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BULLETIN 158

GEOLOGY AND GROUND-WATER RESOURCES OF COWLEY COUNTY, KANSAS

By CHARLES K. BAYNE
(U. S. Geological Survey)

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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GEOLOGY AND GROUND-WATER RESOURCES OF COWLEY COUNTY, KANSAS

By Charles K. Bayne

ABSTRACT

This report describes the geography, geology, and ground-water resources of Cowley County in south-central Kansas. Cowley County, which has an area of about 1,136 square miles, is in the Osage Plains and the Arkansas River Lowlands sections of the Central Lowland physiographic province and is drained by Arkansas River and its tributaries. Walnut River and Grouse Creek are the principal tributaries to Arkansas River in this area. The climate is characterized by wide variations in temperature and precipitation. The normal mean annual temperature at Winfield is 57.8°F and the mean annual precipitation is 31.27 inches. The population of Cowley County was 37,040 in 1959. Arkansas City, the largest city, had a population of 14,606, and Winfield, the county seat, had 10,848.

Agriculture is one of the principal occupations in the county and wheat is the chief crop. In 1955 the value of field crops was $4,665,000, and the value of beef cattle, $5,100,000. The county is an important producer of oil and gas. Cumulative production of crude oil to the end of 1960 was 106,462,000 barrels. The oil is produced principally from the subsurface strata known to drillers as the "Layton sand", "Bartlesville sand", "Mississippi lime", and "Arbuckle lime", but a total of 15 zones produce oil. Most natural gas is produced from rocks of the Admire and Douglas Groups.

Rocks that underlie the county but do not crop out within it range in age from Precambrian to Late Pennsylvanian, and it is from several zones within these rocks that oil is produced. Rocks that crop out in the area range in age from Late Pennsylvanian to Recent, and it is from these rocks that ground water is obtained. Generally the Upper Pennsylvanian and Permian rocks below the Wreford Limestone are less productive aquifers than the cherty and cavernous limestones above in the Chase Group. Moderate yields of water generally can be obtained from the Wreford and Barneston Limestones. The Fort Riley Member of the Barneston Limestone is also an important source of building stone. Pleistocene deposits, which occur in the principal stream valleys and as terrace deposits in the area west of Walnut River, are the most important source of ground water in the county. The largest yields of ground water are obtained from the Wisconsinan terrace deposits and alluvium in the Arkansas River valley.

Water is obtained from wells as deep as 365 feet, but most wells are less than 100 feet deep. Most wells in the area are drilled wells, but large-diameter dug wells are used in the low-producing limestone aquifers, and driven wells are used in the valley areas. Yields range from a few gallons an hour in the poorer limestone aquifers to 1,000 gpm (gallons per minute) in the Arkansas River valley.

About 6,500 acre-feet per year of ground water is used for public and for small industrial and irrigation supplies. At this rate of withdrawal, the quantity of water in storage in the Pleistocene deposits alone would last about 40 years.

The water from the limestone aquifers is generally a calcium bicarbonate water, but the water from the cavernous limestones of the Lower Permian and from deep wells in other aquifers may contain a strong concentration of sulfate salts. The

water from the limestone aquifers generally is hard but usable, except in areas of local pollution.

Water from Kansan and Illinoisan deposits is a calcium bicarbonate type and is hard but otherwise of good quality, except in one small area of pollution in the Illinoisan deposits west of Winfield. Ground water containing excessive chloride and sulfate ions is discharged from Permian shales into Wisconsinan terrace deposits and alluvium in the Arkansas River valley, accounting in part for the poor quality of water in this aquifer, but more serious problems are caused by local pollution from oil-field brines, which in past years were permitted to enter the aquifer. The brines move downgradient in the valley near the base of the aquifer, and several public-supply and domestic wells have been abandoned because of contamination by the brines. Future development of ground-water suplies in the Wisconsinan terrace deposits and alluvium of the Arkansas River valley is likely to be affected by the brines.

The basic field data upon which most of this report is based are given in tables and include records of 202 wells and springs and partial or complete analyses of water from representative wells. Logs of 281 test holes and 4 wells also are given.

INTRODUCTION

Purpose and Scope of Investigation

A program of investigation of the ground-water resources of Kansas was begun in 1937 by the U. S. Geological Survey and the State Geological Survey of Kansas with the co-operation of the Division of Sanitation of the State Board of Health and the Division of Water Resources of the State Board of Agriculture. The investigation upon which this report is based was begun in the fall of 1956 and field work was completed in the summer of 1958. The report is similar to other reports that have been completed or are being prepared on other counties in Kansas. The present status of investigations resulting from this program is shown in Figure 1.

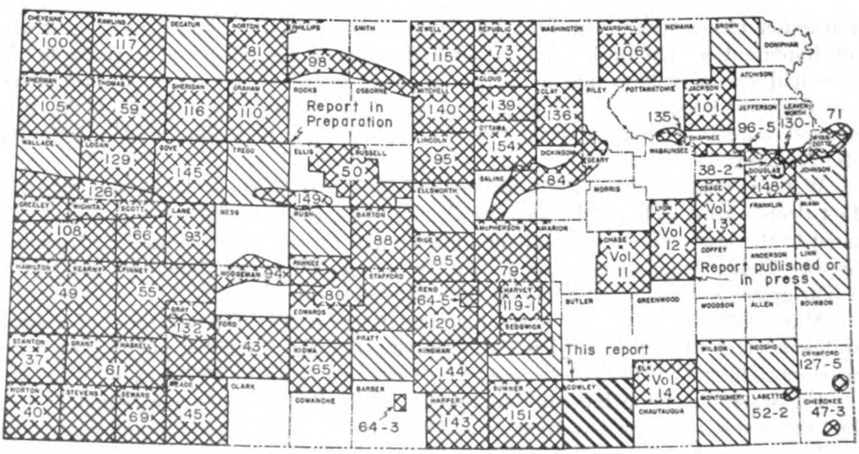

Fig. 1.—Index map of Kansas showing area discussed in this report and other areas for which ground-water reports have been published or are in preparation.

Ground water is one of the principal natural resources of Cowley County. It is the source of all public water supplies, all industrial supplies, and nearly all domestic supplies. Ground water is used to some extent also for irrigation. Fortunately, withdrawal of ground water has not seriously depleted the available water supply, although in some areas the encroachment of water of poor quality has caused the abandonment of wells.

The principal objectives of this study were to determine more fully the quantity of water available and to study the factors affecting the quality of the ground water.

Location and Extent of Area

Cowley County is in the southernmost tier of counties in Kansas and is about 120 miles west of the eastern border of the state. The county is bounded on the west by Sumner County, on the north by Butler County, on the east by Elk and Chautauqua Counties, and on the south by Kay and Osage Counties, Oklahoma.

The county is one of the largest counties in Kansas, extending 35 miles from north to south and 34½ miles from east to west, and comprising an area of about 1,136 square miles.

Previous Investigations

Many geologic studies have been made of rocks of the same age as those in Cowley County, and in many of the reports of these studies, specific reference is made to Cowley County. Only the most important reports having a direct bearing on the geology of Cowley County are mentioned below. Specific references are cited by author and date at appropriate places in the text; all are given in the list of references at the end of the report.

A report by Bass (1929) described the geology of Cowley County with special reference to the occurrence of oil and gas. O'Connor and Jewett (1952) described the stratigraphy of the Red Eagle Formation in Cowley County. Hattin (1957) in a report on the depositional environment of the Wreford megacyclothem described the Wreford Limestone in Cowley County. Lane (1958) described the environment of deposition of the Grenola Limestone. Verville and others (1958), in a report on the geology, mineral resources, and ground-water resources of Elk County, described the rocks and ground-water conditions common to both counties. A report by Walters (1961) described the geology and ground-water resources of Sumner County, in which geology and ground-water conditions in Pleistocene rocks are similar to those in closely associated equivalent deposits in Cowley County.

Methods of Investigation

About a month in the fall of 1956 was spent drilling auger holes and collecting water samples in the valley of Arkansas River. About 4 months in the summers of 1957 and 1958 were spent mapping the geology and collecting hydrologic data. The geology was mapped on areal photographs and was later transferred to a base map modified from a map prepared by the Soil Conservation Service of the Department of Agriculture (Pl. 1). Data pertaining to the wells were obtained from the owners and drillers, and well depths and water levels were measured with a steel tape from a fixed point. The character of the material below the land surface was determined by studying the cuttings of 196 auger holes drilled in 1956-57 and the logs of 83 test holes drilled in 1944. The chemical character of the water was evaluated from analyses of water samples from 101 test holes. Some of the test holes were sampled at more than one depth to determine whether the quality of water changed with depth.

The wells and test holes shown on Plate 2 were located within the sections by use of an odometer and are accurate to 0.1 mile. Altitudes of the measuring points of the wells and test holes were determined in the field by level parties headed by E. L. Reavis and C. V. Fishel. The analyses of the samples of water were made under the direction of Howard A. Stoltenberg, chemist in charge of the Sanitary Engineering Laboratory of the Kansas State Board of Health.

Well-Numbering System

The land in Cowley County is subdivided according to the standard system of the General Land Office except the west tier of sections in Range 8. The wells, test holes, and auger holes in the part of the county containing standard sections are numbered according to the system of land classification of the General Land Office. The component parts of a well number are, in the order given, the township, range, and section numbers, and three lowercase letters, which indicate respectively the quarter section, quarter-quarter section, and quarter-quarter-quarter section in which the well is located. These letters are assigned to the quarter divisions in a counterclockwise direction, beginning in the northeast quarter of each section or subdivision. For example, well 33-3-25bcd (Fig. 2) is in the SE¼ SW¼ NW¼ sec. 25, T. 33 S., R. 3 E. If two or more wells are in the same 10-acre tract, they are numbered serially according to the order in which they were inventoried. The west tier of sections in Range 8 is subdivided so that the east half section is composed of two normal quarter sections, half a mile long from east to west, but the west part, which is about 2 miles long, is divided into lots containing about 40

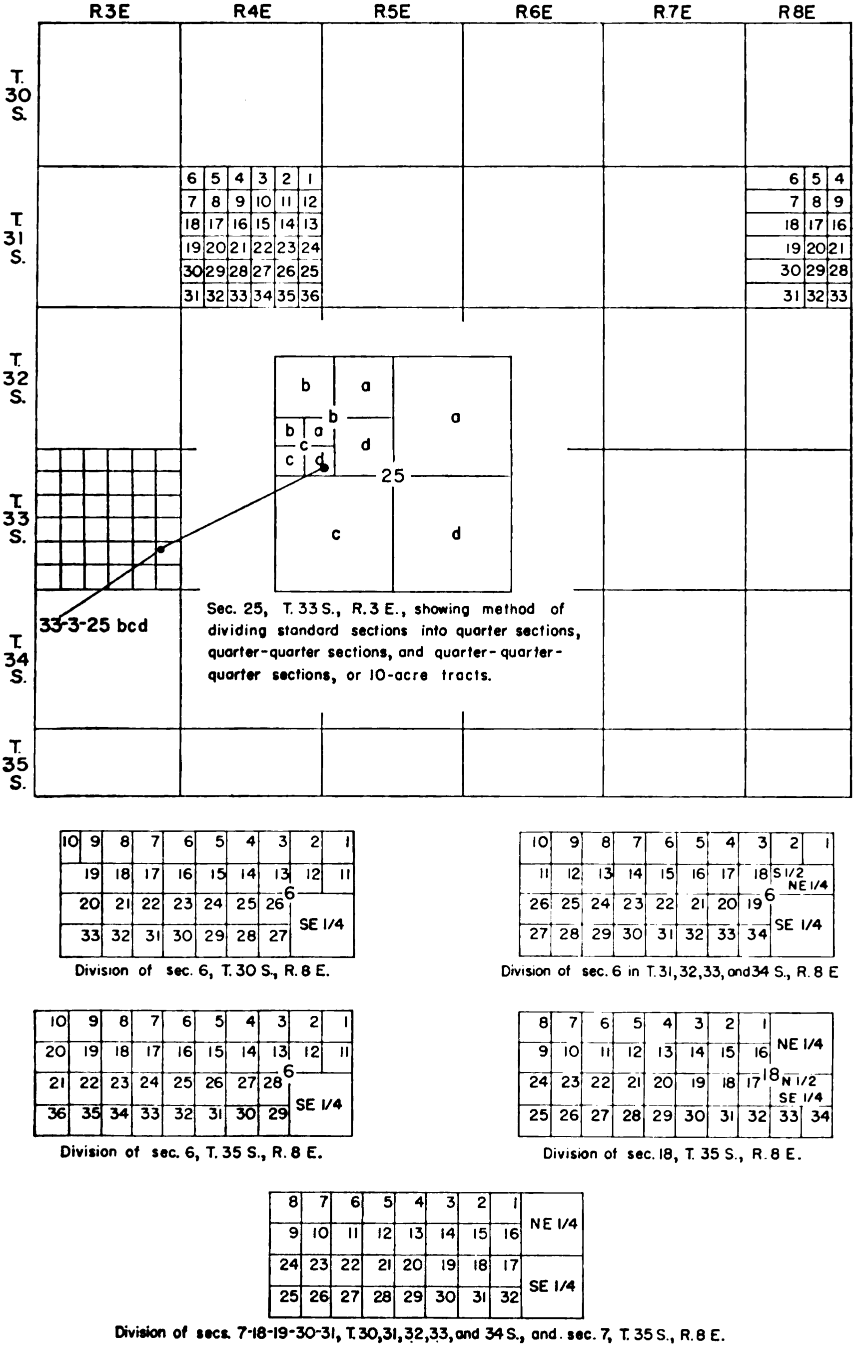

FIG. 2.—Map of Cowley County illustrating well-numbering system used in this report.

acres each. The lots are numbered, but the order of numbering differs according to the location of the section in the township. The five section plats at the bottom of Figure 2 show the system of numbering lots in the various sections. In this report a well or test hole in one of these sections is numbered as follows: the township number, range number, section number, and lot number.

Acknowledgments

Appreciation is expressed to the many residents of Cowley County who supplied information and aided in the collection of field data. Special acknowledgment is due the officials of the cities and industries who supplied information about their water supplies. Acknowledgment is made also to Leonard Bailey, driller, and Walter Hunt for information on many wells in the county.

The manuscript of this report has been reviewed by several members of the U. S. Geological Survey and the State Geological Survey of Kansas; Robert Smrha, Chief Engineer, and Harris Mackey, Engineer, Division of Water Resources, Kansas State Board of Agriculture; and Dwight Metzler, Chief Engineer, and Willard Hilton, Geologist, Division of Sanitation, Kansas State Board of Health.

GEOGRAPHY

Physiography and Topography

Cowley County is in the Osage Plains and the Arkansas River Lowland sections of the Central Lowland physiographic province (Fig 3).

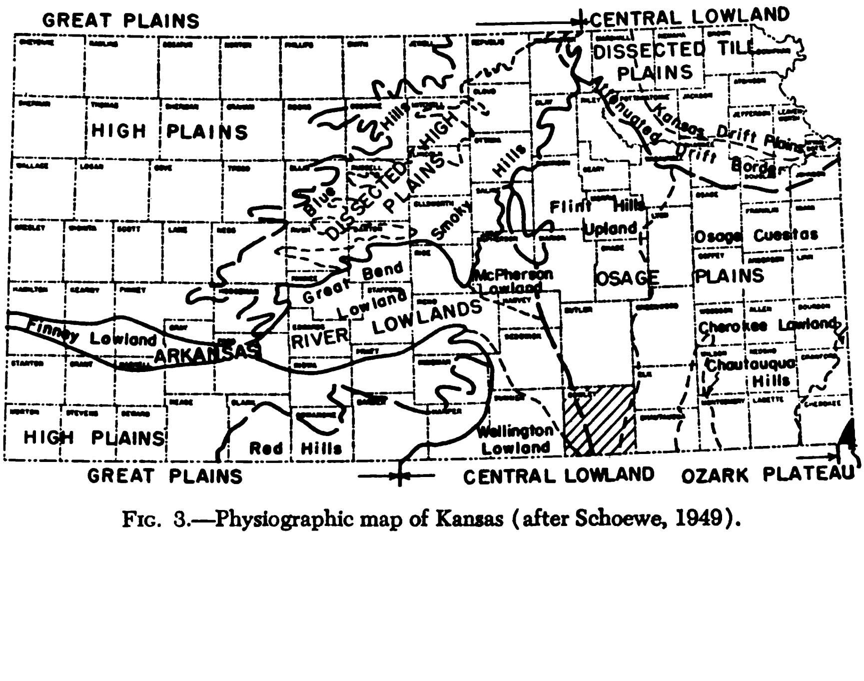

Fig. 3.—Physiographic map of Kansas (after Schoewe, 1949).

Cowley County includes parts of the Flint Hills Upland and Osage Cuestas divisions of the Osage Plains section and part of the Great Bend and Wellington Lowlands divisions of the Arkansas River Lowland section (Schoewe, 1949).

The surface features that make up the physiographic divisions in Cowley County are directly related to the types of outcropping rocks. With the exception of the west tier of townships, almost the entire county is underlain by alternating layers of limestone and shale, which crop out in belts extending across the county in a nearly north-south direction. The limestone layers, being more resistant to weathering, form benches or escarpments, and the softer shale layers, weathering more readily, form steep eastward-facing slopes between the limestone ledges. The part of the county lying west of the outcrop of the Herington Limestone Member of the Nolans Limestone is almost covered by terrace deposits of Pleistocene age, which form a smooth, gently-sloping surface.

The principal physiographic division in Cowley County is the Flint Hills Upland division. In the southeastern part of the county the east boundary of this division is marked by the thick, chert-bearing Foraker Limestone. In this area the Foraker forms a pronounced escarpment, and succeeding younger limestones form widely spaced benches on the upland surface to the west. In northeastern Cowley County the east boundary of the Flint Hills Upland division is formed by the escarpment of the Wreford Limestone. The underlying limestones down to the base of the Foraker form benches, but they are not so widely spaced laterally as those in the southern part of the outcrop (Pl. 7). Below the base of the Foraker Limestone the thin limestone beds in the Admire and Wabaunsee Groups form only low benches in the Osage Cuesta division. Relief along the east border of the Flint Hills Upland may be as much as 300 feet, but in the area adjacent to the Foraker Limestone it is commonly 150 feet. Westward from the eastern edge of the Flint Hills Upland division are a series of steplike escarpments or benches formed by the younger limestones. The surface of each bench slopes gently westward at a rate about equal to the regional dip of the strata. The underlying shale weathers to form steep slopes adjacent to the escarpment of the overlying limestone. The relief of these benches may be as much as 100 feet locally. The west border of the Flint Hills Upland division is marked by the bench formed by the Herington Limestone Member of the Nolans Limestone. This bench is much more pronounced in the southern part of the outcrop area than in the north.

The relatively flat area of low relief west of the Herington outcrop is included in the Great Bend Lowlands physiographic division. This area is underlain by the thick Wellington Formation, which is almost

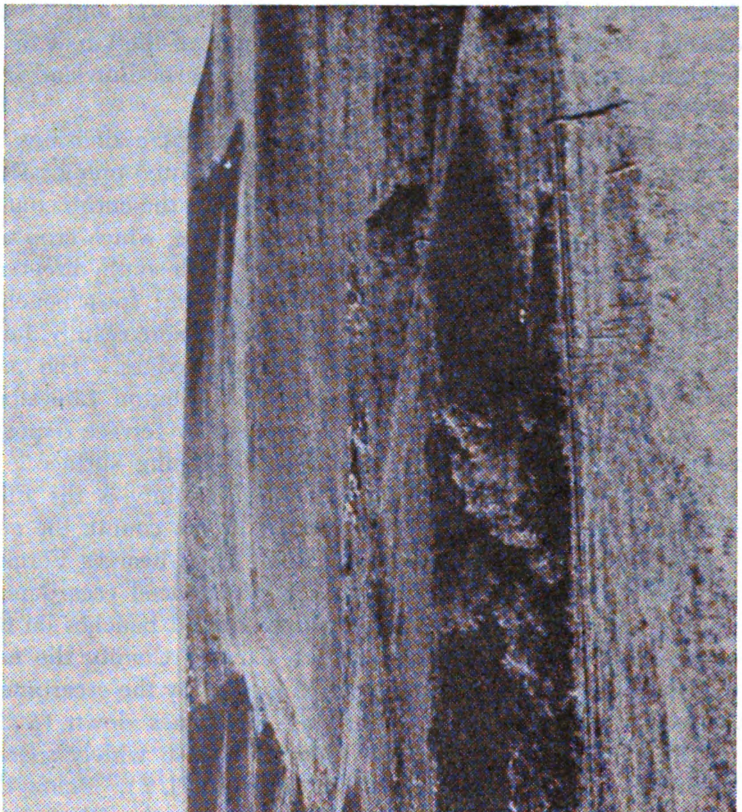

PLATE 7.—Typical Flint Hills topography at Elk-Cowley county line in sec. 4, T. 31 S., R. 8 E. Bench in foreground formed by Grenola Limestone, middle bench formed by Beattie Limestone, and nearby hill capped by Crouse Limestone. In far distance Wreford Limestone caps upland surface.

covered by terrace deposits of Pleistocene age associated with the ancestral Arkansas River.

A small area in extreme southwestern Cowley County lies in the Wellington Lowlands physiographic division. This area lies south and west of Arkansas River and at a higher altitude than the area included in the Great Bend Lowlands. This area also is underlain by the Wellington Formation, which is almost covered by Pleistocene deposits older than those in the Great Bend Lowlands. Topographic relief in the Wellington Lowlands is greater than in the Great Bend Lowlands.

The surface altitude of Cowley County ranges from about 900 feet in the valley of Rock Creek in the southeastern part of the county to about 1,500 feet in the northeastern part. In most of the county, the surface altitude ranges from 1,150 to 1,350 feet above sea level.

Drainage

Arkansas and Walnut Rivers are the principal streams in the county. Walnut River joins Arkansas River from the east at Arkansas City in southern Cowley County. The Walnut flows almost due south through the county. Its eastward-flowing tributaries are short and drain relatively small areas. The westward-flowing tributaries are much longer and, therefore, drain much larger areas. Timber Creek, which rises near the north county line in R. 7 E., is the principal tributary to Walnut River in the county. Grouse Creek, an east tributary to Arkansas River, joins the river about a mile above the Kansas-Oklahoma line and, with its tributaries, drains about a third of the county. The area east of the Foraker outcrop is drained by south- and east-flowing streams tributary to Caney River. The valleys of all the streams, except Arkansas River in western Cowley County, are relatively narrow. These valleys are steep walled and rimmed with resistant limestone. Arkansas River in western Cowley County flows in a very broad valley on Pleistocene deposits. The valley is walled by older Pleistocene deposits and the Wellington Formation. In this area the valley walls lack the resistant limestone cap; hence they are not so steep or high as the valley walls of the other streams. Below Arkansas City, Arkansas River flows through a narrower valley whose walls are capped by thick limestone beds and which here resembles, excepting in size, the valleys of other streams in the county.

Climate

The climate of Cowley County is characterized by wide variations in temperature and precipitation. The winters are usually mild except for periodic cold periods. The summers are generally hot, but because of the relatively low humidity, they are not uncomfortable.

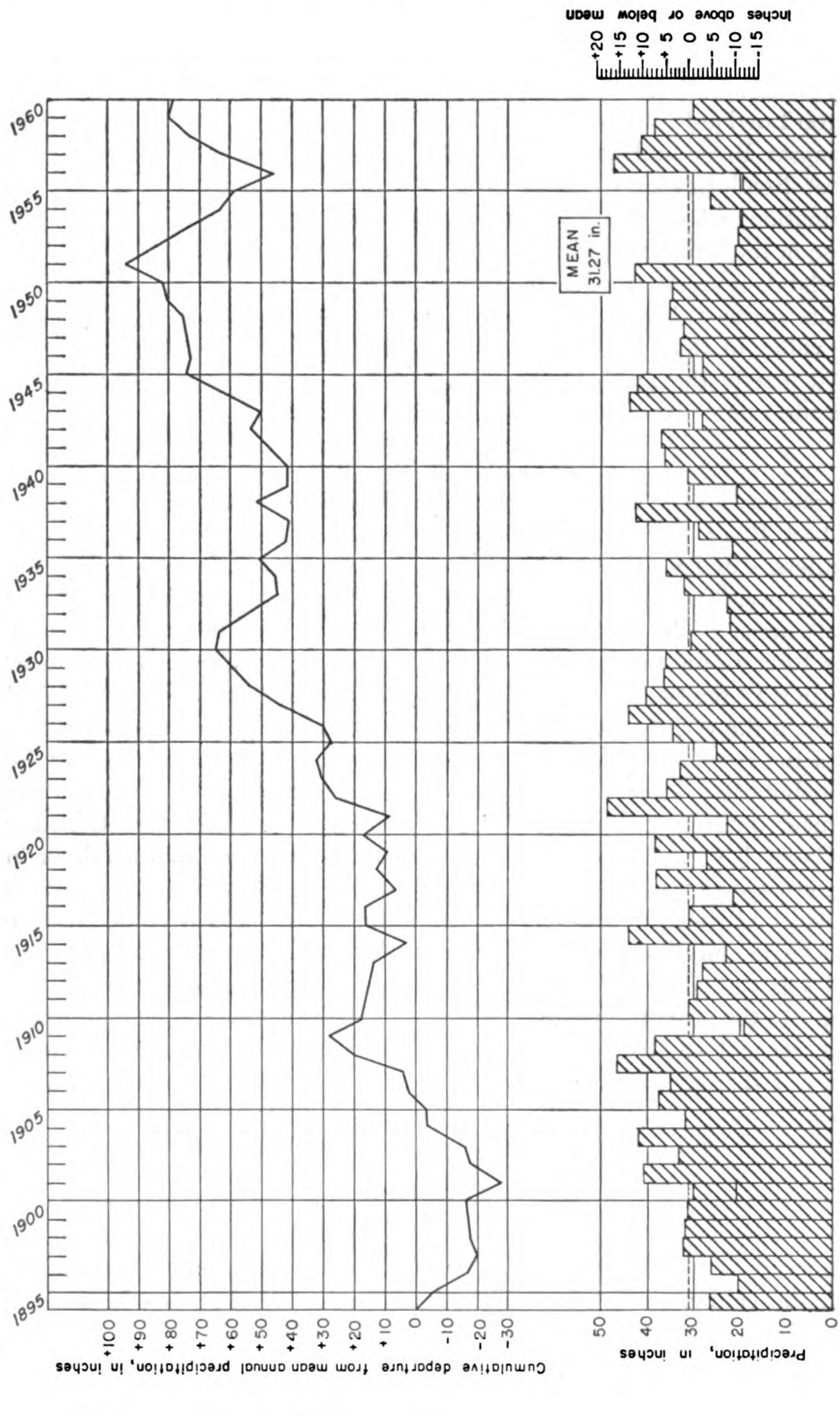

FIG. 4.—Annual precipitation and cumulative departure from mean annual precipitation at Winfield.

The U. S. Weather Bureau has maintained precipitation and temperature gages at Winfield since 1895 and a precipitation gage at Arkansas City since 1916. The mean annual precipitation at Winfield is 31.27 inches. The highest annual precipitation of record, 48.91 inches, was in 1922; the lowest, 19.36 inches, was in 1910. The annual precipitation and the cumulative departure from mean annual precipitation are shown in Figure 4. About 70 percent of the precipitation falls during the growing season, from April through September. Table 1 gives the monthly mean precipitation at Winfield.

TABLE 1.—*Monthly mean precipitation at Winfield*

Month	Precipitation (inches)	Month	Precipitation (inches)
January	1.03	July	3.44
February	1.33	August	2.74
March	1.89	September	3.65
April	3.52	October	2.13
May	4.25	November	1.77
June	4.19	December	1.33

At Arkansas City the mean annual precipitation is 32.18 inches. The highest annual precipitation of record, 48.20 inches, was in 1957; the lowest, 18.38 inches, was only one year earlier, in 1956.

The annual mean temperature at Winfield is 57.8°F. The lowest temperature of record, -27°F, was on February 13, 1905, and the highest temperature, 118°F, was on August 12, 1936. The minimum temperature is 32°F or below for an average of about 100 days a year, and the maximum temperature is 100°F or above for about 15 days a year. The average wind velocity at the Wichita weather station, which is the nearest station to Cowley County equipped to record wind data, is 12.1 miles per hour. The wind movement is generally strong during the afternoon hours in March and April, but the winds almost always diminish in the early evening. The highest average wind velocity is in April and is about 14 miles per hour. The prevailing winds are southerly except during February, when they are northerly.

The growing season has an average length of 188 days but it has been as long as 213 days and as short as 141 days.

POPULATION

According to the 1959 census, the population of Cowley County was 37,040. The average density was 32.6 persons per square mile compared with 23.2 persons per square mile in the state as a whole. The population

2—4036

of the county has decreased at an average yearly rate of about 133 persons since it reached a peak of 40,903 in 1930. Rural population decreased about 2,000 in the period 1940 to 1950. During this same period the urban population increased about 1,000.

Arkansas City, population 14,606 in 1959, and Winfield, population 10,848 in 1959, are the largest cities in the county. Winfield has had a steady growth in population since the city was founded; Arkansas City also has had a steady growth except during the 10-year periods prior to the 1900 and 1940 censuses. All other towns in the county except Burden and Udall have decreased in population since 1930. The populations of the smaller towns in 1959 were as follows: Atlanta, 260; Burden, 670; Cambridge, 161; Dexter, 310; and Udall, 644.

Transportation

Cowley County has good transportation facilities. All the cities are served by one or more railroads. Arkansas City, Winfield, and Udall are on a main line of the Atchison, Topeka & Santa Fe Railway. A branch line of the Atchison, Topeka & Santa Fe extends from Winfield through Burden and Cambridge. Arkansas City, Winfield, and Dexter are on a branch line of the Missouri Pacific Railroad. A branch line of the St. Louis-San Francisco Railway passes through Atlanta, Winfield, and Arkansas City. Arkansas City is served also by the Midland Valley Railroad.

Atlanta is the only city in the county that is not on a state or federal highway. U. S. Highway 160 crosses the county from west to east and passes through Winfield, Burden, and Cambridge. U. S. Highway 166 crosses the southern part of the county from east to west and passes through Arkansas City. U. S. Highway 77 traverses the county from north to south and passes through Winfield and Arkansas City. Kansas Highway 15 crosses the county from northwest to southeast and passes through Udall, Winfield, and Dexter. Kansas Highway 55 is a connecting highway from Udall west to U. S. Highway 81 in Sumner County.

County highways are all hard surfaced and give access to the entire county either by direct connection or by connecting to the federal and state highways. Most of the township roads are graded and many are all-weather roads.

Agriculture

Agriculture is one of the principal occupations in Cowley County. About 30 percent (210,000 acres) of the land is cultivated; in addition, about 50,000 acres is used for alfalfa or wild hay production. The total value of the field crops in 1955 was $4,665,000; wheat accounted for about 50 percent of this amount. The principal crops and the acres harvested in 1955 are listed below:

Crop	*Acres*
Wheat	96,000
Sorghums	39,600
Oats	34,900
Barley	28,300
Rye	5,650
Corn	4,300

The value of livestock and livestock products in the county in 1955 was $7,200,000, considerably greater than the value of other agricultural products. Beef cattle accounted for about $5,100,000 of this total. About 60 percent of the land area is pasture or grazing land, and because so much of the land is devoted to this use, the value of beef cattle produced is high. In the order of value, the livestock and livestock products of the county are beef cattle, milk products, poultry and eggs, hogs, and sheep.

Mineral Resources

Oil and Gas

Cowley County has been an important producer of oil and gas for many years. The first discovery of gas in the county was in 1902 in a well drilled just east of Winfield. Natural gas discovered near Dexter in 1903 attracted wide attention because of its helium content. A plant for the extraction of helium was constructed at Dexter in 1927 and oper-

Table 2.—*Annual production of oil in Cowley County*

Year	Production, thousands of barrels	Year	Production, thousands of barrels	Year	Production, thousands of barrels
1914	15	1930	2,015	1946	2,717
1915	14	1931	1,885	1947	2,813
1916	18	1932	2,743	1948	2,593
1917	29	1933	1,147	1949	2,115
1918	26	1934	1,681	1950	1,908
1919	22	1935	1,622	1951	1,725
1920	60	1936	1,804	1952	2,166
1921	70	1937	1,963	1953	3,197
1922	243	1938	2,318	1954	4,364
1923	629	1939	2,131	1955	4,713
1924	2,266	1940	2,720	1956	4,595
1925	7,039	1941	2,816	1957	4,182
1926	3,943	1942	2,865	1958	4,172
1927	3,304	1943	2,738	1959	3,858
1928	2,284	1944	2,614	1960	3,672
1929	2,065	1945	2,583		

ated for a few years. Oil was discovered near Dexter in 1914, but the first important discovery of oil was in 1916. Extensive development began in the early 1920's and production reached a peak in 1925. The annual production of oil since the first discovery is given in Table 2.

The 1960 production from 1,648 wells was 3,672,300 barrels. Secondary recovery projects accounted for about one-fourth of this production. Cumulative production to the end of 1960 was about 106,462,000 barrels. Gas production in 1960 was 1,413,000 thousand cubic feet as compared with 1,320,000 thousand cubic feet in 1959.

Most of the oil is produced from the following, informally designated units: the "Layton sand", "Bartlesville sand", "Mississippi lime", and "Arbuckle lime", but a total of 15 zones produce oil in the county. Some gas is produced from the oil-producing zones, but most of the gas is produced from shallow zones in the Admire and Douglas Groups.

Construction Materials

Raw materials in Cowley County that would be useful in construction projects include alluvial deposits in the major stream valleys, chert gravel deposits, and limestones of Permian and Pennsylvanian age. For discussion, these materials are classified as to use.

Concrete Aggregate

Aggregate for concrete consists of fragments of hard, durable minerals or rocks of sand and gravel grain size. The constituent particles should be free from adherent coatings or particles that would interfere with the bonding of the cement and aggregate. An almost unlimited supply of sand and gravel is available from the alluvial deposits in the Arkansas River valley. Crushed aggregate can be produced in large quantities from the Permian limestones in the eastern three-fourths of the county. Material for the manufacture of light-weight aggregate is available, but as most of the Permian shale from which this aggregate would be made is calcareous shale, special manufacturing processes would be necessary. In general the chert gravel deposits and alluvial materials from streams other than Arkansas River are not suitable for aggregate, as these deposits contain much clay and silt that would interfere with the cement bond.

Road Metal

Road-surfacing material is available in large quantities from the alluvial materials in Arkansas River valley and also in smaller supply from the other major streams in the county. Crushed limestone from almost all the Permian limestones is available and has been used without binder on many of the secondary roads in the county. This crushed stone tends to powder and become very dusty in dry weather. Silt deposits in the Arkansas River valley and loess deposits adjacent to the river are suitable as a binder for road-surfacing material. Sand and gravel, crushed limestone, and silt binder are used extensively to build asphalt or macadam roads. Terrace deposits composed of chert gravel formerly were used extensively for road metal and are used on many secondary roads. These deposits contain much clay and silt, which form a good binder but also tend to become very soft and sticky after hard rains. In dry weather this type of road metal does not become as dusty as crushed limestone.

Structural Stone

Structural stone is any hard, dense rock that can be quarried and cut to a desired size and shape. Materials that meet these requirements are found in the Cresswell Limestone Member of the Winfield Limestone and in the Fort Riley Limestone Member of the Barneston Limestone. The Cresswell has been used extensively in the past but little of this stone is being used for structural stone at present. The Fort Riley is widely used for cut stone. Two companies produce cut stone from this rock unit from quarries near Silverdale, about 8 miles east of Arkansas City. Small quarries have been opened in nearly all the thicker Permian limestone units that crop out in the county. Most quarries from which stone was used principally for local building projects have been abandoned.

Agricultural Limestone

Limestone having a calcium carbonate content equivalent of 80 percent or more and occurring in ledges sufficiently thick for economical quarrying is regarded as a potential source of agricultural limestone. In Cowley County the Fort Riley Member meets the first requirement, its calcium carbonate content being about 95 percent. No Fort Riley quarries were found from which the limestone was being used for this purpose, however. The Cresswell Member is generally suitable for agricultural limestone, although locally the calcium carbonate content may be below the 80-percent minimum. Two quarries about a mile west of Winfield, one of which is now abandoned, have produced rock used for agricultural limestone. Many of the other Permian limestones and some of the calcareous shales would meet the calcium carbonate requirement, but the deposits probably are not thick enough for economical quarrying.

GEOLOGY OF SUBSURFACE ROCK UNITS

Subsurface rocks in Cowley County were not studied in detail; the description of the rocks is therefore generalized. The rock units are discussed in general by system or a combination of systems. Although the rocks of each system are divided into small units in the Kansas classification, some of these smaller units have not been identified in most well logs, but many "key horizons" can be readily identified in logs of most wells in Cowley County.

Precambrian Rocks

Rocks of Precambrian age do not crop out in Kansas. Logs of deep wells in the county and adjacent areas indicate that this basement complex of crystalline rocks is composed chiefly of granite and schist, but it also may include quartzite, quartz porphyry, diabase, and other types of igneous or metamorphic rocks. A few wells in Cowley County have reached the Precambrian rocks. These wells indicate that the surface of the Precambrian dips in a westerly direction from an altitude of about 2,400 feet below sea level in the eastern part of the county to about 3,800 feet below sea level in the southwestern part. In the northwestern part of the county there is a reversal of dip on the Precambrian surface at the east flank of the Nemaha Anticline. Here the Precambrian surface rises sharply, and locally may be only 2,000 feet below sea level. Locally, detrital material eroded from adjacent areas mantles the Precambrian surface in this area.

Cambrian and Ordovician Systems

Deep wells in Cowley County have penetrated a thick series of strata composed of limestone, sandy limestone, dolomite, sandstone, and minor amounts of shale. These rocks, of Cambrian and Ordovician age, lie on the weathered Precambrian surface and are overlain by rocks of Mississippian age. This group of rocks has been divided, in descending order, into the St. Peter Sandstone, Cotter and Jefferson City Dolomites, Roubidoux Formation, Gasconade Dolomite, and Van Buren Formation of Ordovician age, and the Bonneterre Dolomite and Lamotte Sandstone of Cambrian age.

The St. Peter Sandstone is present only in western Cowley County, and the Bonneterre Dolomite and Lamotte Sandstone are present only in eastern Cowley County. The other units underlie the entire county, but there probably has been some thinning of the upper unit by pre-Mississippian erosion. The rocks between the St. Peter and Lamotte Sandstones are included in the Arbuckle Group in the Kansas classification and are commonly called the "Arbuckle lime" or "Siliceous lime" by oil men.

The St. Peter Sandstone is assigned to the Simpson Group in the Kansas classification. It is probably not more than 50 feet thick in the county.

The thickness of the Arbuckle Group ranges from about 650 feet in northeast Cowley County to about 1,000 feet in southwest Cowley County. Oil and gas are produced from the St. Peter Sandstone and from porous zones in the upper part of the Arbuckle Group. All these rock units locally yield large quantities of mineralized water, which has been used as injection water in secondary recovery of oil. These rocks also are widely used for disposal of brine produced with petroleum.

Mississippian System

Rocks above the post-St. Peter disconformity and below the sub-Pennsylvanian unconformity are included in the Mississippian System in this report, although the lower division, the Chattanooga Shale, in part may be of Devonian age. The Chattanooga consists of black carbonaceous fissile shale, locally somewhat sandy in the basal part, and commonly ranges in thickness from about 50 feet to as much as 200 feet, but it may be absent over some structurally high areas. Structural movement may have elevated the strata one or more times preceding or during deposition of younger Mississippian rocks, allowing erosion to bevel or even remove Chattanooga rocks. The Chattanooga underlies all of Cowley County except an area near Dexter and another in the northeastern part of the county (Bass, 1929, p. 30).

The upper division of the Mississippian System in Cowley County consists of light-gray to dark-gray cherty limestone containing some shale locally. These deposits range in thickness from about 225 feet to as much as 400 feet and collectively are called the "Mississippi lime" by the oil industry. Four rock divisions of formational rank are recognized in the county: the St. Joe Limestone, the Reeds Spring Formation, and the Keokuk Limestone of the Osagian Series, and the Cowley Formation of the Meramecian Series. The Reeds Spring and St. Joe rocks underlie all of the county except small areas where they have been removed by erosion. The Keokuk Limestone is present only in northern Cowley County. The Cowley Formation is the thickest of the Mississippian rock units in the county. This unit was deposited in an erosional basin extending southward from northern Cowley County, where the formation abuts but does not overlap the Keokuk Limestone. The Cowley Formation generally overlies Reeds Springs or St. Joe rocks, but in some places it rests on Chattanooga or older rocks.

The Mississippian rocks thin considerably over structurally high areas, owing to pre-Pennsylvanian erosion there, and are productive of oil and gas from the upper, porous part of the strata. Locally, large yields of strongly mineralized water are obtained from these rocks. This water is used to some extent as injection water in the secondary recovery of oil.

Pennsylvanian System—Middle Pennsylvanian Series

Interbedded limestone, shale, and sandstone having an aggregate thickness ranging from about 2,000 to 2,400 feet compose the Pennsylvanian rock section in Cowley County. Only the upper part of the Middle Pennsylvanian Series and the Upper Pennsylvanian Series of the Pennsylvanian System are represented in the county. The Middle and Upper Pennsylvanian Series have been divided into groups, formations, and members on the outcrop, and although many of these units may be recognized in the subsurface, others are not so easily recognized; hence these rocks are discussed below by groups.

Cherokee Group

The Cherokee Group includes the strata between the Mississippian System at the base and the Fort Scott Limestone at the top. The Cherokee unconformably overlies the Mississippian rocks and in Cowley County is composed of gray and dark-gray shale and small amounts of sandstone. The rocks range in thickness from about 130 feet in northwest Cowley County to about 300 feet in south and southeast Cowley County. The Cherokee rocks thin over areas where the Mississippian rocks are structurally high. Discontinuous sandstone bodies, generally much greater in length than in width, are present at several different horizons in the Cherokee group and seem to be channel or beach deposits. They are important reservoirs for the accumulation of oil and gas.

In some places the basal Cherokee deposits are composed of eroded fragments derived from the "Mississippi lime" and consisting of rounded pebbles and sand grains of chert and small amounts of other resistant rocks. These deposits are present only locally but are commonest along the flank of the Nemaha Anticline. Oil and gas are produced from some of these deposits, which are called "Mississippi chat" by the oil industry. The sandstones and "chat" yield mineralized water in parts of the area. Some of the water obtained in the production of oil is reinjected in secondary recovery operations.

Marmaton Group

The rocks between the top of the Cherokee Group and the disconformity at the base of the Hepler Sandstone are included in the Marmaton Group. This group constitutes the upper part of the Middle Pennsylvanian Series in Kansas. In Cowley County these rocks are composed of limestone, shale, and sandstone and have a thickness ranging from about 200 to 250 feet. Elsewhere in eastern Kansas these sandstones are important producers of oil and gas, but they are not productive in Cowley County. The Marmaton rocks yield relatively small quantities of strongly mineralized water in Cowley County.

Pennsylvanian System—Upper Pennsylvanian Series

The major disconformity at the top of the Marmaton Group marks the boundary between the Middle Pennsylvanian Series and the Upper Pennsylvanian Series.

