	2	57
Shale, light	38	95
Limestone	3	98
Shale, light	14	112
Limestone	1	113
Shale, light	1	114
Limestone	15	129
Shale, black	17	146
Limestone	12	158
Shale, gray	7	165
Shale, sandy, gray	10	175
Shale, muddy	20	195
Shale, sandy	115	310
Shale, muddy, dark	5	315
Limestone, cap rock	3	318
Shale, sandy (water)	32	350

15-18-8ba.—Drillers log of well drilled by Charles Jungmann for George Maichel in NE NW sec. 8, T. 15 S., R. 18 E., in March 1956.

	Thickness, feet	Depth, feet
Soil	2	2
Clay	5	7
Limestone, broken	13	20
Shale	8	28
Limestone	19	47
Shale	23	70
Limestone	8	78
Shale	32	110
Limestone	9	119
Shale	8	127
Limestone	24	151
Shale	5	156
Limestone	4	160
Shale	15	175
Limestone	8	183
Shale	17	200
Limestone	2	202
Shale	24	226
Shale, sandy	54	280
Shale	69	349
Limestone	7	356
Shale	19	375
Shale, sandy	21	396
Shale	7	403

15-18-17bb.—Drillers log of well drilled by W. D. Wilson (0 to 350 feet in January 1953) and Charles Jungmann (350 to 440 feet in 1955) for J. B. Price in NW NW sec. 17, T. 15 S., R. 18 E. Altitude of land surface, ±1,144 feet.

	Thickness, feet	Depth, feet
Soil	13	13
Limestone	6	19
Shale, gray	23	42
Limestone	2	44
Shale, gray	38	82
Limestone	4	86
Shale, gray	19	105
Limestone	15	120
Shale, dark	4	124
Limestone, broken	12	136
Limestone, solid	9	145
Shale, gray	20	165
Shale, sandy, gray	137	302
Limestone, cap	4	306
Sandstone	10	316
Mud, dark blue	9	325
Sandstone	10	335
Sandstone, light gray (200 gal. per hour)	15	350
Shale, sandy (more water)	90	440

15-19-14bb.—Drillers log of well drilled by Raymond Schutz for Leonard Newland in NW NW sec. 14, T. 15 S., R. 19 E., in 1955.

	Thickness, feet	Depth, feet
Dirt and sand	10	10
Sandstone, brown	10	20
Soapstone, gray	3	23
Sandstone, brown	27	50

15-20-8aa.—Drillers log of well drilled by Raymond Schutz for Jack Randell in NE NE sec. 8, T. 15 S., R. 20 E., in September 1955. Altitude of land surface, ±1,066 feet.

	Thickness, feet	Depth, feet
Soil	10	10
Sandstone	25	35
Soapstone, sandy	8	43
Sandstone	12	55
Soapstone, sandy	22	77
Sandstone	10	87
Soapstone, sandy	2	89
Sandstone, white	12	101
Limestone	..	101

15-20-11cda.—Sample log of test hole in NE SE SW sec. 11, T. 15 S., R. 20 E., drilled May 9, 1956. Altitude of land surface, ±1,056 feet.

	Thickness, feet	Depth, feet
PENNSYLVANIAN—Virgilian		
Lawrence Shale		
Soil, friable, silty, dark	0.5	0.5
Clay, oxidized and leached, mottled red and tan	7.5	8
Lawrence Shale—Ireland Sandstone member		
Sandstone, micaceous, very fine to fine, chiefly quartz, slightly cemented, oxidized, tan	30	38
Shale, olive gray	1.5	39.5
Sandstone, micaceous, very fine to fine, quartzose, slightly cemented, tan	22.5	62
Sandstone, calcareous, micaceous, chiefly fine quartz, blue gray to green gray; contains abundant fragments of coal	9.5	71.5
Conglomerate; chiefly fine-grained unfossiliferous light-tan silty limestone, light- to medium-gray fossiliferous limestone, coal fragments, and micaceous fine to very fine grained gray quartzose sandstone	4	75.5
PENNSYLVANIAN—Missourian		
Weston Shale		
Shale, clayey, blue gray; contains hard clay-ironstone concretions, carbonized plant fragments and sparse crinoid fragments	24.5	100
Shale, clayey, slightly silty, medium gray; contains sparse carbonized plant fragments	30	130
Shale, clayey, fissile, hard, gray	52	182
Stanton Limestone—South Bend Limestone member		
Limestone, hard	..	182

15-20-15ad.—Drillers log of well drilled by Lon Dietrich for city of Baldwin in SE NE sec. 15, T. 15 S., R. 20 E., in March 1954.