Pleasanton Group

The rocks between the disconformity at the top of the Marmaton Group and the base of the Hertha Limestone, which marks the base of the Kansas City Group, are included in the Pleasanton Group. In Cowley County this group ranges in thickness from about 50 to 100 feet and is composed chiefly of clastic sediments. The Checkerboard Limestone is the only important limestone in the group and it overlies the lowest formation of the group, the Hepler Sandstone. Pleasanton rocks are not productive of oil or gas in Cowley County and yield only small quantities of strongly mineralized water.

Kansas City Group

Rocks from the base of the Hertha Limestone to the base of the Plattsburg Limestone compose the Kansas City Group. These rocks have been divided into the Bronson, Linn, and Zarah Subgroups. In Cowley County these units have a total thickness of about 450 feet. The Bronson Subgroup forms the lower third of the Kansas City Group. This unit contains more limestone than the two upper units, although the individual limestone and shale beds are thinner. The Linn and Zarah Subgroups are composed principally of clastic materials, but the Iola Limestone, at the top of the Linn Subgroup, is persistent and serves as a good marker bed in subsurface mapping. In northern Cowley County the upper part of the Kansas City Group is composed chiefly of gray limestone. The limestone units locally produce oil and gas. Sandstone in the Linn Subgroup, called the "Layton sand" by the oil industry, and correlative with the Cottage Grove Sandstone Member of the Chanute Shale, is an important reservoir for accumulation of oil and gas. Water contained in the sandstone of the Kansas City Group is strongly mineralized but is used as injection water in some secondary recovery projects.

Lansing Group

The Lansing Group includes three formations which, in ascending order, are the Plattsburg Limestone, Vilas Shale, and Stanton Limestone. In the subsurface in Cowley County this sequence of rocks contains less limestone than on the outcrop to the east of Cowley County. This difference is due partly to facies change, as the shales thicken westward and the Plattsburg Limestone becomes shaly, and partly to cutting out of the Stanton and the overlying Weston Shale of the Pedee Group by erosion early in Douglas time. Where the limestone formations in the Lansing are not present, separation of the Lansing from the underlying Kansas City Group is difficult. The lower boundary of the Lansing Group has been placed at the base of the Plattsburg Limestone for some time, but the upper boundary has in the past been placed as high as the top of the Tonganoxie Sandstone of the Douglas Group ("Stalnaker sand" of the oil industry, Winchell, 1957), thus, as in the past, including it and all of the Pedee Group in the Lansing Group. In the present report, the beds from the base of the Plattsburg to the unconformity at the base of the Douglas Group have been included with the Lansing. Under this grouping, the Weston Shale of the Pedee Group is included with the Lansing.

The thickness of the Lansing Group ranges from about 60 feet in western Cowley County to about 180 feet in eastern Cowley County, where the Weston Shale is present. Here the thickness of the Stanton Limestone, Vilas Shale, and Plattsburg Limestone is about 100 feet. Oil and gas have been produced in Cowley County from sandstone bodies in the shale units of the Lansing. Water in these units is strongly mineralized.

Douglas Group

The Douglas Group includes the strata below the base of the Oread Limestone of the Shawnee Group and above the unconformity at the base of the Tonganoxie Sandstone Member of the Stranger. The rocks of the Douglas Group are composed chiefly of shale and sandstone but include small amounts of limestone, and have a thickness ranging from 300 to 350 feet. The Douglas Group is divided into two formations: the Stranger Formation in the lower part and the Lawrence Shale in the upper part. The Stranger Formation is composed of shale and much sandstone and, locally, two thin limestones.

In Cowley County the Tonganoxie Sandstone Member at the base of the Stranger seems to lie in an erosional basin and to be a sheet deposit rather than a channel fill. Locally the Weston Shale of the Pedee Group and the Stanton Limestone of the Lansing Group have been cut out, leaving the Tonganoxie Sandstone Member in contact with middle or lower Lansing rocks. The thickness of the Tonganoxie ranges from 0 in northeast Cowley County to about 125 feet in the north-central and southern parts of the county. Generally the Tonganoxie yields moderately large quantities of strongly mineralized water, and oil and gas are produced from the sandstone in favorable structural conditions. Some water from the Tonganoxie is used as injection water in secondary recovery projects. The Lawrence Shale consists of shale, sandy shale, and sandstone. The Ireland Sandstone Member of the Lawrence Shale is a channel sandstone, which rests unconformably on rocks of Stranger age, the division between the Lawrence Shale and the Stranger Formation being placed at this contact.

Shawnee Group

The Shawnee Group is composed of four limestone and three shale units. In ascending order these are the Oread Limestone, Kanwaka Shale, Lecompton Limestone, Tecumseh Shale, Deer Creek Limestone, Calhoun Shale, and Topeka Limestone. On the outcrop in eastern Cowley County the limestones in this group are thicker than the limestones in the overlying Wabaunsee Group or those in the underlying Douglas Group, and are the most conspicuous lithologic unit. In Cowley County the Shawnee Group is 450 to 500 feet thick and contains less limestone than in the outcrop area. Sandstone is present in most of the thick shales, and oil and gas have been produced from these sandstone bodies. Water contained in these rock units is strongly mineralized.

Wabaunsee Group

In Cowley County the lower part of the Wabaunsee Group is confined to the subsurface, but inasmuch as the upper part crops out, the entire group is discussed under outcropping rock units.

GEOLOGY AND GROUND-WATER CHARACTERISTICS OF OUTCROPPING ROCK UNITS

The previously described Pennsylvanian rocks crop out in Kansas east of Cowley County. Mississippian rocks of the Osagian Series crop out in extreme southeast Kansas; younger Mississippian rocks are absent at the surface, owing to post-Mississippian erosion. Rocks that crop out in Cowley County are listed in Table 3 and are discussed on the following pages.

Table 3.—*Generalized section of outcropping rock units in Cowley County and their water-bearing characteristics* *

System	Series	Subseries	Stage	Formation or rock unit	Thickness (feet)	Character	Water supply
Quaternary	Pleistocene	Upper Pleistocene	Recent	Alluvium		Silt, clay, and arkosic sand and gravel in Arkansas River valley. Silt, clay, sand and chert gravel in other stream valleys.	Large quantities of water of good to poor quality available in Arkansas River valley. Moderate to small quantities of water in other stream valleys.
			Wisconsinan	Eolian Silts	0–30	Wind-deposited silt generally in upland position. Locally may contain silt older than Wisconsinan age.	Lies above water table and yields no water to wells.
				Terrace Deposits	0–55	Silt, clay, and arkosic sand and gravel in Arkansas River valley. Silt, clay, sand, and chert gravel in other major stream valleys.	Large quantities of water of good to poor quality available in Arkansas River valley. Small to moderate supplies of hard water available in other major stream valleys.
			Sangamonian and Illinoisan	Crete and Loveland Formations	0–55	Upper part principally silt and sandy silt. Lower part silt, clay, and arkosic sand, and some gravel in Arkansas River valley. Locally in Walnut River valley these deposits contain chert gravel.	In Walnut River valley these deposits are above the water table and yield no water. In Arkansas River valley moderate supplies of water of good quality are available.
		Lower Pleistocene	Yarmouthian and Kansan	Sappa and Grand Island Formations	0–40	Upper part silt and sandy silt. Lower part silt, clay, and arkosic sand and gravel in deposits associated with Arkansas River valley. In Walnut River valley and other major streams these deposits contain silt, clay, and chert gravel.	Chert gravel deposits lie above water table. Arkosic deposits yield small to moderate quantities of water of good quality. Locally these deposits are above the water table and yield no water to wells.
System	**Series**	**Group**	**Formation**	**Member**	**Thickness**	**Character**	**Water supply**
	Middle Permian	Sumner	Wellington	Hollenberg Limestone	0–80	Light-gray, green, and some red silty calcareous shale. Contains a few discontinuous limestone beds of which the Hollenberg Limestone seems to be fairly persistent. Locally, thin seams of gypsum occur in lower part.	Generally a poor aquifer, but some hard water may be obtained from the upper, weathered part near the outcrop. Locally, some water is obtained from the Hollenberg bed and from solution channels in gypsum.
			Nolans Limestone	Herington Limestone	10–15	Light-buff limestone and dolomite in upper part. Dolomitic and sandy in appearance; contains calcite geodes. Locally, limestone contains chert.	Locally yields small to large quantities of water of good to poor quality from the upper part, which locally contains solution channels. Little, if any, water is obtained from the middle and lower members.
				Paddock Shale	7–10	Blue and gray calcareous shale; contains some impure limestone.	

Permian	Lower Permian	Chase		Krider Limestone	4–9	An upper and a lower, thinner, more dense limestone separated by gray and buff calcareous shale.	
			Odell Shale		30–38	Chiefly gray and green calcareous shale. Locally, dolomitic zones occur in upper and middle parts.	Yields little water to wells in the area.
			Winfield Limestone	Cresswell Limestone	30±	Upper part light-blue limestone, thin bedded, weathers white; shaly in part. Lower part of Cresswell Member massive light-buff limestone generally in two beds with very thin shale parting, but may be one massive bed 12–15 feet thick; weathers light gray to gray. Locally may contain some chert.	Locally yields small to moderate quantities of water to wells from weathered upper part.
			Doyle Shale	Gage Shale	40–50	Gray, green, and maroon clay shale, limy and concretionary in upper few feet.	Locally, in subsurface, large to moderate supplies of water of good to poor quality are available from solution channels in uppermost few feet. Some water is available from limestone beds near base and from the Towanda. Quality of water ranges from good to poor.
				Towanda Limestone	2–15	Buff to gray limestone, in part platy to slabby. Resistant bed near base. Locally forms bench on Doyle slope. Not well exposed.	
				Holmesville Shale	25–35	Light-gray to green shale containing thin limestone beds in lower part.	
			Barneston Limestone	Fort Riley Limestone	45–55	Light-buff limestone weathering light gray, thin bedded in upper part, shaly near middle part, and thick bedded in lower part. A few thick beds occur just above shaly middle part.	Upper weathered zone of Fort Riley yields small to moderate supplies of hard water to wells. Middle and lower zones yield small to large quantities of water to wells and springs from solution channels in local areas. Florence yields small to large supplies of water to wells and springs unless drained near outcrop area.
				Florence Limestone	12–35	Thick-bedded buff limestone interbedded with gray and blue chert. Lower part contains more limestone and some limy shale. Chert is nodular and occurs in bands separated by limestone containing little chert.	
			Matfield Shale	Blue Springs Shale	20–30	Buff limy shale containing thin limestone bed in upper part.	Yields small supplies of water to wells from Kinney Limestone Member in local area.
				Kinney Limestone	13–18	Two limestones separated by 8 to 10 feet of gray limy shale. Upper limestone variable in thickness; lower limestone hard, massive, and almost uniform in thickness.	
				Wymore Shale	10–15	Gray and maroon shale, in part limy.	
			Wreford Limestone	Schroyer Limestone	6	Limestone: an upper algal zone, which weathers to a pitted surface, a shaly limestone zone, and a lower cherty limestone.	Yields small to moderate quantities of hard water to wells in and west of outcrop area. Water principally from weathered and fractured zones.

TABLE 3.—*Generalized section of outcropping rock units in Cowley County and their water-bearing characteristics* *—*Continued*

System	Series	Group	Formation	Member	Thickness (feet)	Character	Water supply
		Chase	Wreford Limestone	Havensville Shale	5–8	Limy shale, including a persistent cherty limestone near the middle, which weathers to a pitted surface.	Yields small to moderate quantities of hard water to wells in and west of outcrop area. Water principally from weathered and fractured zones.
				Threemile Limestone	17–19	An upper algal limestone weathering to a pitted surface, cherty limestone, shaly limestone, and a lower cherty limestone.	
			Speiser Shale		25–35	Shale, red and green in lower part and gray in upper part; uppermost few feet contains thin limestone beds. Locally a sandstone is present in the lower middle part.	Sandstones may yield small quantities of water to wells locally. Little or no water is obtained from shales.
			Funston Limestone		9–12	Limestone at top, bluish gray; shale and limestone in middle part; and dense gray limestone at base. This basal bed breaks into large blocks on the outcrop.	Yields little or no water to wells.
			Blue Rapids Shale		17–22	Shale, gray, containing a red zone in upper part, in part limy; a thin limestone below the red zone; a gray clay shale below.	Yields little or no water to wells.
			Crouse Limestone		8–12	An upper and a lower limestone bed separated by a thin shaly limestone bed. Upper and lower beds contain some chert.	Not a good aquifer but locally yields small quantities of hard water to wells.
			Easly Creek Shale		10–15	Mostly red shale but some gray shale in uppermost part and in lower part.	Yields no water to wells in the area.
			Bader Limestone	Middleburg Limestone	5–8	Limestone; upper part thin bedded to platy, containing some shale, lower part slabby to massive.	Locally yields small quantities of hard water to wells and springs.
				Hooser Shale	3–9	Shale, gray, green, buff, and locally some red.	
				Eiss Limestone	8–10	Two limestones separated by shale. Upper limestone is dense and massive. Shale is gray and limy. Lower limestone is earthy and dense.	
			Stearns Shale		6–10	Gray and green shale, in part limy. Locally contains some red shale.	Yields no water to wells in the area.

Permian	Lower Permian	Council Grove	Beattie Limestone	Morrill Limestone	3–9	Limestone, thin bedded or slabby to massive, upper part algal.	Yields very small quantities of hard water to a few wells and springs. Supplies are generally inadequate.
				Florena Shale	2.5–11	Limy shale, gray brown and bluish gray, very fossiliferous.	
				Cottonwood Limestone	5–6	An upper white massive to slabby limestone and a gray shale or shaly limestone. A lower massive limestone, locally siliceous.	
			Eskridge Shale		21–35	Shale, gray and green in upper part and red in lower part. Limy and very fossiliferous in upper part.	Yields little or no water to wells in the area.
			Grenola Limestone	Neva Limestone	17–25	Limestone interbedded with thin shale layers, weathers gray to buff, contains some chert in upper part.	Yields small to moderate quantities of hard water to wells and springs locally, principally from Neva Member.
				Salem Point Shale	6–10	Gray to brown shale, in part limy.	
				Burr Limestone	4–7	Blue-gray, dense limestone; generally two beds separated by a thin shale.	
				Legion Shale	3–8	Buff, limy shale.	
				Sallyards Limestone	3–4	Bluish-gray, massive to platy limestone, massive in upper part, thin bedded in lower part.	
			Roca Shale		10–15	Shale, gray in upper part and red and green in lower part; in part, limy.	Yields no water to wells in the area.
			Red Eagle Limestone	Howe Limestone	20	Limestone, upper part massive; middle part thin-bedded limestone layers separated by very thin shale partings; lower part very thin limestone, which may be absent locally.	Locally may yield small quantities of hard water to wells from weathered upper part of unit near the outcrop.
				Bennett Shale			
				Glenrock Limestone			
			Johnson Shale		20–30	Varicolored shale, limy to very limy in lower part.	Yields no water to wells in the area.
			Foraker Limestone	Long Creek Limestone	8–12	Gray to tan limestone, weathering to nearly white; massive to flaggy lower part contains chert.	Locally yields small to moderate quantities of hard water to wells and springs, principally from the Hughes Creek Shale Member.
				Hughes Creek Shale	25–35	Limestone and cherty limestone. Upper bed forms bench and breaks off in great slabs. Lower part contains shale.	

TABLE 3.—*Generalized section of outcropping rock units in Cowley County and their water-bearing characteristics *—Concluded*

System	Series	Group	Formation	Member	Thickness (feet)	Character	Water supply
Permian	Lower Permian	Council Grove	Foraker Limestone	Americus Limestone	9	Two dense blue cherty limestones separated by shale.	Locally yields small to moderate quantities of hard water to wells and springs, principally from the Hughes Creek Shale Member.
		Admire	Janesville Shale	Hamlin Shale	40–47	Two shale units separated by an earthy limestone. Upper shale is brown grading to dark gray, lower is green and red.	Generally a poor aquifer; locally may yield small quantities of hard water from channel sandstones and from the Falls City and Aspinwall. Locally, seeps may occur in the Towle.
				Five Point Limestone	2–4	Massive dark-brownish-gray limestone weathering yellow orange.	
				West Branch Shale	12–14	Greenish-gray to bluish-gray shale; locally contains limestone stringers.	
			Falls City Limestone		3–5	Earthy, dense, dark-blue to gray limestone, weathering yellow orange. Massive in lower part and slabby in upper part.	
			Onaga Shale	Hawxby Shale	35–45	Shale, gray in upper part, varicolored in lower part. Locally contains a channel sandstone.	
				Aspinwall Limestone	1–3	Gray to blue-gray limestone weathering yellow orange. Dense but somewhat slabby, locally containing shale streaks.	
				Towle Shale	13–20	Yellow and gray shale, locally sandy and limy.	
			Wood Siding	Brownville Limestone	1–2	Dense blue-gray limestone, weathering yellow orange or yellow brown.	Generally a poor aquifer, but locally may yield small quantities of water of poor quality from sandy zones.
				Pony Creek Shale	15–20	Shale, gray brown in upper part, grading downward to yellow gray. May contain a thin coal seam locally.	
				Grayhorse Limestone	2–4	Massive buff limestone, weathering yellow brown.	
				Plumb Shale	20	Blue-gray to yellow-gray shale, locally sandy and limy.	
				Nebraska City Limestone	1–2	Blue-gray dense limestone, weathering buff orange.	

Pennsylvanian	Upper Pennsylvanian	Wabaunsee	Root Shale	French Creek Shale	30–35	Gray and blue-gray shale; locally contains sandstone.	Generally a poor aquifer. Locally small quantities of water of poor quality are obtained from sandstone in upper part.
				Jim Creek Limestone	1–2	Dark-blue to blue-gray massive, dense limestone.	
				Friedrich Shale	18–35	Gray to blue-gray shale, sandy at top; contains sandstone locally in upper part. Coal occurs locally near top.	
			Stotler Limestone	Grandhaven Limestone	4–6	Several limestone beds separated by shale. Blue-gray limestone weathering to rusty brown.	Generally a poor aquifer, but in places small quantities of water of poor quality may be obtained from weathered part of lower unit.
				Dry Shale	5–7	Gray and brown clay shale, locally limy.	
				Dover Limestone	8–10	Blue-gray limestone beds separated by shale. Locally, coal occurs in shale below upper limestone.	
			Pillsbury and Willard Shales		10–15	Varicolored shale, commonly blue gray. A persistent impure limestone occurs below the middle part; coal commonly occurs near top and bottom of the formation.	Locally yields small quantities of water of poor quality to shallow wells.
			Emporia Limestone	Elmont Limestone	2–5	Blue-gray limestone, locally massive.	Small quantities of water of good to poor quality available, principally from the sandstone in the shale member.
				Harveyville Shale	10–14	Gray shale, commonly contains coal in upper part. Locally, sandstone occurs in middle part.	
				Reading Limestone	6–10	Several thin limestones separated by shale layers.	
			Auburn Shale		5–10	Green-gray to gray shale, locally containing thin limestone beds.	Yields little or no water to wells in the area.

*** The stratigraphic nomenclature is that of the State Geological Survey of Kansas.**

Pennsylvanian System—Upper Pennsylvanian Series

Wabaunsee Group

The rocks of the Wabaunsee Group constitute the uppermost rocks of Pennsylvanian age in Kansas. The lower boundary of this group is placed at the top of the Topeka Limestone, and the upper boundary is placed at the unconformity at the base of the Indian Cave Sandstone where this unconformity is observable, or, in areas where the Indian Cave is absent, as in Cowley County, at the top of the Brownville Limestone Member of the Wood Siding Formation.

Total thickness of the Wabaunsee Group in Cowley County is about 500 feet, but only the upper 200 feet crops out within the county. These deposits are characterized by alternating thin limestone beds and relatively thick shale units containing some sandstone and coal. The Wabaunsee Group includes six limestone formations and six shale formations (Moore and Mudge, 1956), but only three limestone units (Emporia, Stotler, and Wood Siding) and three shale units (Auburn, Pillsbury-Willard, and Root) crop out in Cowley County, where they can be seen in only a part of Townships 33, 34, and 35 in Range 8. Because they are poorly exposed, the units were not shown separately on the geologic map (Pl. 1). The oldest rocks exposed in the county are assigned to the Auburn Shale. The Auburn is exposed only in cuts adjacent to streams along the county line near Cedarvale, where it is composed chiefly of gray shale containing sandstone in the upper part. Outcrops of the overlying units of the Wabaunsee Group are poorly exposed and most of them consist of small, more resistant limestone ledges adjacent to streams. These exposures generally extend only short distances laterally, and rarely are they complete sections of the units. Coal is present in some of these exposures and has been mined for local use in three localities adjoining Cedar Creek valley; it is found in the Willard and Pillsbury Shales and in the Harveyville Shale Member of the Emporia Limestone.

Small quantities of hard water are obtained from shallow wells in sandstones in the upper part of the Wabaunsee. Two wells in and near sec. 30, T. 34 S., R. 8 E., obtain fresh water (Table 11) from a sandstone in the Willard and Pillsbury Shales at a depth of about 360 feet, but water from this sandstone in nearby areas is too mineralized for use.

Permian System—Lower Permian Series

Admire Group

The Admire Group consists chiefly of clastic deposits but contains thin beds of limestone and some sandstone. Shale predominates in this group of rocks, and the relative softness of the rock is evident in the steep soil-covered slopes, on which the limestone units are evident only as small soil-covered benches. The Admire occupies the steeply inclined slope beneath the scarp-forming Foraker Limestone. The Admire Group has been divided by Moore and Mudge (1956) into three formational units, which in ascending order are the Onaga Shale, Falls City Limestone, and Janesville Shale. In Cowley County the Admire Group has an almost uniform thickness of about 130 feet.

The scale of the map and the discontinuity of the exposures of the Admire Group necessitated mapping the entire group as a unit; it is shown by the symbol Pal on Plate 1.

Onaga Shale

The Onaga Shale is composed of three members: The Towle Shale at the base, the Aspinwall Limestone, and the Hawxby Shale at the top. Thickness of the Onaga ranges from 50 to 70 feet in the county.

The Towle Shale Member is composed chiefly of red and gray shale, which is sandy in some places. The thickness of the unit ranges from about 13 to 20 feet.

The Aspinwall Limestone Member commonly forms the lowest bench on the steep slope of the Admire outcrop. This unit is composed of limestone in the upper part and shaly limestone in the lower part. Mollusks and productid brachiopods are common in the upper part. In Cowley County the thickness of this unit ranges from 1 to 3 feet or slightly more.

The Hawxby Shale Member is chiefly a gray shale, but it contains some red shale in the lower part and a lenticular sandstone in the upper part. Its thickness in the county ranges from 35 to 45 feet.

Natural gas is produced from sandstone in the Admire Group, and although the sandstone in the Hawxby Shale Member has not been definitely correlated with the gas-producing sandstone, it is believed to be the principal producer of natural gas in the area. The helium content of the gas from some wells in the Admire is relatively large (as much as 2 percent) compared to the natural gas from other wells, which may contain only a trace of helium.

A few springs issue from the sandstone in the Hawxby, but no wells are known to obtain water from this sandstone. Small yields of good water probably could be obtained from it near the outcrop, but owing to the topographic location of the outcrop and to the small demand for water in this area, which is principally grassland, this source of water has not been utilized.

Falls City Limestone

The Falls City Limestone is composed of an upper thin slabby unit, a middle massive unit, and a lower slabby to platy unit. The limestone is gray to blue gray and weathers yellow orange. The upper two units are hard, brittle limestone, which breaks into conchoidal chips and contains fragments of crinoid stems and sparse mollusks and brachiopods. The thickness of the formation ranges from about 3 to 5 feet in exposures in the county.

Little if any water is available to wells from the Falls City Limestone.

Janesville Shale

The Janesville Shale is composed chiefly of clastic deposits. Two shale members and one limestone member having an aggregate thickness of about 54 to 64 feet make up this unit.

The lowermost member, the West Branch Shale, is about 20 feet thick and is composed of greenish-gray to bluish-gray and red shale containing some sandy shale and, locally, sandstone in the upper part.

The Five Point Limestone Member, which overlies the West Branch, is a massive to slabby limestone, which is dark brownish gray to blue gray on fresh breaks and yellow orange on weathered exposures. Mollusks and brachiopods are common throughout the bed. The Five Point generally forms the first bench below the Foraker Limestone on the slope of the Admire outcrop, but exposures of the limestone are rare. The thickness of this member ranges from 2 to 4 feet in the few exposures in the county.

The Hamlin Shale Member, the uppermost member of the Admire Group, is chiefly dark-gray clastic material, though it contains some red shale, and in some places it contains sandstone in the lower part. An impure yellow-brown porous limestone (Houchen Creek bed) lies 10 to 20 feet below the top of the Hamlin. In some places this bed forms a bench on the Admire slope, but rarely, except in fresh cuts, is it exposed.

Part of the gas produced from the Admire in Cowley County is probably obtained from the sandstone lenses in the Janesville Shale, but these sandstone bodies are not as continuous as those in the Hawxby Member of the Onaga and are not as productive.

Water in small quantities is probably available near the outcrop of the sandstone bodies in the Janesville, but none of the wells visited utilized this source of supply. Logs of deep wells in the upland area west of the outcrop of the Foraker Limestone do not record water from these sandstone bodies.

Council Grove Group

The Council Grove Group comprises seven shale formations and seven limestone formations having a total thickness in Cowley County of about 300 feet. The rocks that make up this group have a much different appearance on the outcrop than those of the underlying Admire and Wabaunsee Groups. The limestone formations are generally much thicker than those of the underlying groups, and the limestones of the Council Grove weather gray to nearly white instead of the characteristic tan brown of the Admire limestones. Most limestone units in the Council Grove Group contain chert, whereas those of the underlying groups contain little if any chert. The rock units of the Council Grove Group are discussed in ascending order.

Foraker Limestone

The three members that compose the Foraker Limestone are, in ascending order, the Americus Limestone, Hughes Creek Shale, and Long Creek Limestone. The thickness of the Foraker in Cowley County is about 50 feet. The formation is characterized by thick-bedded limestones containing much chert and minor amounts of shale and shaly limestone. The chert is interstratified with the limestone beds and commonly appears as nodular and lenticular masses parallel with the bedding planes. The chert is blue gray on fresh breaks but tan where weathered. An outstanding characteristic of the Foraker is the presence of many large fusulinids in both the chert and the limestone. In some places the thin beds are composed almost entirely of fusulinids. The presence of these fossils in the chert and the topographic position of the Foraker as the capping rock above the steep slope formed on the Admire and Wabaunsee rocks serve to identify it in southern Kansas.

The Foraker Limestone and the overlying Johnson Shale are shown on Plate 1 by the symbol Pcgl.

A representative section through the Foraker Limestone, measured along the railroad cut about a quarter of a mile east of the east line of Cowley County, in sec. 3, T. 31 S., R. 8 E., is given below:

	Thickness (feet)
PERMIAN SYSTEM—Lower Permian Series	
Council Grove Group	
Johnson Shale	
Shale, gray; contains thin limestone streaks and many fossils	26±
Foraker Limestone	
Long Creek Limestone Member	
Limestone, thin bedded to slabby in upper part; some massive limestone in lower part; contains many small fusulinids	10.1
Hughes Creek Shale Member	
Limy shale to shaly limestone, thin bedded, soft	5.0

	Thickness (feet)
Limestone, cherty, massive, thick bedded in part; contains many large fusulinids	15.0
Shale, gray; contains thin beds of limestone	9.6
Americus Limestone Member	
Limestone, dark blue gray, dense; fusulinids in upper part, a few small chert nodules in middle part	4.3
Shale, dark gray to nearly black	1.8
Limestone, blue gray; fusulinids abundant near top, small rounded pebbles in lower part	2.5
Total thickness of Foraker Limestone	48.3
Admire Group	
Janesville Shale	
Hamlin Shale Member	
Shale, dark gray	4+

In Cowley County the Americus Limestone Member of the Foraker Limestone is composed of dense blue-gray limestone, 4 to 9 feet thick. The unit generally consists of two limestone layers separated by gray to very dark gray shale. Chert nodules are common in the upper limestone, and fusulinids are present in both limestone layers.

The Hughes Creek Shale Member overlies the Americus. In northern Kansas this unit is a gray to dark-gray shale, but in southern Kansas it contains much limestone and chert. In Cowley County the Hughes Creek is composed of shaly limestone, limestone and chert, and gray shale. The upper part of the unit is composed of massive to thin-bedded light-gray limestone containing much chert in the thick-bedded units. Fusulinids are present in both the limestone and the chert. In Cowley County the Hughes Creek ranges in thickness from 25 to 35 feet.

The Long Creek Limestone, the uppermost member of the Foraker Limestone, is composed of gray to tan limestone, which weathers light gray to nearly white. The Long Creek is generally more slabby and thin bedded than the underlying members of the Foraker. This unit contains sparse chert and is less resistant to weathering than the Hughes Creek or Americus; hence its outcrop may be a considerable distance back from the escarpment formed by the Hughes Creek and Americus. Small fusulinids are present throughout the Long Creek. A massive bed about 1 foot thick, which lies near the base of the Long Creek, characteristically breaks into huge slabs that form a conspicuous belt along the outcrop. In Cowley County, the Long Creek ranges in thickness from about 8 to 12 feet.

A few wells obtain water from the Foraker in northeastern Cowley County. Yields are generally small and the water is hard but otherwise good. Springs along the outcrop in northern and central Cowley County yield water from the Foraker, but inasmuch as yields from these springs are dependent on weather conditions, they fluctuate greatly with the wet and dry seasons; many of the springs cease flowing in late summer. A spring in the NW cor. sec. 29, T. 32 S., R. 8 E. (32-8-29bbb, Table 11) flowed at an estimated rate of 50 gpm (gallons per minute) in early June 1958, but flow had diminished to about 5 gpm in late August 1958. Logs of holes drilled for oil in southeast Cowley County do not record water in the Foraker.

Johnson Shale

In Cowley County the Johnson Shale ranges in thickness from about 20 to 30 feet and is composed of shale containing thin beds of limestone. The formation is poorly exposed in the county, occupying the grassy slope between the Foraker Limestone below and the Red Eagle Limestone above. The upper few feet of the Johnson is composed of dark-gray shale overlying about 10 feet of gray shale containing thin nodular beds of limestone; the lower part is composed of very limy shale. Fossils are generally abundant in the upper part of the formation, pelecypods and productid brachiopods being the most abundant.

Red Eagle Limestone

The Red Eagle Limestone is about 20 feet thick in Cowley County. In northern Kansas two limestone members and an intervening shale member are recognized, but in Cowley County the formation is almost entirely limestone; the members are separable in the county, however, according to their faunal and lithologic character.

The Red Eagle Limestone and the overlying Roca Shale are shown on Plate 1 by the symbol Pcg2.

A section measured by O'Connor and Jewett (1952) in a road cut along Kansas Highway 38 in sec. 21, T. 32 S., R. 8 E., is given below:

	Thickness (feet)
PERMIAN SYSTEM—Lower Permian Series	
Council Grove Group	
Red Eagle Limestone	
Howe Limestone Member	
Limestone, speckled gray, tan, and brown; spergenite of shell fragments, ostracodes, bryozoans, gastropods, echinoid fragments, and fusulinids (exposed)	2.8
Bennett Shale Member	
Limestone, tan gray, fine grained	6.4
Limestone, massive, hard, part brecciated; light to medium gray; dark-brown fossil molds; contains sparse bryozoans, fusulinids, ostracodes, foraminifers, brachiopods, and echinoderm fragments	5.1

	Thickness (feet)
Shale, gray	0.1
Limestone, gray, hard, fine to medium crystalline; sparse bryozoans, abundant brachiopod and echinoderm fragments	3.8
Shale, tan to gray	0.2
Limestone, medium gray; brachiopods	1.0
Limestone, medium gray, hard, crystalline	0.6
Shale, gray to nearly black, very thin bedded; small fusulinids and fragments of *Orbiculoidea*	0.2
Glenrock Limestone Member	
Limestone, grades laterally into limestone nodules interbedded with shale; contains sparse echinoderm fragments, small fusulinids, ostracodes, gastropods, and brachiopods	0.5
Total thickness of Red Eagle Limestone	20.7
Johnson Shale	
Shale, light gray and tan	0.4
Shale, gray, thin bedded; nodular to limy siltstone and tan-gray to dark-gray thin-bedded shale; upper part contains bryozoans, crinoid fragments, *Nucula* and other clams, *Ambocoelia*, *Chonetes*, abundant *Linoproductus*, and *Juresania*	4.6

The Glenrock Limestone is the lowermost member of the Red Eagle Limestone. In Cowley County the Glenrock is probably not more than 1 foot thick and is composed of nodular gray limestone containing fusulinids, brachiopods, bryozoans, gastropods, and ostracodes.

The Bennett Shale member of the Red Eagle Limestone is about 18 feet thick and is almost entirely limestone. The only shale present is in the partings in the limestone and at the base of the member and is generally not more than 0.2 foot thick. The limestone of the Bennett is massive, crystalline, and medium gray, and contains chiefly fusulinids, gastropods, ostracodes, brachiopods, and bryozoans. The lowermost bed of the Bennett contains a persistent *Orbiculoidea* fauna, which is not found in beds above nor in the underlying Glenrock, hence serves as an aid in identifying the Bennett and Glenrock.

The uppermost member of the Red Eagle is the Howe Limestone. In Cowley County this member is about 2.5 to 3 feet thick in most exposures but may be thicker in the southern part of the outcrop area and in the subsurface. The Howe is a massive, hard, gray-brown to buff limestone. The weathered surface has a granular texture, owing to uneven weathering of the calcareous fossils and the calcite matrix. Tiny gastropods, ostracodes, and fusulinids and fragments of brachiopods are the principal fossils. The buff color and the weathering characteristics aid in the identification of the Howe.

Little if any water is available to wells from the Red Eagle Limestone. Shallow, large-diameter wells in the proper topographic position may yield small quantities of water from the formation, but such wells probably would not provide a dependable supply. Nearly the entire area of outcrop of the Red Eagle is used for grazing, and surface water is generally used.

Roca Shale

The Roca Shale is about 15 feet thick in Cowley County. The formation occupies the grassy slope between the Red Eagle Limestone below and the Grenola Limestone above and is poorly exposed except in road cuts and in small ravines. The Roca is composed of gray to brownish-gray shale containing very thin nodular limestone beds in the upper part and red shale in the lower 10 feet. In some areas the lowermost beds are green.

The Roca is of little or no importance as a source of ground water.

Grenola Limestone

The Grenola Limestone comprises three limestone members and two shale members. The thickness of the formation in the county ranges from about 33 feet in the northern part of the outcrop area to about 54 feet in southern Cowley County. The increase in thickness is due principally to an increase in thickness of the upper member of the formation.

The Grenola Limestone and the rock units above it to the base of the Crouse Limestone are shown on Plate 1 by the symbol Pcg3.

A section measured by N. Gary Lane (1958) along the Santa Fe Railroad and an adjacent small stream in the SE¼ sec. 4, T. 31 S., R. 8 E., is given below:

	Thickness (feet)
Grenola Limestone (35.9 feet)	
Neva Limestone Member (17.3 feet)	
28. Limestone, massive, wavy bedded, gray chert layer in center; top of limestone contains small *Osagia,* sparse fusulinids throughout ..	2.2
27. Shale, calcareous, light brown; echinoid spines, fenestrate bryozoans,	0.7
26. Limestone, medium bedded, gray, weathers light yellow gray; robust fusulinids, fenestrate bryozoans	2.1
25. Limestone, thin bedded, flaggy, light gray; echinoid spines, calcareous foraminifers, fenestrate bryozoans	1.4
24. Shale, blocky, very calcareous, light yellow brown; fusulinids, crinoid stems, calcareous foraminifers	0.5
23. Limestone, thin bedded, shaly to platy, light gray to whitish brown; abundant fusulinids near base	1.0
22. Limestone, thin bedded to medium bedded, gray to light brown; gray chert nodules 1.3 feet below top; fusulinids, ramose bryozoans, large shell fragments, sparse ostracodes	5.1

	Thickness (feet)
21. Shale, platy, dark gray, two thin, nodular limestone beds at base. Shale contains *Composita, Meekella, Dictyoclostus, Hustedia, Chonetina,* fusulinids, ramose and fenestrate bryozoans, echinoid spines and plates, sparse conodonts, selacian remains, and *Ditomopyge?*	2.2
20. Limestone, thin bedded, nodular, blue gray; small fusulinids, ramose bryozoans, sparse ostracodes	2.1
Salem Point Shale Member (6.1 feet)	
19. Shale, platy, calcareous, dark gray; a thin, nodular, blue-gray limestone in center containing abundant small high-spired gastropods	2.4
18. Limestone, argillaceous, blue gray to dark gray, irregular tubelike nodules on lower bedding plane; contains sparse small well-rounded, light-gray limestone fragments, small gastropods, sparse crinoid stems	0.2
17. Shale, platy, dark gray; charophytes, very sparse selacian remains	0.3
16. Limestone, nodular, argillaceous, dark gray brown to light yellow brown; numerous small *Ammovertella*	0.8
15. Shale, platy, gray, nonfossiliferous; includes two thin earthy limestone beds containing *Aviculopecten, Septimyalina, Pleurophorus,* and small gastropods	1.5
14. Limestone, wavy bedded, light brownish gray; numerous pectinoid fragments, small high-spired gastropods	0.2
13. Shale, blocky, dark gray brown, nonfossiliferous	0.7
Burr Limestone Member (4.1 feet)	
12. Limestone, dense, limonitic, blue gray; abundant *Osagia* and small high-spired gastropods; separated from bed 11 by 0.1-foot brown shale parting	2.6
11. Limestone, dense, blue gray; abundant *Osagia,* crinoid stems, small gastropods, ostracodes	1.3
10. Limestone, shaly, flaggy, limonitic, brownish gray; large pectinoid fragments, sparse crinoid stems, echinoid spines	0.2
Legion Shale Member (3.8 feet, upper 2.7 feet exposed)	
9. Shale, blocky, slightly silty, hard, light brown to yellow brown; productid spines, abundant *Cavellina*; two 2-inch limestone beds, dense, earthy, nonfossiliferous, in center	3.8
Sallyards Limestone Member (4.6 feet)	
8. Limestone, medium bedded, limonitic, light gray; very abundant *Osagia,* small high- and low-spired gastropods	2.9
7. Limestone, thin bedded, wavy bedded, argillaceous, grayish brown; sparse large pectinoid fragments	0.9
6. Limestone, medium bedded, light gray; small gastropods, ostracodes, small shell fragments	0.5
5. Limestone, wavy bedded, yellowish gray to gray, weathers light brown; long pectinoid fragments, sparse small gastropods	0.3
Roca Shale (8.6 feet exposed)	
4. Shale, clayey, blocky, light yellow gray to brown, green mottling at base, nonfossiliferous	2.1
3. Shale, clayey, blocky, light maroon	2.7
2. Shale, light green, deeply weathered	0.8
1. Shale, silty, calcareous, red to light maroon	3.0

The Sallyards Limestone is the lowermost member of the Grenola Limestone. This member is a relatively thin limestone composed of bluish-gray, massive to thin-bedded limestone about 3 to 5 feet thick. The Sallyards weathers to a rough, dark-gray surface as a result of differential weathering of the contained fossils and the matrix. Pelecypods, bryozoans, and crinoid fragments are common, and the alga *Osagia* is common in the upper part.

The Legion Shale Member, which overlies the Sallyards, is about 3 to 8 feet thick. It is composed of gray to buff shale, and in some areas it contains beds of limestone. It is sparsely fossiliferous but contains *Osagia* in the upper part, and the beds of limestone contain a sparse molluskan fauna. Pelecypods and the brachiopod *Juresania* are the most common fossils.

The Burr Limestone Member, overlying the Legion, is about 4 feet thick and consists of two massive blue-gray to dark-gray dense limestone beds containing *Osagia,* separated by a very thin shale. In some places a third limestone, thin and somewhat flaggy, is present in the base.

The Salem Point Shale Member, which overlies the Burr Limestone, consists of gray to dark-gray shale containing thin limestone beds. A "box-work" limestone near the middle of the unit is fairly persistent. The Salem Point contains small gastropods, and pelecypods are present in the lower part.

The uppermost and most conspicuous member of the Grenola is the Neva Limestone Member. It is buff on fresh breaks, but gray where weathered, and characteristically forms a ledge of very rough limestone on the outcrop. The Neva forms a pronounced bench on the surface between the escarpment formed by the Wreford Limestone and the escarpment formed by the Foraker Limestone (Pl. 7). The Neva thickens southward from about 17 feet in the northern part of the outcrop to about 25 feet in the southern part of the county. The member contains chert in the upper part, and the amount of chert increases to the south. Fusulinids are plentiful throughout the member.

A few wells obtain water from the Grenola in the vicinity of Grand Summit. Yields are generally small and the water is hard but otherwise good (Table 6). Small springs issue from the Grenola, principally from the Neva Member, in the northern part of the area of outcrop. Flow from these springs is dependent on weather conditions; many of the springs cease flowing in periods of prolonged drought. No wells or springs were observed that obtain water from the Grenola in the southern part of the county.

Eskridge Shale

The Eskridge Shale is composed principally of gray, red, and green shale but also contains some limestone. The formation is poorly exposed, as it occupies the lower part of the grassy slope between the Grenola Limestone and the Crouse Limestone. A persistent limestone about 1 foot thick, in the lower middle part of the formation, in some places forms the lowest small bench on the slope between the Grenola and the Crouse. The Eskridge ranges in thickness from about 21 feet in the northern part of the county to about 35 feet in the southern part. Locally the upper part is very fossiliferous. The Eskridge is of little importance as an aquifer.

Beattie Limestone

The Beattie Limestone is composed of two limestone members and one shale member. Its total thickness ranges from about 22 feet in the northern part of the county to about 11 feet near the south boundary. The Beattie forms a small bench near the middle of the grassy slope between the Grenola and the Crouse (Pl. 7). The formation is poorly exposed, in road cuts and small ravines, for only short distances laterally.

The lowermost member of the Beattie Limestone is the Cottonwood Limestone Member, which maintains a uniform thickness of about 5 or 6 feet across most of the state. In northern and central Kansas the Cottonwood is a light-buff to nearly white massive limestone containing abundant fusulinids, but in the southern part it becomes shaly. Generally, exposures in Cowley County are composed of thin limestone layers and interbedded thin calcareous shale layers containing a large variety of fossils. This fauna is similar to that of the overlying Florena Shale Member. Thickness of the Cottonwood ranges from about 6 feet in northern Cowley County to about 5 feet in the southern part. The Cottonwood maintains a thickness of 5 feet for about 20 miles into Oklahoma and there thins to only a few inches.

The Florena Shale Member, overlying the Cottonwood, is composed of gray to dark-gray shale containing a rich fauna. *Chonetes granulifer* is abundant in the outcrop area, and other brachiopods, pelecypods, bryozoans, and small trilobites are common. The Florena thins from about 11 feet in northern Cowley County to about 2.5 feet near the southern border.

The uppermost member of the Beattie Limestone is the Morrill Limestone, which commonly is about 3.5 feet thick in the southern part of Cowley County but may be as much as 9 feet thick in the northern part, where it may be divided into three units. The upper of these three units is a whitish irregular-bedded limestone containing algae. The middle unit is composed of massive bluish-gray limestone, which weathers to a light-gray, deeply pitted surface. The outcrop of this bed has a very rough appearance caused by the weathering out of softer material filling vertical borings in the rock. The lower unit of the Morrill is a buff thin-bedded nodular limestone interbedded with fossiliferous shale. Only the lowermost two beds were observed in the southern part of the county.

A few wells obtain small quantities of water from the Beattie Limestone in Cowley County, but the formation is of little importance as an aquifer. On some exposures small seeps issue above the Florena Shale Member. These seeps support a line of shrubs or brush along parts of the outcrop of the Beattie.

Stearns Shale

The Stearns Shale is principally gray shale but it contains some red shale near the middle and some nodular limestone in the upper and lower parts. The thickness of the formation ranges from about 6 to 10 feet in the county. Brachiopods and pelecypods are present in the nodular limestone of the upper part. The formation is poorly exposed and occupies the slope between the underlying Beattie Limestone and the overlying Bader Limestone. The Stearns is of no importance as an aquifer in the county.

Bader Limestone

The Bader Limestone is composed of two limestone members and one shale member having a total thickness of about 26 feet in Cowley County. The Bader forms a small bench on the upper part of the slope between the Crouse Limestone and the Grenola Limestone. The Bader is poorly exposed, mainly in small ravines and fresh road cuts.

The Eiss Limestone Member, the lowermost member of the Bader Limestone, is about 10 feet thick. It may be divided into two limestone units separated by a thin shale. The lowest unit is composed of buff to gray thin-bedded limestone and is rarely exposed. The upper unit is composed of about 2 feet of blue-gray massive hard limestone, which weathers to a gray pitted surface much like the upper bed in the Morrill Limestone Member of the Beattie. This upper 2-foot bed of limestone is the most commonly exposed part of the Bader Limestone.

The Hooser Shale Member, which overlies the Eiss, is about 9 feet thick in the county. It is composed of buff to yellow shale in the upper part and gray to green shale in the lower part. Thin beds of limestone are present in the middle part of the Hooser.

The Middleburg Limestone is the upper member of the Bader. This member is about 5 to 8 feet thick and is composed of gray thin-bedded limestone containing thin shale partings throughout. The limestone weathers whitish and is sparsely fossiliferous. Although exposed in only a few places, this limestone forms a bench on the slope between the Crouse Limestone and the Grenola Limestone. Where the massive bed in the Eiss crops out, it is below this bench.

The Bader Limestone yields small quantities of water to a few wells, but it is not an important aquifer in the county.

Easly Creek Shale

The Easly Creek Shale overlies the Bader Limestone and is composed of 10 to 15 feet of red and gray shale. In some places the formation is somewhat limy and is sparsely fossiliferous. The unit has very few exposures and is of no importance as an aquifer.

Crouse Limestone

The Crouse Limestone is about 8 to 12 feet thick in Cowley County. Although the formation is not divided into named members, three separate units consisting of limestone and small amounts of shale can be recognized. The upper unit consists of yellowish to buff flaggy limestone about 3 to 4 feet thick, which weathers readily and crops out in very few places. The middle unit is composed of about 4 to 5 feet of dense bluish-gray limestone, which contains some chert locally. In southern Cowley County this unit contains vertical pits or borings similar to those in the Wreford Limestone higher in the section or in the Morrill Limestone Member of the Beattie Limestone; however, the pits in the Crouse are larger and more widely spaced and have nearly vertical sides, thus giving the outcrop a smoother appearance than that of the Wreford or the Morrill. The lower unit of the Crouse is composed of about 2 or 3 feet of nodular thin-bedded shaly limestone containing many algal colonies. Locally these *Ottonosia* or "biscuit algae" compose most of the unit. This unit of the Crouse Limestone is softer than the overlying beds and weathers faster, tending to undercut the overlying massive middle unit, allowing it to break into large slabs on the outcrop in central Cowley County. The middle unit thus forms a distinctive outcrop, and it is the base of this unit that is mapped on Plate 1 and forms the lower boundary of the area shown by the symbol Pcg4. This area includes also the overlying beds to the base of the Wreford Limestone. The outcrop as mapped is practically the same as the base of the Crouse Limestone, inasmuch as the softer, lower unit undercuts the massive beds, and the outcrop is nearly vertical to the base of the Crouse. Southward from about the center of T. 34 S. the Crouse Limestone thins and does not crop out as prominently as in the central part of the county. A section through the Crouse Limestone measured along the road east of Dexter in the SE¼ NW¼ sec. 18, T. 33 S., R. 7 E., is given below.

	Thickness (feet)
Blue Rapids Shale (16 feet)	
Shale, gray at top, red in lower part	8.5
Shale, gray, clayey and sandy	7.5
Crouse Limestone (11.8 feet)	
Limestone, yellowish gray, flaggy to massive; contains some chert	3.1
Shale, gray, very limy	0.8
Limestone, massive, pitted; contains chert	4.6
Limestone, shaly, soft; contains many algal colonies; weathers more readily than overlying limestone	2.0
Limestone, massive, gray	1.3
Easly Creek Shale (8.5 feet exposed)	
Shale, gray at top, red in lower part	8.5

The Crouse Limestone yields small quantities of water to wells near the outcrop but is not an important aquifer in the county.

Blue Rapids Shale

The Blue Rapids Shale is composed of gray and red shale and a minor amount of limestone; aggregate thickness ranges from about 17 feet in southern Cowley County to about 22 feet in the northeastern part of the county. The uppermost part of the formation is composed of gray shale underlain by red shale. Next below the red shale is a persistent limy zone, which may contain one or more thin limestone beds. The lowest unit of the Blue Rapids is a gray clay shale, which is sandy locally. The Blue Rapids is of little importance as an aquifer in the county.

Funston Limestone

The Funston Limestone is composed of two limestone layers separated by a limy shale bed, the total thickness in the county ranging from 9 to 12 feet. The lowest unit is a dense blue-grey limestone 1 to 2 feet thick, which breaks into large blocks on the outcrop. Above the lower limestone is about 5 to 8 feet of light-gray limy shale, which is fossiliferous in some places. The uppermost part of the Funston is composed of 2 to 4 feet of flaggy to massive limestone, which in some areas is very fossiliferous. It weathers readily, and generally only a thin massive bed at the base of this upper unit is observed on the outcrop. The Funston is well exposed in northeastern Cowley County, where it is marked by almost continuous exposures on the slope between the Crouse Limestone and the Wreford Limestone, but farther southward the formation is not well exposed, and in many places only a small bench is observed at its position between the Crouse and Wreford.

The Funston is not an important aquifer in the county. A few wells obtain water from the formation in local areas of favorable topographic and structural conditions.

Speiser Shale

The Speiser Shale consists of gray, green, and red shale and small amounts of limestone and sandstone. Its thickness in Cowley County ranges from about 29 feet in the northeastern part to about 35 feet in the southern part. The upper 10 feet of the Speiser is composed of gray shale containing thin limestone beds. This bed is abundantly fossiliferous. *Derbyia, Juresania,* and *Septimyalina* are the most common fossils in this unit. The upper gray limy shale beds are underlain by about 25 feet of red and green shale, which in some parts of southern Cowley County contains a channel sandstone. This sandstone was observed in several outcrops south of Dexter but was not observed in northern Cowley County. The sandstone is, in general, fine grained and light tan on a fresh break and rusty brown where weathered. In some places the sandstone is cross bedded and discontinuous on the outcrop, grading from 10 or 12 feet of sandstone to red or maroon shale in short distances laterally.

No wells were observed that yielded water from the sandstone in the Speiser, but some water should be available in the sandstone.

Chase Group

The Chase Group in Cowley County is composed of interbedded limestone, in part cherty, and shale, having a total thickness of about 350 feet, of which about half is limestone and half is shale. The limestone beds weather to a light-buff, gray, or nearly white surface, and the shale units are gray, chocolate brown, and red. Chert is found chiefly in the two lower limestone formations and is probably the most noticeable characteristic feature of the group. The Wreford Limestone is the lowermost formation in the group and it forms a prominent escarpment along the outcrop. The uppermost formation of the Chase Group is the Nolans Limestone, which is not as well exposed as the other limestone formations of the group because the rocks composing it are not as resistant to weathering as the underlying rocks. The formations composing the Chase Group are, in ascending order, the Wreford Limestone, Matfield Shale, Barneston Limestone, Doyle Shale, Winfield Limestone, Odell Shale, and Nolans Limestone. More than half the surface area of the county is occupied by rocks of the Chase Group, which extend from the Flint Hills escarpment on the east to the divide between Arkansas and Walnut Rivers on the west.

Wreford Limestone

The Wreford Limestone, composed of limestone, chert, and a small amount of shale, is the lowermost formation of the Chase Group. Having a total thickness of about 33 feet in the county, the formation is divided into three members which, in ascending order, are the Threemile Limestone, the Havensville Shale, and the Schroyer Limestone. The Wreford is the capping ledge at the top of the second prominent eastward-facing escarpment in eastern Cowley County. Between this escarpment and the escarpment capped by the younger Barneston Limestone, the Wreford crops out on the relatively flat upland, which has a gentle westward slope about equal to the regional dip in the area. Relatively narrow steep valleys cut into or through the Wreford result in many good exposures of the formation. Small outliers of the Wreford cap hills in the major valleys and east of the main Wreford escarpment (Pl. 1). The most striking features of the formation are the chert beds and the several massive limestone beds, which weather to a deeply pitted surface. These pits are believed to be developed in borings of clams that burrowed into the soft, limy muds before consolidation. These pits are similar to those in the upper part of the Crouse Limestone, but they are more closely spaced and are much rougher on the weathered outcrop. The depositional environment of the Wreford Limestone has been described by Hattin (1957). A section through the Wreford, measured by Bass (1929) and located near the center of the north line of sec. 10, T. 34 S., R. 6 E., is given below.

	Thickness (feet)
Matfield Shale	
Wreford Limestone	
Schroyer Limestone and Havensville Shale Members	
Limestone, massive, deeply pitted, dingy white, capping a covered slope	5.5
Limestone, deeply pitted, light gray, capping covered slope strewn with chert; no chert above	6.0
Limestone, massive, light gray; contains chert; weathers to a relatively smooth surface	5.0
Threemile Limestone Member	
Limestone, thick bedded, light gray; contains no chert here, though locally this bed contains scattered chert and is pitted	5.5
Limestone, light buff, and interbedded chert	9.0
Limestone, weathered, light buff to brown; contains no chert	2.0
Speiser Shale	

The Threemile Limestone Member of the Wreford Limestone is composed of limestone and chert having a total thickness of 17 to 19 feet. The chert is in the lower two-thirds of the member and is interbedded with thin beds of limestone; it appears in layers and as scattered nodules.

The upper third of the Threemile is composed of limestone that in some places weathers to a deeply pitted surface (Pl. 8A). Small nodules of chert are scattered throughout this member. The contact of the Speiser Shale and the Threemile was mapped in the field and is shown on Plate 1 as the lower boundary of the area designated by the symbol Pcl.

The Havensville Shale Member overlies the Threemile, and in Cowley County it is composed principally of limestone and interbedded chert containing shale at the top and bottom of the member. Generally the shale is less than 1 foot thick, and more chert is present in the lower part of the limestone. Because the shale is thin and the slopes are heavily strewn with chert, the shale is not generally exposed except in fresh cuts. The shale in exposures is yellowish gray, silty, and calcareous. Total thickness of the Havensville Member is about 5 to 8 feet in Cowley County.

The Schroyer Limestone Member is the upper unit of the Wreford Limestone and is about 6 feet thick in Cowley County. This member is not as resistant to weathering as the Havensville Shale and the Threemile Limestone Members, and generally its outcrop is some distance back from the escarpment capped by the lower members. Chert occurs in layers and as nodules in the lower part of the unit. The upper part of the Schroyer is composed of limestone that is deeply pitted on the weathered surface.

Osagia-like algae, bryozoans, productids, crinoids, and echinoids are common in the fossiliferous zones in the Wreford, and the clams *Aviculopinna* and *Allorisma* are found in the pitted limestones, generally in the base of the borings.

The Wreford is an important aquifer in Cowley County, and many wells obtain water from it. Water seems to be transmitted through fractures in the chert. Yields, which range from a few gallons an hour to about 20 gpm, are not as large as from the Barneston Limestone, but they generally are adequate for domestic and stock use. Near the outcrop the rocks are almost drained, and the yields of wells may be very small. Water from the Wreford is generally hard but otherwise good. In some areas, however, the water may be polluted and in the deeper parts of the formation it may be mineralized.

Matfield Shale

The Matfield Shale, having a thickness ranging from about 55 to 60 feet, consists of varicolored shale interbedded with gray limestone. The Matfield is divided into the Wymore Shale Member, Kinney Limestone Member, and Blue Springs Shale Member. The upper boundary of the Matfield is not well marked, and the contact with the Florence Limestone

PLATE 8.—**A**, Typical weathering of Threemile Limestone Member of Wreford Limestone. Cylindrical openings are clam borings enlarged by weathering. Photograph by D. E. Hattin. **B**, Outcrop of Florence Limestone Member of Barneston Limestone, at SW cor. sec. 28, T. 34 S., R. 5 E. The Florence here is about 16 feet thick.

Member of the Barneston Limestone is placed at the base of the lowest bed that contains chert. The uppermost few feet of the Matfield contain much shaly limestone and limy shale. The lower boundary of the Matfield is generally well marked and the contact is placed at the top of the uppermost massive bed in the Wreford Limestone.

The outcrop of the Matfield is generally narrow, occupying the steep slope beneath the escarpment made by the Barneston Limestone, but it is wider in areas where a thin remnant of the lower part of the Matfield overlies wide benches of the Wreford on long dip slopes. The Matfield is shown on Plate 1 as the upper part of the area designated by the symbol Pcl. A section measured in the center of sec. 3, T. 35 S., R. 5 E., above and below cuts in the railroad and the road, is given below.

	Thickness (feet)
Barneston Limestone	
Florence Limestone Member (5.5 feet exposed)	
Limestone and chert, thin interbedded layers	4.0
Limestone, massive, buff, weathers gray; contains some chert	1.5
Matfield Shale	
Blue Springs Shale Member (34.2 feet)	
Shale, gray, limy	4.0
Covered, mostly shale, some red shale	25.0
Shale, gray, limy; thin limestones near base	5.2
Kinney Limestone Member (14.3 feet)	
Limestone, gray, weathers dark gray; has sandy rough appearance; contains fusulinids	2.3
Shale, gray	1.0
Limestone, upper part is yellow gray, slabby; lower 1.3 feet is massive	2.3
Shale, gray to yellow gray, limy	6.2
Limestone, gray, weathers gray brown; contains silicified fossils	2.5
Wymore Shale Member (12.5 feet)	
Shale, gray to yellow buff, limy	4.0
Covered, mostly shale	8.5
Wreford Limestone	
Schroyer Limestone Member (4 feet exposed)	
Limestone, massive, white to buff; contains brachiopods	2.5
Shale, gray buff, limy	0.5
Limestone, massive, white	1.0

The Wymore Shale is the lowermost member of the Matfield Shale and in Cowley County is composed of about 10 to 15 feet of maroon and gray shale. It is generally poorly exposed except in small draws and fresh road cuts.

The Kinney Limestone Member, overlying the Wymore, is composed of gray to buff limestone and interbedded gray limy shale and has a total thickness ranging from about 13 to 18 feet in the county. The fauna is composed principally of brachiopods, and in the southern part of the county these fossils are silicified. The uppermost limestone contains fusulinids and many small crinoid fragments. The fossils are partly silicified and upon weathering give a rough, sandy appearance to the outcrop.

The uppermost member of the Matfield is the Blue Springs Shale. This member is composed of red shale, gray limy shale, and limestone. The red shale is restricted to the lower part; much limestone and limy shale is found in the upper part. In northern Cowley County a limestone about 6 feet below the top of the Blue Springs is very persistent, but in southern Cowley County it was not observed. Brachiopods are common in the limy shales of the upper part of the Blue Springs. Fusulinids are present although not common.

The Matfield Shale is not an important aquifer in the county. In areas where the overlying Barneston Limestone does not yield an adequate supply, however, wells have been drilled into the underlying Kinney Limestone Member. Yields from the Kinney range from about 0.5 to 4 gpm. The water is hard but otherwise good.

Barneston Limestone

In northern Kansas the Barneston Limestone comprises the Florence Limestone Member, the Oketo Shale Member, and the Fort Riley Limestone Member. In Cowley County only the Florence Limestone and Fort Riley Limestone Members are present. The thickness of the Barneston in Cowley County ranges from about 80 feet in the northern part to about 65 feet in the southern part. The southward thinning of the formation is due principally to thinning of the Florence Limestone Member, which in northern Cowley County is about 35 feet thick and on the southern border is about 12 feet thick. The Fort Riley Limestone Member thickens somewhat to the south.

The Barneston Limestone occupies the largest area of any of the geologic units mapped in the county. Most of Range 5, all of Range 6, and parts of Ranges 4 and 7 are underlain by the Barneston. The base of the formation is placed at the base of the lowest limestone containing chert in the Florence Member and is mapped on Plate 1 as the lower limit of the area designated by the symbol Pc2. The upper limit of the Barneston is not easily identified. The contact between the Barneston and the overlying Doyle Shale is transitional, the flaggy limestone in the upper part of the Barneston grading into limy shale in the Doyle. This contact, although not sharp, is made evident in the field by a change in soil types formed on the two units and is shown on Plate 1 as a dashed line roughly dividing the area designated by the symbol Pc2. A section including the upper part of the Matfield Shale, the Florence Limestone Member of the Barneston, and all but about 10 feet of the Fort Riley Limestone Member was measured in road cuts from the creek northward to the top of the hill, beginning near the SW cor. sec. 28, T. 34 S., R. 5 E., and is described below.

	Thickness (feet)
Barneston Limestone	
Fort Riley Limestone Member (56.6 feet)	
Limestone, slabby to thin bedded, covered at this locality but exposed across valley to west	10.0±
Limestone, thin bedded to slabby, white	8.0
Limestone, massive, gray to dark gray, surface pitted; contains crinoid fragments	3.0
Shale, limy, platy to flaggy	1.0
Limestone, massive to blocky, gray, weathers dark gray; contains many small crinoid fragments	4.0
Limestone, very thin bedded to platy, light gray; contains many small crinoids and a few productids	6.3
Limestone, dark gray to buff, in 2 beds 18 in. thick; contains echinoid spines	3.0
Limestone, massive to blocky, light gray, weathers dark gray	1.5
Limestone, three massive beds, white, weathers rusty brown; top bed 3 feet thick, middle bed 4.1 feet, and bottom bed 1.5 feet; contains sparse productids (Silverdale Quarry zone)	8.6
Limestone, slabby, light gray, weathers rusty brown	2.5
Limestone, massive to blocky, light gray, weathers dark gray	2.0
Limestone, massive, light gray, weathers rusty brown; contains a few productids and echinoid spines	6.7
Florence Limestone Member (16 feet)	
Limestone and interbedded chert; a series of limestone beds 12 to 16 in. thick, interbedded with chert beds 3 to 6 in. thick; some chert nodules interspersed in the limestone. Chert increases in quantity downward to about two-thirds the distance through the member and then decreases in lower one-third. Echinoid spines, crinoids, and productids occur throughout the limestones; fusulinids in lower 6 or 7 feet. Base of Florence placed at lowest chert-bearing bed	16.0
Matfield Shale	
Blue Springs Shale Member	
Shale, gray, limy; contains *Derbyia*	1.0
Limestone, dense; contains productids, echinoid spines and plates, crinoids, and fusulinids	1.2
Shale, limy; contains many crushed brachiopods	1.1
Limestone, two layers separated by shale; contains *Derbyia*	1.5
Shale, brown to buff, blocky	2.0
Limestone, gray, buff	0.5
Shale, brown to buff and gray	10.0
Covered slope to creek; upper part mostly shale, lower part may contain some limestone	20.0±

Thick-bedded limestone interbedded with chert, having an aggregate thickness of 12 to 35 feet, constitutes the Florence Limestone Member. The limestone beds are relatively soft and have a massive to slabby appearance on the outcrop; they are light buff on fresh breaks but are light gray or white where weathered. The chert, in layers about 3 to 6 inches thick, is interbedded with limestone 12 to 16 inches thick. The chert is nodular, but the nodules are so closely spaced in some places that they seem to be a solid layer of chert (Pl. 8B). Isolated nodules of chert also are interspersed in the limestone. Freshly broken surfaces of the chert are blue gray but weathered surfaces are tan or dark rusty brown. The quantity of chert increases from the top toward the middle of the member, because of a thinning of the intervening beds of limestone, and decreases again toward the bottom. Echinoid spines and plates, crinoid fragments, and productids are common throughout the beds of limestone. Fusilinids are present in the lower half of the member, and the fossils increase in the basal beds. The Florence thins from about 35 feet in the northern part of the county to about 12 feet at the south line. Both the overlying Fort Riley Limestone Member and the underlying Matfield Shale thicken in the south, but it is not clear whether this has had any effect on the thinning of the Florence. The Blue Springs Shale Member of the Matfield Shale has a uniform thickness across the county, and the massive beds in the lower part of the Fort Riley seem to be continuous across the area. It would seem, therefore, that the thickness of the containing beds has little effect on the thickness of the Florence. The upper part of the Florence weathers more readily than the lower part and forms gentle slopes strewn with the residual chert. The lowermost part of the member is more resistant and forms exposures that can be traced over considerable distances.

The Fort Riley Limestone Member is composed almost entirely of limestone, although the upper part contains a few thin shale zones. The lower 25 feet is composed principally of thick-bedded limestone, which is quarried extensively in the southern part of the county for building stone (Pl. 9A). The thickness of the Fort Riley ranges from about 45 feet in northern Cowley County to about 55 feet in the southern part. The contact of the Fort Riley and the Florence is placed at the top of the highest limestone bed that contains chert. In parts of southern Cowley County a thin stylolitic zone separates two beds of limestone, the upper of which contains no chert whereas the lower contains chert. This stylolitic zone may be indicative of a weak zone in the depositional sequence in which there has been solution and redeposition. Individual beds in the lower 25 feet of the Fort Riley can be traced over considerable dis-

PLATE 9.—**A**, Fort Riley Limestone Member of Barneston Limestone near SW cor. sec. 28, T. 34 S., R. 5 E. Beds shown are in Silverdale Quarry zone and are about 12 feet above the base of the member. **B**, Fort Riley Limestone Member near SE cor. sec. 19, T. 32 S., R. 6 E. Section shown is near middle of Fort Riley. Uppermost bed is cross-bedded limestone.

tances and may be continuous across the entire county. Above the massive beds, thin-bedded to platy limestone predominates although a few massive beds and also some thin shale beds are present in this part of the member. In northern Cowley County and northward into Butler County the uppermost beds of the Fort Riley are thick-bedded limestone in which shallow sinks or depressions are common. These sinkholes are caused by solution and probably are related to the joint pattern in the area, as some of the depressions seem to line up with a particular joint when viewed on areal photographs. These sinkholes are especially well developed in the northern part of T. 30 S., R. 5 E. In central Cowley County, principally in the south half of T. 33 S., R. 6 E., there is a fairly thick bedded limestone having a cross-bedded appearance. This bed (Plate 9B) was observed at some outcrops in an area of about 10 square miles but was not observed elsewhere in the county. It lies a short distance below the upper third of the Fort Riley. In the southeastern part of T. 32 S., R. 5 E., and the northeastern part of T. 33 S., R. 5 E., shallow sinkholes have developed in a bed that may be just above the middle of the formation. These sinkholes also are related to the joint pattern in the area, but are not as well developed as those in the northern part of the county.

The Barneston Limestone is the most important bedrock aquifer in the county. It is the most widely used aquifer, principally because of its wide areal extent. Yields of wells and springs in the Barneston depend on topography and structure and may range from only a few gallons an hour to more than 100. The largest yields are obtained in the synclinal area east of the Winfield Anticline and in an area in northern Cowley County where the Florence Limestone Member thickens. Water is transmitted through the formation through solution channels developed along bedding planes and joints in the Fort Riley and through joints and fractures in the chert beds in the Florence. The water is hard but unless locally contaminated is suitable for most uses. Wells more than 200 feet deep may yield water excessive in sulfates.

Doyle Shale

The steep slopes below the Winfield Limestone and the gently rolling slopes above the Barneston Limestone are formed by the Doyle Shale. The Doyle is composed principally of soft rocks that weather readily and, except the uppermost few feet of the formation, are poorly exposed in the county. The Doyle comprises three members, which in ascending order are the Holmesville Shale, Towanda Limestone, and Gage Shale. The thickness of the formation ranges from 75 to 90 feet, and changes considerably over relatively short distances, but generally an entire section of the formation is not exposed in the outcrops. A section measured by Bass (1929), near the middle of the east side of sec. 1, T. 35 S., R. 4 E., is described below.

	Thickness (feet)
Winfield Limestone	
Cresswell Limestone Member (capping hill)	
Doyle Shale	
Gage Shale Member	
Shale, limy, grayish tan, green in lower part, containing thin-bedded, shaly limestone; limestone increases upward; fossiliferous, upper 4 feet contains many limy concretions, which may be algal in origin	11.0
Shale, clayey, maroon, green in lower part	27.0
Shale, clayey, green, chiefly noncalcareous; a bed of limestone composed almost entirely of shells lies about 4 feet above base	19.0
Covered slope, probably mostly shale	10.0
Towanda Limestone Member	
Limestone, light buff to light gray, cherty; contains abundant *Pleurophorus subcostatus*; locally forms a ledge	2.0
Holmesville Shale Member	
Covered slope; shale and limy shale	23.0
Total thickness of Doyle Shale	92.0
Barneston Limestone.	

The Holmesville Shale Member is composed of about 25 feet of limy, gray and buff shale and locally some red shale. The contact with the underlying Fort Riley Limestone Member of the Barneston is not sharp but is a gradational change from limestone to limy shale. Variation in thickness and composition of this gradational zone may account in part for the difference in thickness of the Doyle through the county.

A limestone approximately 2 feet thick that is about 25 to 30 feet above the base of the Doyle Shale is believed to be the Towanda Limestone Member of the Doyle Shale. This limestone is fairly persistent in southern Cowley County and is composed of light-buff or gray limestone, which in some areas contains scattered chert and is very resistant to weathering. North from about T. 34 S. this limestone does not crop out, but in some areas a slight bench is observed at about this position on the slope between the Winfield and Barneston Limestones. *Pleurophorus subcostatus* is common in most outcrops of the Towanda in southern Cowley County.

The uppermost member of the Doyle Shale is the Gage Shale. It ranges in thickness from about 55 to 65 feet in the county and is composed of gray-green shale in the lower part, red or maroon shale in the middle part, and gray-buff limy shale in the upper part. The lime content of the upper part of the Gage increases toward the top, and in places the member contains several thin-bedded shaly limestones. The upper part of the Gage is very fossiliferous, *Derbyia, Allorisma, Deltopecten* and *Pleurophorus* being common. In nearly every exposure observed, the uppermost few feet of the Gage contain small concretions, as much as half an inch in diameter but more commonly a fourth of an inch, which may be of algal origin. This concretionary zone marks the contact with the overlying Winfield Limestone. The logs of some wells north of T. 33 S. indicate the presence of a limestone near the middle or in the lower part of the Gage. This limestone is not persistent and generally is not exposed, but may be the limestone at about the same stratigraphic position that crops out in a small area adjacent to Rock Creek near the county line in T. 30 S., R. 4 E. That limestone is thin bedded to platy and somewhat nodular and is buff on fresh breaks but light gray where weathered.

The Doyle Shale is not an important aquifer in the county but it yields some water to wells from the upper limy zone and from the Towanda Limestone Member. Yields of wells from the upper zone are small, but yields from the Towanda are generally larger, ranging from a few gallons an hour to as much as 50 gpm. In northern Kansas the Towanda is a platy, impure limestone containing many calcite veinlets and it seems to be very permeable. A similar zone may be present in the Towanda in parts of Cowley County where the larger yields of water are obtained.

Winfield Limestone

The Winfield Limestone is the uppermost prominent scarp-forming rock unit in Cowley County. In northern and central Kansas this formation is composed of the Stovall Limestone Member at the base, the Grant Shale Member, and the Cresswell Limestone Member at the top. In Cowley County only the Cresswell Member is recognized. The Winfield Limestone is shown on Plate 1 as the lower part of the area designated by the symbol Pc3. The Cresswell Limestone Member in Cowley County ranges in thickness from about 20 feet to as much as 30 feet. It may be divided into two units, a lower massive unit 10 to 12 feet thick, which forms the conspicuous outcrop, and an upper unit composed of thin-bedded to shaly limestone ranging in thickness from 15 to 20 feet. This upper unit, formerly named the Luta Limestone, is well defined at the base, where the rock changes from thin-bedded limestone to the massive, scarp-forming limestone below. The upper boundary is not well defined, as the rock grades into the overlying Odell Shale. This upper unit was formerly classed as a part of the shale unit overlying the Winfield Limestone, and for mapping, such a classification would be desirable. The

Plate 10.—**A,** Cresswell Limestone Member of Winfield Limestone along highway west of Walnut River in NW¼ sec. 29, T. 32 S., R. 4 E. Upper and lower resistant beds are separated by more easily weathered bed. **B,** Cresswell Limestone Member in SE¼ NE¼ sec. 20, T. 34 S., R. 4 E., near Arkansas City Country Club, showing massive nature of Cresswell in southern Cowley County.

lower unit of the Cresswell Limestone Member is composed of massive, gray-weathering, buff limestone, which in the northern and central parts of the county may be divided, on its weathering characteristics, into three beds. The upper bed, 3 or 4 feet thick, has a rough, sandpaper appearance and the surface is pitted. The rough appearance is caused by many fragments of fossils, partly silicified, which are more resistant to weathering than the surrounding matrix. The middle bed, which ranges in thickness from only a few inches to about 1½ feet, is much less resistant to weathering than the beds above and below and makes a deep indentation in the face of weathered exposures. The lower bed is a massive limestone similar to the top bed and is about 6 feet thick. This bed seems to be more resistant to weathering than the upper bed (Pl. 10A). Southward from the southern part of T. 34 S. the deeply weathered bed is absent, and exposures along the outcrop are composed of one massive ledge 10 to 12 feet thick (Pl. 10B). The most common fossils in the lower, massive part of the Cresswell are *Archaeocidaris* spines and plates, and the brachiopods *Derbyia, Composita,* and productids. The upper thin-bedded unit (formerly called Luta) is very fossiliferous. Bryozoans, *Composita, Derbyia,* and *Chonetes* are the most common fossils. Parts of a small trilobite also are common, and rare specimens of a larger, coiled trilobite, as much as three-fourths of an inch across, were found. Large specimens (as much as 6 inches in diameter) of a cephalopod are found in these beds, but they are rare. A section through the Nolans and Winfield Limestones along the road on "140-foot hill" just south of Arkansas River in the SE¼ SW¼ SE¼ sec. 5, T. 35 S., R. 4 E., is described below.

	Thickness (feet)
Soil cover	3±
Nolans Limestone (10.9 feet)	
Herington Limestone Member	
Limestone, massive, white; contains small chert nodules; nonfossiliferous	5.3
Limestone, white, thin bedded to slabby; contains no chert; small geodes present in lower part; contains *Archaeocidaris* spines	5.6
Paddock Shale Member (7.3 feet)	
Shale, platy, gray to blue gray; contains crinoids, *Deltopecten,* and many fragments of other fossils	7.3
Krider Limestone Member (9.8 feet)	
Limestone, dark blue gray, weathers buff, hard	1.6
Shale, gray, platy	1.0
Limestone, shaly, very fossiliferous; contains small crinoids, *Composita,* and biscuit algae	2.0
Limestone, blue gray; contains crinoids and bryozoans	1.0

	Thickness (feet)
Limestone, very fossiliferous; contains crinoids, *Myalina*, *Composita*, and many minute gastropods adhering to *Composita* shells; contains biscuit algae in lower 1 foot	3.1
Limestone, gray, hard; contains fossil fragments	1.1
Odell Shale (38.1 feet)	
Shale, gray, platy	4.0
Shale, gray, clayey; contains many secondary calcareous fillings in joints and bedding planes (boxwork appearance)	5.2
Shale, gray to very dark gray	2.0
Shale, gray, clayey; contains secondary calcite in joints and bedding planes	6.1
Limestone, shaly; has breccia appearance owing to filling of joints and seams by calcite	2.2
Limestone, vuggy; contains concretions as much as 2 inches in diameter	1.1
Shale, gray, clayey; contains secondary calcite in joints and seams	6.0
Limestone, white, thin bedded; contains a few concretions	2.5
Shale, limy, platy	9.0
Winfield Limestone (30.5 feet)	
Cresswell Limestone Member	
Limestone, thin bedded to platy, white	9.5
Limestone, same as above but contains *Archaeocidaris* spines and crinoid fragments	1.5
Limestone, thin bedded; contains *Composita*, *Derbyia*, crinoids, *Archaeocidaris* spines, and small trilobites	1.2
Limestone, thin bedded to shaly, nonfossiliferous	6.0
Limestone, white to gray, one massive bed; has rough appearance; contains productids and a few *Archaeocidaris* plates	12.3
Doyle Shale (8.0 feet exposed)	
Gage Shale Member	
Shale, gray to tan gray, poorly exposed, limy	8.0+

The Winfield Limestone yields water to wells in northwest Cowley County. Yields of the wells visited were not large, although they were generally adequate for stock and domestic supplies. West of Winfield, in sec. 25, T. 32 S., R. 3 E., test holes indicate that the Winfield Limestone is cavernous, and probably wells 32-3-24bdc and 32-3-25bdc obtain part of their water from it. East of Walnut River, the Winfield caps isolated hills or buttes and is almost drained, although a few shallow wells probably obtain some water from it. In southern Cowley County little if any water is obtained from the formation.

Odell Shale

The rocks between the top of the Winfield Limestone and the base of the Nolans Limestone are included in the Odell Shale. The Odell is composed principally of calcareous shale, but the material ranges from clayey shale to impure shaly limestone. Gray is the dominant color. A thin very dark gray or dark-blue-gray zone about 10 feet below the top of the formation seems to be persistent in the southern part of the county. Small calcareous geodes are present in a zone composed of very limy shale and impure limestones just below the middle of the formation. The Odell occupies the greater part of a gently graded slope between the scarp-forming part of the Winfield Limestone and the Herington Limestone Member of the Nolans Limestone. The outcrop belt is relatively narrow, and lies principally west of Walnut River. It becomes even narrower in southern Cowley County, where the Nolans Limestone is more resistant to weathering and forms a steeper scarp than in the north. The formation is nonfossiliferous. A description of a measured section of the Odell accompanies that of the Winfield.

The Odell Shale is not known to yield water to wells in Cowley County.

Nolans Limestone

The Nolans Limestone is the uppermost formation of the Chase Group. This formation, having a total thickness in Cowley County of about 40 feet, is composed of three members: in ascending order, the Krider Limestone, Paddock Shale, and Herington Limestone. The lower part of the Herington is the most resistant part of the formation and forms the only conspicuous bench or scarp in the outcrop area. Even this part of the Herington weathers in most areas, however, and over much of the outcrop area produces no apparent break in the slope rising from the Winfield Limestone. The Nolans forms the upper part of the area shown on Plate 1 by the symbol Pc3. A section from the resistant part of the Herington Limestone Member down through the Krider Limestone Member has been described in connection with the Winfield.

The Krider Limestone Member is composed of an upper, thin, blue-gray limestone that weathers buff, and a lower limestone, separated by about 3 feet of gray shale. The Krider ranges in thickness from about 4 to 9 feet; its maximum thickness is attained in the southern part of the county. The upper limestone is hard and brittle and is seemingly nonfossiliferous; the lower limestone consists of alternating hard and soft beds and some shaly limestone. The shale separating the two limestone beds is limy in the lower part and contains many fossils, the most common being crinoids, *Composita*, and biscuit algae. The lower limestone is also very fossiliferous; almost the entire middle part of the bed is composed of the brachiopod *Composita* and biscuit algae. The *Composita* shells in this bed are covered by specimens of a very small gastropod ranging from 1/16 to 1/8 inch across.

The Paddock Shale Member is composed of about 7 feet of gray, calcareous shale, the lower part being very calcareous. Fragments of crinoids and of many other fossils are in the lower part.

The Herington Limestone Member is composed of a lower limestone unit, about 10 feet thick, and an upper dolomitic unit. The contact between them is not sharp but gradational. The total thickness of the Herington may be as much as 30 feet, but the upper part weathers readily, and good exposures are rare; where observed, this part of the Herington has a sandy or granular appearance, and contains calcite geodes in the lower part. The limestone unit in the lower part of the Herington is the ledge-forming part, and it varies considerably in lithology and appearance across the outcrop area in the county. In the south, the Herington is composed of a fairly pure massive limestone containing chert nodules in the upper part and geodes in the lower part. In the north-central part of the outcrop in an exposure near the center of the south line of sec. 34, T. 30 S., R. 3 E., the lower part of the Herington is massive and has a blocky rectangular structure. In the NE¼ sec. 4, T. 30 S., R. 3 E., an exposure in a creek bed on the county line shows the same blocky limestone, but here the upper part contains chert nodules and the lower part contains geodes.

The Nolans Limestone yields water to wells in Cowley County, principally from the Herington Limestone Member. The quantity ranges widely, however. In southern Cowley County little if any water is obtained from the Nolans Limestone. In northwestern Cowley County, principally in T. 30 S., R. 3 E., domestic supplies are obtained from the Nolans. The city of Udall formerly obtained its municipal supply from this formation through large-diameter wells near the city, but it abandoned the wells because of insufficient supply and poor quality of the water. West of Winfield, in sec. 24 and 25, T. 32 S., R. 3 E., the Herington is cavernous, probably from solution of gypsum, and wells in this area yield as much as 1,000 gpm. The city of Winfield uses water from this area as a supplementary supply to blend with water from the Arkansas River valley. Water from the cavernous limestone is low in chlorides but almost always high in sulfates. South from T. 32 S. the cavernous limestone thins or is absent, and it is difficult to obtain an adequate supply of water for domestic and stock use.

Permian System—Middle Permian Series

Sumner Group

In Kansas the Sumner Group comprises the Stone Corral Dolomite, the Ninnescah Shale, and the Wellington Formation and has a total thickness of about 1,000 feet. Gray silty shale is predominant, but there are also red and green shale, dolomite, limestone, anhydrite, gypsum, and salt.

In Cowley County only the lower part of the Wellington Formation is present.

Wellington Formation

Although in other parts of Kansas the total thickness of the Wellington may be as much as 700 feet, only about 80 feet of rock, composed principally of soft gray shale, constitutes the Wellington Formation in Cowley County. This portion of the Wellington contains a few thin limestone beds, which are exposed only in small areas and, except for one gypsiferous limestone about 50 feet above the Herington Limestone Member, have not been correlated elsewhere. The gypsiferous limestone is exposed in a few small areas in the county but is reported in many drill holes, and it may correlate with the Hollenberg Limestone. The Wellington is composed mainly of soft materials that weather readily, hence good exposures of the formation are rare. Generally, the formation occupies the gentle soil-covered slope rising above the Herington Limestone. In some places the Wellington is overlain by silts of Pleistocene age, and as the soil types and topographic expression of the two units are similar, the contact of the two is difficult to define. The Wellington Formation is shown on Plate 1 by the symbol Pw.

The Wellington Formation yields water to a few wells in the upland area of western Cowley County. The water is obtained principally from the thin limestones or limy zones within the formation. Yields of the wells are generally inadequate for domestic needs, and the water is generally of poor quality. The city of Geuda Springs formerly obtained water from a well dug in the Wellington, but the supply was inadequate, and the well was abandoned.

Quaternary System—Pleistocene Series

Quaternary deposits in Kansas are of continental origin and are assigned to the Pleistocene Series. They are composed of silt, clay, sand and gravel, and small amounts of volcanic ash. The Pleistocene Epoch as defined by the State Geological Survey of Kansas is the last of the major divisions of geologic time and has been called the "Ice Age," owing to the presence of continental glaciers in North America and elsewhere. The Pleistocene Series in Kansas has been divided into the Nebraskan, Kansan, Illinoisan, and Wisconsinan glacial stages, and the Aftonian, Yarmouthian, and Sangamonian interglacial stages. Events in each of the periods of continental glaciation followed a cyclic repetition. Each cycle consists of a glacial and an interglacial interval or stage. The cycle in a marginal belt around a glaciated area is characterized by a period of downcutting in the valleys and some local deposition of sediment, followed by a period of deposition of coarse material beyond the glacial limit, deposition of progressively finer material as the glacier retreated, and finally the development of a soil profile over a large area where surface conditions were relatively stable.

During the Nebraskan and Kansan times, continental glaciers covered northeastern Kansas with glacial drift. During the Illinoisan and Wisconsinan advances the continental glaciers did not reach Kansas, but the climatic changes accompanying their approach had a direct effect on the Pleistocene deposits over Kansas.

Cowley County is about 175 miles beyond the southernmost advance of any of the ice sheets and did not receive outwash material from the glaciated area. The principal effect of the glaciers in Cowley County, therefore, was climatic. The trunk stream draining Cowley County in Early Pleistocene time headed in western Kansas and had no direct connection with the Rocky Mountains until late Kansan time. During Illinoisan time the present drainage pattern of most of the large streams of the state was established. Arkansas River established its present course during Illinoisan time, and drainage from the mountains was carried through south-central Kansas, including Cowley County. Throughout Pleistocene time the major streams draining central and eastern Cowley County were cutting their channels near their present courses. Sediments deposited by these streams were composed of locally derived material, chiefly pebbles of limestone and chert, whereas sediments deposited by Arkansas River were principally arkosic and were derived mainly from the Ogallala Formation (Pliocene) in the western part of the state.

The State Geological Survey divides the Pleistocene Series into a Lower Pleistocene Subseries and an Upper Pleistocene Subseries. The Nebraskan, Aftonian, Kansan, and Yarmouthian Stages are included in the Lower Pleistocene Subseries, and the Illinoisan, Sangamonian, Wisconsinan, and Recent Stages are included in the Upper Pleistocene Subseries.

Lower Pleistocene Subseries

Deposits of Nebraskan and Aftonian age have not been recognized in Cowley County. Deposits of this age probably were laid down in western Cowley County by an ancestral Arkansas River but were later removed by erosion. High-level chert gravel observed in a few small areas in north-central and eastern Cowley County may be of this age. These deposits are very thin and are not shown on Plate 1.

Kansan and Yarmouthian Stages

Grand Island and Sappa Formations.—Some deposits in western and southwestern Cowley County that are associated with the Arkansas River drainage compose the Grand Island and Sappa Formations of Kansan and Yarmouthian age. These deposits, which are derived from the west, consist principally of silt, clay, and arkosic sand and gravel. Deposits adjacent to Walnut River and Grouse Creek, consisting of chert and limestone gravel and small amounts of sand, silt, and clay, also are included in the Grand Island and Sappa Formations. These deposits are of local origin and indicate drainage during Kansan and Yarmouthian time closely paralleling present drainage.

The Grand Island and Sappa deposits associated with the Arkansas River drainage are as much as 40 feet thick and are overlain almost everywhere by eolian silts ranging in thickness from a few feet to as much as 30 feet; they are shown on Plate 1 by the symbol Qs/Qka. Coarse material in the basal part, becoming progressively finer upward through sandy silt to a compact silt in the upper part, is recorded in logs of test holes penetrating these deposits. The coarse basal material consisting of sand and gravel is not present everywhere, and logs may indicate only the finer material commonly found in the upper part of the formation.