	Thickness, feet	Depth, feet
Soil	3	3
Sandstone	38	41

15-21-3bbb.—Sample log of test hole in NW NW NW sec. 3, T. 15 S., R. 21 E., drilled May 1956. Altitude of land surface, ±1,091 feet.

	Thickness, feet	Depth, feet
Road fill	1	1
PENNSYLVANIAN—Virgilian		
Lawrence Shale—Ireland Sandstone member		
Sandstone, micaceous, ferruginous, slightly cemented, brown red	2	3
Sandstone, micaceous, slightly cemented, tan; contains thin ferruginous zones	20	23
Sandstone, micaceous, light gray tan; contains red-brown ironstone fragments	22	45
Sandstone, micaceous, chiefly fine to very fine quartz, gray; contains abundant fragments of coal	10	55
Conglomerate, chiefly hard fine-grained light-gray siltstone, gray limestone, and gray sandstone	2	57
PENNSYLVANIAN—Missourian		
Weston Shale		
Shale, clayey, slightly silty, thin bedded, gray blue	43	100
Shale, clayey, fissile, hard, medium gray; contains abundant clay-ironstone concretions in lower part	50	150
Shale, thin bedded, light gray; contains thin soft clay-ironstone concretions	6.6	156.6
Stanton Limestone—South Bend Limestone member		
Limestone, hard, fossiliferous, gray brown	0.4	157

15-21-4bb.—Drillers log of well drilled by Carl Moore & Son for city of Wellsville in NW NW sec. 4, T. 15 S., R. 21 E., in March 1956.

	Thickness, feet	Depth, feet
Sandstone	69	69
Shale	27	96

15-21-4bcc.—Sample log of test hole in SW SW NW sec. 4, T. 15 S., R. 21 E., drilled May 1956. Altitude of land surface, ±1,070 feet.

	Thickness, feet	Depth, feet
PENNSYLVANIAN—Virgilian		
Lawrence Shale—Ireland Sandstone member		
Sandstone, micaceous, chiefly fine to very fine quartz, very slightly cemented, speckled brown and tan	6	6
Sandstone, micaceous, chiefly fine to very fine quartz, slightly cemented, tan to olive tan	52	58
Shale, silty, gray	1	59
Sandstone, micaceous, fine to very fine, gray; contains abundant coal fragments	10	69
Conglomerate; approximately 50 percent hard fossiliferous gray limestone and fossiliferous and unfossiliferous gray siltstone, 45 percent fine to very fine gray, quartzose sandstone, 5 percent coal	19.5	88.5
Shale, blue green	3.5	92
Sandstone, gray; contains thin shaly streaks, gray limestone pebbles, and coal fragments	8	100
Conglomerate, comprises about half limestone and half sandstone fragments. Drills very uneven, hard and soft	15	115
PENNSYLVANIAN—Missourian		
Weston Shale		
Shale, clayey, fissile, hard, medium gray	11	126
Shale, clayey, fissile, hard, medium gray; contains abundant clay-ironstone concretions	18	144
Stanton Limestone—South Bend Limestone member		
Limestone, hard, gray brown	0.2	144.2

15-21-16dc.—Drillers log of well drilled by Carl Moore for Densil Cox in SW SE sec. 16, T. 15 S., R. 21 E., in 1954. Altitude of land surface, ±1,145 feet.

	Thickness, feet	Depth, feet
Soil and clay	6	6
Shale	8	14
Sand and clay	14	28
Shale	71	99
Limestone	27	126
Shale	9	135
Limestone	9	144
Shale	5	149
Limestone	21	170
Shale	25	195
Sandstone	5	200
Shale	5	205

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INDEX

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28-5329