The surface of the area underlain by the Grand Island and Sappa Formations between Walnut and Arkansas Rivers is topographically higher than adjacent deposits of Illinoisan and Sangamonian age, and bedrock incision is not so deep under the deposits of Kansan and Yarmouthian age. Locally a bedrock bench is present beneath Grand Island and Sappa Formations adjacent to the Crete and Loveland Formations, of Illinoisan and Sangamonian age (Pl. 4). The former probably were much more extensive originally but large parts have been removed. In T. 32 S. the Grand Island and Sappa Formations occupy a narrow belt just west of the divide between Walnut and Arkansas Rivers and probably were continuous westward for about 10 miles, as similar deposits are present in Sumner County. Southward, in T. 34 S., R. 4 E., these deposits may not have been laid down over the high upland area north of Walnut River; remnants in sec. 36, T. 33 S., R. 4 E., lie at a lower altitude than either the Winfield Limestone or the upland area to the south and west. Between extreme western Cowley County and a point near the southeastern corner of T. 33 S., R. 4 E., these deposits seem to be entirely arkosic. In the area just east of Walnut River east of Arkansas City, deposits of Kansan and Yarmouthian age occupy a high upland position. Here the deposits, although chiefly arkosic, contain a small percentage of chert gravel, and southward into Oklahoma in deposits of equivalent age the ratio of locally derived material to arkosic material increases.

Deposits of chert gravel occupy a high terrace position along the valley walls of Walnut River and Grouse Creek and are present locally along other streams draining the area of Permian exposures in north-central and eastern Cowley County. These deposits, which are probably Kansan and Yarmouthian in age, are generally thin and are not continuous. A projection of the profile through these deposits seems to merge with the Grand Island and Sappa Formations associated with the Arkansas River drainage. The chert gravel deposits of Kansan and Yarmouthian age are shown on Plate 1 by the symbol Qs/Qkc. Only the thicker and more extensive deposits were mapped, but in many areas thin deposits of chert gravel were observed at about the same level as those mapped.

The Grand Island and Sappa Formations yield moderate amounts of water to wells in Cowley County. Domestic and stock supplies are obtained from these formations over much of the area of outcrop. In some areas these deposits are principally silt, and the yields of wells are very low, and in other areas thin deposits associated with the Arkansas River drainage are above the water table and yield no water to wells. The Grand Island and Sappa Formations just east of Walnut River east of Arkansas City are composed of coarse gravel in the lower part, and large yields of water can be obtained, but these gravels are very limited in areal extent and their water supply depends entirely on local recharge. In part of the area southwest of Arkansas River west of Arkansas City, the Grand Island and Sappa Formations contain gravels in the basal part that are thick enough to yield relatively large quantities of water, but these gravels are present only in the deepest part of the buried channel underlying this area (Pl. 3A).

Chert gravel deposits of Kansan and Yarmouthian age are above the water table except during periods of very heavy precipitation.

Water from the Kansan deposits is somewhat hard but is generally usable.

Upper Pleistocene Subseries

The Upper Pleistocene Subseries includes all units of the Pleistocene Series younger than Yarmouthian. Deposits representing all major subdivisions of the Upper Pleistocene are present in Cowley County.

Illinoisan and Sangamonian Stages

Crete and Loveland Formations.—Climatic changes immediately preceding and during early Illinoisan time reactivated Arkansas River; much of the Grand Island and Sappa Formations was removed, and the channel was cut below the base of these deposits (Pl. 4). Arkansas River drainage during this time roughly paralleled the present Arkansas River in west-central Cowley County and then flowed eastward to a point near the southeast corner of T. 33 S., R. 4 E., where the stream was joined by Walnut River. From this junction the stream followed the present Walnut River to a point near its present junction with Arkansas River. That part of the present Arkansas River between Arkansas City and a point near the southwest corner of T. 33 S., R. 3 E., does not seem to have been a part of the through-flowing stream but, rather, a tributary that joined the old Arkansas River near Arkansas City. This part of the Arkansas River valley is narrow, and deposits older than Wisconsinan age were not observed.

Chert gravel deposits in terrace position to other major streams, which drain north-central and eastern Cowley County, indicate that these streams were deepening their channels during this period. These deposits were observed in only a few localities, and in only one area were they thick enough to map. These deposits are shown on Plate 1 by the symbol Qic. Chert gravel about 10 feet thick is present near the middle of the north line of sec. 4, T. 33 S., R. 4 E., in an intermediate position about 80 feet below the projected level of Kansan deposits and about 30 feet above the level of Wisconsinan terrace deposits.

Major drainage changes or adjustments affected the Arkansas River drainage during Illinoisan time. "Wilson Valley," which drained Saline River into Smoky Hill River, and "McPherson Channel," which drained Smoky Hill River into Arkansas River, were abandoned, and a large part of the former drainage into Arkansas River was diverted into Kansas River. These diversions were upstream from Cowley County and presumably affected the lithologic character of the Crete and Loveland Formations in the county. In the area related to the Arkansas River drainage, the Illinoisan and Sangamonian deposits, shown on Plate 1 by the symbol Qia, are composed of a basal arkosic sand and gravel overlain by sandy silt, which is overlain by a reddish silt. The basal gravels in this part of the formation are generally relatively thin, and the predominance of silts may reflect the loss of drainage through the diversions mentioned above. The upper surface of these deposits lies about 35 feet above the surface of the younger Wisconsinan terrace deposits, and a pronounced terrace scarp marks the boundary between them (Pl. 11A). Southward from a point near the southeast corner of T. 33 S., R. 4 E., where the old Arkansas River in Illinoisan time was joined by Walnut River, both arkosic and chert gravel are present in these deposits, indicating a western and an eastern source of the materials. The Crete and Loveland Formations in western Cowley County range in thickness from about 40 to 55 feet. Southward from the junc-

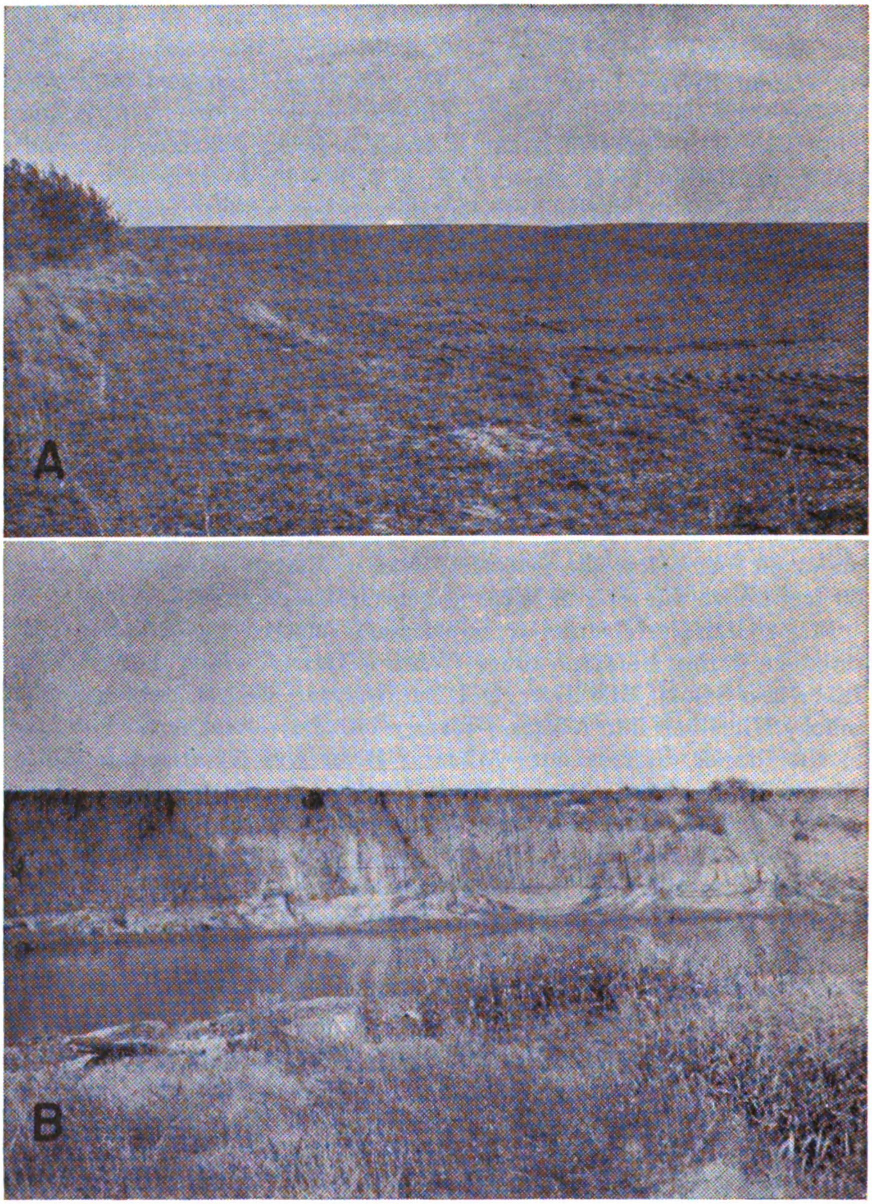

PLATE 11.—**A**, Illinoisan terrace scarp east of Arkansas River in NE¼ sec. 20, T. 32 S., R. 3 E. Wisconsinan terrace level in foreground. **B**, Wisconsinan terrace cut through by Walnut River in NE¼ SE¼ sec. 23, T. 33 S., R. 4 E.

tion of Walnut and Arkansas Rivers, resistant Permian limestone underlies the surface; incision by the stream during Illinoisan time was not great, and the deposits are thin.

The Crete and Loveland Formations are important sources of ground water in western Cowley County. In the area designated by the symbol Qia on Plate 1, yields of most wells range from about 50 to 200 gpm, and those of some wells are as much as 300 gpm. Many domestic and stock wells and four irrigation wells obtain water from these deposits. Formerly the Army air base midway between Arkansas City and Winfield obtained water from wells drilled in these deposits. Hydraulic connection with adjacent aquifers is poor or absent, and recharge is entirely from precipitation on the area. Southward from the point where Walnut River joined Arkansas River during Illinoisan time, the Crete and Loveland Formations are almost drained, and water is obtained from them only locally. Chert gravel deposits associated with Walnut River and Grouse Creek are above the water table.

The water from these deposits is hard (carbonate), but chloride concentration is low except in parts of sec. 26, 27, and 34, T. 32 S., R. 3 E., where some domestic supplies and one irrigation well have been polluted. The source of the chloride in this area is a small abandoned oil field near the northeast corner of sec. 26, T. 32 S., R. 3 E., and the northwest corner of sec. 27, T. 32 S., R. 3 E.

Wisconsinan Stage

Terrace deposits.—Climatic changes at the beginning of the Wisconsinan Stage rejuvenated Arkansas River and caused it to remove much of the material deposited in Illinoisan and Sangamonian time. The new channel was incised below the level of the base of the Crete and Loveland Formations and was partly filled with silt, clay, sand, and gravel. The surface of these deposits lies a few feet above the Recent alluvium in a terrace position to the present Arkansas River. The surface of this terrace has about the same altitude as the base of the Crete and Loveland Formations that border the terrace on the east (Pl. 4). The Wisconsinan terrace deposits are composed of arkosic sand and gravel in the basal part and silt and clay in the upper part. The thickness ranges from about 40 feet to about 55 feet in the Arkansas River valley. These deposits are shown on Plate 1 by the symbol Qtwa.

Terrace deposits equivalent in age to the Wisconsinan terrace deposits in the Arkansas River valley are present in all the major stream valleys that drain northern and eastern Cowley County. Generally these deposits are much thinner than those in the Arkansas River valley and are composed of lithologically different materials from different sources.

These terrace deposits are composed of limestone, chert gravel, and sand, intermixed with different amounts of silt and clay. The deposits contain beds of silt, beds of gravel containing almost no silt, and much gravel interspersed with silt. These terrace deposits are shown on Plate 1 by the symbol Qtwc. Plate 11B shows Wisconsinan terrace deposits that have been cut by Walnut River.

The Wisconsinan terrace deposits are the most important source of ground water in the county. In the Arkansas River valley, yields as great as 1,000 gpm are common. Arkansas City, Winfield, and Oxford obtain their supplies from these deposits. Many domestic and stock supplies and several irrigation wells also utilize this aquifer.

The quality of the water from this aquifer is not uniform throughout the area. In much of the area the concentrations of mineral constituents in the water exceed recommended standards of the Public Health Service but are within the range of standards for usable water. Although large quantities of water are available from these deposits, irrigation is not practiced extensively in the county, owing in part to the quality of the water. Oil has been produced in this area for about 35 years, and for many years brine produced from oil wells recharged the aquifer from "evaporation" ponds. The salt water entering the aquifer, although diluted to some extent, settles to the bottom of the aquifer as a salt-water body or unit. This salt-water body then moves downgradient at a very slow rate, although its rate of movement may be increased by the pumping of nearby wells or by the pumping operations in active gravel pits. The salt content of the ground water in parts of the area is very large, chloride concentration ranging to about 60,000 ppm. The cities of Winfield and Oxford and many domestic users have had to abandon wells because the water became salty. In areas of no pollution, the water is hard but is suitable for most uses.

Water containing chloride is discharged from Permian rocks into the alluvium and Wisconsinan terrace deposits in the vicinity of Belle Plaine in Sumner County. As this water moves downgradient, it is diluted with water of better quality and, except for the local area of discharge near Belle Plaine, is of usable quality. Near Geuda Springs, salt water is discharged from the Permian rocks as springs and by seepage into the alluvium and Wisconsinan terrace deposits. Local concentrations of chloride are probably from this source.

Some of the water in the Wisconsinan terrace deposits bordering the streams that drain northern and eastern Cowley County also has been polluted. These deposits are thin and contain much silt, but large yields can be obtained from wells locally. The Dexter water supply is obtained from these deposits.

The chloride concentration in the water from Walnut River terrace deposits is excessive in some areas. In past years the surface water has been polluted, and probably some of this water has entered the aquifer from the river, but most of the pollution in the aquifer has resulted from seepage from disposal ponds, which were formerly permitted in the valley. The partial analyses of samples of water from these deposits, given in Table 7, indicate that the water contains less chloride than many of the samples collected from the Arkansas River valley.

Eolian silt deposits.—Wind-deposited silts overlie older deposits in much of western Cowley County. Deposits of Kansan and Yarmouthian age are overlain nearly everywhere by these silts, which may have a thickness of as much as 30 feet. These silts occupy a high upland position and are of similar origin, and they could not be differentiated from the older deposits by study of logs of drill holes. The uppermost silts are almost certainly Late Pleistocene in age and in this report are assumed to be Wisconsinan. They are shown on Plate 1 by the symbol Qs. Silts of eolian origin are present in surface exposures and drill holes in the south valley wall of Arkansas River. They extend well down into the valley and seem to be continuous with the silts overlying the deposits of Kansan and Yarmouthian age. Late Pleistocene origin is indicated by the low position of the silts in the valley. Silts that seem to be of eolian origin are present also in part of the area underlain by deposits of Illinoisan and Sangamonian age. These silts were observed in some drill cuttings. They are relatively thin and on the geologic map they are not distinguished from the underlying deposits. The eolian silts probably were deposited over a much larger area but have been altered by weathering or have been removed.

The eolian silts are above the water table in much of the area, hence yield no water to wells, but they have a considerable effect on recharge of the underlying deposits.

Recent Stage

Alluvium.—Recent alluvium occupies the valleys of all the major streams in Cowley County, but all streams except Arkansas River are deepening their channels over most of their courses and, consequently, alluvium is present only in the narrow, active channels of the streams. The deposits are thin and are not mapped separately on Plate 1. They are composed of silt, sand, chert, and limestone gravel, but because of their small areal extent they are not important sources of ground water.

In the Arkansas River valley the Recent alluvium adjacent to the stream is as much as a mile wide. Lithologically these deposits are similar to the Wisconsinan terrace deposits, and it is difficult to differentiate the two by use of subsurface data. The alluvium in the Arkansas River valley was distinguished from the terrace deposits on the basis of surface position and topographic expression. The surface of the alluvium is a few feet below the terrace surface, and in some places a terrace scarp of a few feet separates the two deposits. The surface of the alluvium is rough and hummocky, and old meander scars are common, whereas the surface of the Wisconsinan terrace is relatively flat and exhibits a more mature stage of development. The Recent alluvium, which is as much as 50 feet thick in the Arkansas River valley, is shown on Plate 1 by the symbol Qal.

Ground-water conditions in the alluvium are very similar to those in the terrace deposits. Much ground water is available, but much of it is unsuitable for use. The alluvium has received pollution from oil-field brines and by water of poor quality entering the aquifer from the river; most of the time, however, the stream gains water from the aquifer. The salt content of the water in Arkansas River increases considerably at its junction with Salt Creek in the NE¼ sec. 7, T. 33 S., R. 3 E. Salt Creek heads in Permian shales in eastern Sumner County and is fed by mineral springs.

GEOLOGIC STRUCTURE

Structural Features and Relation to Occurrence of Oil and Gas

The regional dip of the rocks in Cowley County is westward and averages about 25 feet per mile, as in most of the eastern half of Kansas. This westward dip or tilting, which in part accounts for the parallel belts of outcrop of the rock units, is modified by local structures in which the beds are almost horizontal, or even dip eastward. Many of the important oil fields in the county have been developed on these structural features—anticlines, synclines, anticlinal noses, domes, and basins—which are generally of small areal extent. Even the major structures, which may extend many miles beyond the borders of the county, seem to be composed of groups of smaller features that are aligned in one general trend.

The most pronounced surface structural anomaly in the county is the Dexter Anticline, which trends due north from a point near Otto to Dexter and thence northeast. The east flank of this fold is steeper than the west flank; the rocks dip eastward more than 100 feet in about half a mile eastward from the axis of the anticline, but they dip westward only about 100 feet in a mile west of the axis. This anticline is divided into a series of local "highs" by transverse sags or saddles. The structure in this part of the county is evident where inliers caused by structural movement are exposed by subsequent erosion in sec. 24, T. 34 S., R. 6 E., and sec. 7 and 18, T. 34 S., R. 7 E. (Pl. 1).

The Winfield Anticline, whose axis trends northeast-southwest about 2 miles east of Winfield is a prominent structural feature that is evident in the surface rocks, although the dips along the flanks of this structure are even more gentle than those on the Dexter Anticline.

The third prominent structure in Cowley County crosses T. 30 S., R. 3 E., in the northwestern part of the county. This structure is a part of the Nemaha Anticline, which trends from Nemaha County in northeast Kansas southwest into Oklahoma. In Cowley County this structure is not so apparent on the surface as is the Dexter Anticline, because the surface rocks over it are principally soft shale. Thin limestone beds within the shale indicate some tilting of the strata, and the Winfield Limestone crops out west of where it would under normal structural conditions.

Many smaller structural features, some of which have a surface relief of less than 10 feet, lie between and roughly parallel with these anticlines. Structural relief in the subsurface is more pronounced than on the surface, and the trace of the axis on the surface may not be directly over the trace of the axis in the subsurface. Plate 5 shows the structure at the top of the Douglas Group, including the three large and many of the small structural features. Contours of the top of the Douglas Group show more structural relief than do contours of the surface rocks, but they more nearly reflect surface conditions than would contours on any deeper strata. Many producing oil and gas wells have been drilled on the three large anticlines and on the small structures.

Relation of Structure to Occurrence of Ground Water

The availability of ground water in an area underlain by alternating layers of shale and limestone is closely related to the structure of the area. Water entering an aquifer moves downdip and collects in synclines or basins. Wells drilled in these structural depressions generally yield more water and are more dependable in periods of drought than nearby wells situated higher structurally. Porosity and permeability are increased by fractures and joints over the sharper flexures in the anticlines and synclines. Water enters the aquifer more readily through these fractures, and movement within the aquifer is aided by the joints and fractures. The greater recharge rate and transmissibility increase the quantity of water available from wells in the structurally low areas. Wells in the synclinal or basin areas east of both the Dexter and the Winfield Anticlines yield more water than nearby wells outside these low areas. More water is recorded in logs of oil wells drilled in structurally low areas than in structurally high areas.

GROUND WATER

Principles of Occurrence

The rocks and surficial deposits that form the crust of the earth are not solid throughout but contain many openings, called voids or interstices. It is in these spaces that water is found beneath the surface of the earth and it is from them that water is recovered through wells and springs. There are many types of rocks, and they differ greatly in the number, size, and arrangement of their interstices and, therefore, in their water-bearing properties.

The interstices of rocks in Cowley County range in size from pores of microscopic dimensions to openings several inches in width. These can be divided into primary and secondary interstices. Primary, or original, interstices, are the pore spaces between the rock grains and were formed during the deposition of the rocks. Secondary interstices are the joints, open bedding planes, and solution channels that were developed by the different processes that affected the rock after deposition. In Cowley County all the water-bearing rocks are of sedimentary origin and contain both primary and secondary interstices.

The amount of water that can be stored in any rock depends upon the porosity of that rock. Porosity is expressed as the percentage of the total volume of the rock that is occupied by interstices. When all the interstices in a rock are filled with water, the rock is said to be saturated. The amount of water that a saturated rock will yield to the force of gravity is known as the specific yield. The amount of water a rock can hold is determined by its porosity, but the amount of water that the rock can yield to wells is determined by its specific yield. The rate at which a rock will yield water to a well is determined by its permeability, *i. e.*, its ability to transmit water under a hydraulic gradient, which is the measured rate at which a rock will transmit water through a given cross section under a given loss of head per unit of distance. Some beds of clay or shale may be porous, but because the interstices are small and poorly connected, they transmit little or no water, and the rock may be regarded as virtually impermeable. Rocks differ greatly in their degree of permeability, according to the number, size, and interconnection of their interstices.

Source

Water in the open pores or interstices of the rocks below the surface of the earth, in the zone that is completely saturated, is called ground water. In Cowley County, ground water is derived from precipitation, in the form of rain or snow, which falls on the county or on nearby areas. Part of the precipitation leaves the area as surface runoff discharged by streams, part evaporates, and part is transpired by vegetation into the atmosphere. The part that escapes direct surface runoff, evaporation, and transpiration moves slowly downward through the soil and underlying strata until it reaches the zone of saturation. After reaching the ground-water body, the water percolates slowly through the rocks in a direction determined by the geology, topography, and geologic structure, until it is discharged through wells and springs, or by evaporation and transpiration in areas where the water table is relatively near the land surface, or is discharged into a stream or other body of water.

When the upper surface of the zone of saturation is in a permeable rock, this surface is called the water table, and the water is under water-table conditions. If the upper surface is in an impermeable rock, water will rise in a drill hole above the level of the saturated permeable rock, and the water is then under artesian conditions. The level at which water stands in an open hole under artesian conditions is not a water table but is a piezometric surface. In Cowley County ground water occurs under both artesian and water-table conditions.

Artesian Conditions

In much of the eastern two-thirds of Cowley County, where the interbedded limestones, sandstones, and shales of Permian and Pennsylvanian age crop out, the ground water generally occurs under artesian conditions. No artesian wells flow in this area, but the hydrostatic pressure in many wells is sufficient to raise the water above the point at which it is first encountered in the well.

Water entering permeable zones along the outcrop moves downdip in the aquifer. Where impermeable rock overlies the aquifer, the water is confined, and a pressure head is built up in the aquifer. When the aquifer is tapped by a well, the water in the well will rise above the point at which it was encountered to a point determined by this pressure head.

The many structurally low areas in the surface and near-surface rocks in Cowley County are favorable areas for the occurrence of artesian water. Wells drilled there will yield more water and will be more dependable than wells drilled in surrounding structurally high areas. Wells under some artesian head and more productive than wells elsewhere in these rocks were observed in the synclinal areas on the east sides of the Winfield and the Dexter Anticlines.

The Water Table and Movement of Ground Water

The water table is not a plane surface but is a sloping surface in which are irregularities caused by differences in permeability of water-bearing materials, by unequal additions to or withdrawals of water from the aquifer, and by topographic features.

Plate 2 shows the location and depth to water of wells and test holes for which data are given in Table 11 or in the logs at the end of the report. Plate 3B shows the location of wells and test holes in unconsolidated deposits associated with Arkansas River drainage, the altitude of the water table, and contours on the water table. No attempt was made to draw water-table contours in the area of outcrop of Permian and Penn-

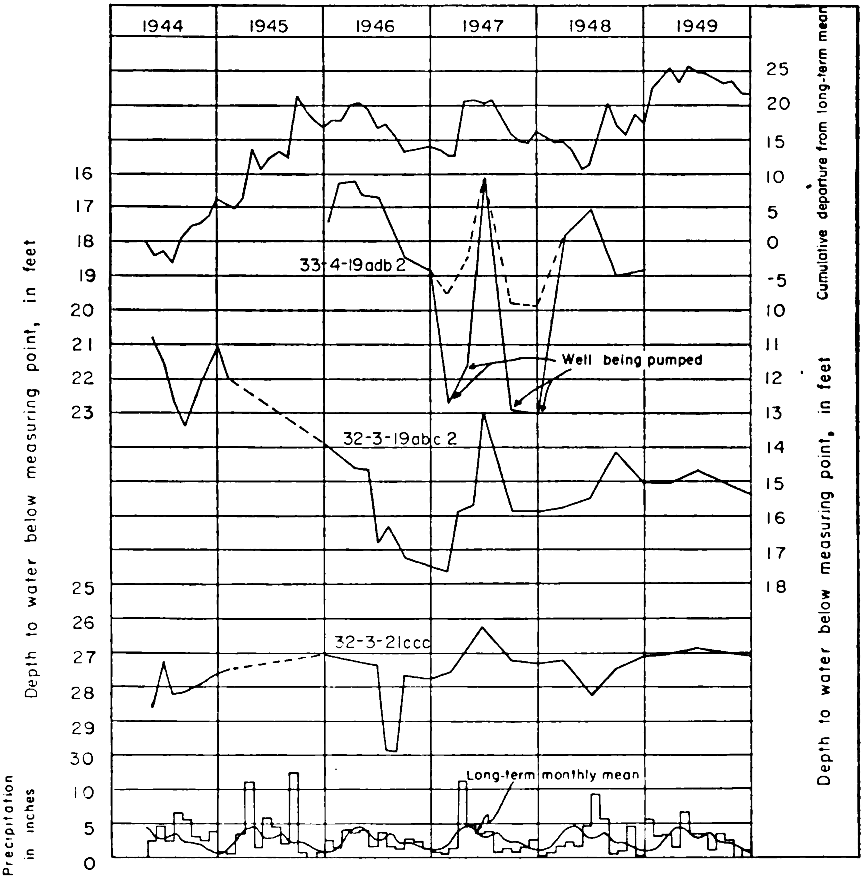

Fig. 5.—Hydrographs of three wells, precipitation at Winfield, long-term monthly mean, and cumulative departure from long-term mean precipitation.

sylvanian rocks, because in parts of the area the water is under artesian head and in other parts of the area the water table is discontinuous.

The water table is not stationary, but fluctuates in response to additions to and withdrawals of water from storage. Figure 5 shows the hydrographs of three wells over a period of about 6 years. The monthly precipitation and the cumulative departure from the long-term mean precipitation also are shown. These wells are in terrace deposits associated with Arkansas River. Fluctuations of the water level in these wells correlate with precipitation, the water rising sharply after periods of excessive precipitation and declining during periods of deficient precipitation. Other factors, such as heavy pumping, evaporation and transpiration, and discharge into streams, also cause declines in the water table.

Direction of movement of the water may be determined from the water-table contours on Plate 3B. Water moves at a right angle to the contour at any given point. In the area north of T. 34 S. water moves generally southwestward toward Arkansas River; however, in sec. 13, 24, and 25, T. 33 S., R. 3 E., a low ground-water divide causes the water east of this divide to move eastward toward Walnut River. South of T. 33 S. the water moves directly toward the streams in the valley areas, and in the extreme southwestern part of the county it moves east-southeastward.

The spacing of contours on the water-table map may be an indication of the relative permeability of the water-bearing material, but other factors such as topography, recharge, and discharge also affect the spacing. The close spacing of contours just west of Winfield indicates a steep slope of the water table due to low permeability and topography. In this area the water-bearing deposits are of Kansan age and they contain a larger percentage of fine material than the younger, lower terrace materials. Also, the closely spaced contours near the northeast corner of sec. 29, T. 32 S., R. 3 E., are near the scarp of the Illinoisan terrace; here too the steep slope of the water table is the result of low permeability and the topography. The Wisconsinan terrace deposits near the foot of the Illinoisan terrace scarp are composed generally of finer materials, which were derived chiefly from slope wash, than those of the Wisconsinan terrace deposits nearer the river.

Recharge of Ground Water

The addition of water to the ground-water reservoir is known as ground-water recharge. In Cowley County the principal source of recharge is precipitation that falls directly on the county. Some water enters the county by subsurface movement from adjacent areas, and some is received from influent streams.

Recharge from Precipitation

The mean annual precipitation in Cowley County is 31.27 inches, but only a small part of this amount reaches the ground-water reservoir. A small part of the precipitation in Cowley County becomes direct runoff into the streams, part infiltrates into the soil and becomes soil moisture, and part is discharged through evaporation and transpiration. The small remainder moves downward to the zone of saturation to become ground water. The rate of precipitation, the type of soil or surface, and the character of the underlying rocks all affect the rate and quantity of recharge.

Except for a small area just northwest of Arkansas City where the surface is very sandy, the best area for recharge in Cowley County is in the alluvium and Wisconsinan terrace deposits in the Arkansas River valley. The sandy soils and permeable underlying materials are favorable for ground-water recharge, whereas less permeable silts and clays in the older terrace materials prevent much recharge.

The effect of precipitation on the water table is shown in Figure 5. Well 32-3-19abc2 is in Wisconsinan terrace deposits and wells 32-3-21ccc and 33-4-19adb2 are in Illinoisan deposits. Parts of the hydrographs correlate with the precipitation and show the response of the water table to recharge of water to and discharge (natural and by pumping) from the aquifer.

Permian and Pennsylvanian rocks have a wide range of geologic, structural, and topographic conditions and hence diverse recharge conditions. Recharge is very low in areas underlain by thick shale, but conditions are favorable for recharge where limestone or sandstone lies at the surface. Chert-bearing limestone is at or near the surface in large areas and receives much recharge through fractures and joints. Fluctuations in the discharge of many perennial springs and the rejuvenation of wet-weather springs during periods of precipitation indicate a considerable amount of recharge in these rocks. Some sinkholes in the upper part of the Barneston Limestone probably were caused by solution. Precipitation entering these sinkholes moves downward through solution channels and fractures and is discharged by springs in the same general vicinity. The flow of many of these springs fluctuates considerably in direct response to the precipitation. This response to precipitation is so rapid in some springs that the issuing water becomes turbid soon after a heavy rain.

Recharge from Adjacent Areas

Subsurface movement of water from outside the county is a relatively unimportant source of recharge to the ground-water reservoir in Cowley County. Some water moves across the west border, in the high upland area, into the southwestern part of the county, and some moves toward

Arkansas River from the west into west-central Cowley County. Almost no water moves across the north or south borders of the county, because the dip of the strata is about parallel with the county boundaries. Precipitation on the outcrops of sandstone in the Wabaunsee and Admire Groups east of Cowley County moves downdip, and part of this may eventually enter the county, but the quantity is probably small because the permeability of the sandstone is low.

Recharge from Streams

During periods of high water in Arkansas River, some water is contributed to the aquifer from the stream. This type of recharge is temporary in that as soon as the stage of the stream drops below the level of the water in the aquifer, the direction of movement of the water is reversed, and discharge into the stream begins. A small part of this recharge is utilized by wells before the rest is discharged back into the streams. Streams crossing permeable beds of Permian and Pennsylvanian rocks that dip away from the streams contribute water to these beds. This water moves downdip to the ground-water reservoir and may be recovered by wells or may be discharged farther downdip. The amount of recharge to the Permian and Pennsylvanian rocks in Cowley County is not large.

Discharge of Ground Water

Ground water is discharged in Cowley County by evaporation and transpiration, by seepage into streams, by subsurface movement to adjacent areas, and by springs and wells. The rate of natural discharge depends greatly on the stage of the water table and on the season of the year. Local differences in geology and topography cause more water to be discharged in some parts of the county than in others. At present only a small part of the ground-water discharge is by wells, but the amount is increasing almost annually.

Discharge by Evaporation and Transpiration

More ground water is discharged in Cowley County by evaporation and transpiration than by all other means combined. Ground water is discharged by direct evaporation in nearly all the valleys, where the water table is near the surface, and from seeps along the steep slopes of the valley walls. Much ground water is transpired by plants in the valley areas. In the Arkansas River valley the roots of nearly all plants penetrate the zone of saturation or the capillary fringe. In the upland areas, where the water table is relatively deep or discontinuous, few of the plants tap the ground-water reservoir.

Discharge by Seeps and Springs

Much ground water is discharged through seeps and springs, chiefly along valley walls adjacent to upland areas. A part of the water thus discharged is evaporated directly to the atmosphere and part is transpired by plants during the growing season. Any water that is not evaporated or transpired flows into streams and may leave the county as surface runoff. After the growing season, the amount of streamflow increases, as the ground water that has previously been intercepted by vegetation now discharges into the stream.

Discharge by Subsurface Movement

Discharge of ground water through subsurface movement into adjacent areas is relatively unimportant in Cowley County. The water-table contours (Pl. 3B) indicate only one area in which water moves out of the county. In this area, along the west line of T. 31 S., water moves toward Arkansas River before the river enters Cowley County.

The north and south borders of the county nearly parallel the westerly dip of the strata, and little water moves in or out of the county along these borders. Along the east border of the county, water moves down the westward dip of the strata into the county.

Discharge by Wells

The preceding discussion considers the natural discharge of ground water, which is the way in which most of the discharge from the county takes place. The rest of the water that is discharged is by wells, and this method is discussed under the subject of recovery and utilization of ground water. The importance of discharge through wells will become greater with the increase in the use of water for irrigation and for industrial, public, and domestic purposes.

Recovery of Ground Water

When a well is standing idle, static equilibrium exists between the water in the well and the water outside the well. When water is withdrawn from the well, a difference in head is created between the water in the well and the water outside. The water table in the vicinity of the well develops a cone of depression (Fig. 6), which is deepest at the wall of the well and extends some distance from the well. The greater the pumping rate in the well, the greater the drawdown of the water level.

The specific capacity of a well is its rate of yield per unit of drawdown, and it usually is expressed as the yield in gallons per minute per foot of drawdown. The specific capacity of a well may be used in predicting the approximate drawdown in a well at various rates of pumping. If the

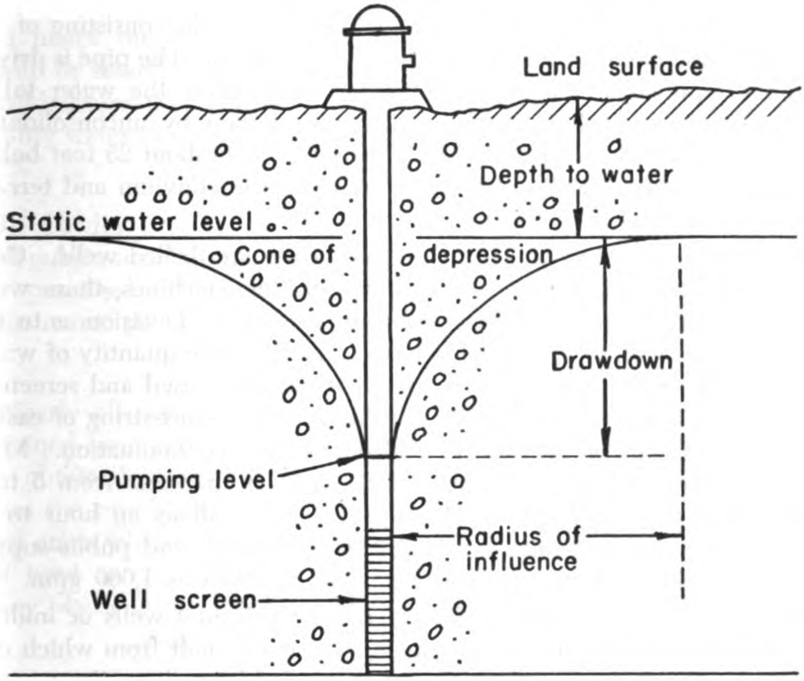

Fig. 6.—Diagrammatic section of well being pumped.

specific capacity of a well is lower than that of nearby wells, it may be an indication of improper screening, insufficient development of the well, or partial plugging of the screen. The character of the water-bearing material determines the specific capacity of a properly constructed well. Large yields will be obtained from homogeneous, coarse-grained material, and smaller yields will be obtained from finer-grained materials.

Several types of wells are used to obtain water supplies in Cowley County. The type of well depends on the use for which the well is intended, the geologic materials to be penetrated, the depth to water, and the depth to which the well is to be constructed or drilled. In the following paragraphs the several types of wells are described briefly.

Dug wells.—Dug wells are generally large-diameter wells excavated with hand tools or power equipment. The wells dug with hand tools penetrate the aquifer for only a short distance below the water table. Few dug wells are used in Cowley County in the areas underlain by Pleistocene deposits, but in upland areas in the county, which are underlain by stratified deposits of limestone and shale from which only small yields can be obtained, many of the wells are dug to provide the additional storage space needed because of the slow rate of infiltration.

Driven wells.—Driven wells are small-diameter wells consisting of 1¼- to 2-inch pipe having a screen attached to the bottom. The pipe is driven into the aquifer far enough that the screen is below the water table. Use of a driven well is limited to areas underlain by unconsolidated materials in which the water table is not more than about 25 feet below the surface. Many wells have been driven in the alluvium and terrace deposits in the Arkansas River valley.

Drilled wells.—Most wells in Cowley County are drilled wells. Constructed with either percussion or rotary drilling machines, these wells range in diameter from about 4 inches to 36 inches. Decision as to the diameter of a well to be drilled is based chiefly on the quantity of water needed. Wells in unconsolidated deposits must be cased and screened, but wells in consolidated deposits may have only a short string of casing in the upper part of the well to seal out surface contamination. Most domestic and stock wells in the county range in diameter from 5 to 8 inches, and their yields range from only a few gallons an hour to as much as 50 gallons a minute. Irrigation, industrial, and public-supply wells have larger diameters and may yield as much as 1,000 gpm.

Horizontal wells or infiltration galleries.—Horizontal wells or infiltration galleries are constructed by sinking a vertical shaft from which one or more perforated pipes or screens are extended laterally. Water entering these horizontal pipes flows into the shaft, from which it is pumped. The laterals, which may extend several hundred feet from the shaft, can be forced into the aquifer from the shaft or can be laid in open trenches, which are backfilled with permeable materials. To induce infiltration from streams, one or more laterals are extended under the stream. In installations away from streams, the laterals may extend in all directions from the vertical shaft. Pumping large quantities of water from such installations lowers the water table much less than would pumping of the same volume from an ordinary vertical well.

In Cowley County this type of well construction could be used in thin permeable gravels near the base of the Illinoisan terrace deposits to obtain larger yields than can be obtained from a vertical well. The terrace deposits in the Arkansas River valley are relatively thin, and over much of the area the water in the basal part is of poor quality. A horizontal well in which the laterals extended from the central shaft at a depth only a short distance below the water table would yield larger quantities of water than a vertical well to the same depth. Water moves into a pumped well from all directions, and hence the poor-quality water moves upward into such a well. The terrace deposits are stratified, however, so the horizontal permeability is greater than the vertical permeability, and hence the upward movement of water having a greater density would be retarded. Proper setting of the laterals and regulated pumping would insure that a horizontal well would skim off the upper, good-quality water in the aquifer.

Utilization of Ground Water

In Cowley County, ground water is used chiefly for domestic, stock, and public supplies. Some water is used for irrigation, but irrigation is not practiced extensively in the county. Most industries use water from municipal supplies, but a few industries have their own supplies.

Domestic and Stock Supplies

Nearly all the domestic and stock water supplies in rural areas are obtained from privately-owned wells. In the valley areas these supplies are obtained principally from driven or drilled wells. In the upland areas the supplies are obtained from dug or drilled wells. In some upland areas where adequate water supplies are difficult to obtain, cisterns are used to catch rainwater to supplement the ground water, and at many places in the county ponds have been constructed for stock water.

Public Supplies

Seven public water-supply systems obtain their water in Cowley County. Two other cities formerly obtained water from within the county, but now obtain their supply from Sumner County.

Arkansas City.—Arkansas City, the largest city in Cowley County, built its first public water supply in 1885. This supply was obtained from wells in the alluvial deposits in Arkansas River valley in the southwestern part of the city. Later wells were drilled in the valley at the south edge of the city near Summit Street. In 1915, two wells in this area provided 500,000 gpd. In 1918, four wells, 42 feet deep, supplied an average of 1.25 mgd. In 1932 the average daily pumpage from the four wells was about 2 mgd. The quality of the water deteriorated from 1912 to 1933, however; the water contained about 119 ppm of chloride in 1912 and 750 to 950 ppm in 1933. The old wells were therefore abandoned, and eight new wells were drilled west of Arkansas River. These wells range in depth from 35 to 40 feet and are equipped with 750-gpm turbine pumps. The average pumpage in 1958 was about 2 mgd, or about 2,200 acre-feet per year. Storage is provided by a 2.6-million-gallon reservoir at the pumping station and two 250,000-gallon elevated steel tanks. The water is chlorinated and treated with Calgon. Fluoride salts are added to raise the fluoride content to about 1 ppm.

Atlanta.—The Atlanta water supply is obtained from an improved spring (30-6-28bdd1) about 2 miles south of the city in the Florence Limestone Member of the Barneston Limestone. The average pumpage is about 6,000 gallons a day or about 6 acre-feet per year. Well 30-6-28bdd2, which is adjacent to the spring, yielded about 1,000 gpd at a depth of 240 feet. The well was deepened to 300 feet, where it obtained salt water and was abandoned. Storage is provided by a 35,000-gallon elevated steel tank. The water is chlorinated at the spring pumphouse but receives no other treatment.

Bolton Township Water Cooperative.—The Bolton Township Water Cooperative serves a suburban and rural area south and southeast of Arkansas City. In much of this area, ground water of usable quality is difficult to find in adequate quantity for domestic and stock use. The Cooperative obtains its water supply from one well (35-4-6bdc) in terrace deposits in the Arkansas River valley just south of Arkansas City. The well is 52 feet deep and is pumped at a rate of 225 gpm directly into the mains. The Cooperative serves 121 customers on 19 miles of pipeline. Storage and pressure are supplied by a 100,000-gallon elevated steel tank located in the upland area near the southwest corner of the Cooperative service area. The water is hard; it is chlorinated at the well but receives no other treatment. The annual pumpage is about 13 acre-feet.

Burden.—For about 50 years the water supply for Burden has been obtained from an improved spring (31-6-28caa) in the Florence Limestone located in a branch of Silver Creek about 1½ miles west of the city. In years of normal rainfall the supply is adequate, but in years of drought the yield declines, and water is shipped in to supplement the supply. Average pumpage is about 35,000 gallons a day or about 40 acre-feet per year. The water is chlorinated at the spring pumphouse and, although it is hard, it receives no other treatment.

Dexter.—The water supply for Dexter is obtained from a dug well (33-6-13bcd) about half a mile west of the city in the terrace deposits adjacent to Grouse Creek. The well is 36 feet deep and 40 inches in diameter. In past years the city has had considerable difficulty with salt-water contamination of its water supply. Many oil and gas wells have been drilled in and adjacent to the city, and some of the wells were not properly plugged when abandoned. Brine-disposal ponds, although not now permitted, have in the past contributed salt water to the aquifer. In 1946 the chloride content of the water in well 33-6-13bcd was 1,600 ppm, and in June 1958 the concentration was 870 ppm. The average pumpage is about 25,000 gallons a day or about 27 acre-feet per year.

The water is chlorinated at the well, and storage is provided by a 100,000-gallon elevated steel tank.

Geuda Springs.—Part of the city of Geuda Springs is in Cowley County and part is across the county line in Sumner County. The city has had no public water supply since about 1950 and the residents have been using private wells. A public supply system for the city was constructed in 1918, and water was obtained from one dug well (34-3-7cba) about a quarter of a mile east of the city. The well was 52 feet deep and 8 feet in diameter. Water was obtained from porous zones in the lower part of the Wellington Formation. Storage was provided by two underground steel pressure tanks having a total capacity of about 8,000 gallons. Pressure in the mains was maintained by the pressure head in the tanks. The well was equipped with a centrifugal pump of about 175-gpm capacity, but the yield of the well was about 5 to 10 gpm. The depth to water in the well was 40 feet in 1919 and 43.5 feet in 1945. This well was abandoned shortly after 1950 because of contamination. The average daily pumpage at that time was 6,000 gallons.

Oxford.—The city of Oxford is in Sumner County but it obtains its water supply from Cowley County. The first public supply was provided in 1914 and was obtained from shallow wells in the western part of the city. Water from these wells was good and had a chloride content of about 20 ppm, but yields were inadequate, and in 1920 a well was drilled in the alluvium on the east side of Arkansas River. This well was 46 feet deep and was pumped at a rate of 200 gpm, but the well became contaminated with salt water. In 1937 the city drilled a new well 1¼ miles east, in Cowley County. In 1958 Oxford obtained its water supply from two wells at this location. These wells are 37.5 feet deep and 18 inches in diameter and are pumped at about 500 gpm. Drawdown at this pumping rate is about 3 feet. The average pumpage is about 80,000 gallons a day or about 90 acre-feet per year. Water is pumped directly into the mains, and pressure and storage are provided by an elevated steel tank of 55,000-gallon capacity. The water is chlorinated at the wells and receives no other treatment.

Udall.—The first public water-supply system for Udall was constructed prior to 1905. Wells drilled in and near the townsite obtained water from the lower part of the Wellington Formation and from the Nolans Limestone. In 1929 a well was dug in the southern part of the townsite. This well was 60 feet deep and obtained water from the Nolans Limestone. It yielded about 60 gpm during years of normal precipitation, but in periods of drought the yield decreased and the quality deteriorated. In 1954 two wells were drilled in terrace deposits adjacent to Arkansas

River in Sumner County, about 3½ miles west of the city. These wells are about 30 feet deep and yield about 130 gpm each. In 1959 all wells near the townsite had been abandoned. The average pumpage is about 60,000 gallons a day or about 65 acre-feet per year. Storage and pressure are provided by an elevated steel tank of 50,000-gallon capacity. The water is chlorinated at the wells but receives no other treatment.

Winfield.—The original public water supply for the city of Winfield was obtained from Walnut River at the west edge of the city. About 1916, wastes from oil fields and allied industries began polluting the stream, making the water unsuitable for domestic use. By June 1918, eight wells had been drilled about 4 miles west of the city. The wells were about 30 feet deep. Two additional wells were drilled in 1921, at which time the average daily pumpage was about 1.25 mgd. By 1923 the yields of these wells were inadequate to supply the water requirements of the city, and this well field was abandoned. Wells were then drilled in the alluvium of Arkansas River about 9 miles west of the city. Six wells were drilled in three groups of two wells each. The wells in each pair were spaced about 150 feet apart and were pumped by one centrifugal pump located in a pit midway between them. The four east wells were 38 feet deep and the two west wells were 46 feet deep; all were cased with 25-inch concrete casings. The yield from each pair of wells was about 1,000 gpm.

In 1937 the chloride content of the water in the wells increased. The largest increase was in the middle group of wells (32-3-18dcc) from 507 ppm in 1938 to 12,000 ppm in 1939. The source of these chlorides was traced to disposal ponds and leaky casing in a disposal well south of the well field. These sources of contamination were eliminated, and the chloride content of the well water declined. In 1940 a new well was drilled a quarter of a mile north of well 32-3-18dcc. This well (32-3-18dbc) is 48 feet deep and yields 1,000 gpm. Continued difficulties with salt water in the well field caused the city to drill six new wells about 3 miles south of the old well field in sec. 5 and 6, T. 33 S., R. 3 E. The northernmost well in this group was never equipped with a pump because of salt-water intrusion during the time between the drilling of test holes and the drilling of the well. In 1959 the chloride concentration in other wells in this field was increasing, but no additional wells were abandoned.

In 1955, wells 32-3-24bdc and 32-3-25bdc were drilled. These wells obtained water from cavernous Nolans and Winfield Limestones at a depth of 165 feet and 113 feet respectively. Yield of each of these wells was about 1,000 gpm, but because the sulfate content of the water in well 32-3-24bdc was excessive, only well 32-3-25bdc has been used.

The average pumpage by the city is about 1.5 mgd, or about 1,700 acre-feet per year. Water is stored in a concrete reservoir at the water plant, which has a capacity of about one million gallons, and a concrete reservoir on a hill in the eastern part of the city, which has a capacity of about two million gallons. The water is very hard at times and is chlorinated and treated with Calgon at the water plant.

Industrial Supplies

The industrial use of water in Cowley County is considerably less than the domestic or municipal use. Most industries depend on the public supplies for their water, but a few industries obtain part of their water from their own wells. The largest industrial user in the county is the Anderson-Prichard Oil Co. refinery in Arkansas City, and it obtains its supply from three wells in the Arkansas River valley, in southeast Arkansas City. The wells are pumped continuously at a rate of about 300 gpm each, or about 1,400 acre-feet annually. The water is used as boiler-feed water and for cooling.

The Maurer Neuer Packing Co. has one well to provide water for cooling. This well is 48 feet deep and is pumped intermittently at a rate of about 300 gpm; the annual pumpage is probably about 100-acre feet.

Wells at the former Army Air Force base (Strother Field) about 6 miles north of Arkansas City now provide water for industrial use. The base facilities are owned jointly by the cities of Arkansas City and Winfield, which lease the buildings and hangars to several industries. When the Air Force base was operated by the Army, the water supply was obtained from six wells about 40 feet deep. The wells were equipped with turbine pumps and their yields ranged from 97 to 188 gpm. In 1958 only one well was in operation. This well (33-4-18ddc) is pumped intermittently to supply the industries located at the former air base. The average pumpage is less than 10,000 gallons a day, and the annual pumpage is probably about 10 acre-feet.

Other smaller industries in the county obtain a part of their supply from privately-owned wells, but pumpage from these wells is small.

Irrigation Supplies

Irrigation has not been practiced extensively in Cowley County. There was some irrigation in the Arkansas River valley from 1920 to 1940, but most of the projects were operated for only a few years. Since 1940 other irrigation projects have been carried on for short periods. In 1958 there were 11 irrigation plants in operation in the county, most of which had been built during the drought years from 1952 through 1956.

Thirteen irrigation plants were visited during the investigation. Eleven were in operation, one was partly dismantled, and another (32-3-34abb2) had been abandoned because of salt-water contamination. Of the operating irrigation plants, six were in the Arkansas River valley and obtained water from Wisconsinan terrace deposits or alluvium. Their yields ranged from 500 to 1,000 gpm. Four wells obtained water from Illinoisan deposits east of the Arkansas River valley. These wells have relatively low yields; the water is pumped into ponds from which it flows over the land to be irrigated. One well (34-4-20dbc) is in terrace deposits adjacent to Walnut River, and it yields about 300 gpm. The combined yield of the irrigation wells in the county is about 6,200 gpm, or about 1,000 acre-feet per year, and the total acreage irrigated is about 700 acres.

Water in Storage

Saturated thickness of the Pleistocene deposits in the Arkansas River valley, Walnut River valley, and adjacent areas was mapped (Pl. 3C). The volume of saturated material in the Pleistocene deposits was computed from this map. A specific yield of 20 percent was applied to the volume of sediments in the Wisconsinan terrace deposits and alluvium in the Arkansas River valley, and a specific yield of 10 percent was applied to the other saturated deposits, which are less permeable. The area underlain by and the volume of water in storage in Wisconsinan terrace deposits and alluvium in Arkansas River valley are given in Table 4, and similar information for the Illinoisan, Kansan, and Walnut River terrace deposits are given in Table 5.

In the deposits listed in Table 5, the quantity of water in storage is about 1.6 feet of water per acre, or about the quantity that would be pumped in 1 year if all the acreage underlain by these deposits were irrigated. In the Arkansas River valley the quantity of water in storage

TABLE 4.—*Area underlain by, and volume of water in storage in, Wisconsinan terrace deposits and alluvium in Arkansas River valley*

Township	Area (acres)	Water in storage[a] (acre-feet)
T. 31 S., R. 3 E.	3,770	13,000
T. 32 S., R. 3 E.	7,630	33,000
T. 33 S., R. 3 E.	10,120	45,000
T. 34 S., R. 3 E.	9,700	34,000
T. 34, 35 S., R. 4, 5 E.	6,250	32,000
Total	37,470	157,000

a. Based on a specific yield of 20 percent.

TABLE 5.—*Area underlain by, and volume of water in storage in, the Illinoisan, Kansan, and Walnut River terrace deposits*

Township	Area (acres)	Water in storage [a] (acre-feet)
T. 31 S., R. 3 E.	5,700	5,000
T. 32 S., R. 3 E.	11,190	18,000
T. 33 S., R. 3 E.	10,160	18,000
T. 33 S., R. 4 E.	9,750	18,000
T. 34 S., R. 4 E.	4,800	7,000
T. 34, 35 S., R. 3 E.	9,100	15,000
Total	50,700	81,000

a. Based on a specific yield of 10 percent.

is about 4.2 feet per acre, or about 3 years' supply under the same pumping conditions.

CHEMICAL CHARACTER OF GROUND WATER

When water comes into contact with the rocks that form the crust of the earth, it dissolves a part of the rock material. The type and composition of the rock through which the water passes thus determines, to a large degree, the chemical character of such ground water. The more soluble minerals are naturally taken into solution more easily and in greater concentration than the less soluble minerals.

The chemical character of ground water in Cowley County is indicated by analyses of 57 samples of water from wells and test holes (Table 6) and by partial analyses of 158 samples (Table 7). Of the 57 complete analyses, 9 are of water from public-supply wells or springs. Five partial analyses are from surface-water samples. Although not all minerals present in the water samples are reported, those that commonly are present in sufficient quantity to affect adversely the quality of the water for domestic, industrial, and irrigation use are reported.

The mineral constituents listed in Table 6 are reported in parts per million (ppm) by weight. One part per million is equivalent to one pound of substance per million pounds of water, or 8.34 pounds of substance per million gallons of water. The concentrations of minerals in the water in equivalents can be computed by multiplying the parts per million by the conversion factors given in Table 8. When expressed in equivalents per million, the sum of the anions is equal to the sum of the cations.

The samples of water from the wells and test holes in Cowley County were analyzed by Howard A. Stoltenberg, chemist in the Sanitary

TABLE 6.—*Analyses of water, in parts per million,*[a] *from representative wells, springs, and test holes in Cowley County*

Well number	Depth (feet) (b)	Geologic source	Date of collection	Temperature (°F)	Dissolved solids (residue at 180°C)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium, potassium as sodium (Na)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Hardness as $CaCO_3$: Calcium, magnesium	Hardness as $CaCO_3$: Noncarbonate
30-4-19add	31	Terrace deposits	9-25-58	57	566	26	1.5	128	25	45	489	48	44	0.0	9.3	422	21
30-6-28dbd1	Spring	Barneston Limestone	5- 5-58	57	290	18	.23	80	7.9	14	273	16	12	.2	5.3	232	8
30-8-21cac	42	Bader Limestone	10- 2-58	56	483	19	.26	63	38	68	478	38	20	.1	1.9	313	0
31-3-1abb	123	Barneston Limestone	9-14-58	55	1,570	14	.07	262	86	127	359	722	150	1.3	28	1,000	710
31-4-18cbb	34	Terrace deposits	9-25-58	56	621	25	.13	115	21	62	237	96	105	.2	80	374	180
31-6-28caa	Spring	Barneston Limestone	5-19-58	56	368	15	.16	105	7.3	17	327	18	12	.1	30	292	24
31-7-10bdd	24	Terrace deposits	10- 2-58	56	422	24	.31	122	12	18	427	19	15	.0	2.2	354	4
31-8-17cdd	75	Bader Limestone	10- 2-58	57	392	14	1.6	17	12	116	306	44	25	.9	12	92	0
32-3-6dcc	37-42	Alluvium	6- 5-44	...	12,100	...	...	1,330	333	2,790	168	46	7,500	.1	5.8	4,700	4,560
32-3-7ddd1	37.5	Terrace deposits	9-13-54	...	530	17	.02	97	24	43	317	107	37	.5	12	340	80
32-3-9abb	38-43	do.	4-27-44	...	342	...	...	55	16	52	295	16	22	.2	33	203	0
32-3-18dba	40	do.	1-14-59	56	486	18	.05	99	25	41	373	82	30	.5	4.2	350	44
32-3-21ccc	36-38	do.	4-10-44	...	269	...	...	54	13	33	256	19	18	.5	3.3	188	0
32-2-24bdc	167	Nolans and Winfield Limestones	3-20-56	58	1,690	14	.13	304	89	108	329	918	94	.8	.9	1,120	850
32-3-32cdd	40	Terrace deposits	8-20-43	...	468	...	2.3	77	27	66	403	46	47	.3	1.4	303	0
32-3-32ddc	52	do.	9-22-58	56	382	17	.04	71	17	46	332	24	22	.4	22	247	0
32-3-34abb	32	do.	10- 3-58	57	2,500	21	.12	414	150	288	217	134	1,380	.0	6.6	1,650	1,470
32-4-6ccc	90	Terrace deposits and Barneston Limestone	9-25-58	56	395	22	.78	82	21	25	299	26	23	.1	49	291	46
32-4-8aaa	100	Doyle Shale	10- 3-58	56	364	14	.05	91	22	16	395	5.3	11	.0	9.7	318	0
32-4-34ccb	30	Terrace deposits	9-26-58	57	360	14	.12	82	17	26	312	50	15	.3	2.4	274	18
32-5-4aaa	180	Barneston and Wreford Limestones	10- 2-58	56	575	10	.08	126	32	28	390	76	31	.4	80	446	126
32-5-24cbc	140	Barneston Limestone	9-11-58	56	423	11	2.0	90	29	28	404	48	14	.5	3.6	344	13
32-7-11aaa	120	Wreford Limestone	10- 2-58	56	369	13	1.8	75	30	23	393	26	7	.5	.9	310	0
33-3-5bbb	20	Terrace deposits	8-16-43	...	304	...	1.2	74	15	18	256	53	12	.5	2.3	246	36
33-3-5cac	44	do.	1-14-59	56	1,590	18	.02	312	65	179	248	84	810	.1	1.5	1,040	840
33-3-10ccc	35	do.	8-20-43	57	422	...	.17	76	22	56	383	42	26	.3	8.4	280	0
33-3-13aaa	47-52	Crete and Loveland Formations	4-15-44	...	435	...	...	64	21	74	361	56	34	.4	4.9	246	0
33-3-14dda	40	do.	8-20-43	...	448	...	.33	72	20	70	361	74	26	.3	4.4	262	0
33-3-17aaa1	43-47	Terrace deposits	4- 3-44	...	6,980	...	...	558	125	1,940	238	90	4,140	.3	6.6	1,900	1,710
33-3-20dcc	39-44	do.	3-28-44	...	28,000	...	...	1,640	408	8,710	214	140	17,300	...	...	5,770	5,590
33-3-25bbb	29-34	Crete and Loveland Formations	3-20-44	...	525	...	...	72	18	108	427	60	51	.3	2.2	254	0
33-3-34cdd	48	Wellington Formation	8-18-43	...	379	...	.43	75	22	32	321	12	15	.3	62	278	15
33-3-34dcc	45	do	9-22-58	57	498	17	.04	72	24	78	332	18	92	.2	33	278	6
*33-4-7ddd	30	Winfield Limestone	8-20-43	...	650	...	1.0	116	43	43	306	216	34	.2	44	466	215
*33-4-7ddd	30	do.	9-22-58	56	796	20	.08	132	46	65	329	291	38	.2	42	518	248
33-4-19adc	41	Crete and Loveland Formations	9- 2-42	...	560	...	2.6	95	25	78	349	86	89	.3	10	340	54
33-4-21cdd	33-38	do.	4-17-44	...	458	...	...	76	25	58	344	82	26	.2	19	292	10

33-4-23ccc2	29	do	9-26-58	56	729	23	.06	155	30	58	406	60	128	.1	75	510	177
33-4-30add1	40	do	8-20-43	....	525	....	.99	69	20	103	368	78	64	.3	5.3	254	0
33-5-33bbb	110	Barneston Limestone	10- 2-58	57	558	13	.56	87	58	31	464	87	13	.5	40	456	76
33-6-1acc	25	Terrace deposits	4-21-44	....	581	12	.38	148	23	17	461	42	32	.1	43	464	86
33-6-13bcd	36	do	6- 2-58	58	1,870	15	.13	333	35	325	371	104	870	.1	5.3	975	671
33-7-14adc	100	Bader Limestone	10- 2-58	57	423	14	.08	44	49	49	442	20	17	.3	12	312	0
*34-3-4bbb	29	Terrace deposits	8-18-43	....	1,070	....	.17	161	27	197	254	140	410	.5	8.4	512	304
*34-3-4bbb	29	do	9-22-58	57	697	16	.24	97	16	135	298	100	167	.5	19	308	64
34-3-7baa	16	Alluvium	8-19-43	....	1,400	....	.38	215	66	162	443	635	80	.6	26	808	445
34-3-23cbb	39-44	do	4-20-44	....	451	....	....	94	27	32	312	109	31	.2	2.0	346	90
34-3-26bad2	40	do	5-26-59	57	808	17	.4	67	16	205	203	144	255	.6	1.5	233	67
34-4-12bbb	28	do	9-26-58	56	373	21	.54	88	10	28	281	23	25	.0	40	260	30
34-4-21dcc	41	do	9-23-58	57	459	22	.09	97	19	22	245	46	21	.1	111	320	119
34-4-28aba	242	Barneston Limestone	9-23-58	56	2,670	10	.22	233	56	600	359	1,190	410	3.0	2.2	812	518
34-4-33ddd	16	Terrace deposits	8-18-43	....	595	....	.09	86	13	121	264	68	170	.3	4.9	268	52
34-4-34ddd	22	do	8-18-43	....	991	....	.22	150	23	191	345	93	352	.2	8.8	468	185
34-8-30 Lot 3	365	Sandstone in Willard and Pillsbury Shales	10- 2-58	....	838	15	.06	8.2	.9	329	537	33	184	1.5	1.5	24	0
**35-3-1aaa	46-48	Terrace deposits	8-27-58	48	773	13	.22	78	20	172	200	177	213	.5	1.0	276	112
35-4-2add	42-47	Alluvium	4-20-44	....	402	....	....	102	20	22	374	49	16	.3	5.8	336	30
35-4-6bdc	52	do	10- 4-58	56	936	17	.6	91	25	258	232	230	326	.6	.7	330	148

(a) One part per million is equivalent to one pound of substance per million pounds of water or 8.33 pounds per million gallons of water.

(b) Total depth of well except where two numbers are given; 37-42 indicates depth from which sample was pumped.

* Two samples of water from same well on different dates.

** Partial analysis given in Table 7.

TABLE 7.—*Partial analyses of water, in parts per million,[a] from wells and test holes in Cowley County*

Well number	Depth (feet) (b)	Geologic source	Date of collection	Sulfate (SO_4)	Chloride (Cl)
31-3-16cdd	54-56	Terrace deposits	6-16-57	....	31
31-3-29dcc	38-43	do	4-29-44	....	14
31-3-30ccc	41-43	do	9- 8-55	....	56,400
	43-48	do	5-26-44	....	40,700
31-3-30dcc	27-32	do	5-26-44	....	23
31-3-31ccc	33-35	Alluvium	6-21-56	....	26,200
31-3-31ccd	30	do	8-21-43	....	196
31-3-32bbb	20-22	Terrace deposits	8-10-56	162	26
	26-28	do	8-10-56	384	43
31-3-32ddc	18-20	do	8-10-56	116	3,150
31-3-33abb	14-19	do	5- 2-44	....	3,980
31-4-6bdd	28	do	4-15-58	....	512
32-3-5baa	16-18	do	8-10-56	200	66
	25-27	do	8-10-56	246	104
32-3-5ccc1	30	do	8-21-43	....	11
32-3-5ccc2	30-35	do	5- 2-44	....	19
32-3-5ccc3	15-17	do	8-10-56	62	63
	26-28	do	8-10-56	70	67
32-3-5dcc	29-34	do	5- 2-44	....	50
32-3-6aaa	11-13	do	8-10-56	38	10
	26-28	do	8-10-56	68	20
32-3-6ccc	40-45	Alluvium	6- 6-44	....	38,000
32-3-7dca	Surface	....	8-10-56	132	5,310
32-3-8dbb	Surface	....	8-10-56	166	2,490
32-3-10baa	28-33	Terrace deposits	5- 3-44	....	6
32-3-17abb	18-20	do	8-11-56	48	16
32-3-17bbb	13-15	do	8-11-56	216	57
	27-29	do	8-11-56	84	31
33-3-17dcc	9-11	do	8-11-56	28	27
33-3-18abb	15-19	do	8-11-56	78	30
	34-36	do	8-11-56	68	58
32-3-18bba	7-9	Alluvium	8-12-56	78	570
	33-35	do	8-12-56	122	8,330
32-3-19aaa	16-18	Terrace deposits	8-11-56	56	13
	25-27	do	8-11-56	62	16
	19-21	do	6-25-57	....	50
32-3-19abb	36-38	do	6-25-57	....	1,760
32-3-19abc1	33-35	do	4- 7-44	....	4,300
32-3-19abc2	37-39	do	4- 7-44	....	34,800
32-3-19bbb	12-14	do	6-25-57	....	85
	23-25	do	6-25-57	....	80
	45-47	do	6-25-57	....	290
32-3-19ddd	25	Alluvium	8-21-43	....	46
32-3-20dbc	15-17	Terrace deposits	8-11-56	98	21
32-3-29cdc	13-15	do	8-12-56	50	51
32-3-30aaa	5-7	Alluvium	8-12-56	74	37
	14-16	do	8-12-56	58	20
32-3-30ddd	7-9	do	8-12-56	64	19
	14-16	do	8-12-56	60	21
32-3-31aaa	20	do	8-20-43	....	19
32-3-31dac	14-18	Terrace deposits	8-14-56	52	60
	34-36	do	8-14-56	152	485
32-3-31dca	42	do	8-10-56	142	325
32-3-31dcd	13-15	do	8-14-56	36	26
	33-35	do	8-14-56	116	365
	11-13	do	8-17-57	....	23
	36-38	do	8-17-57	....	2,800
32-3-32ccc2	13-15	do	8-14-56	32	28
	26-28	do	8-14-56	60	33
32-4-5ccc	27-32	do	5- 5-44	....	12
32-4-7bba	36-41	do	5- 5-44	....	31
33-3-3bbb	29-34	do	4-21-44	....	31
33-3-5ccc1	12-14	Alluvium	8-13-56	86	34
	14-16	do	8-17-57	....	46
	34-36	do	8-17-57	....	332
33-3-5ddc	15-17	Terrace deposits	8-13-56	32	39
	32-34	do	8-13-56	44	29
33-3-6bab	13-15	do	8-14-56	64	235
	33-35	do	8-14-56	364	7,770
	15-17	do	6-25-57	....	87
	35-37	do	6-25-57	....	14,700
33-3-7aaa	30	Alluvium	8-20-43	....	64
33-3-8ccc	11-13	Terrace deposits	8-14-56	68	41
33-3-8dcc	35-40	Alluvium	4- 3-44	....	4,750

TABLE 7.—*Partial analyses of water, in parts per million,*[a] *from wells and test holes in Cowley County—Continued*

Well number	Depth (feet) (b)	Geologic source	Date of collection	Sulfate (SO_4)	Chloride (Cl)
33-3-15aaa	34-39	Terrace deposits	4- 4-44	....	35
33-3-17aaa2	15-17	do	8-15-56	112	330
	33-35	do	8-15-56	162	475
33-3-17aaa3	25	do	8-20-43	....	81
33-3-17bba	19-24	do	4- 1-44	....	285
33-3-17daa	14-16	do	8-15-56	....	68
	33-35	do	8-15-56	52	193
33-3-19ccc	20-25	do	4- 1-44	....	426
33-3-19dcc	33-38	do	3-30-44	....	1,680
33-3-20ddc	20	do	8-20-43	....	115
33-3-21aaa	40	do	8-20-43	....	12
33-3-21dda	35-40	do	3-27-44	....	7,600
33-3-21ddb	19-24	Alluvium	3-27-44	....	3,090
33-3-23ccc	11-15	Crete and Loveland Formations	3-22-44	....	100
33-3-27dcc	25-30	do	3-23-44	....	6.0
33-3-28bbb	42-47	Terrace deposits	3-27-44	....	16,900
33-3-28dbc1	17-19	do	8-16-56	36	122
	30-32	do	8-16-56	146	462
33-3-28dbc2	Surface	....	8-16-56	168	720
33-3-29cca1	15-17	Alluvium	8-16-56	182	890
	34-36	do	8-16-56	146	2,620
33-3-29cca2	Surface	....	8-16-56	172	790
33-3-29ddd1	28-30	Terrace deposits	8-15-56	124	324
33-3-29ddd2	21-23	do	8-15-56	114	391
	48-50	do	8-15-56	162	1,580
33-3-30aaa	25-30	do	3-30-44	....	1,120
33-3-31aaa	16-18	do	8-16-56	176	480
	39-41	do	8-16-56	176	13,000
33-3-31add	20	do	8-20-43	....	248
33-3-31daa	13-15	do	8-16-56	116	740
	30-32	do	8-16-56	162	1,220
33-3-32daa	23-25	do	8-16-56	148	343
	39-41	do	8-16-56	208	435
33-3-33abb	15-17	do	8-15-56	44	26
	24-26	do	8-15-56	46	33
33-3-33dcc	23-28	do	3-23-44	....	43
33-4-17cbb	48-53	Crete and Loveland Formations	3-16-44	....	14
33-4-19aaa	37-42	do	3-16-44	....	13
33-4-29abb	38-43	do	4-17-44	....	56
33-4-30add2	38-43	do	3-18-44	....	64
33-6-12aaa	32	Terrace deposits	8-13-46	....	19
34-3-4abb	23-25	do	8-17-56	68	31
34-3-4dcc	25-27	do	9- 2-56	48	40
	43-45	do	9- 2-56	76	83
34-3-5aab	10-12	do	8-17-56	136	292
	20-22	do	8-17-56	176	512
	35-37	do	8-17-56	208	5,160
34-3-5add	40-45	do	3-23-44	....	1,660
34-3-5bab	12-14	do	8-18-56	88	298
	29-31	do	8-18-56	148	690
	43-45	do	8-18-56	196	4,950
34-3-5bbb	23-25	do	8-17-56	144	419
34-3-5caa	21-23	do	9- 2-56	178	810
	37-39	do	9- 2-56	178	9,160
34-3-5dcc1	20	Alluvium	8-20-43	....	103
34-3-5dcc2	37-42	do	3-24-44	....	5,750
34-3-8aaa	19-21	Terrace deposits	9- 2-56	178	308
	34-36	do	9- 2-56	220	1,060
34-3-8acc1	22-24	Alluvium	9- 2-56	642	1,105
34-3-8acc2	Surface	....	9- 2-56	348	1,580
34-3-8baa	10-12	Alluvium	9- 2-56	198	212
	32-34	do	9- 2-56	196	1,570
34-3-8cdd	15-17	Terrace deposits	9- 2-56	1,490	265
34-3-9dad	20	do	8-20-43	....	19
34-3-15bbb	26-28	do	6-22-57	....	36
34-3-15cdd	34-36	Alluvium	6-22-57	....	560
34-3-15dcd	20	do	8-20-43	....	30
34-3-16bbb	15-17	Terrace deposits	9- 2-56	198	63
	30-32	do	9- 2-56	564	277
34-3-23ccc	19-21	do	6- 5-57	....	157
34-3-26add	28-30	Alluvium	6- 7-57	....	530
34-3-26bab	26-28	Terrace deposits	6- 6-57	....	960
34-3-26bdc	28-30	do	6- 6-57	....	650

TABLE 7.—*Partial analyses of water, in parts per million,*[a] *from wells and test holes in Cowley County—Concluded*

Well number	Depth (feet) (b)	Geologic source	Date of collection	Sulfate (SO_4)	Chloride (Cl)
34-3-35aab	28-30	Terrace deposits	6- 7-57	....	505
34-3-36bab	22-24	do	6- 6-57	....	155
34-4-20cab	19-21	do	6-12-57	....	302
34-4-30adc	24-26	do	6-12-57	....	86
34-4-31aba	21-23	do	6-11-57	....	399
*35-3-1aaa	34-36	do	6- 8-57	....	390
35-4-3ada	31-33	do	6- 9-57	....	317
35-4-4aad	18-20	do	6- 9-57	....	157
35-4-5abb	28-30	Alluvium	6-11-57	....	610
35-4-5daa	17-19	Terrace deposits	6- 8-57	....	585
35-5-18bbb	12-14	do	6- 9-57	....	372

(a) One part per million is equivalent to one pound of substance per million pounds of water or 8.33 pounds per million gallons of water.

(b) Total depth of well except where two numbers are given; 54-56 indicates depth from which water sample was pumped.

* Complete analysis given in Table 6.

TABLE 8.—*Factors for converting parts per million to equivalents per million*

Mineral constituent	Chemical symbol	Factor
Calcium	Ca^{++}	0.0499
Magnesium	Mg^{++}	.0822
Sodium	Na^{+}	.0435
Carbonate	CO_3^{--}	.0333
Bicarbonate	HCO_3^{-}	.0164
Sulfate	SO_4^{--}	.0208
Chloride	Cl^{-}	.0282
Nitrate	NO_3^{-}	.0161
Fluoride	F^{-}	.0526

Engineering Laboratory of the Kansas State Board of Health. The analyses give only the dissolved mineral content of the water and do not indicate sanitary conditions.

Chemical Constituents in Relation to Use

The dissolved solids, hardness, iron, fluoride, nitrate, sulfate, and chloride in the samples of water from Cowley County are summarized in Table 9 and are discussed briefly in the following paragraphs.

Dissolved Solids

After water has been evaporated, the residue consists of mineral matter, some organic matter, and water of crystallization. The kind and quantity of minerals in the water determine its suitability for various uses. Water containing less than 500 ppm of dissolved solids generally is satisfactory for domestic use. Water containing more than 1,000 ppm of dissolved solids may contain enough of certain constituents to cause

TABLE 9.—*Summary of dissolved mineral constituents in water in Cowley County*

Range, in parts per million	Number of samples
Dissolved Solids	
500 or less	27
500 to 1,000	19
more than 1,000	11
Hardness	
50 or less	1
51 to 150	1
151 to 300	20
more than 300	35
Iron	
0.1 or less	14
.11 to 0.3	14
.31 to 1.0	11
more than 1.0	7
Fluoride	
less than 1.0	53
1.0 to 1.5	2
more than 1.5	1
Nitrate	
45 or less	50
46 to 90	5
91 to 150	1
more than 150	0
Sulfate	
50 or less	37
51 to 250	90
more than 250	11
Chloride	
250 or less	128
251 to 500	31
501 to 750	12
751 to 5,000	27
more than 5,000	17

a noticeable taste or to render it unsuitable for use in some other respect.

The dissolved solids in the 57 samples of water from Cowley County ranged from 290 ppm to 28,300 ppm; in 11 samples the concentration exceeded 1,000 ppm.

Hardness

The hardness of water, the property that generally receives the most attention, is commonly recognized by the effect of the use of soap in the water; the soap does not lather readily and it leaves a curd on the water. Calcium and magnesium cause nearly all the hardness of ordinary water. These constituents are also the active agents in the formation of scale in steam boilers or other containers in which water is evaporated.

The calcium carbonate hardness, the calcium and magnesium, and the noncarbonate hardness of the water samples from Cowley County are given in Table 6. The carbonate or "temporary" hardness is caused by calcium and magnesium bicarbonates and is almost entirely removed by boiling. The noncarbonate or "permanent" hardness is caused by calcium and magnesium sulfates and chlorides and other salts and cannot be removed by boiling. Carbonate hardness and noncarbonate hardness react to soap in the same manner.

Water having a hardness of less than 50 ppm is regarded as soft, and under ordinary circumstances no treatment for removal of hardness is necessary. Hardness of 50 to 150 ppm does not seriously affect the use of water for most purposes but does increase the use of soap. Water hardness exceeding 150 ppm is easily noticeable, and if it is much more than 150 ppm, the water may need to be softened. When municipal supplies are softened, generally the hardness is decreased to about 100 ppm. Further softening of municipal supplies may not be economically justified. In most softening processes, only the carbonate or temporary hardness is removed.

The hardness of 57 samples of water from Cowley County ranged from 24 to 5,770 ppm as $CaCO_3$. All but two samples of water had hardness in excess of 150 ppm.

Iron

Next to hardness, iron is the constituent of natural water that generally is most objectionable. The quantity may differ greatly from place to place even in water from the same formation. If water contains more than 0.3 ppm of iron in solution, the iron, upon oxidation by exposure to air, may settle out as a reddish sediment. Iron may be present in sufficient quantity to give a disagreeable taste to the water, stain cooking utensils and plumbing fixtures, and be objectionable in the preparation of foods and beverages. Aeration, followed by settling or filtration, will remove the iron from some water, but treatment with chemicals is required for others.

In the 47 samples of water analyzed for iron, the concentration ranged from 0.02 to 2.6 ppm. In 18 of the samples the amount of iron exceeded 0.3 ppm.

Fluoride

Although the quantity of fluoride present in natural water is relatively small in comparison to other common constituents, the amount present in water used by children should be known. Fluoride in water has been associated with the dental defect known as mottled enamel, which may appear on the teeth of children who, during the formation of the permanent teeth, habitually drink water containing more than 1.5 ppm of fluoride (Dean, 1936). A smaller quantity of fluoride in the drinking water (about 1 ppm) is likely to be beneficial by preventing or decreasing the incidence of caries in the permanent teeth of children (Dean and others, 1941). Flouride is now added to many public supplies in quantities sufficient to increase the total flouride concentration to about 1 ppm.

The fluoride content of 56 samples of water from Cowley County ranged from 0.0 to 3.0 ppm, but only one sample contained more than 1.5 ppm.

Nitrate

Large amounts of nitrate in water may cause cyanosis in infants when the water is used for drinking or in the food formula. Water containing less than 45 ppm of nitrate is generally regarded as safe, but water containing more than 90 ppm is regarded by the Kansas State Board of Health as likely to cause severe, possibly fatal, cyanosis if used continually (Metzler and Stoltenberg, 1950). The source of nitrate in natural water is not definitely known, but excessive concentrations of the constituent may be an indication of pollution.

The nitrate content in the 56 samples of water ranged from 0.9 to 111 ppm. In 50 samples the nitrate concentration was less than 45 ppm and in only one sample was it more than 90 ppm.

Sulfate

Sulfates when combined with calcium or magnesium contribute most of the "permanent hardness" to a natural water, and the removal of these salts is both difficult and expensive. Sulfate in excessive amount (more than 500 ppm) in a domestic or stock water supply is undesirable because of the laxative effect when the water is first used for drinking. A concentration of less than 250 ppm is recommended for human consumption, although a concentration as great as 2,000 ppm may be tolerated; a somewhat greater tolerance by cattle has been observed.

The sulfate content in 138 water samples ranged from 5.3 to 1,490 ppm; 11 samples contained more than 250 ppm.

Chloride

Chloride salts are found in nature in abundance and are dissolved in widely varying quantities from many rock materials. They are found in sea water and in many ground waters at appreciable depths. Most oil-field brines contain considerable chloride. Chloride has little effect on the suitability of water for ordinary use unless present in sufficient quantity to make the water unpotable or corrosive to metal pipes and storage containers. Permissible quantities of chloride in irrigation waters vary considerably with the crop being irrigated. Removal of the chloride ion from water has been prohibitively expensive in the past, but research in recent years has discovered methods for the removal of salt from brackish water that are economically feasible.

Chloride salts in solution having a concentration of less than 250 ppm cannot be detected by taste, and such waters are regarded as satisfactory for ordinary uses. Water containing between 250 and 500 ppm of chloride may have a slightly salty taste but can be used for drinking and household uses. Water containing more than 500 ppm has a disagreeable taste but ordinarily causes no ill effects. It is reported that cattle can drink water having a chloride content of 5,000 ppm.

During the last 25 years the city of Winfield has had to abandon several wells because of salt-water contamination, and many individuals in the Arkansas River valley have reported salt-water contamination of their water supply. In the spring of 1944 about 75 test holes were drilled in the alluvium and terrace deposits in and adjacent to the Arkansas River valley. Samples were collected from these test holes and from wells in the area and these were analyzed. (See Tables 6 and 7 and Pl. 6.) During the present investigation, many additional test holes were augered and water samples collected; the results of these analyses also are given in Tables 6 and 7 and shown on Plate 6. Samples were collected at different depths in many of these later test holes, to determine whether the chlorides were confined to any particular horizon within the aquifer. In general, the greatest concentration of chlorides was near the base of the aquifer.

Of 215 water samples analyzed for chloride content, 87 contained chloride in excess of 250 ppm; and all but 1 were collected from wells in alluvium or terrace deposits in the Arkansas River valley and adjacent areas. Well 34-4-28aba obtains water containing 410 ppm of chloride from the Barneston Limestone at a depth of 242 feet. The chloride content of 128 samples was less than 250 ppm, and that of 17 samples was more than 5,000 ppm.

Temperature

Ordinarily the temperature of ground water receives little attention in a discussion of the quality of water or its suitability for use. Ground water is preferred by many industries that use large quantities of water for cooling because of its relatively uniform temperature. In areas where industrial users return large quantities of water to the aquifer, a marked rise in temperature of the ground water may be noted.

In Cowley County the temperature of the water, given in Table 6, ranged from 55°F to 58°F, excluding that from test hole 35-3-1aaa, in which the temperature was exceptionally low. On June 8, 1957, a sample from this test hole had a temperature of 48°F. On August 27, 1958, this test hole was redrilled and resampled at a depth of 47 feet and the temperature was again 48°F. The cause for this abnormally low temperature was not determined.

Suitability of Water for Irrigation

This discussion of the suitability of water for irrigation is adapted from Agriculture Handbook No. 60, U. S. Department of Agriculture (U. S. Salinity Laboratory Staff, 1954).

The development and maintenance of successful irrigation projects involve not only the supplying of irrigation water to the land, but also the control of the salinity and alkalinity of the soil. Soil that was originally nonsaline and nonalkaline may become unproductive if excessive soluble salts or exchangeable sodium are allowed to accumulate because of improper irrigation and soil management or poor drainage.

The characteristics of an irrigation water that seem to be most important in determining its quality are (1) total concentration of soluble salts; (2) relative proportion of sodium to total principal cations (magnesium, calcium, sodium, and potassium); (3) concentration of boron or trace elements that may be toxic to the plant; and (4) under some conditions the concentration of bicarbonate as related to the concentration of calcium and magnesium.

For classification of irrigation water, the disolved solids content can be adequately expressed in terms of specific conductance, which is a measure of the ability of the inorganic salts in solution to conduct an electric current. The conductivity is usually expressed in terms of micromhos per centimeter at 25°C and may be approximated by multiplying by 100 the total equivalents per million of calcium, magnesium, sodium, and potassium. Factors for converting parts per million to equivalents per million are given in Table 8. In general, water having a conductance of less than 750 micromhos is satisfactory insofar as salt content is concerned, although some salt-sensitive crops may be adversely affected by water having a conductance in the range of 250 to 750 micromhos per centimeter. Waters ranging from 750 to 2,250 micromhos per centimeter are widely used, and satisfactory crop growth is obtained under good management and favorable drainage conditions. Very few instances can be cited where water having a conductivity greater than 2,250 micromhos per centimeter has been used successfully.

The relative proportion of sodium to other cations in irrigation water may be expressed simply as the percentage of sodium. The U.S. Department of Agriculture uses the sodium-adsorption ratio (SAR) to express the relative activity of sodium ions in exchange reactions with the soil, and to measure the suitability of water for irrigation. The sodium-adsorption ratio may be determined by the formula

$$SAR = \frac{Na^{+}}{\sqrt{\frac{Ca^{++} + Mg^{++}}{2}}}$$

where the ionic concentrations are expressed in equivalents per million. The sodium-adsorption ratio may also be determined by the use of the nomogram shown in Figure 7. To use the nomogram the concentration of sodium in equivalents per million is plotted on the left or A scale, and the sum of the concentrations of calcium and magnesium in equivalents per million is plotted on the right or B scale. The point where a line between these points intersects the SAR or C scale indicates the sodium-adsorption ratio of the water. When the sodium-adsorption ratio and the electrical conductivity of a water are known, the suitability of the water for irrigation can be determined by plotting these values on the diagram shown in Figure 8. Low-sodium water (S1) can be used on almost all soils with little danger of development of harmful levels of exchangeable sodium. Medium-sodium water (S2) will present an appreciable sodium hazard in fine-textured soils, especially under poor drainage or low leaching conditions. This water may be safely used on soils having a high permeability. High-sodium water (S3) may produce harmful levels of exchangeable sodium in most soils and will require good soil management and good drainage, through leaching, and addition of organic matter. Very high sodium water (S4) is generally unsuitable for irrigation unless special practices are used, such as addition of gypsum to the soil.

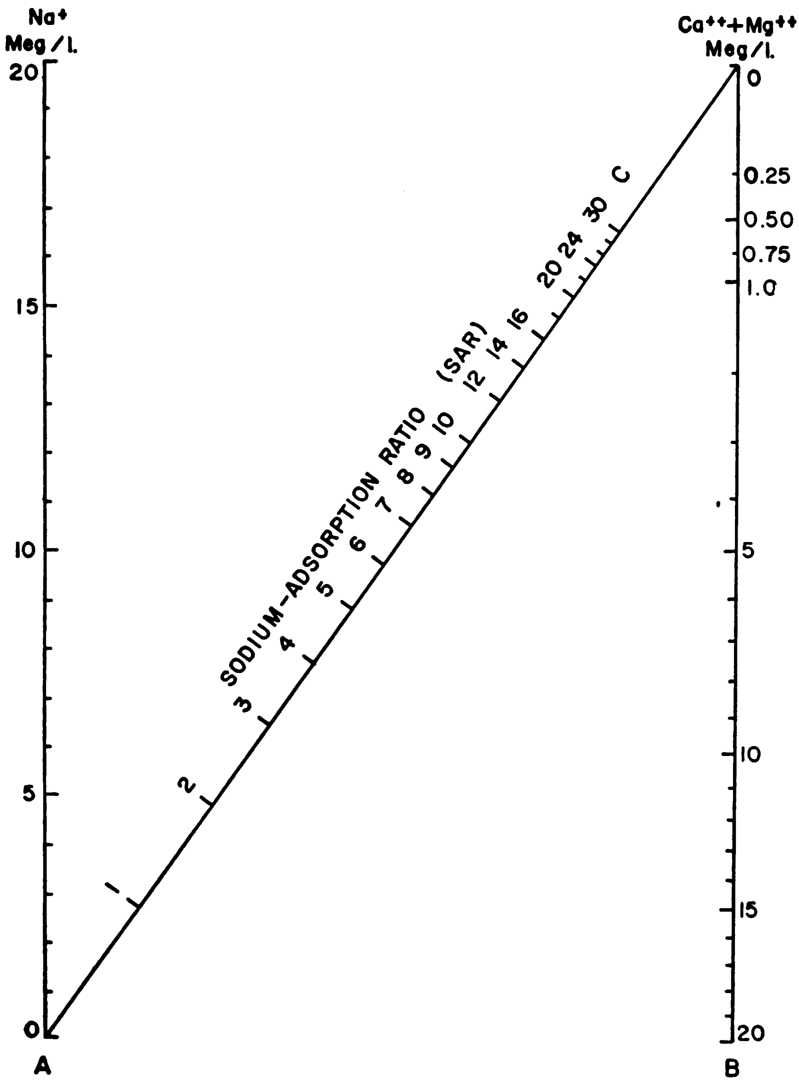

FIG. 7.—Nomogram for determining sodium-adsorption ratio of water for irrigation.

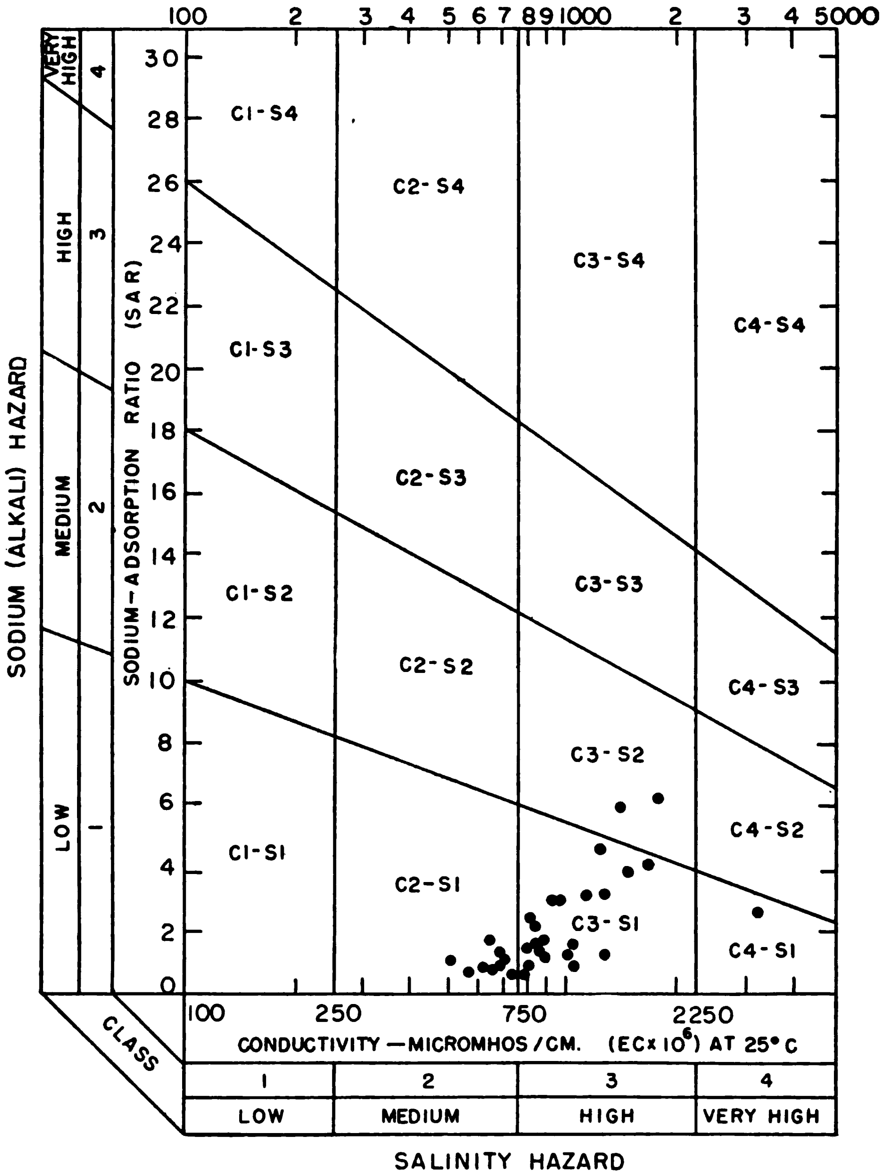

Fig. 8.—Diagram showing classification of water samples from Cowley County for irrigation use.

Low-salinity water (C1) (Fig. 8) can be used on most soils with little likelihood that salinity will develop. Medium-salinity water (C2) can be used if there is a moderate amount of leaching. Moderately salt-tolerant crops such as potatoes, corn, wheat, oats, and alfalfa can be irrigated with such water without special practices. High-salinity water (C3) cannot be used on soils having restricted drainage. Very high salinity water (C4) can be used only on certain very salt-tolerant crops, and then only if special practices are used. The sodium-adsorption ratio, conductivity, and class of irrigation water for samples from 37 wells in the Arkansas River valley and Walnut River valley are given in Table 10. Water from six of the wells is not suitable for irrigation. Three of the six samples of water have very large values for both the sodium-adsorption ratio and the conductivity; they are probably from areas contaminated by oil-field brines. In the other three samples, the alkali hazard is not great, but the salinity hazard exceeds the limit of satisfactory water for use in irrigation.

The values for the other 32 samples from wells given in Table 10 are plotted in Figure 8. Nine samples of water are in the C2-S1 class and can be used in areas of good drainage and moderate leaching. Twenty samples of water are in the C3-S1 class and should not be used in areas of restricted drainage; they will require some leaching. Two samples of water in the C3-S2 class should be used only in permeable soils where considerable leaching can take place. One sample of water in the C4-S1 class would present a salinity hazard and could be used only on certain crops and would require very good soil management.

Most of the soils in the Arkansas River valley are relatively permeable, drain readily, and are thoroughly leached. In parts of the Walnut River valley and in the area underlain by Illinoisan terrace deposits (Pl. 1), some of the soils are heavy and poorly drained and cannot be leached readily.

Available information concerning trace elements in ground water in Kansas is sparse. Elements that might be toxic to plants are not known to be present in harmful quantities, however.

SUMMARY

The principal aquifers in the area that lies mainly east of Grouse Creek are limestone and sandstone units of Early Permian and Late Pennsylvanian age. Yields of wells are small in this area and may not be adequate for domestic and stock use. The water is hard but of usable quality except in the southern part of the area, where it locally contains excessive chloride and sulfate. The land is used principally for grazing, and ponds are used for stock water.

TABLE 10.—*Sodium-adsorption ratio (SAR), conductivity (C), and class of irrigation water from wells in Arkansas River valley and Walnut River valley*

Well number	SAR	Conductivity	Class
30–4–19add........	0.9	1,040	C3–S1
31–4–18cbb........	1.3	1,010	C3–S1
32–3–6dcc..........	18	21,500	No plot
32–3–7ddd1........	1.0	870	C3–S1
32–3–9abb..........	1.6	630	C2–S1
32–3–18ddc........	1	880	C3–S1
32–3–21ccc........	.9	520	C2–S1
32–3–24bdc........	1.4	2,720	No plot
32–3–32cdd........	1.6	890	C3–S1
32–3–32ddc........	1.2	690	C2–S1
32–3–34abb........	3.1	4,550	No plot
32–4–6ccc..........	.6	690	C2–S1
32–4–34ccb........	.7	660	C2–S1
33–3–5bbb..........	.4	570	C2–S1
33–3–5cbc..........	2.4	2,870	No plot
33–3–10ccc........	1.4	800	C3–S1
33–3–13aaa........	2.1	810	C3–S1
33–3–14dda........	2	830	C3–S1
33–3–17aaa1	19	12,200	No plot
33–3–20dcc........	50	49,400	No plot
33–3–25bbb........	2.9	970	C3–S1
33–3–34cdd........	1	700	C2–S1
33–4–19adc........	1.8	1,020	C3–S1
33–4–21cdd........	1.5	840	C3–S1
33–4–23ccc2	1.1	1,270	C3–S1
33–4–30add1.......	2.8	960	C3–S1
34–3–4bbb..........	3.8	1,880	C3–S1
34–3–4bbb..........	3.2	1,200	C3–S1
34–3–7baa..........	2.5	2,320	C4–S1
34–3–23cbb........	.8	830	C3–S1
34–3–26bad2.......	5.9	1,360	C3–S2
34–4–12bbb........	.8	640	C2–S1
34–4–21dcc........	.4	740	C2–S1
34–4–33ddd........	3.1	1,060	C3–S1
34–4–34ddd........	3.9	1,770	C3–S1
35–3–1aaa..........	4.5	1,300	C3–S1
35–4–2add..........	.4	770	C3–S1
35–4–6bdc..........	6.1	1,780	C3–S2

The Wreford and Barneston Limestones, of Permian age, are the principal aquifers of the area extending from a line near Walnut River on the west to Grouse Creek on the east. In parts of this area much water is available from cavernous Nolans Limestone still higher in the section. Adequate water supplies for domestic and stock use are available in much of the area, but in some parts the water has become polluted and unusable. The water from cherty limestone formations is a hard, calcium bicarbonate water but is suitable for most uses. Water from the cavernous limestone formations generally contains sulfate, and in some areas it contains too much for most uses.

The area that lies principally west of Walnut River has the largest supplies of available ground water. The aquifers are composed of unconsolidated rocks of Pleistocene age and represent all but the first of the major divisions of the Pleistocene Series.

The Kansan and Yarmouthian deposits are the least important of the Pleistocene aquifers. They occupy the highest topographic position in relation to younger deposits and contain a larger percentage of silt and clay than other Pleistocene deposits. Supplies of good water adequate for domestic and stock use are available in parts of the area.

The Illinoisan and Sangamonian deposits occupy an intermediate topographic position between the Kansan deposits and the younger Wisconsinan terrace deposits, and are an important source of ground water. Yields range to 200 gpm and the water is good except in one small area of pollution. The water is used principally for domestic and stock needs, but some water is used for irrigation and industrial purposes. This aquifer might be considered for development as a supplemental supply for the city of Winfield.

The Wisconsinan terrace deposits and alluvium of the Arkansas River valley are the most important sources of ground water in the county and produce the greatest yields. Although the water is generally of usable quality, some of the water in this area is not suitable for irrigation use; some has been polluted in past years by oil-field brine in the valley area. Oil fields are present throughout this area, and brine from some of them has entered the aquifer and then has moved laterally downgradient. The brine seems to move as a body, becoming only slightly diluted around the edges. Several public-supply and domestic wells have been abandoned because of this contamination. Inasmuch as the strongest concentration of brine is in the lower part of the aquifer, some usable water can be obtained from partially penetrating wells of low yield.

RECORDS OF WELLS, TEST HOLES, AND SPRINGS

Information pertaining to 234 wells, springs, and test holes and 5 surface-water sampling points is given in Table 11. The number of wells, springs, and test holes are listed according to use, as follows:

Domestic and stock wells or springs	149
Public-supply wells or springs	30
Industrial wells	11
Irrigation wells	13
Observation wells	4
Wells or test holes not in use	27
Surface-water sampling points	5

TABLE 11.—*Records of wells, test holes, and springs in Cowley County, Kans.*

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)	Depth to water level below land surface (feet) (7)	Date of measurement	Remarks
	T. 29 S., R. 3 E.													
29-3-33ddc	SW SE SE sec. 33	C. Millen	Dr	60.0	6	GI	Limestone	Winfield Limestone	Cy, W	S	....	53.62	9-14-58	
	T. 29 S., R. 7 E.													
29-7-31ddb	NW SE SE sec. 31	N. Murtaugh	Dr	43	8	S	do	Barneston Limestone	Cy, W	S	....	34.85	9-12-58	
	T. 30 S., R. 3 E.													
30-3-6bbb	NW cor. sec. 6	C. Walker	Dr	51.0	6	GI	do	Nolans Limestone	Cy, W	D, S	....	37.46	9-14-58	
30-3-11ddd	SE cor. sec. 11	J. N. Williams	Du	32.0	36	R	do	Winfield Limestone	Cy, W	D, S	....	20.46	9-14-58	
30-3-18ccd	SE SW SW sec. 18	N. L. Penick	Dr	46.0	6	GI	do	Nolans Limestone	Cy, W	D, S	....	30.57	9-14-58	
30-3-22bbb	NW cor. sec. 22	L. T. Ratley	Dr	55.0	6	GI	do	Nolans and Winfield Limestones	Cy, W	S	....	37.48	9-14-58	
30-3-24ada	NE SE NE sec. 24	L. N. Littell	Du	28.0	40	R	do	Nolans Limestone	Cy, W	S	....	23.70	9-14-58	
30-3-29ddd	SE cor. sec. 29	City of Udall	Dr	64.0	6	GI	Sha'e and limestone	Wellington Formation and Nolans Limestone	T, E	PS	....	....	1-13-45	Water very hard, reported high in sulfate salts.
	T. 30 S., R. 4 E.													
30-4-2abb	NW NW NE sec. 2	E. B. Shaver	Dr	83.0	6	GI	Limestone	Barneston Limestone	Cy, W	S	....	40.05	10-21-58	
30-4-7aab	NW NE NE sec. 7	P. J. Trompeter	Dr	31.0	6	GI	Sand, gravel	Terrace deposits	Cy, E	S	....	19.92	9-14-58	
30-4-17cba	NE NW SW sec. 17	V. E. Sims	Dr	24.5	6	GI	do	do	N	N	....	12.11	9-14-58	Well abandoned.
**30-4-19add	SE SE NE sec. 19	C. L. Pierson	Du	31.0	30	R	do	do	Cy, H	D, S	....	21.29	9-25-58	
30-4-21ccc	SW cor. sec. 21	Geo. McNeir	Dr	110.0	8	S	Limestone	Barneston Limestone	Cy, E	D, S	....	84.00	10-1-58	Yield 0.5 gpm.
30-4-33dbd	SE NW SE sec. 33	Estell Watt	Dr	125.0	10	S	do	Doyle Shale and Barneston Limestone	Cy, W	D, S	....	25.50	10-1-58	Yield 3± gpm.
30-4-36cbb	NW NW SW sec. 36	A. E. Baxter	Dr	98.0	6	GI	do	do	Cy, W	S	....	57.50	10-21-58	

	T. 30 S., R. 5 E.												
30-5-3ccc	SW cor. sec. 3	O. H. Lanier	Dr	36.5	6	GI	do	Barneston Limestone	Cy, W	S		25.81	9-12-58	
30-5-18ccb	NW SW SW sec. 18	M. M. Powers	Dr	92.0	6	GI	do	do	Cy, W	S		55.70	10-21-58	
30-5-24dcd	SE SW SE sec. 24	E. Wakefield	Dr	56.0	8	S	do	do	Cy, W	S		41.40	9-12-58	
30-5-28aaa	NE cor. sec. 28	J. W. Flint	Dr	70.0	6	GI	do	do	Cy, W	S		55.70	9-12-58	
	T. 30 S., R. 6 E.												
30-6-2dad	SE NE SE sec. 2	E. Cook	Dr	80.0	6	S	do	do	N	N		28.00	9-25-58	Bailed 20 gpm.
30-6-4baa	NE NE NW sec. 4	R. Hughes	Dr	38.4	6	GI	do	do	Cy, W	N		32.22	9-12-58	
30-6-6cca	NE SW SW sec. 6	E. Shaver	Dr	48.0	6	GI	do	do	Cy, W	S		38.05	9-12-58	
30-6-11add	SE SE NE sec. 11	A. B. Dennce	Dr	100.0	6	S	do	Kinney Limestone	N	N		75.00	9-25-58	Yield 4 gpm.
30-6-15cba	NE NW SW sec. 15	A. Biegel	Dr	135.0	6	S	do	Barneston Limestone	Cy, H	D		75.00	6-23-58	Yield 1.5 gpm.
**30-6-28dbd1	SE NW SE sec. 28	City of Atlanta	Sp				do	do	Ce, E	PS		Flow	6-23-58	Yield ±130 gpm; flow is variable.
30-6-28dbd2	SE NW SE sec. 28	do	Dr	300	8	S	do	Barneston and Wreford Limestones	T, E	PS			6-23-58	Drilled to Neva Limestone at 300 feet; water salty; plugged back. Yield 1 gpm.
	T. 30 S., R. 7 E.												
30-7-4dcc	SW SW SE sec. 4	C. V. Smith	Dr	100.0	8	S	do	Barneston and Kinney Limestones	Cy, W	D, S		26.00	10- 1-58	Yield 3 gpm.
30-7-8ccc	SW cor. sec. 8	R. L. Shields	Dr	85.0	8	S	do	Kinney Limestone	Cy, W	S		57.00	10- 1-58	Yield 4 gpm.
30-7-17ddd	SE cor. sec. 17	M. Murer	Dr	115.0	8	S	do	Wreford Limestone	Cy, W	D, S		90.00	10- 1-58	Yield 12 gallons per hour.
30-7-33ddd	SE cor. sec. 33	J. J. Smith	Dr	80.0	11	S	do	Bader Limestone	Cy, W	D, S		72	10- 1-58	Very low yield.
	T. 30 S., R. 8 E.												
30-8-6	Lot 29 of sec. 6	T. L. Womack	Dr	124.0	8	S			N	N			10- 1-58	Dry through the Grenola Limestone.
**30-8-21cac	SW NE SW sec. 21	W. Ferguson	Dr	42.0	6	S	Limestone	Bader Limestone	Cy, G	D, S		35.50	10- 2-58	Yield 0.5 gpm.
	T. 31 S., R. 3 E.												
**31-3-1abb	NW NW NE sec. 1	Paul Winter	Dr	123.0	6	GI	do	Doyle Shale and Barneston Limestone	S, E	S		90.90	9-14-58	
31-3-5add	SE SE NE sec. 5	City of Udall	Du	64.0	54	R	do	Nolans Limestone	T, E	PS		48.80	1-13-45	Maximum capacity 15 gpm; water very hard; well abandoned.
31-3-18cbb	NW NW SW sec. 18	F. M. Latham	Dr	59.5	6	GI	Sand, gravel	Terrace deposits	Cy, W	S	1206.8	33.67	6- 3-55	
31-3-19acc	SW SW NE sec. 19	M. Harness	B	39.0	6	GI	do	do	Cy, H	S	1196.1	36.70	6-29-56	
*31-3-31ccc	SW cor. sec. 31	M. Alexander	B	40.5	6	GI	do	Alluvium	Cy, H	S	1152.9	8.50	6-21-56	
*31-3-31ccd	SE SW SW sec. 31	do	Dn	30.0	1¼	GIP	do	do	Cy, H	D		7.40	8-21-43	
	T. 31 S., R. 4 E.												
31-4-2cbc	SW NW SW sec. 2	R. Hanna	Dr	60.0	10	S	Limestone	Barneston Limestone	Cy, W	S		41.20	10-21-58	Very good well.

TABLE 11.—*Records of wells, test holes, and springs in Cowley County, Kans.*—*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)	Depth to water level below land surface (feet) (7)	Date of measurement	Remarks
*31-4-6bdd	SE SE NW sec. 6	Fred Clarke	Du	28.0	48	R	Sand, gravel	Terrace deposits	T, E	D, S		21.70	9-14-58	
31-4-14aab	NW NE NE sec. 14	J. E. King	Dr	62.0	8	S	Limestone	Barneston Limestone	Cy, W	S		40.50	10-1-58	Yield 35 gpm.
31-4-17cda	NE SE SW sec. 17		Dr	26.0	8	GI	Sand, gravel	Terrace deposits	Cy, H	S		17.61	9-25-58	
**31-4-18cbb	NW NW SW sec. 18	M. Frier	Du	31.0	36	R	do	do	Cy, H	S		18.80	9-25-58	
31-4-21dcd	SE SW SE sec. 21	L. Goodrich	Dr	85.0	6	GI	Limestone	Towanda Limestone	Cy, H	D		64.90	10-21-58	
	T. 31 S., R. 5 E.													
31-5-1ddd	SE cor. sec. 1	A. V. Hoskins	Dr	100.0	8	S	do	Kinney Limestone	Cy, W	S		65.00	10-1-58	
31-5-2ccc	SW cor. sec. 2	L. Lewis	Dr	53.0	8	S	do	Barneston Limestone	Cy, W	S		38.80	9-12-58	
31-5-10ccc	SW cor. sec. 10	W. Foster	Du	30.5	36	R	do	do	Cy, W	S		20.49	9-12-58	
31-5-22dcc	SW SW SE sec. 22	F. L. Jordan	Dr	128.0	8	S	do	do	Cy, W	D, S		22.20	10-1-58	Yield 4 gpm.
31-5-25dcd	SE SW SE sec. 25	C. Treadway	Dr	40.0	6	GI	do	do	Cy, H	D, S		22.46	9-25-58	
31-5-25ddd	SE cor. sec. 25	C. Walter	Du	21.0	48	R	do	do	N	N		16.35	9-25-58	Well abandoned.
31-5-27ccc	SW cor. sec. 27	C. E. Stevenson	Dr	100.0	8	S	do	do	Cy, W	D, S		47.40	10-1-58	Yield 2.5 gpm.
31-5-32ada	NE SE NE sec. 32	J. Dodgeon	Dr	40.0	6	GI	do	do	Cy, G	S		28.05	9-24-58	
	T. 31 S., R. 6 E.													
31-6-3ccc	SW cor. sec. 3	H. L. Moore	Dr	46.0	6	GI	do	do	N	N		32.60	10-1-58	Well abandoned
31-6-4cbc1	SW NW SW sec. 4	J. Stout	Dr	65.0	6	GI	do	do	Cy, W	D, S		52.40	9-12-58	
31-6-4cbc2	SW NW SW sec. 4	do	Dr	60.0	6	GI	do	do	Cy, W	D, S		50.37	9-12-58	
31-6-8baa	NE NE NW sec. 8	A. Stout	Dr	28.0	8	GI	Chert gravel	Alluvium	Cy, E	D, S		18.60	9-12-58	
31-6-15ccc	SW cor. sec. 15	F. Weigle	Dr	138.0	6	S	Limestone	Barneston Limestone	Cy, W	D, S		50.00	10-1-58	Yield 0.5 gpm.
31-6-26cbc	SW NW SW sec. 26	R. Daniels	Dr	150.0	8	S	do	Barneston and Wreford Limestones	Cy, W	D		35.50	10-1-58	
31-6-27ddd	SE cor. sec. 27	C. Brown	Dr	150.0	8	S	do	do	Cy, E	D		45.40	10-1-58	Yield 0.5 gpm.
**31-6-28caa	NE NE SW sec. 28	City of Burden	Sp				do	Barneston Limestone	Ce, E	PS		Flow	6-26-58	Yield in normal years about 35 gpm; in drought years about 10 gpm.

	T. 31 S., R. 7 E.											
31-7-2bbb	NW cor. sec. 2	E. Fox	Dr	100.0	8	S	do	Bader and Beattie Limestones	Cy, W	S	....	48.60	10- 1-58	Yield 12 gallons per hour.
**31-7-10bdd	SE SE NW sec. 10	Cities Service Gas Co.	Du	24.0	72	C	Sand and gravel	Terrace deposits	Cy, H	D	....	18.60	10- 2-58	
31-7-23cca	NE SW SW sec. 23	Earl Kielhorn	Dr	78.0	12	S	Limestone	Crouse Limestone	Cy, W	S	....	26.55	10- 1-58	
31-7-28ddb	NW SE SE sec. 28	W. A. Bonnell	Dr	50.0	8	S	do	do	Cy, E	D	....	33.00	10- 1-58	Yield 6 gallons per hour.
31-7-32abb	NW NW NE sec. 32	M. E. Watt	Dr	80.0	8	S	do	do	Cy, W	D, S	....	36.50	10- 1-58	
	T. 31 S., R. 8 E.													
31-8-8acd	SE SW NE sec. 8	Santa Fe Railway	Dr	50.0	8	GI	do	Grenola Limestone	Cy, W	S	....	41.08	9-12-58	Grand Summit stockyards well.
31-8-8bcc	SW SW NW sec. 8	B. Hiatt	Dr	60.0	6	GI	do	do	Cy, W	S	....	34.85	9-12-58	
**31-8-17cdd	SE SE SW sec. 17	B. McClure	Dr	75.0	6	GI	do	do	Cy, W	S	....	46.75	9-12-58	Poor well.
	T. 32 S., R. 3 E.													
*32-3-5baa	NE NE NW sec. 5	G. Beaman	Dr	33.0	18	S	Sand, gravel	Terrace deposits	T, N	Ir	1155.9	15.76	9-10-58	Yield 500 gpm.
*32-3-5ccc1	SW cor. sec. 5	School District	Dn	30.0	1¼	GIP	do	do	Cy, H	D	1152.5	13.48	8-21-43	
*32-3-7dca	NE SW SE sec. 7	....	....	....	....	....	....	....	....	....	....	....	....	Surface water from sand pit.
**32-3-7ddd1	SE cor. sec. 7	City of Oxford	Dr	37.5	18	S	Sand, gravel	Terrace deposits	T, E	PS	....	7.50	6-26-58	Yield 500 gpm, drawdown 3 feet.
32-3-7ddd2	SE cor. sec. 7	do	Dr	37.5	18	S	do	do	T, G	PS	....	16.30	6-26-58	Yield 300 gpm, drawdown 2.5 feet.
*32-3-8dbb	NW NW SE sec. 8	....	....	....	....	....	....	....	....	....	....	....	....	Surface water from washout in field.
**32-3-18dba	NE NW SE sec. 18	City of Winfield	Dr	40.0	12	S	Sand, gravel	Terrace deposits	T, E	PS	....	9.06	9-30-58	Yield 800 gpm.
32-3-18dbc	SW NW SE sec. 18	do	Dr	48.2	18	C	do	do	T, E	PS	1148.0	8.83	9-30-58	Log given; yield 1000 gpm; drawdown 4.33 feet.
32-3-18dca	NE SW SE sec. 18	do	Dr	43.0	12	S	do	do	T, E	PS	....	8.50	9-30-58	Yield 500 gpm.
32-3-18dcc	SW SW SE sec. 18	do	Dr	38.0	18	C	do	do	Ce, E	PS	....	11.12	9-30-58	Two identical wells on one pump. Yield 1000 gpm.
32-3-18ddc	SW SE SE sec. 18	do	Dr	38.0	18	C	do	do	Ce, E	PS	....	10.56	9-30-58	do
*32-3-19abc1	SW NW NE sec. 19	....	Tr	36.5	1¼	GIP	do	do	N	O	1146.0	10.70	4- 7-44	Log given.
*32-3-19abc2	SW NW NE sec. 19	....	Tr	39.5	1¼	GIP	do	do	N	O	1144.3	10.80	4- 7-44	do
32-3-19bab	NW NE NW sec. 19	City of Winfield	Dr	46.0	18	C	do	do	Ce, E	PS	....	8.65	7-19-58	Two identical wells on one pump. Yield 1000 gpm.
*32-3-19ddd	SE cor. sec. 19	H. A. Waite	Dn	25.0	1¼	GIP	do	do	Cy, H	D	....	11.46	8-21-43	
**32-3-21ccc	SW cor. sec. 21	....	Tr	40.0	1¼	GIP	do	do	N	O	1175.6	22.90 30.11	2-11-58 5-23-57	Log given.
32-3-23bbb	NW cor. sec. 23	M. B. Lester	Dr	42.0	6	GI	do	do	N	N	....	31.05	9-23-58	
32-3-24bdc	SW SE NW sec. 24	City of Winfield	Dr	167.5	12	S	Limestone	Nolans Limestone	N	N	....	106.50	9-30-58	City well abandoned; yield 1000 gpm on test; high-sulfate content.
**32-3-25bdc	SW SE NW sec. 25	do	Dr	113.0	10	S	do	do	T, E	PS	....	68.63	9-30-58	Yield 976 gpm.

TABLE 11.—*Records of wells, test holes, and springs in Cowley County, Kans.*—*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)	Depth to water level below land surface (feet) (7)	Date of measurement	Remarks
32-3-26cbb	NW NW SW sec. 26	E. Cadwell	Dr	26.0	6	GI	Sand and gravel	Terrace deposits	Cy, H	O	....	18.50	10- 3-58	Well abandoned because of salt-water intrusion.
32-3-27ddd	SE cor. sec. 27	C. Fritz	Dr	40.0	8	S	do	do	J, E	D, S	....	21.50	10- 3-58	do
*32-3-31aaa	NE cor. sec. 31	Ben Grallapp	Dn	20.0	1¼	GIP	do	Alluvium	Cy, H	S	....	....	8-20-43	
32-3-31aac	SW NE NE sec. 31	do	Dr	40.0	18.0	S	do	do	T, B	Ir	....	15.30	9-10-58	Yield 1000 gpm, drawdown 8 feet.
32-3-31adc	SW SE NE sec. 31	do	Dr	46.0	18.0	S	do	Terrace deposits	T, B	Ir	....	17.81	9-10-58	Yield 1000 gpm, drawdown 7 feet.
*32-3-31dca	NW SW SE sec. 31	W. Workman	Dr	42.0	6	GI	do	do	J, E	D, S	....	16.05	9-10-58	
32-3-31ddc	SW SE SE sec. 31	City of Winfield	Dr	48.5	12	S	do	do	N	N	....	15.40	9-30-58	City well abandoned because of salt-water intrusion.
32-3-32ccc1	SW cor. sec. 32	A. Bonnewell	Dn	15.5	2	GIP	do	do	N	N	....	7.83	8-16-43	
**32-3-32cdd	SE SE SW sec. 32	School District	Dr	40.0	6	GI	do	do	Cy, H	D	....	12.65	8-20-43	
**32-3-32ddc	SW SE SE sec. 32	M. E. Waldroupe	Dr	52.0	6	GI	do	do	J, E	D, S	....	25.50	9-22-58	Shale at 50 feet.
**32-3-34abb1	NW NW NE sec. 34	E. M. Cadwell	Dr	32.0	6	GI	do	do	J, E	D, S	....	18.00	10- 3-58	Well endangered by salt-water intrusion; chloride 1800 ppm.
**32-3-34abb2	NW NW NE sec. 34	do	Dr	32.0	18	S	do	do	N	Ir	....	18.50	10- 3-58	Well abandoned; chloride content high.
32-3-35cbc	SW NW SW sec. 35	E. Caldwell	Dr	36.0	6	GI	do	do	J, E	D, S	....	16.00	10- 3-58	
	T. 32 S., R. 4 E.													
32-4-4ddc	SW SE SE sec. 4	J. Watson	Dr	107.0	8	S	Limestone	Barneston Limestone	J, E	D, S	....	55.55	10- 1-58	Yield 2 gpm.
**32-4-6ccc	SW cor. sec. 6	B. T. Hanna	Dr	90.0	6	GI	do	do	J, E	D, S	....	21.70	9-25-58	
**32-4-8aaa	NE cor. sec. 8	Jim Watson	Dr	100.0	8	S	do	Towanda Limestone	J, E	D, S	....	40.30	10- 1-58	Yield 16 gpm.
32-4-22cac	SW NE SW sec. 22	W. McClure	Dr	100.0	8	S	do	Barneston Limestone	J, E	D	....	55.00	10- 1-58	Yield 10 gpm.
32-4-29baa	NE NE NW sec. 29	L. Hittle	Dr	85.0	10	S	do	Towanda Limestone	J, E	D, S	....	62.56	10- 1-58	Yield 50 gpm.
**32-4-34ccb	NW SW SW sec. 34	S. Shockey	Dr	30.0	8	S	Sand, gravel	Terrace deposits	J, E	D, S	....	18.03	9-26-58	

	T. 32 S., R. 5 E.													
32-5-3bca	NE SW NW sec. 3	E. A. Elrod	Sp	...	...	...	Limestone	Barneston Limestone	N	S	...	Flow	9-11-58	Yield 50 gpm.
**32-5-4aaa	NE cor. sec. 4	do	Dr	180.0	6	GI	do	Barneston and Wreford Limestones	J, E	D, S	...	52.60	9-11-58	
32-5-4abd	SE NW NE sec. 4	do	Dr	120	12	S	do	Barneston Limestone	Cy, W	S	...	88.50	9-11-58	
32-5-19cba	NE NW SW sec. 19	E. Boyd	Dr	120	10	S	do	do	N	N	...	...	9-13-58	Surface hole for oil well bailed 50 gpm; good water.
**32-5-24cbc	SW NW SW sec. 24	A. Bartlow	Dr	140	6	GI	do	do	Cy, E	D, S	...	48.65	9-11-58	
32-5-24cdd	SE SE SW sec. 24	do	Sp	...	...	...	do	do	N	S	...	Flow	9-11-58	Spring fluctuates between 50 and 100 gpm, never much below 50 during worst drought.
32-5-27bcb	NW SW NW sec. 27	N. Archer	Dr	60.0	6	GI	do	do	Cy, H	D, S	...	41.66	10-22-58	
32-5-28cdd	SE SE SW sec. 28	H. Snyder	Dr	150.0	10	S	do	Barneston and Wreford Limestones	J, E	D	...	60.00	10- 1-58	Yield 1 gpm.
32-5-30bba	NE NW NW sec. 30	J. L. Lunsford	Dr	120.0	6	S	do	Barneston Limestone	J, E	D, S	...	73.06	9-13-58	Yield 50 gpm.
32-5-32dcc	SW SW SE sec. 32	R. Stuber	Sp	...	...	...	do	do	N	S	...	Flow	9-26-58	do
	T. 32 S., R. 6 E.													
32-6-1dcc	SW SW SE sec. 6	J. H. Rerick	Dr	75.0	8	S	do	Kinney Limestone	Cy, W	D, S	...	56.40	10- 1-58	Yield 0.5 gpm.
32-6-16ddc	SW SE SE sec. 16	T. M. Bolack	Dr	185.0	8	S	do	Funston Limestone	Cy, W	D, S	...	120.0	10- 1-58	
32-6-19ddb	NW SE SE sec. 19	S. Shields	Du	20.0	50	R	Sand, gravel	Terrace deposits	T, E	D, S	...	15.20	10- 1-58	
32-6-24dcc	SW SW SE sec. 24	M. Butler	Dr	32.0	10	S	Silt, sand and gravel	Colluvium	Cy, W	S	...	18.60	10-21-58	
	T. 32 S., R. 7 E.													
32-7-4abb	NW NW NE sec. 4	Radcliff	Dr	79.0	10	S	Limestone	Crouse Limestone	N	N	...	29.00	10- 1-58	Oil-well surface-pipe hole.
32-7-4dbb	NW NW SE sec. 4	L. T. Redford	Dr	60.0	10	S	do	do	Cy, W	S	...	35.36	10- 1-58	Yield 1.5 gpm.
32-7-4ddd	SE cor. sec. 4	do	Dr	116.0	10	S	do	do	Cy, W	D, S	...	27.00	10- 1-58	Yield 2 gpm.
**32-7-11aaa	NE cor. sec. 11	N. L. Miller	Dr	120.0	12	S	do	Wreford Limestone	Cy, E	D, S	...	60.78	9-25-58	
32-7-16acc	SW SW NE sec. 16	W. G. Anderson	Dr	148.0	10	N	do	Crouse Limestone	N	N	...	70.00	9-25-58	Drilling surface-pipe hole.
32-7-34aaa	NE cor. sec. 34	W. Johnson	Dr	40.0	10	GI	do	Wreford Limestone	Cy, H	D, S	...	24.60	10-23-58	
	T. 32 S., R. 8 E.													
32-8-6	Lot 30 of sec. 6	...	Dr	140.0	11	S	do	Foraker Limestone	N	N	...	100	9-25-58	Surface-pipe hole; very little water.
32-8-29bbb	NW cor. sec. 29	M. F. Jarvis	Sp	...	...	...	do	do	N	S	...	Flow	10-21-58	Yield 5 to 50 gpm. Considerable fluctuation with rainfall.

TABLE 11.—*Records of wells, test holes, and springs in Cowley County, Kans.*—*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)	Depth to water level below land surface (feet) (7)	Date of measurement	Remarks
	T. 33 S., R. 3 E.													
**33-3-5bbb	NW cor. sec. 5	G. Hendrickson	Dn	20.0	6	GI	Sand, gravel	Terrace deposits	Cy, W	S		18.40	8-16-43	
33-3-5bbc	SW NW NW sec. 5	City of Winfield	Dr	41.25	12	S	do	Alluvium	T, E	PS		11.40	9-30-58	Obs. well 10 feet from pumping well yielding 500 gpm; has drawdown of 3 feet.
33-3-5bcc	SW SW NW sec. 5	do	Dr	48.3	12	S	do	do	T, E	PS		15.30	9-30-58	Obs. well 10 feet from pumping well yielding 500 gpm; has drawdown of 5.4 ft.
**33-3-5cac	SW NE SW sec. 5	do	Dr	44.3	12	S	do	do	T, E	PS		10.90	9-30-58	Obs. well 10 feet from pumping well yielding 500 gpm; has drawdown of 5.2 ft.
33-3-5cbc	SW NW SW sec. 5	do	Dr	45.4	12	S	do	do	T, E	PS		11.00	9-30-58	Obs. well 10 feet from pumping well yielding 500 gpm; has drawdown of 5.5 ft.
33-3-5ccc2	SW cor. sec. 5	do	Dr	41.6	12	S	do	do	T, E	PS		9.60	9-30-58	Obs. well 10 feet from pumping well yielding 300 gpm; has drawdown of 1.25 feet.
*33-3-7aaa	NE cor. sec. 7	C. Roberts	Dn	30.0	1¼	GIP	do	do	Cy, H	S		13.80	8-20-43	
**33-3-10ccc	SW cor. sec. 10	School District	Dn	35.0	1¼	GIP	do	Terrace deposits	Cy, H	D			8-20-43	
**33-3-14dda	NE SE SE sec. 14	do	Du	40.0	36	R	do	do	Cy, H	D		22.46	8-20-43	
*33-3-17aaa3	NE cor. sec. 17	B. McClung	Dn	25.0	1¼	GIP	do	do	Cy, W	D, S		8.48	8-20-43	
*33-3-20ddc	SE SE SW sec. 20	D. Johnson	Dn	20.0	1¼	GIP	do	do	Cy, W	S			8-20-43	
*33-3-21aaa	NE cor. sec. 21	Beaver Township	Dn	40.0	1¼	GIP	do	do	Cy, H	D			8-20-43	
33-3-25bcd1	SE SW NW sec. 25	W. A. Hunt	Dr	44.0	16	S	do	do	T, E	Ir		25.83	9-22-58	Yield 130 gpm.
33-3-25bcd2	SE SW NW sec. 25	do	Dr	44.0	16	S	do	do	T, B	Ir		25.03	9-22-58	Yield 150 gpm.
33-3-25cdd	SE SE SW sec. 25	do	Dr	42.0	12	S	do	do	T, B	Ir		25.22	9-22-58	Yield 250 gpm.
33-3-25dca	NE SW SE sec. 25	J. Mumaw	Dr	42.0	16	S	do	do	T, B	Ir		27.41	9-22-58	Yield 130 gpm.
*33-3-28dbc2	SW NW SE sec. 28												8-16-56	Arkansas River surface water.
*33-3-29cca2	NE SW SW sec. 29												8-16-56	do
*33-3-29ddd1	SE cor. sec. 29	H. Moldenhawr	Dr	56.0	18	S	Sand, gravel	Terrace deposits	T, G	Ir		20.60	9-10-58	Yield 800 gpm.
*33-3-31add	SE SE NE sec. 31	W. Hansen	Dn	20.0	1¼	GIP	do	Alluvium	Cy, H	D			8-20-43	

33-3-33bbc	SW NW NW sec. 33	C. Auman	Dr	36.0	20	S	do	Terrace deposits	Ce, N	Ir			9-23-58	
**33-3-34cdd	SE SE SW sec. 34	C. Abrams	Du	48.0	38	R	do	do	Cy, W	S		26.80	8-18-43	
**33-3-34dcc	SW SW SE sec. 34	M. O. Brown	Dr	45.0	8	GI	Shale	Wellington Formation	J, E	D, S		40.00	9-22-58	
	T. 33 S., R. 4 E.													
**33-4-7ddd	SE cor. sec. 7	L. Crane	Du, Dn	30.0	36-1¼	GIP	Sand, gravel	Terrace deposits	Cy, H	S		20.0	8-20-43	
33-4-8aab	NW NE NE sec. 8	V. Nelson	Dr	119.0	8	S	Limestone	Barneston Limestone	Cy, W	D, S		46.00	10- 1-58	
33-4-9caa	NE NE SW sec. 9	E. L. Sullivan	Dr	156.0	8	S	do	do	J, E	D		49.40	9-13-58	Yield 1 gpm.
33-4-16bab	NW NE NW sec. 16	H. Humbert	Dr	139.0	8	S	do	do	J, E	D		120.00	10- 1-58	Yield 0.5 gpm.
33-4-16cdd	SE SE SW sec. 16	C. T. Franks estate	Dr	120.0	6	S	do	do	J, E	D		51.50	9-10-58	Yield 4 gpm.
33-4-18ddc	SW SE SE sec. 18	Arkansas City and Winfield	Dr	44.0	8	S	Sand and gravel	Terrace deposits	T, E	In		17.86	9-30-58	Yield 165 gpm; formerly U.S. Air Force well 1.
33-4-19aab	NW NE NE sec. 19	do	Dr	43.5	8	S	do	do	T, E	In	1155.3	20.00	8-28-42	Yield 110 gpm; log given; formerly U.S. Air Force well 2.
33-4-19aac	SW NE NE sec. 19	do	Dr	41.0	8	S	do	do	T, E	In	1153.4	17.93	8-28-42	Yield 125 gpm, drawdown 12.5 feet; log given; formerly U.S. Air Force well 3.
33-4-19adb1	NW SE NE sec. 19	do	Dr	44.2	8	S	do	do	T, E	In	1152.2	16.78	8-28-42	Yield 97 gpm; formerly U.S. Air Force well 4.
33-4-19adb2	NW SE NE sec. 19	do	Dr	41.0	8	S	do	do	T, E, G	In	1151.5	16.66	9-25-58	Yield 188 gpm, drawdown 11 feet; log given; formerly U.S. Air Force well 5.
**33-4-19adc	SW SE NE sec. 19	do	Dr	41.0	8	S	do	do	T, E	In	1151.2	16.22	8-28-42	Yield 157 gpm; formerly U.S. Air Force well 6.
**33-4-23ccc2	SW cor. sec. 23	H. Wright	Du	28.6	40	C	Sand	do	J, E	S		12.60	9-26-58	
**33-4-30add1	SE SE NE sec. 30	School district	Du, Dn	40.0	72-1¼	GIP	Sand, gravel	do	Cy, H	D			8-20-43	
	T. 33 S., R. 5 E.													
33-5-15baa	NE NE NW sec. 15	School district	Dr	50.0	6	GI	Limestone	Barneston Limestone	Cy, H	D		38.10	10-22-58	
33-5-18baa	NE NE NW sec. 18	M. Mercer	Dr	65.0	6	GI	do	do	Cy, W	S		43.00	10-23-58	
33-5-25aaa	NE cor. sec. 25	M. Cochran	Dr	65.0	6	GI	do	do	Cy, H	S		36.18	10-22-58	
**33-5-33bbb	NW cor. sec. 33	R. C. Bacon	Dr	110.0	6	GI	do	do	Cy, E	D, S		52.60	10- 2-58	
	T. 33 S., R. 6 E.													
**33-6-1acc	SW SW NE sec. 1	O. D. Rathburn	Dr	25.0	6	GI	Gravel	Terrace deposits	Cy, H	D			4-24-44	
33-6-4bbb	NW cor. sec. 4	B. Rhodes	Dr	50.0	6	GI	Limestone	Barneston Limestone	Cy, W	S		28.60	10-22-58	
33-6-6ccc	SW cor. sec. 6	S. Rambo	Du	22.0	40	R	do	do	N	N		19.55	10-22-58	

TABLE 11.—*Records of wells, test holes, and springs in Cowley County, Kans.*—*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)	Depth to water level below land surface (feet) (7)	Date of measurement	Remarks
	T. 33 S., R. 6 E.													
•33-6-12aaa	NE cor. sec. 12	F. Allred	Dr	32.0	9	S	Gravel	Terrace deposits	N	N	....	17.78	8-13-46	Yield 27 gpm on bailer test.
••33-6-13bcd	SE SW NW sec. 13	City of Dexter	Du	36.0	40	C	do	do	S, E	PS	....	23.00	6-25-58	
33-6-32add	SE SE NE sec. 32	R. G. Miller	Du	20.0	60	C	do	Alluvium	T, E	D, S	....	11.16	10-22-58	
	T. 33 S., R. 7 E.													
••33-7-14adc	SW SE NE sec. 14	V. Clark	Dr	100.0	12	S	Limestone	Bader Limestone	J, E	D	....	45.00	10- 2-58	
33-7-20baa	NE NE NW sec. 20	K. Crow	Du	32.0	36	R	do	Wreford Limestone	B, H	D, S	....	26.75	10-22-58	
33-7-36cdd	SE SE SW sec. 36	M. F. Jarvis	Dr	200	10	S	....	....	....	....	....	Dry	10-21-58	Surface-pipe hole; very little water.
	T. 33 S., R. 8 E.													
33-8-9daa	NE NE SE sec. 9	G. J. Huffman	Dr	208.0	8	S	Limestone	Elmont Limestone	N	N	....	72.50	9-24-57	Yield 0.5 gpm: water too salty for use.
33-8-33dda	NE SE SE sec. 33	B. Simpson	Du	16.4	54	R	Silt, gravel	Colluvium	P, H	S	....	10.00	10-21-58	
	T. 34 S., R. 3 E.													
••34-3-4bbb	NW cor. sec. 4	School district	Dr	28.5	1¼	GIP	Sand, gravel	Terrace deposits	Cy, H	D	....	16.56	8-18-43	
34-3-4dcb	NW SW SE sec. 4	E. M. Quinn	Dr	50.0	18	GI	do	do	T, B	Ir	....	16.25	9-10-58	Yield 600 gpm.
•34-3-5dcc1	SW SW SE sec. 5	R. C. Brewer	Dn	20.0	1¼	GIP	do	do	Cy, H	S	....	8.00	8-20-43	
••34-3-7baa	NE NE NW sec. 7	Joe Rutter	Dr	15.9	6	GI	do	Alluvium	Cy, H	S	....	18.05	8-19-43	
34-3-7cba	NE NW SW sec. 7	City of Geuda Springs	Du	52.5	108	C	Shale	Wellington Formation	Ce, G	PS	....	40.84	1-12-45	Abandoned in 1956.
•34-3-8acc2	SW SW NE sec. 8	....	....	....	....	....	....	....	....	....	....	....	9- 2-56	Surface water from Arkansas River.
•34-3-9dad	SE NE SE sec. 9	W. Walker	Dn	20.0	1¼	GIP	Sand, gravel	Terrace deposits	Cy, W	D, S	....	....	8-20-43	
•34-3-15dcd	SE SW SE sec. 15	....	Dn	20.0	1¼	GIP	do	Alluvium	Cy, H	D, S	....	....	8-20-43	
34-3-26bad1	SE NE NW sec. 26	City of Arkansas City	Dr	37.0	18	C	do	Terrace deposits	T, E	PS	....	12.30	9-23-58	Yield 500 gpm.
••34-3-26bad2	SE NE NW sec. 26	do	Dr	40.0	18	C	do	do	T, E	PS	....	12.30	9-23-58	do
34-3-26bda1	NE SE NW sec. 26	do	Dr	36.0	18	C	do	do	T, E	PS	....	11.50	9-23-58	Yield 500 gpm; drawdown 5 feet.
34-3-26bda2	NE SE NW sec. 26	do	Dr	35.0	18	C	do	do	T, E	PS	....	....	9-23-58	Yield 500 gpm.
34-3-26dbc	SW NW SE sec. 26	do	Dr	40.0	18	C	do	do	T, E	PS	....	12.00	9-23-58	Yield 750 gpm; drawdown 5 feet.

34-3-26dcb	NW SW SE sec. 26	do	Dr	40.0	18	C	do	do	T, E	PS	....	....	9-23-58	do
34-3-26dcc	SW SW SE sec. 26	do	Dr	40.0	18	C	do	do	T, E	PS	....	....	9-23-58	do
34-3-26dcd	SE SW SE sec. 26	do	Dr	39.0	18	C	do	do	T, E	PS	....	....	9-23-58	Yield 750 gpm.
34-3-31aaa	NE cor. sec. 31	D. McMillen	Du	66.0	48.0	R	Limestone	Wellington Formation	Cy, E	S	....	63.00	8-22-58	
	T. 34 S., R. 4 E.													
34-4-2ccb	NW SW SW sec. 2	J. Heuszel	Dn	25.0	1¼	GIP	Sand, gravel	Terrace deposits	T, E	D, S	....	17.30	9-10-58	
34-4-10ddd	SE cor. sec. 10	L. Estus	Dr	90.0	6	S	Limestone	Barneston Limestone	J, E	D, S	....	40.80	9-10-58	
**34-4-12bbb	NW cor. sec. 12	V. Duncan	Du	28.0	48	R	Sand, gravel	Terrace deposits	Cy, H	D, S	....	20.08	9-26-58	
34-4-15ddb	NW SE SE sec. 15	J. Blass	Dr	95.0	6	GI	Limestone	Barneston Limestone	Cy, E	D, S	....	61.00	9-26-57	
34-4-20cba	SW NW NE sec. 20	R. Birdsell	Du	34.0	72	S	Sand, gravel	Terrace deposits	C, G	Ir	....	13.20	6-22-57	Yield 300 gpm.
**34-4-21dcc	SW SW SE sec. 21	A. L. Parker	Dr	41.0	6	GI	do	do	Cy, E	D, S	....	31.06	9-10-58	
34-4-23bdc	SW SE NW sec. 23	G. Barringer	Dr	165.0	6	GI	Limestone	Barneston Limestone	Cy, E	D, S	....	64.50	9-26-57	
34-4-23cab	NW NE SW sec. 23	R. Marrs	Dr	164.0	6	GI	do	do	J, E	D, S	....	63.90	9-26-57	
**34-4-28aba	NE NW NE sec. 28	A. Miller	Dr	242	8	S	do	do	J, E	D, S	....	121.0	9-10-58	
34-4-31ddd1	SE cor. sec. 31	Anderson-Pritchard Oil Co.	Du	32.0	96	S	Sand and gravel	Terrace deposits	T, E	In	....	8.16	9-23-58	Yield 300 gpm; test pumped 1200 gpm with drawdown 3 feet.
34-4-31ddd2	SE cor. sec. 31	do	Du	33.0	96	S	do	do	T, E	In	....	10.40	9-23-58	Yield 300 gpm; test pumped at 1000 gpm.
**34-4-33ddd	SE cor. sec. 33	E. Buzzi	Dn	16.0	1¼	GIP	do	do	Cy, W	S	....	....	8-18-43	
**34-4-34ddd	SE cor. sec. 34	A. Gilstrap	Dn	22.0	1¼	GIP	do	do	Cy, H	D	....	10.00	8-18-43	
	T. 34 S., R. 5 E.													
34-5-9cbb	NW NW SW sec. 9	M. Arthur	Du	14.5	48	R	do	Colluvium	Cy, H	S	....	6.52	10-23-58	
34-5-18ccc	SW cor. sec. 18	J. Messner	Dr	120.0	6	GI	Limestone	Barneston Limestone	Cy, W	S	....	84.10	10-23-58	
34-5-24bbb	NW cor. sec. 24	G. Rahn	Du	25.0	48	R	Sand, gravel	Terrace deposits	Cy, E	D, S	....	14.41	10-22-58	
34-5-33bcb	NW SW NW sec. 33	C. Boggs	Dr	65.0	8	S	Limestone	Wreford Limestone	Cy, E	D, S	....	37.90	10-21-58	
	T. 34 S., R. 6 E.													
34-6-3daa	NE NE SE sec. 3	J. A. Frith	Du	28.0	38	R	do	do	B, H	D	....	20.75	10-22-58	
	T. 34 S., R. 7 E.													
34-7-7bbb	NW cor. sec. 7	C. Glass	Du	18.0	48	R	Gravel	Colluvium	Cy, H	D, S	....	14.06	10-22-58	
34-7-8cdc	SW SE SW sec. 8	W. L. Brown	Dr	190.0	8	S	Limestone	Beattie Limestone	Cy, W	D	....	110.0	10- 1-58	Poor yield at 110 feet; salt water at 188 feet.
	T. 34 S., R. 8 E.													
34-8-7	Lot 31 sec. 7	C. Willison	Dr	35.0	6	GI	Sandstone	Wood Siding Formation	N	N	....	20.40	10-21-58	
34-8-8ddd	SE cor. sec. 8	N. Kilson	Du	16.8	48	R	Silty gravel	Alluvium	N	N	....	10.26	10-21-58	

TABLE 11.—*Records of wells, test holes, and springs in Cowley County, Kans.*—*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)	Depth to water level below land surface (feet) (7)	Date of measurement	Remarks
	T. 34 S., R. 8 E.													
34-8-19	Lot 32 sec. 19	Ellis Call	Dr	365	8	S	Sandstone	Willard and Pillsbury Shale	Cy, W	S	....	....	9-24-57	
**34-8-30	Lot 3 sec. 30	do	Dr	365	8	S	do	do	Cy, E	D, S	....	....	9-24-57	
34-8-31	Lot 32 sec. 31	O. Olson	Dr	125.0	10	S	....	....	N	N	....	Dry	10-21-58	Very little water near surface; abandoned as dry.
	T. 35 S., R. 3 E.													
35-3-2bbb1	NW cor. sec. 2	E. Marshall	Dr	33.0	8	GI	Gravel	Terrace deposits	Cy, H	S	....	28.20	8-21-58	
35-3-2bbb2	NW cor. sec. 2	do	Dr	55.0	8	GI	Gravel and shale	Terrace deposits and Wellington Formation	J, E	D, S	....	30.50	8-21-58	Water from Permian reported high in sulfates
	T. 35 S., R. 4 E.													
35-4-4bac	SW NE NW sec. 4	A. Denton	Dr	33.0	18	S	Sand and gravel	Terrace deposits	T, B	Ir	....	11.62	9-10-58	Yield 1000 gpm; drawdown 7 feet.
35-4-5bbb	NW cor. sec. 5	Anderson-Pritchard Oil Co.	Du	32.0	96	S	do	do	T, E	In	....	10	9-23-58	Yield 300 gpm; test pumped at 1000 gpm.
35-4-6bbb	NW cor. sec. 6	Mauer Neur Packing Co.	Dr	48.0	18	S	do	Alluvium	T, E	In	....	15	9-25-58	Yield 300 gpm.
**35-4-6bdc	SW SE NW sec. 6	Bolton Twp. Cooperative	Dr	52.0	12	S	do	Terrace deposits	T, E	PS	....	12.00	7-28-58	Yield 400 gpm; drawdown 7 feet.
35-4-7aaa	NE cor. sec. 7	Earl Brown	Dr	210	6	GI	Limestone	Barneston Limestone	Cy, W	N	....	190	9-11-58	Water reported very high in sulfates; abandoned.
35-4-11daa	NE NE SE sec. 11	T. Casement	Dr	186.0	6	GI	do	do	Cy, W	S	....	150.00	9-11-58	High-sulfate water.
35-4-15dad	SE NE SE sec. 15	P. Hight	Du	34.0	36	R	Shale	Doyle Shale	Cy, H	N	....	22.60	9-11-58	
35-4-17cdd	SE SE SW sec. 17	R. Dowler	Dr	160.0	8	S	Limestone	Barneston Limestone	Cy, G	D, S	....	105.50	9-12-58	Poor well.
	T. 35 S., R. 5 E.													
35-5-8bca	NE SW NW sec. 8	School district	Du	22.0	40	C	Sand, gravel	Terrace deposits	N	N	....	14.30	10-23-58	Abandoned.
35-5-10baa	NE NE NW sec. 10	J. Warren	Dr	75.0	6	GI	Limestone	Wreford Limestone	Cy, W	N	....	43.02	10-22-58	do

	T. 35 S., R. 6 E.													
35-6-4bab	NW NE NW sec. 6	C. Chapman	Du	18.5	48	R	do	Crouse Limestone	Cy, H	S		14.25	10-21-58	
35-6-11abc	SW NW NE sec. 11	M. Lawson	Du	23.5	40	R	do	Wreford Limestone	P, H	D, S		17.65	10-21-58	
	T. 35 S., R. 7 E.													
35-7-1abb	NW NW NE sec. 1	S. Smith	Dr	125.0	10	S			N	N		Dry	10-21-58	Oil-well surface-pipe hole. Little water near surface.
35-7-3aaa	NE cor. sec. 3	D. Belles	Du	16.4	48	R	Limestone	Beattie Limestone	Cy, H	S		10.00	10-21-58	

(1.) One asterisk indicates partial analysis given in Table 7; two asterisks indicate complete analysis given in Table 6.
(2.) B, bored well; Dn, driven well; Dr, drilled well; Du, dug well; Sp, spring; Ta, auger test hole; Tr, rotary test hole.
(3.) Measured depth given in feet and tenths; reported depth given in feet.
(4.) C, concrete; GI, galvanized iron; GIP, galvanized iron pipe; N, none; R, rock; S, steel.
(5.) B, bailer; Ce, centrifugal; Cy, cylinder; J, jet; N, none; P, pitcher; S, submersible; T, turbine.
B, butane; E, electric; G, gasoline motor; H, hand; N, none; W, wind.
(6.) D, domestic; In, industrial; Ir, irrigation; N, none; O, observation; PS, public supply; S, stock.
(7.) Measured depth to water given in feet, tenths, and hundredths; reported depth given in feet.

LOGS OF WELLS AND TEST HOLES

The logs of 285 wells and test holes are given in the following pages and are summarized as follows:

Augered test holes	196
Drilled test holes	85
Wells	4

One asterisk preceding the well or test-hole number indicates that partial analysis is given in Table 7. Two asterisks indicate that complete analysis is given in Table 6.

30-3-30ccc.—Sample log of test hole in SW cor. sec. 30, T. 30 S., R. 3 E., 30 feet north and 6 feet east of center of crossing; augered June 15, 1957; dry hole; altitude of land surface, 1,253.5 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Wisconsinan Stage		
Eolian deposits		
Silt, red	5	5
Silt, tan	10	15
Silt, buff	5	20
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, gray	1	21

30-3-31bcc.—Sample log of test hole in SW cor. SW NW sec. 31, T. 30 S., R. 3 E., on south road shoulder at ½-mile line; augered June 15, 1957; dry hole; altitude of land surface, 1,235.5 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Wisconsinan Stage		
Eolian deposits		
Silt, brown	5	5
Silt, clayey, gray	5	10
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, gray	2	12

30-3-31ccc.—Sample log of test hole in SW cor. sec. 31, T. 30 S., R. 3 E., 20 feet north and 8 feet east of center of crossing; augered June 15, 1957; depth to water, 34.00 feet; altitude of land surface, 1,238.7 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Wisconsinan Stage		
Eolian deposits		
Silt, black	10	10
Silt, tan	5	15

	Thickness, feet	Depth, feet
Silt, gray, some very fine sand	5	20
Silt, gray	5	25
Silt, brownish gray	10	35
Silt, gray, some fine sand	5	40
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, light gray	10	50
Shale, gray	25	75

30-3-31ddd.—Sample log of test hole in SE cor. sec. 31, T. 30 S., R. 3 E., 30 feet north and 8 feet west of center of crossing; augered June 15, 1957; dry hole; altitude of land surface, 1,249.1 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Wisconsinan Stage		
Eolian deposits		
Silt, tan gray, clayey streaks	20	20
Silt, gray	10	30
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, gray	5	35

30-3-32cdd.—Sample log of test hole in SE cor. SE SW sec. 32, T. 30 S., R. 3 E., on north road shoulder, 50 feet west of ½-mile line; augered June 15, 1957; dry hole; altitude of land surface, 1,275.4 feet.

	Thickness, feet	Depth, feet
Soil, dark brown	3	3
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, gray green	7	10
Shale, reddish tan	5	15

30-4-19cdd.—Sample log of test hole in SE SE SW sec. 19, T. 30 S., R. 4 E., on north side of road, 50 feet west of ½-mile line; augered June 14, 1957; depth to water, 23.00 feet; altitude of land surface, 1,158.6 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Wisconsinan Stage		
Terrace deposits		
Silt, black	5	5
Silt, brown	10	15
Silt, clayey, sandy, fine, brown	10	25

30-4-20dcd.—Sample log of test hole in SE SW SE sec. 20, T. 30 S., R. 4 E., on north road shoulder, 5 feet east of private road to north; augered June 14, 1957; depth to water, 11.70 feet; altitude of land surface, 1,153.0 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Wisconsinan Stage		
Terrace deposits		
Silt, brown	5	5
Silt, gray brown	5	10
Silt, clayey, brown	5	15
Gravel, coarse (chert)	5	20
PERMIAN—Lower Permian Series		
Chase Group		
Doyle Shale		
Shale, gray	1	21

31-3-8ccc.—Sample log of test hole in SW cor. sec. 8, T. 31 S., R. 3 E., 58 feet north and 8 feet east of center of crossing; drilled April 28, 1944; depth to water, 52.96 feet; altitude of land surface, 1,256.5 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Wisconsinan Stage		
Eolian deposits		
Silt, sandy, fine, dark brown	2	2
Silt, light brown	6	8
Silt, buff	5	13
Silt, tan	11	24
Lower Pleistocene—Yarmouthian and Kansan Stages		
Sappa and Grand Island Formations		
Silt, buff; contains fine sand	16	40
Silt, buff	3	43
Silt, buff; contains fine to medium sand and caliche	7	50
Silt, buff; contains much fine to medium sand	10	60
Sand, fine to medium, and buff silt	5	65
Sand and gravel, fine to coarse; cemented in lower part	5	70
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, light gray green	3	73

* **31-3-16cdd.**—Sample log of test hole in SE cor. SE SW sec. 16, T. 31 S., R. 3 E., on north road shoulder at ½-mile line; augered June 16, 1957; depth to water, 52.50 feet; altitude of land surface, 1,242.4 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Wisconsinan Stage		
Eolian deposits		
Silt, brown	5	5
Silt, clayey, light brown	5	10
Silt, tan	15	25

	Thickness, feet	Depth, feet
Lower Pleistocene—Yarmouthian and Kansan Stages		
Sappa and Grand Island Formations		
Silt, clayey, buff	20	45
Silt, tan	10	55
Sand, fine to medium, silty	5	60
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, gray	1	61

31-3-16ddd.—Sample log of test hole in SE cor. sec. 16, T. 31 S., R. 3 E., 20 feet north and 8 feet west of center of crossing; augered June 16, 1957; dry hole; altitude of land surface, 1,256.9 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Wisconsinan Stage		
Eolian deposits		
Silt, black	5	5
Silt, red brown	20	25
Lower Pleistocene—Yarmouthian and Kansan Stages		
Sappa and Grand Island Formations		
Clay, buff	5	30
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, gray	1	31

31-3-17cdd.—Sample log of test hole in SE cor. SE SW sec. 17, T. 31 S., R. 3 E., on north road shoulder at ½-mile line; augered June 16, 1957; depth to water, 21.00 feet; altitude of land surface, 1,209.7 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Sangamonian and Illinoisan Stages		
Loveland and Crete Formations		
Sand, fine, silty	5	5
Silt, sandy, tan brown	5	10
Silt, brown	5	15
Sand, fine, silty and clayey	20	35
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, gray	3	38

31-3-18cdd.—Sample log of test hole in SE cor. SE SW sec. 18, T. 31 S., R. 3 E., on north road shoulder at ½-mile line; augered June 15, 1957; depth to water, 40.00 feet; altitude of land surface, 1,214.7 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Sangamonian and Illinoisan Stages		
Loveland and Crete Formations		
Silt, brown	5	5
Sand, fine, silty	15	20
Silt, brown, some fine sand	5	25
Sand, fine, silty	15	40
Sand, fine to coarse	3	43
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, gray	1	44

31-3-18ddd.—Sample log of test hole in SE cor. sec. 18, T. 31 S., R. 3 E., on west road shoulder, 30 feet north of center of crossing; augered June 15, 1957; altitude of land surface, 1,224.4 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Sangamonian and Illinoisan Stages		
Loveland and Crete Formations		
Silt, very sandy, red brown	5	5
Silt, sandy, brown	5	10
Silt, tan	10	20
Silt, sandy, tan	5	25
Sand, fine to coarse	15	40
Sand, fine to coarse, silty	5	45

31-3-21add.—Sample log of test hole in SE cor. NE sec. 21, T. 31 S., R. 3 E., on west road shoulder at ½-mile line; augered June 16, 1957; depth to water, 49.50 feet; altitude of land surface, 1,235.4 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Wisconsinan Stage		
Eolian deposits		
Silt, black	5	5
Silt, red brown	5	10
Clay, silty, tan	5	15
Silt, tan	15	30
Lower Pleistocene—Yarmouthian and Kansan Stages		
Sappa and Grand Island Formations		
Silt, buff	15	45
Silt, tan	10	55
Silt, brown, some fine sand	5	60
Sand, fine to coarse	5	65
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, gray	3	68

31-3-21bbb.—Sample log of test hole in NW cor. sec. 21, T. 31 S., R. 3 E., 56 feet south and 28 feet east of center of crossing; drilled April 28, 1944; depth to water, 20.20 feet; altitude of land surface, 1,209.8 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Sangamonian and Illinoisan Stages		
Loveland and Crete Formations		
Clay, gray to brown	1	1
Silt, dark gray	6	7
Silt, gray green; contains some medium sand	5	12
Silt, clayey; contains some fine to medium sand	10	22
Sand, fine to coarse	11	33
Sand, fine to coarse, and some fine gravel	3.5	36.5
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, gray to blue gray	2.5	39

31-3-21ddd.—Sample log of test hole in SE cor. sec. 21, T. 31 S., R. 3 E., 20 feet north and 8 feet west of center of crossing; augered June 17, 1957; depth to water, 16.80 feet; altitude of land surface, 1,206.7 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Sangamonian and Illinoisan Stages		
Loveland and Crete Formations		
Silt, brown	5	5
Silt, tan	10	15
Clay, sandy, tan	5	20
Sand, fine	5	25
Sand, fine to coarse	5	30
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, gray	3	33

31-3-28add.—Sample log of test hole in SE cor. NE sec. 28, T. 31 S., R. 3 E., on west road shoulder at ½-mile line; augered June 17, 1957; dry hole; altitude of land surface, 1,218.9 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Sangamonian and Illinoisan Stages		
Loveland and Crete Formations		
Silt, brown; contains some fine sand	5	5
Silt, brown	15	20
Silt, sandy, tan	5	25
Sand, fine	5	30
Silt, sandy, fine, tan	5	35
Sand, fine to coarse	5	40
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, gray	3	43

31-3-28ddd.—Sample log of test hole in SE cor. sec. 28, T. 31 S., R. 3 E., in NW cor. of intersection; augered June 17, 1957; dry hole; altitude of land surface, 1,218.8 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Sangamonian and Illinoisan Stages		
Loveland and Crete Formations		
Silt, sandy, brown	10	10
Silt, sandy, reddish brown	5	15
Silt, brown	10	25
Sand, fine to medium	10	35
Sand, fine to coarse	5	40
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, gray	3	43

31-3-29aaa.—Sample log of test hole in NE cor. sec. 29, T. 31 S., R. 3 E., 30 feet south and 31 feet west of center of crossing; drilled April 27, 1944; depth to water, 31.80 feet; altitude of land surface, 1,208.1 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Sangamonian and Illinoisan Stages		
Loveland and Crete Formations		
Silt, dark gray	3.5	3.5
Silt, gray buff; contains some fine to medium sand	6.5	10
Silt, buff; contains some fine sand	3	13
Silt, tan	13	26
Silt and clay, light gray	5	31
Sand, fine to coarse, and some fine to medium gravel	12	43
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, light gray	4.5	47.5

* **31-3-29dcc.**—Sample log of test hole in SW cor. SE sec. 29, T. 31 S., R. 3 E., 50 feet east and 12 feet north of center of road at ½-mile line; drilled April 29, 1944; depth to water, 24.49 feet; altitude of land surface, 1,195.2 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Sangamonian and Illinoisan Stages		
Loveland and Crete Formations		
Silt, dark gray to brown	2	2
Silt, light brown	9	11
Silt, tan buff	12	23
Silt, buff; contains much fine to medium sand	8.5	31.5
Sand, fine to coarse, and some fine to coarse gravel	9	40.5
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, gray to blue gray	2.5	43

* **31-3-30ccc.**—Sample log of test hole in SW cor. sec. 30, T. 31 S., R. 3 E., 7 feet north of center of "T" road; drilled May 26, 1944; depth to water, 7.40 feet; altitude of land surface, 1,158.6 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Wisconsinan Stage		
Terrace deposits		
Sand, medium to fine, silty, gray	4	4
Sand, coarse to fine; contains some medium to fine gravel,	6	10
Sand, fine to coarse, grading downward to fine to coarse gravel	10	20
Gravel, fine to coarse, and fine to coarse sand; some gray clay	10	30
Gravel, fine to coarse	10	40
Gravel, fine to medium, and fine to coarse sand	6.5	46.5
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, gray, and hard white limestone	1.5	48

* **31-3-30dcc.**—Sample log of test hole in SW cor. SE sec. 30, T. 31 S., R. 3 E., 12 feet north and 69 feet east of center of "T" road; drilled May 26, 1944; depth to water, 3.00 feet; altitude of land surface, 1,157.2 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Wisconsinan Stage		
Terrace deposits		
Silt, dark gray; contains some fine sand	6	6
Silt, clayey, yellow gray to blue gray	2	8
Sand, fine to medium, and some coarse gravel	12	20
Gravel, fine to coarse, and fine to coarse sand	9	29
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, light gray, and hard limestone	4	33

* **31-3-32bbb.**—Sample log of test hole in NW cor. sec. 32, T. 31 S., R. 3 E., 75 feet east of corner in south road ditch; augered Aug. 10, 1956; depth to water, 21.80 feet; altitude of land surface, 1,165.6 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Wisconsinan Stage		
Terrace deposits		
Silt, sandy, brown	10	10
Silt, black	13	23
Silt, sandy, brown	2	25
Sand, fine, silty	5	30
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, gray	0.5	30.5

*** 31-3-32ddc.**—Sample log of test hole in SW SE SE sec. 32, T. 31 S., R. 3 E., in drive on north side of road 0.8 mile east of corner; augered Aug. 10, 1956; depth to water, 14.40 feet; altitude of land surface, 1,166.9 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Wisconsinan Stage		
Terrace deposits		
Silt, sandy, brown	5	5
Sand, fine	10	15
Sand, fine, silty	5	20
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, gray	0.5	20.5

*** 31-3-33abb.**—Sample log of test hole in NW cor. NE sec. 33, T. 31 S., R. 3 E., 108 feet east and 9 feet south of center of road at ½-mile line; drilled May 2, 1944; depth to water, 6.52 feet; altitude of land surface, 1,180.2 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Sangamonian and Illinoisan Stages		
Loveland and Crete Formations		
Silt, dark gray	1	1
Silt, gray to brown; contains some fine sand	4	5
Silt, buff; contains much fine sand	3	8
Sand, medium to fine, and much buff silt	5	13
Sand, fine to coarse	3.5	16.5
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, light gray	3.5	20

31-3-33ddd.—Sample log of test hole in SE cor. sec. 33, T. 31 S., R. 3 E., in NW cor. of intersection; augered June 17, 1957; depth to water, 23.30 feet; altitude of land surface, 1,204.3 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Sangamonian and Illinoisan Stages		
Loveland and Crete Formations		
Silt, sandy, red brown	10	10
Silt, brown	10	20
Sand, fine, silty	5	25
Sand, fine to coarse	5	30
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, gray	3	33

31-3-35ccc.—Sample log of test hole in SW cor. sec. 35, T. 31 S., R. 3 E., in NW cor. of intersection; augered June 17, 1957; dry hole; altitude of land surface, 1,211.0 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Wisconsinan Stage		
Eolian deposits		
Silt, brown	5	5
Silt, red	5	10
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, gray	20	30

31-4-7ccc.—Sample log of test hole in SW cor. sec. 7, T. 31 S., R. 4 E., 20 feet north and 10 feet east of center of crossing; augered June 14, 1957; depth to water, 17.40 feet; altitude of land surface, 1,113.8 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Wisconsinan Stage		
Terrace deposits		
Silt, black	5	5
Silt, brown	5	10
Silt, brown; contains some fine to coarse sand and chert gravel	5	15
Silt, clayey, brown	10	25
PERMIAN—Lower Permian Series		
Chase Group		
Doyle Shale		
Shale, tan	10	35
Shale, blue gray	5	40

31-4-7dcc.—Sample log of test hole in SW SW SE sec. 7, T. 31 S., R. 4 E., on south road shoulder 25 feet east of drive to house; augered June 14, 1957; depth to water, 22.00 feet; altitude of land surface, 1,123.2 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Wisconsinan Stage		
Terrace deposits		
Silt, sandy, red brown	5	5
Silt, red brown	10	15
Silt, sandy, fine, tan	5	20
Gravel, coarse (chert), silty	4	24
PERMIAN—Lower Permian Series		
Chase Group		
Doyle Shale		
Shale, gray	1	25

31-4-7ddd.—Sample log of test hole in SE cor. sec. 7, T. 31 S., R. 4 E., 20 feet north and 10 feet west of center of crossing; augered June 14, 1957; depth to water, 32.00 feet; altitude of land surface, 1,133.5 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Wisconsinan Stage		
Terrace deposits		
Silt, red brown	5	5
Silt, tan	10	15
Silt, sandy, fine to coarse, tan	15	30
Gravel (chert), coarse, and fine silty sand	4	34

31-4-8cdd.—Sample log of test hole in SE cor. SE SW sec. 8, T. 31 S., R. 4 E., on south road shoulder 50 feet west of highway; augered June 14, 1957; depth to water, 30.00 feet; altitude of land surface, 1,133.3 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Wisconsinan Stage		
Terrace deposits		
Silt, dark brown	5	5
Clay, red brown	5	10
Silt, clayey, tan	10	20
Silt, sandy, brown	20	40
PERMIAN—Lower Permian Series		
Chase Group		
Doyle Shale		
Shale, gray	2	42

32-3-4ccc.—Sample log of test hole in SW cor. sec. 4, T. 32 S., R. 3 E., 105 feet east and 7 feet north of center of crossing; drilled April 27, 1944; depth to water, 15.45 feet; altitude of land surface, 1,174.9 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Sangamonian and Illinoisan Stages		
Loveland and Crete Formations		
Silt, dark gray to brown	6	6
Silt, tan; contains some fine sand	5	11
Silt and clay, gray green	6	17
Sand, fine to coarse, and some fine to medium gravel	11	28
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, light gray	2	30

* **32-3-5ccc2.**—Sample log of test hole in SW cor. sec. 5, T. 32 S., R. 3 E., 90 feet east and 8 feet north of center of crossing; drilled May 2, 1944; depth to water, 9.10 feet; altitude of land surface, 1,149.3 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Wisconsinan Stage		
Terrace deposits		
Silt, gray brown; contains some coarse to fine sand	2	2
Silt, dark gray	2	4
Silt, gray; contains fine sand	3	7

	Thickness, feet	Depth, feet
Sand and gravel, fine to coarse, silty	13	20
Gravel, fine to coarse, and fine to coarse sand	13	33
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, hard, light gray	5.5	38.5

* **32-3-5ccc3.**—Sample log of test hole in SW cor. sec. 5, T. 32 S., R. 3 E., in east road ditch, 100 feet north of corner; augered Aug. 10, 1956; depth to water, 8.90 feet; altitude of land surface, 1,146.9 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Wisconsinan Stage		
Terrace deposits		
Silt, sandy, black	5	5
Silt, sandy, dark gray	5	10
Sand, fine to medium, silty	5	15
Sand and gravel, fine to coarse, silty	10	25
Sand and gravel, fine to coarse	8	33
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, gray	0.5	33.5

* **32-3-5dcc.**—Sample log of test hole in SW cor. SE sec. 5, T. 32 S., R. 3 E., 67 feet east and 7 feet north of center of road at ½-mile line; drilled May 2, 1944; depth to water, 1.85 feet; altitude of land surface, 1,148.1 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Wisconsinan Stage		
Terrace deposits		
Silt, black to dark gray	3	3
Silt, buff; contains some fine sand	4	7
Sand, fine to coarse, and some fine to coarse gravel	6	13
Sand, fine to coarse	17	30
Sand, fine to coarse, and some fine to coarse gravel	3.5	33.5
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, light gray	5.5	39

* **32-3-6aaa.**—Sample log of test hole in NE cor. sec. 6, T. 32 S., R. 3 E., in south road ditch, 30 feet west of corner; augered Aug. 10, 1956; depth to water, 12.10 feet; altitude of land surface, 1,153.4 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Wisconsinan Stage		
Terrace deposits		
Silt, black	5	5
Silt, tan	5	10
Sand, fine	5	15

	Thickness, feet	Depth, feet
Sand, medium to coarse	5	20
Sand and gravel, fine to coarse	13	33
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, gray	0.5	33.5

* **32-3-6ccc.**—Sample log of test hole in SW cor. sec. 6, T. 32 S., R. 3 E., near fence corner post at river bank; drilled June 6, 1944; depth to water, 4.50 feet; altitude of land surface, 1,148.6 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Recent Stage		
Alluvium		
Sand, fine to medium, and buff silt	4	4
Sand, fine to coarse and medium to fine gravel	6	10
Gravel and sand, fine to coarse	20	30
Gravel, fine, and coarse sand; much coarse gravel	14.5	44.5
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, gray; contains some chert nodules	3.5	48

** **32-3-6dcc.**—Sample log of test hole in SW cor. SE sec. 6, T. 32 S., R. 3 E., 15 feet east and 8 feet south of center of road at ½-mile line; drilled June 6, 1944; depth to water, 2.78 feet; altitude of land surface, 1,147.8 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Recent Stage		
Alluvium		
Silt, dark gray	1	1
Sand, fine to coarse, some fine to medium gravel	19	20
Gravel, fine to medium, and fine to coarse sand	21	41
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, very hard, buff grading to gray; contains chert nodules	1.5	42.5

** **32-3-9abb.**—Sample log of test hole in NW cor. NE sec. 9, T. 32 S., R. 3 E., 5 feet south of center of road at ½-mile line; drilled April 27, 1944; depth to water, 23.53 feet; altitude of land surface, 1,186.9 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Sangamonian and Illinoisan Stages		
Loveland and Crete Formations		
Silt, dark gray brown	2	2
Silt, dark brown	12	14
Silt, clayey, gray green	5	19
Silt, buff; contains fine sand	5	24

	Thickness, feet	Depth, feet
Sand, medium	8	32
Sand, fine to coarse; some fine to medium, silty gravel	4	36
Sand and gravel, fine to coarse	4	40
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, gray	3	43

*** 32-3-10baa.**—Sample log of test hole in NE cor. NW sec. 10, T. 32 S., R. 3 E., 43 feet west and 6 feet south of center of road at ½-mile line; drilled May 3, 1944; depth to water, 28.13 feet; altitude of land surface, 1,196.0 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Wisconsinan Stage		
Eolian deposits		
Silt, dark gray	2	2
Silt, brown	3	5
Silt, tan	13	18
Lower Pleistocene—Yarmouthian and Kansan Stages		
Sappa and Grand Island Formations		
Clay, silty, light gray	10	28
Sand, very fine, silty	1	29
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, blue gray	6	35

32-3-10bbb.—Sample log of test hole in NW cor. sec. 10, T. 32 S., R. 3 E., 38 feet south and 8 feet east of center of crossing; drilled April 27, 1944; altitude of land surface, 1,189.7 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Sangamonian and Illinoisan Stages		
Loveland and Crete Formations		
Silt, gray	3	3
Silt, brown	5	8
Silt, tan to buff	2	10
Silt, buff; contains some fine sand	3	13
Clay, gray green	5	18
Clay, light gray	2	20
Sand, fine	3	23
Sand, fine to coarse, and some fine to medium gravel	10	33
Sand, fine to coarse, and much fine to medium, silty gravel	3	36
Gravel, fine to coarse, and fine to coarse sand	8.5	44.5
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, light gray	2	46.5

32-3-12baa.—Sample log of test hole in NE cor. NW sec. 12, T. 32 S., R. 3 E., 124 feet north and 6 feet east of center of crossing; drilled May 4, 1944; depth to water, 1.96 feet; altitude of land surface, 1,130.6 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Wisconsinan Stage		
Terrace deposits		
Silt, dark gray	2	2
Silt, clayey, dark gray	4	6
Silt, clayey, gray green	2	8
Silt, clayey, light gray	10	18
Silt, soft, gray	11	29
Clay, silty, light gray	2.5	31.5
Sand, fine to coarse; contains much fine to coarse chert gravel	9.5	41
PERMIAN—Lower Permian Series		
Chase Group		
Doyle Shale		
Shale, blue gray	4	45

32-3-16baa.—Sample log of test hole in NE cor. NW sec. 16, T. 32 S., R. 3 E., 28 feet east and 8 feet south of center of road at ½-mile line; drilled May 8, 1944; depth to water, 15.56 feet; altitude of land surface, 1,179.7 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Sangamonian and Illinoisan Stages		
Loveland and Crete Formations		
Silt, dark gray	1	1
Silt, clayey, light gray	3	4
Silt, hard, blocky, gray, mottled brown	4	8
Silt, clayey, light gray; contains some medium sand	8	16
Clay, silty, blue gray; contains fine to medium sand	6.5	22.5
Sand, fine to medium; contains coarse sand and fine gravel near bottom	7.5	30
Gravel and sand, fine to coarse	6	36
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, blue gray	2	38

* **32-3-17abb.**—Sample log of test hole in NW NW NE sec. 17, T. 32 S., R. 3 E., in south road ditch 0.6 mile east of corner; augered Aug. 11, 1956; depth to water, 9.80 feet; altitude of land surface, 1,147.4 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Wisconsinan Stage		
Terrace deposits		
Silt, brown	8	8
Clay, fine sandy, tan	2	10
Sand, fine, brown stain	5	15

	Thickness, feet	Depth, feet
Sand, medium to coarse	5	20
Sand and gravel, fine to coarse	3	23
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, gray	0.5	23.5

* **32-3-17bbb.**—Sample log of test hole in NW cor. sec. 17, T. 32 S., R. 3 E., in south road ditch 150 feet east of corner; augered Aug. 11, 1956; depth to water, 11.30 feet; altitude of land surface, 1,147.3 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Wisconsinan Stage		
Terrace deposits		
Silt, brown	3	3
Silt, fine sandy, buff	7	10
Silt, very sandy, gray	10	20
Sand and gravel, fine to coarse, silty, gray	10	30
Sand and gravel, fine to coarse	5	35
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, gray	2	37

* **32-3-17dcc.**—Sample log of test hole in SW SW SE sec. 17, T. 32 S., R. 3 E., augered Aug. 11, 1956; depth to water, 9.80 feet; altitude of land surface, 1,151.0 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Wisconsinan Stage		
Terrace deposits		
Silt, sandy, brown	7	7
Sand, fine to medium	3	10
Sand, medium to coarse	5	15

* **32-3-18abb.**—Sample log of test hole in NW cor. NW NE sec. 18, T. 32 S., R. 3 E., on south road shoulder 0.4 mile west of corner; augered Aug. 11, 1956; depth to water, 12.30 feet; altitude of land surface, 1,148.5 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Wisconsinan Stage		
Terrace deposits		
Silt, sandy, brown	10	10
Sand, fine, silty, tan	2	12
Sand, fine, silty, brown	3	15
Sand, fine, silty, black	10	25
Sand, fine to medium	5	30
Sand and gravel, fine to coarse, silty	15	45
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, gray	0.5	45.5

* **32-3-18bba.**—Sample log of test hole in NE cor. NW NW sec. 18, T. 32 S., R. 3 E., in south road ditch 50 feet west of a bridge; augered Aug. 12, 1956; depth to water, 5.20 feet; altitude of land surface, 1,141.0 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Recent Stage		
Alluvium		
Sand, fine, tan	8	8
Sand, medium to coarse	17	25
Sand and gravel, fine to coarse	15	40
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, gray	1	41

32-3-18dbc.—Sample log of Winfield city well 4 in SW NW SE sec. 18, T. 32 S., R. 3 E., 60 feet south of highway and 20 feet east of ½-mile line; drilled by Layne-Western Co.; depth to water, 10.83 feet; altitude of land surface, 1,150.0 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Wisconsinan Stage		
Terrace deposits		
Sand, fine to medium	13	13
Gravel, fine to coarse, and fine to coarse sand	4	17
Sand, fine to coarse	3	20
Gravel, fine to coarse, and medium to coarse sand	8	28
Gravel, fine to coarse, and coarse sand	14	42
Gravel, fine to coarse, and coarse sand; contains a thin zone of chert gravel near 45 feet	6	48
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, gray brown	0.2	48.2

* **32-3-19aaa.**—Sample log of test hole in NE cor. sec. 19, T. 32 S., R. 3 E., in south road ditch 200 feet east of highway; augered Aug. 11, 1956; depth to water, 14.20 feet; altitude of land surface, 1,142.3 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Wisconsinan Stage		
Terrace deposits		
Silt, fine sandy, dark brown	5	5
Silt, clayey, brown	5	10
Sand, fine, silty	10	20
Sand, fine	7	27
Sand, fine to medium	1	28

* **32-3-19abb.**—Sample log of test hole in NW cor. NE sec. 19, T. 32 S., R. 3 E., in south road ditch 60 feet east of ½-mile line; augered June 25, 1957; depth to water, 8.60 feet; altitude of land surface, 1,143.1 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Wisconsinan Stage		
Terrace deposits		
Silt, brown; contains some very fine sand	5	5
Silt, clayey, brown	3	8
Silt, tan; contains much very fine sand	7	15
Sand and gravel, fine to coarse	28	43
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale and limestone	0.5	43.5

* **32-3-19abc1.**—Sample log of observation well 41 in SW NW NE sec. 19, T. 32 S., R. 3 E., 700 feet south and 500 feet east of center of road at ½-mile line; drilled April 7, 1944; depth to water, 10.70 feet; altitude of land surface, 1,146.0 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Wisconsinan Stage		
Terrace deposits		
Silt, light brown	4	4
Silt, brown; contains some fine sand	3	7
Sand, fine to coarse, and fine to medium gravel	3	10
Sand and gravel, fine to coarse	17	27
Sand, fine to coarse, and some fine to coarse gravel	3	30
Sand, fine to coarse, and some fine gravel	5	35
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, light blue gray; contains some chert	1.5	36.5

* **32-3-19abc2.**—Sample log of observation well 40 in SW NW NE sec. 19, T. 32 S., R. 3 E., 700 feet south and 40 feet east of center of road at ½-mile line; drilled April 7, 1944; depth to water, 10.80 feet; altitude of land surface, 1,144.3 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Wisconsinan Stage		
Terrace deposits		
Silt, gray	2.5	2.5
Silt, buff	6.5	9
Sand, fine to coarse; contains some fine to coarse gravel	11	20
Sand and gravel, fine to coarse, buff silt zone 37 to 39 feet	19	39
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, gray; contains some chert	0.5	39.5

* **32-3-19bbb.**—Sample log of test hole in NW cor. sec. 19, T. 32 S., R. 3 E., 20 feet south of sec. corner; augered June 25, 1957; depth to water, 10.20 feet; altitude of land surface, 1,146.0 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Wisconsinan Stage		
Terrace deposits		
Silt, black; contains fine sand	2	2
Silt, tan	6	8
Silt, buff; caliche at top	8	16
Sand and gravel, fine to coarse	37	53
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, blue gray	1	54

* **32-3-20dbc.**—Sample log of test hole in SW NW SE sec. 20, T. 32 S., R. 3 E., in south ditch 150 yards west of highway bridge; augered Aug. 11, 1956; depth to water, 10.80 feet; altitude of land surface, 1,139.3 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Wisconsinan Stage		
Terrace deposits		
Silt, sandy, tan	6	6
Sand, fine, silty, tan	2	8
Sand, fine to medium, silty, black	12	20

32-3-21aaa.—Sample log of test hole in NE cor. sec. 21, T. 32 S., R. 3 E., 7 feet south and 51 feet west of center of crossing; drilled April 21, 1944; altitude of land surface, 1,174.4 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Sangamonian and Illinoisan Stages		
Loveland and Crete Formations		
Silt, dark gray	4	4
Silt, clayey, blocky, greenish gray	12	16
Silt, clayey, greenish gray grading to yellow buff	5	21
Sand, medium to coarse, some fine to medium gravel	12	33
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, gray	4	37

** **32-3-21ccc.**—Sample log of observation well 42 in SW cor. sec. 21, T. 32 S., R 3 E., 4 feet north of NW cor. of cemetery; drilled April 8, 1944; depth to water, 22.90 feet; altitude of land surface, 1,175.6 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Sangamonian and Illinoisan Stages		
Loveland and Crete Formations		
Silt, dark gray to brown	3.5	3.5
Silt, green to buff	7.5	11
Silt, tan; contains much fine to medium sand	9	20

	Thickness, feet	Depth, feet
Silt, tan, and interbedded fine to medium sand	8	28
Sand, fine to medium	5	33
Sand, fine to coarse, and fine to medium gravel	4	37
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, light blue gray	1	38

32-3-23ccc.—Sample log of test hole in SW cor. sec. 23, T. 32 S., R. 3 E., 25 feet east and 25 feet north of center of road crossing; augered June 18, 1957; depth to water, 24.00 feet; altitude of land surface, 1,183.2 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Sangamonian and Illinoisan Stages		
Loveland and Crete Formations		
Silt, black	2	2
Silt, red brown	8	10
Silt, sandy, tan	10	20
Silt, buff, clayey	5	25
Silt, tan, some fine sand	12	37
Sand, fine, very silty, tan	8	45
Sand, fine to coarse, silty	11	56
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, gray	1	57

32-3-23dcc.—Sample log of test hole in SW SW SE sec. 23, T. 32 S., R. 3 E., on north shoulder of road at field entrance; augered June 18, 1957; depth to water, 27.50 feet; altitude of land surface, 1,183.5 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Sangamonian and Illinoisan Stages		
Loveland and Crete Formations		
Silt, gray	5	5
Silt, yellow gray	5	10
Silt, brown	10	20
Sand, fine, silty	10	30
Sand, fine to coarse	10	40
Clay, gray, sandy	5	45
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, gray	5	50

32-3-23ddd.—Sample log of test hole in SE cor. sec. 23, T. 32 S., R. 3 E., 200 feet north and 6 feet west of center of road crossing; augered June 17, 1957; altitude of land surface, 1,209.4 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Wisconsinan Stage		
Eolian deposits		
Silt, red brown	6	6
Silt, tan	6	12
Lower Pleistocene—Yarmouthian and Kansan Stages		
Sappa and Grand Island Formations		
Silt, sandy, buff	4	16
Silt, dark gray to black	3	19
Sand, fine to coarse, silty, tan	5	24
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, gray	1	25

32-3-24cdd.—Sample log of test hole in SE cor. SW sec. 24, T. 32 S., R. 3 E., on north road shoulder at ½-mile line; augered June 17, 1957; dry hole; altitude of land surface, 1,221.4 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Wisconsinan Stage		
Eolian deposits		
Silt, black	2	2
Silt, reddish brown	6	8
Silt, gray green	7	15
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, gray	1	16

32-3-25bbd.—Drillers log of test hole in SE cor. NW NW sec. 25, T. 32 S., R. 3 E., 175 feet southeast of pumped well; drilled by Hydraulic Drilling Co., Oct. 11, 1955.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Wisconsinan Stage		
Eolian deposits		
Silt and clay, tan	7	7
Lower Pleistocene—Yarmouthian and Kansan Stages		
Sappa and Grand Island Formations		
Silt and clay, gray	15	22
Silt and fine sand	5	27
PERMIAN—Lower Permian Series		
Chase Group		
Nolans Limestone		
Shale and limestone, blue and gray	18	45
Shale, green	2	47
Shale, gray, and interbedded limestone	6	53

	Thickness, feet	Depth, feet
Odell Shale		
Shale, gray, red, and green, interbedded	5	58
Shale, gray, some interbedded limestone	6	64
Shale, red and gray	3	67
Limestone	1	68
Shale, green	2	70
Shale, gray, interbedded with limestone	15	85
Winfield Limestone		
Limestone, thin bedded and shaly	16	101
Limestone, gray, speckled	11.5	112.5

32-3-25bcd.—Drillers log of test hole in SE SW NW sec. 25, T. 32 S., R. 3 E., on south line of ¼ sec. due south of pumped well; drilled by Hydraulic Drilling Co., July 1, 1955.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Wisconsinan Stage		
Eolian deposits		
Silt, light brown	4	4
Silt and clay, red and gray	8.5	12.5
Lower Pleistocene—Yarmouthian and Kansan Stages		
Sappa and Grand Island Formations		
Silt and sand	4	16.5
Gravel, fine to medium, and sand	2	18.5
PERMIAN—Lower Permian Series		
Chase Group		
Nolans Limestone		
Limestone (cavity at 20 feet)	3	21.5
Shale, gray	1.5	23
Shale and limestone	11.5	34.5
Limestone, light gray	1	35.5
Shale, blue, thin limestone zones	2.5	38
Odell Shale		
Shale, green, gray, and red interbedded	27	65
Shale, blue	14	79
Winfield Limestone		
Limestone, gray, interbedded with light- and dark-gray shale; contains cherty concretions at 90 feet	11	90
Shale, dark gray, some gypsum	3.5	93.5
Limestone, light gray, speckled, very fossiliferous	13	106.5
Doyle Shale		
Shale, blue	6	112.5
Limestone and shale, interbedded	4.5	117
Shale, green	3	120

32-3-27abb.—Sample log of test hole in NW cor. NE sec. 27, T. 32 S., R. 3 E., 52 feet east and 27 feet south of center of highway at ½-mile line; drilled April 21, 1944; altitude of land surface, 1,173.9 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Sangamonian and Illinoisan Stages		
Loveland and Crete Formations		
Silt, clayey, blocky, light gray, mottled yellow	8	8
Silt, clayey, light gray tan; contains some fine to medium sand	2.5	10.5
Sand, medium to coarse, and some fine gravel	9.5	20
Sand and gravel, fine to coarse, silty, yellow gray	10	30
Sand, medium to coarse, and fine gravel	8	38
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, blue gray	1	39

32-3-27bbb.—Sample log of test hole in NW cor. sec. 27, T. 32 S., R. 3 E., 120 feet south and 6 feet east of center of intersection; augered June 18, 1957; depth to water, 17.00 feet; altitude of land surface, 1,176.4 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Sangamonian and Illinoisan Stages		
Loveland and Crete Formations		
Silt, black	2	2
Silt, reddish brown	4	6
Silt, sandy, brown	5	11
Silt, buff, some fine sand	16	27
Sand, fine to coarse, and fine to medium, silty gravel	6	33
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, gray	3	36

* **32-3-29cdc.**—Sample log of test hole in SW cor. SE SW sec. 29, T. 32 S., R. 3 E., on south road shoulder 0.3 mile east of corner; augered August 12, 1956; depth to water, 10.30 feet; altitude of land surface, 1,134.2 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Wisconsinan Stage		
Terrace deposits		
Silt, tan	5	5
Silt, brown	2	7
Clay, light brown	3	10
Silt, black	2	12
Sand, fine, silty, brown	4	16

* **32-3-30aaa.**—Sample log of test hole in NE cor. sec. 30, T. 32 S., R. 3 E., in west road ditch 30 feet south of corner; augered Aug. 12, 1956; depth to water, 5.80 feet; altitude of land surface, 1,132.8 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Recent Stage		
Alluvium		
Sand, fine, tan	8	8
Sand, fine to medium, brown	2	10
Sand, fine to coarse	10	20

* **32-3-30ddd.**—Sample log of test hole in SE cor. sec. 30, T. 32 S., R. 3 E., in west road ditch 200 feet north of corner; augered Aug. 12, 1956; depth to water, 7.30 feet; altitude of land surface, 1,128.7 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Recent Stage		
Alluvium		
Silt, sandy, brown	2	2
Sand, fine, tan	8	10
Sand, coarse	8	18

* **32-3-31dac.**—Sample log of test hole in SW cor. NE SE sec. 31, T. 32 S., R. 3 E., east along lane leading from house at end row of trees on north side; augered Aug. 14, 1956; depth to water, 16.20 feet; altitude of land surface, 1,140.4 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Wisconsinan Stage		
Terrace deposits		
Silt, sandy brown	5	5
Silt, sandy, tan	10	15
Sand, medium to coarse, silty	5	20
Sand, coarse	5	25
Sand, coarse, and fine to coarse, silty gravel	15	40

* **32-3-31dcd.**—Sample log of test hole in SE cor. SW SE sec. 31, T. 32 S., R. 3 E., 200 feet west of city well 8 in north road ditch; augered Aug. 14, 1956; depth to water, 13.70 feet, Aug. 14, 1956; 4.00 feet, June 25, 1957; altitude of land surface, 1,136.5 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Wisconsinan Stage		
Terrace deposits		
Silt, sandy, black	5	5
Sand, fine	10	15
Sand, fine, silty	5	20
Sand, fine	5	25
Sand, medium to coarse	10	35
Sand, coarse, and fine to coarse gravel	10	45
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, gray	1	46

* **32-3-32ccc2.**—Sample log of test hole in SW cor. sec. 32, T. 32 S., R. 3 E., in east road ditch 50 feet north of corner; augered Aug. 14, 1956; depth to water, 11.40 feet; altitude of land surface, 1,136.3 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Wisconsinan Stage		
Terrace deposits		
Silt, black	5	5
Sand, fine to medium	5	10
Sand, fine to coarse, silty	5	15
Sand, coarse, and fine to coarse gravel	10	25
Gravel, coarse	8	33

32-3-34ddd.—Sample log of test hole in SE cor. sec. 34, T. 32 S., R. 3 E., 60 feet west and 8 feet north of center of crossing; augered June 18, 1957; depth to water, 19.60 feet; altitude of land surface, 1,169.5 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Sangamonian and Illinoisan Stages		
Loveland and Crete Formations		
Silt, black	5	5
Silt, clayey, reddish brown	5	10
Sand, fine, very silty, brown	5	15
Sand, fine to medium	20	35
Sand and gravel, fine to coarse	4.5	39.5
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, red	0.5	40

32-3-36bbb.—Sample log of test hole in NW cor. sec. 36, T. 32 S., R. 3 E., 9 feet south and 57 feet east of center of crossing; drilled April 11, 1944; depth to water, 26.64 feet; altitude of land surface, 1,184.3 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Sangamonian and Illinoisan Stages		
Loveland and Crete Formations		
Silt, dark brown	3	3
Silt, clayey, gray; contains some fine to coarse sand	7	10
Sand, medium to coarse	2	12
Silt, light brown; contains some fine to medium sand	15.5	27.5
Sand, medium to coarse	1.5	29
Clay, silty, light gray green	6	35
Sand, fine to coarse; some fine to medium gravel	5	40
Sand and gravel, fine to medium	8	48
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, gray green	2	50

32-3-36cdd.—Sample log of test hole in SE SE SW sec. 36, T. 32 S., R. 3 E., on north road shoulder 0.35 mile east of corner; augered June 18, 1957; depth to water, 27.10 feet; altitude of land surface, 1,192.4 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Wisconsinan Stage		
Eolian deposits		
Silt, gray brown, mottled	5	5
Silt, reddish brown, some very fine sand	7	12
Lower Pleistocene—Yarmouthian and Kansan Stages		
Sappa and Grand Island Formations		
Silt, gray, clayey	4	16
Silt, tan to buff, some very fine sand	14	30
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, blue gray	2	32

32-3-36ddc.—Sample log of test hole in SW SE SE sec. 36, T. 32 S., R. 3 E., on north road shoulder 0.2 mile west of railroad; augered June 18, 1957; depth to water, 43.80 feet; altitude of land surface, 1,237.8 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Wisconsinan Stage		
Eolian deposits		
Silt, reddish brown	5	5
Silt, tan	20	25
Lower Pleistocene—Yarmouthian and Kansan Stages		
Sappa and Grand Island Formations		
Silt, gray, some fine sand	25	50
Sand, fine to medium, and much silt	22	72
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, gray green	0.5	72.5

* **32-4-5ccc.**—Sample log of test hole in SW cor. sec. 5, T. 32 S., R. 4 E., 40 feet north and 9 feet east of center of "T" road; drilled May 5, 1944; depth to water, 21.77 feet; altitude of land surface, 1,142.3 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Wisconsinan Stage		
Terrace deposits		
Silt, dark gray to brown	2	2
Silt, reddish brown	4	6
Silt, light brown	7	13
Silt, light brown to tan; contains fine sand	10	23
Gravel (chert), coarse to fine, and fine sand	5	28
PERMIAN—Lower Permian Series		
Chase Group		
Doyle Shale		
Shale, buff to tan, grading into blue-gray shale	7	35

32-4-5cdd.—Sample log of test hole in SE cor. SW sec. 5, T. 32 S., R. 4 E., on north road shoulder 30 feet west of mail box; augered June 17, 1957; depth to water, 33.70 feet; altitude of land surface, 1,150.8 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Wisconsinan Stage		
Terrace deposits		
Silt, reddish brown	5	5
Silt, red	10	15
Silt, clayey, brown	5	20
Clay, brown	5	25
Sand, clayey and silty, fine to coarse	10	35

32-4-6cdd.—Sample log of test hole in SE SE SW sec. 6, T. 32 S., R. 4 E., 190 feet east and 9 feet south of center of east end of river bridge; drilled May 5, 1944; depth to water, 17.50 feet; altitude of land surface, 1,135.8 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Wisconsinan Stage		
Terrace deposits		
Silt, clayey, brown	3	3
Silt, brown to buff	7	10
Silt, buff	5	15
Gravel (chert), fine to coarse, and some fine to coarse sand	9	24
PERMIAN—Lower Permian Series		
Chase Group		
Doyle Shale		
Shale, tan buff, soft calcite concretions	5	29
Shale, blue gray	3	32
Limestone, light gray to white	3	35

* **32-4-7bba.**—Sample log of test hole in NE cor. NW NW sec. 7, T. 32 S., R. 4 E., 102 feet west and 9 feet south of center of west end of river bridge; drilled May 5, 1944; depth to water, 10.30 feet; altitude of land surface, 1,127.2 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Wisconsinan Stage		
Terrace deposits		
Silt, dark gray to brown	3	3
Silt, light brown	25	28
Gravel and sand, fine to coarse, silty	7	35
Sand, fine to coarse, and some fine to coarse gravel	4	39
PERMIAN—Lower Permian Series		
Chase Group		
Doyle Shale		
Shale, light gray	6	45

32-4-31cdc.—Sample log of test hole in SW SE SW sec. 31, T. 32 S., R. 4 E., on north road shoulder 0.3 mile east of corner; augered June 18, 1957; dry hole; altitude of land surface, 1,231.7 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Wisconsinan Stage		
Eolian deposits		
Silt, reddish brown	10	10
Lower Pleistocene—Yarmouthian and Kansan Stages		
Sappa and Grand Island Formations		
Silt, buff; contains some fine sand and limestone gravel	5	15
Silt, sandy, buff	20	35

33-3-1bbb.—Sample log of test hole in NW cor. sec. 1, T. 33 S., R. 3 E., 63 feet south and 9 feet east of center of road crossing; drilled April 14, 1944; depth to water, 30.72 feet; altitude of land surface, 1,179.0 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Sangamonian and Illinoisan Stages		
Loveland and Crete Formations		
Silt, dark gray	3	3
Silt, clayey, blocky, tan	15	18
Silt, yellow buff; contains fine to medium sand	8	26
Sand, fine to medium, some coarse sand and fine gravel	14	40
Gravel, fine to coarse, and fine to coarse sand, some yellow clay	10	50
Gravel, fine to medium, some yellow clay	3	53
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, hard, gray	1	54

33-3-1ccc.—Sample log of test hole in SW cor. sec. 1, T. 33 S., R. 3 E., 39 feet north and 9 feet east of center of crossing; drilled April 14, 1944; depth to water, 24.60 feet; altitude of land surface, 1,171.7 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Sangamonian and Illinoisan Stages		
Loveland and Crete Formations		
Silt, dark gray	3	3
Silt, clayey, blocky, gray mottled yellow brown	5	8
Silt, light gray green and tan; contains some fine to medium sand	11	19
Sand, fine, grading downward to fine gravel	11	30
Gravel, fine, and some fine to coarse sand	10	40
Gravel, fine to medium, some coarse gravel and coarse sand	6	46
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, hard, gray	4	50

* **33-3-3bbb.**—Sample log of test hole in NW cor. sec. 3, T. 33 S., R. 3 E., 48 feet east and 6 feet south of center of crossing; drilled April 21, 1944; altitude of land surface, 1,156.6 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Sangamonian and Illinoisan Stages		
Loveland and Crete Formations		
Silt, clayey, dark gray	4	4
Silt, tan; contains some fine to medium sand	2	6
Sand, fine to medium	2	8
Silt, clayey, light gray; contains some fine to medium sand	1	9
Sand, fine to medium; some coarse sand	11	20
Clay, silty, light gray; contains much fine to medium sand	3	23
Sand, fine to coarse, and much fine gravel	8	31
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, blue gray; contains small white chert nodules	3	34

33-3-4ddd.—Sample log of test hole in SE cor. sec. 4, T. 33 S., R. 3 E., 100 feet north and 8 feet west of center of road crossing; augered June 24, 1957; depth to water, 17.20 feet; altitude of land surface, 1,153.9 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Sangamonian and Illinoisan Stages		
Loveland and Crete Formations		
Silt, red brown	6	6
Silt, brown; contains some fine sand	6	12
Silt, gray green	4	16
Sand, very fine to fine, silty	6	22
Sand, fine to coarse	7	29
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, gray green	1	30

33-3-5aaa.—Sample log of test hole in NE cor. sec. 5, T. 33 S., R. 3 E., 50 feet west and 6 feet south of center of crossing; augered June 18, 1957; depth to water, 24.50 feet; altitude of land surface, 1,167.6 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Sangamonian and Illinoisan Stages		
Loveland and Crete Formations		
Silt, black, sandy	5	5
Silt, red brown, sandy	11	16
Sand, fine to medium, silty, tan	7	23
Sand, fine to medium	15	38
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, gray and red	0.5	38.5

*** 33-3-5ccc1.**—Sample log of test hole in SW cor. sec. 5, T. 33 S., R. 3 E., 10 feet north of corner; augered Aug. 13, 1956; depth to water, 11.00 feet, Aug. 13, 1956; 3.40 feet, June 25, 1957; altitude of land surface, 1,124.1 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Recent Stage		
Alluvium		
Silt, sandy, fine, black	5	5
Silt, sandy, tan	5	10
Sand, fine to medium, tan	3	13
Sand, coarse, silty	7	20
Sand, coarse, and fine to coarse gravel	26	46
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, gray	0.5	46.5

*** 33-3-5ddc.**—Sample log of test hole in SW cor. SE SE sec. 5, T. 33, S., R. 3 E., in north road ditch 0.25 mile west of corner; augered Aug. 13, 1956; depth to water, 13.60 feet; altitude of land surface, 1,124.9 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Wisconsinan Stage		
Terrace deposits		
Silt, sandy, fine, brown	5	5
Silt, sandy, tan	5	10
Sand, fine	5	15
Sand, fine to coarse, silty	5	20
Sand and gravel, fine to coarse, silty	5	25
Sand, coarse, and fine to coarse gravel	21	46
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, gray	1	47

*** 33-3-6bab.**—Sample log of test hole in NW cor. NE NW sec. 6, T. 33 S., R. 3 E., on west edge of drive leading to house; augered Aug. 14, 1956; depth to water, 12.60 feet, Aug. 14, 1956; 2.50 feet, June 25, 1957; altitude of land surface, 1,134.6 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Wisconsinan Stage		
Terrace deposits		
Sand, fine	10	10
Sand, fine, silty	5	15
Sand, fine to medium	5	20
Sand, coarse, and fine to coarse gravel	26	46
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, gray	1	47

* **33-3-8ccc.**—Sample log of test hole in SW cor. sec. 8, T. 33 S., R. 3 E., on north road shoulder 300 feet east of corner in field entrance; augered Aug. 14, 1956; depth to water, 10.40 feet; altitude of land surface, 1,112.4 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Wisconsinan Stage		
Terrace deposits		
Silt, sandy, brown	3	3
Sand, fine, silty	7	10
Sand, fine to medium	5	15

* **33-3-8dcc.**—Sample log of test hole in SW SW SE sec. 8, T. 33 S., R. 3 E., 48 feet east and 45 feet north of east end of river bridge; drilled April 3, 1944; depth to water, 11.69 feet; altitude of land surface, 1,122.5 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Recent Stage		
Alluvium		
Sand, fine to coarse, some very coarse gravel; contains gray to buff silt	10	10
Sand, fine to coarse, and fine gravel; some medium to coarse gravel	10	20
Gravel, fine to medium, and fine to coarse sand	10	30
Gravel, fine to coarse	7	37
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, gray green; contains some chert nodules	4	41
Shale, blue gray	3	44

33-3-9bbb.—Sample log of test hole in NW NW NW sec. 9, T. 33 S., R. 3 E., 600 feet east and 10 feet south of center of road crossing; augered June 25, 1957; depth to water, 21.50 feet; altitude of land surface, 1,154.8 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Sangamonian and Illinoisan Stages		
Loveland and Crete Formations		
Sand, fine to medium	15	15
Sand, fine to medium, silty	17	32
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, gray	2	34

33-3-10aaa.—Sample log of test hole in NE cor. sec. 10, T. 33 S., R. 3 E., 200 feet south and 8 feet west of center of road crossing; augered June 24, 1957; depth to water, 19.20 feet; altitude of land surface, 1,167.0 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Sangamonian and Illinoisan Stages		
Loveland and Crete Formations		
Silt, red brown	4	4
Silt, buff to gray	4	8

	Thickness, feet	Depth, feet
Silt, tan, and interbedded fine sand	7	15
Silt, brown	8	23
Sand and gravel, fine to coarse	16.5	39.5
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, dark gray	0.5	40

33-3-12dcc.—Sample log of test hole in SW cor. SE sec. 12, T. 33 S., R. 3 E., 78 feet east and 7 feet north of center of railroad crossing; drilled April 12, 1944; depth to water, 24.33 feet; altitude of land surface, 1,165.1 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Sangamonian and Illinoisan Stages		
Loveland and Crete Formations		
Silt, gray	4	4
Silt, clayey, light gray mottled yellow brown	4	8
Silt, clayey, light gray green; contains some fine to medium sand	17	25
Sand, fine to coarse; contains some fine to medium gravel	5	30
Gravel, fine, and fine to coarse sand, some medium to coarse gravel	10	40
Gravel, fine to medium, and fine to coarse sand, some coarse gravel	6.5	46.5
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, dark gray	1.5	48

** **33-3-13aaa.**—Sample log of test hole in NE cor. sec. 13, T. 33 S., R. 3 E., 138 feet west and 10 feet south of center of crossing; drilled April 15, 1944; depth to water, 27.75 feet; altitude of land surface, 1,165.7 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Sangamonian and Illinoisan Stages		
Loveland and Crete Formations		
Silt, dark gray	3	3
Silt, clayey, blocky, gray and light brown	5	8
Silt, clayey, tan to light gray	12	20
Silt, clayey, yellow buff and gray; contains some fine sand	6.5	26.5
Sand, fine to medium; some coarse sand	11.5	38
Gravel, fine to medium, and fine to coarse sand, some coarse gravel	12	50
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, gray green	3	53

33-3-14aaa.—Sample log of test hole in NE cor. sec. 14, T. 33 S., R. 3 E., 63 feet south and 6 feet west of center of crossroads; drilled April 12, 1944; depth to water, 22.49 feet; altitude of land surface, 1,162.5 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Sangamonian and Illinoisan Stages		
Loveland and Crete Formations		
Clay, silty, light gray; contains some fine to medium sand	10	10
Clay, silty, light gray green; contains some fine to coarse sand, some fine to medium gravel	9	19
Sand, fine to medium; some fine to medium gravel and light-gray silt	11	30
Sand, fine to coarse, and some fine gravel	10	40
Gravel, fine, and fine to coarse sand; some medium gravel,	3	43
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, hard, gray; contains many white chert nodules	3	46

33-3-14baa.—Sample log of test hole in NE cor. NW sec. 14, T. 33 S., R. 3 E., 33 feet west and 12 feet south of center of road at ½-mile line; drilled April 4, 1944; depth to water, 20.40 feet; altitude of land surface, 1,160.7 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Sangamonian and Illinoisan Stages		
Loveland and Crete Formations		
Silt, compact, dark gray	3	3
Silt, clayey, gray green; contains some fine sand	8	11
Clay, silty, light gray	5	16
Silt, reddish tan	1	17
Sand, fine to coarse; some fine to medium gravel and light-gray silt	13	30
Sand, fine to coarse, and fine to coarse gravel	11	41
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, light gray to blue gray; contains much chert	4	45

* **33-3-15aaa.**—Sample log of test hole in NE cor. sec. 15, T. 33 S., R. 3 E., 42 feet south and 7 feet west of center of road crossing; drilled April 4, 1944; depth to water, 21.00 feet; altitude of land surface, 1,160.8 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Sangamonian and Illinoisan Stages		
Loveland and Crete Formations		
Silt, dark gray	3	3
Silt, gray green	2	5
Clay, silty, light gray	8	13
Silt, light gray; contains fine sand	4	17
Sand, fine to coarse, and fine to medium, silty gravel	8	25

	Thickness, feet	Depth, feet
Sand, fine to coarse, and some fine to coarse gravel	10	35
Sand and gravel, fine to coarse	2	37
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, light gray	3	40

33-3-15baa.—Sample log of test hole in NE cor. NW sec. 15, T. 33 S., R. 3 E., 51 feet west and 9 feet south of center of road at ½-mile line; drilled April 4, 1944; depth to water, 18.50 feet; altitude of land surface, 1,157.6 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Sangamonian and Illinoisan Stages		
Loveland and Crete Formations		
Silt, dark gray	2	2
Silt, compact, gray green	3	5
Silt, soft, yellow buff	11	16
Sand, fine to coarse, and some fine to coarse gravel	9	25
Sand, fine to coarse, and much fine to coarse silty gravel	5	30
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, dark gray to light gray; contains chert nodules	4	34

33-3-15bbb.—Sample log of test hole in NW cor. sec. 15, T. 33 S., R. 3 E., 125 feet south and 12 feet east of center of road crossing; drilled April 4, 1944; depth to water, 16.16 feet; altitude of land surface, 1,147.9 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Sangamonian and Illinoisan Stages		
Loveland and Crete Formations		
Silt, dark gray	1	1
Silt, gray green	5	6
Silt, light gray; contains some fine sand	4	10
Silt, light buff; contains fine sand	7	17
Sand, fine	1.5	18.5
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, hard, light gray green grading downward to blue gray; contains some chert	5	23.5

33-3-16baa.—Sample log of test hole in NE cor. NW sec. 16, T. 33 S., R. 3 E., 100 feet west and 7 feet south of center of road at ½-mile line; drilled April 3, 1944; depth to water, 22.66 feet; altitude of land surface, 1,150.0 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Sangamonian and Illinoisan Stages		
Loveland and Crete Formations		
Silt, clayey, buff tan; contains fine to medium sand	2	2
Sand, fine to medium	6	8

	Thickness, feet	Depth, feet
Silt, clayey, tan; contains some fine to medium sand	13	21
Sand, fine to coarse, and some fine to medium gravel	9	30
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, blue gray	2	32

** **33-3-17aaa1.**—Sample log of test hole in NE cor. sec. 17, T. 33 S., R. 3 E., 75 feet south and 54 feet west of center of bridge; drilled April 3, 1944; depth to water, 6.10 feet; altitude of land surface, 1,116.0 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Wisconsinan Stage		
Terrace deposits		
Silt, gray black grading downward to gray brown	4	4
Sand, fine to medium	13	17
Gravel, fine, and fine to coarse sand; some medium gravel,	13	30
Sand, fine to coarse, and fine to medium gravel	17	47
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, light gray green	3	50

* **33-3-17aaa2.**—Sample log of test hole in NE NE NE sec. 17, T. 33 S., R. 3 E., 300 feet west of corner on south road shoulder; augered Aug. 15, 1956; depth to water, 13.80 feet; altitude of land surface, 1,116.8 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Wisconsinan Stage		
Terrace deposits		
Sand, fine	15	15
Sand, fine to medium	5	20
Sand, medium to coarse	15	35
Sand, coarse, and fine to coarse gravel	12	47
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, gray	1	48

* **33-3-17bba.**—Sample log of test hole in NE cor. NW NW sec. 17, T. 33 S., R. 3 E., 12 feet south of center of road 225 feet east of a pipe line; drilled April 1, 1944; depth to water, 4.85 feet; altitude of land surface, 1,116.7 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Wisconsinan Stage		
Terrace deposits		
Silt, sandy, gray	2	2
Silt, light gray	4	6
Sand, fine to coarse, much fine to coarse gravel	15.5	21.5

PERMIAN—Middle Permian Series
Sumner Group
Wellington Formation

	Thickness, feet	Depth, feet
Shale, dark gray; contains some chert	4.5	26

* **33-3-17daa.**—Sample log of test hole in NE cor. NE SE sec. 17, T. 33 S., R. 3 E., on west road shoulder 100 feet north of gate to oil lease; augered Aug. 15, 1956; depth to water, 12.10 feet; altitude of land surface, 1,115.1 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Wisconsinan Stage		
Terrace deposits		
Silt, brown	3	3
Silt, tan	7	10
Sand, fine, silty	5	15
Sand, medium to coarse	5	20
Sand, coarse, and fine to coarse gravel	27	47
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, gray	1	48

33-3-18bbb.—Sample log of test hole in NW cor. sec. 18, T. 33 S., R. 3 E., in east road ditch 20 feet south of corner; augered Aug. 13, 1956; depth to water, 19.70 feet; altitude of land surface, 1,158.8 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Sangamonian and Illinoisan Stages		
Loveland and Crete Formations		
Silt, brown	7	7
Clay, brown	3	10
Clay, red	5	15
Clay, reddish brown	10	25
Clay, silty and sandy, reddish brown	5	30
Sand, fine to coarse, very silty	7	37
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, gray	1	38

* **33-3-19ccc.**—Sample log of test hole in SW cor. sec. 19, T. 33 S., R. 3 E., 192 feet east and 6 feet north of center of "T" road; drilled April 4, 1944; depth to water, 12.48 feet; altitude of land surface, 1,098.8 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Wisconsinan Stage		
Terrace deposits		
Silt, buff; contains fine to coarse sand	5	5
Silt, black	3	8
Clay, gray green	8	16
Sand, fine to coarse, much fine to coarse gravel	7.5	23.5

	Thickness, feet	Depth, feet
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, light gray	3	26.5

* **33-3-19dcc.**—Sample log of test hole in SW cor. SE sec. 19, T. 33 S., R. 3 E., on west shoulder of north-south road in line with hedge to east; drilled March 30, 1944; depth to water, 12.44 feet; altitude of land surface, 1,103.8 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Wisconsinan Stage		
Terrace deposits		
Silt, clayey, dark gray	3	3
Clay, gray green	8	11
Clay, yellow gray	5	16
Clay, gray	5.5	21.5
Sand, fine to coarse; some fine to medium gravel	8.5	30
Sand, fine to coarse, and fine to coarse gravel	6.5	36.5
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, light gray	3.5	40

** **33-3-20dcc.**—Sample log of test hole in SW cor. SE sec. 20, T. 33 S., R. 3 E., 45 feet east and 7 feet north of center of road at ½-mile line; drilled March 28, 1944; altitude of land surface, 1,102.2 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Wisconsinan Stage		
Terrace deposits		
Sand, fine to medium, and dark-gray silt	2	2
Silt, gray; contains some fine to medium sand	2	4
Sand, fine to medium	6	10
Sand, fine to coarse, and much fine to medium gravel	15	25
Gravel, fine to medium, and fine to coarse sand	17.5	42.5
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, gray	3.5	46

* **33-3-21dda.**—Sample log of test hole in NE cor. SE SE sec. 21, T. 33 S., R. 3 E., 10 feet north of center of road opposite gate to south; drilled March 27, 1944; depth to water, 11.95 feet; altitude of land surface, 1,108.2 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Wisconsinan Stage		
Terrace deposits		
Silt, dark gray	4	4
Silt, gray; contains fine to medium sand	2	6
Sand, fine to coarse, and some fine to coarse gravel	33	39
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, hard, gray	1	40

* **33-3-21ddb.**—Sample log of test hole in NW SE SE sec. 21, T. 33 S., R. 3 E., 130 feet west and 8 feet north of center of west end of river bridge; drilled March 27, 1944; depth to water, 6.70 feet; altitude of land surface, 1,104.9 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Recent Stage		
Alluvium		
Sand, fine to coarse, and fine to coarse gravel	21	21
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, gray green	4	25

33-3-22ccc.—Sample log of test hole in SW cor. sec. 22, T. 33 S., R. 3 E., 90 feet east and 9 feet north of center of "T" road; drilled March 25, 1944; altitude of land surface, 1,154.5 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Sangamonian and Illinoisan Stages		
Loveland and Crete Formations		
Silt, dark gray	3	3
Silt, buff; contains some fine to medium sand	10	13
Silt, buff	13	26
Silt, buff; contains fine to medium sand	10	36
Sand, fine to coarse, and some fine gravel	8	44
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, gray	2	46

33-3-22cdd.—Sample log of test hole in SE SE SW sec. 22, T. 33 S., R. 3 E., on north road shoulder 0.55 mile west of corner; drilled March 25, 1944; altitude of land surface, 1,159.1 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Sangamonian and Illinoisan Stages		
Loveland and Crete Formations		
Silt, clayey, tan	15	15
Clay, silty, light gray to tan	4	19
Sand, fine to coarse, and fine to medium gravel, some coarse gravel	20	39
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, soft, light gray	11	50

33-3-23bbb.—Sample log of test hole in NW cor. sec. 23, T. 33 S., R. 3 E., 120 feet east and 6 feet south of center of road crossing; augered June 24, 1957; depth to water, 22.70 feet; altitude of land surface, 1,158.4 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Sangamonian and Illinoisan Stages		
Loveland and Crete Formations		
Silt, black	2	2
Silt, brown	3	5
Silt, red brown; contains some fine sand	8	13
Silt, red brown; contains some fine to medium sand	7	20
Sand, fine to medium, silty	6	26
Sand, fine to medium	11	37
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, light gray	1	38

* **33-3-23ccc.**—Sample log of test hole in SW cor. sec. 23, T. 33 S., R. 3 E., 60 feet east and 8 feet south of center of crossroads; drilled March 22, 1944; depth to water, 4.89 feet; altitude of land surface, 1,133.4 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Sangamonian and Illinoisan Stages		
Loveland and Crete Formations		
Silt and clay, gray	8	8
Sand, fine to coarse, contains some fine to coarse gravel near bottom	5.5	13.5
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, gray, grading to blue gray	3.5	17

33-3-23cdd.—Sample log of test hole in SE cor. SW sec. 23, T. 33 S., R. 3 E., 24 feet west and 6 feet north of center of road at ½-mile line; drilled March 22, 1944; depth to water, 5.77 feet; altitude of land surface, 1,140.4 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Sangamonian and Illinoisan Stages		
Loveland and Crete Formations		
Silt, dark gray	2	2
Clay, sandy, buff to gray	9	11
Sand, fine to coarse, brown	5	16
Gravel, fine to coarse, and fine to coarse sand	2	18
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, gray	2	20

33-3-24bbb.—Sample log of test hole in NW cor. sec. 24, T. 33 S., R. 3 E., 45 feet east and 6 feet south of center of crossing; drilled April 14, 1944; depth to water, 29.04 feet; altitude of land surface, 1,167.5 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Sangamonian and Illinoisan Stages		
Loveland and Crete Formations		
Silt, dark gray	2	2
Silt, brown and gray; contains fine to medium sand	6	8
Silt, tan; contains some fine to medium sand	4	12
Silt, clayey, buff	15	27
Sand, fine to medium; coarser downward to coarse sand and fine gravel	13	40
Gravel, fine to medium, and fine to coarse sand; some coarse gravel	10.5	50.5
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, thin bedded, blue gray; contains some chert	1.5	52

33-3-24ddd.—Sample log of test hole in SE cor. sec. 24, T. 33 S., R. 3 E., 25 feet west and 9 feet north of center of crossroad; drilled March 22, 1944; depth to water, 17.45 feet; altitude of land surface, 1,153.1 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Sangamonian and Illinoisan Stages		
Loveland and Crete Formations		
Silt, dark gray	2	2
Silt, gray	2	4
Clay, light gray	2	6
Clay, gray to buff	1	7
Clay, gray green	2	9
Clay, dark buff	5	14
Clay, buff	9	23
Sand, fine to coarse	3	26
Sand, fine to coarse; contains some fine gravel	4	30
Sand, fine to coarse	7	37
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, light gray	6	43

33-3-25baa.—Sample log of test hole in NE cor. NW sec. 25, T. 33 S., R. 3 E., 54 feet west and 7 feet south of center of railroad crossing; drilled March 22, 1944; depth to water, 14.13 feet; altitude of land surface, 1,160.2 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Sangamonian and Illinoisan Stages		
Loveland and Crete Formations		
Silt, dark gray	2	2
Silt, light gray; contains fine sand	5	7
Clay, gray green; contains much caliche	4	11

	Thickness, feet	Depth, feet
Clay, gray green	5	16
Clay, buff	8	24
Sand, fine to coarse; some fine to medium gravel	6	30
Sand, fine to coarse, some fine to medium gravel and some coarse gravel	10	40
Gravel, fine to medium, and fine to coarse sand; some coarse gravel	3	43
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, dark gray	2	45

** **33-3-25bbb.**—Sample log of test hole in NW cor. sec. 25, T. 33 S., R. 3 E., 30 feet east and 27 feet south of center of east end of bridge; drilled March 20, 1944; depth to water, 15.30 feet; altitude of land surface, 1,151.4 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Sangamonian and Illinoisan Stages		
Loveland and Crete Formations		
Silt, dark gray to gray	6	6
Clay, silty, compact, light gray green; contains some fine to coarse sand and fine to medium gravel	4	10
Clay, silty, light gray green mottled yellow; contains some fine to coarse sand	6	16
Sand, fine to medium	9	25
Sand, fine to coarse, much fine to medium gravel and some coarse gravel	7.5	32.5
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, thin bedded, gray	2.5	35

33-3-25ccc.—Sample log of test hole in SW cor. sec. 25, T. 33 S., R. 3 E., 57 feet east and 8 feet north of center of road crossing; drilled March 20, 1944; altitude of land surface, 1,162.0 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Sangamonian and Illinoisan Stages		
Loveland and Crete Formations		
Silt, clayey, dark gray	2	2
Silt, clayey, gray	4	6
Silt, tan; contains some fine to coarse sand	12	18
Clay, silty, gray green	1	19
Clay, silty, yellow gray; contains fine to coarse sand	3	22
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, clayey, buff; contains some white chert	6	28

33-3-25ddd.—Sample log of test hole in SE cor. sec. 25, T. 33 S., R. 3 E., 66 feet west and 6 feet north of center of crossing; drilled March 20, 1944; altitude of land surface, 1,164.7 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Sangamonian and Illinoisan Stages		
Loveland and Crete Formations		
Silt, clayey, dark gray	3	3
Silt, clayey, gray, grading to dull tan gray	2	5
Silt, tan; contains some medium gravel	24	29
Clay, silty, light gray; some caliche and fine to medium sand	5	34
Sand, fine to medium	6	40
Sand, fine to coarse, grading downward to fine to medium gravel; some coarse gravel	10	50
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, gray	3	53
Shale, hard, gray	2	55

33-3-26bcc.—Sample log of test hole in SW cor. NW sec. 26, T. 33 S., R. 3 E., 14 feet north and 8 feet west of center of road at ½-mile line; drilled March 23, 1944; depth to water, 18.50 feet; altitude of land surface, 1,152.6 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Sangamonian and Illinoisan Stages		
Loveland and Crete Formations		
Silt, dark gray	1	1
Clay, silty, light brown; contains some fine to medium sand	5	6
Clay, buff	10	16
Sand, fine to coarse; some fine to coarse gravel	14	30
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, light gray	4	34

* **33-3-27dcc.**—Sample log of test hole in SW cor. SE sec. 27, T. 33 S., R. 3 E., 5 feet north of center of road at ½-mile line; drilled March 23, 1944; depth to water, 24.30 feet; altitude of land surface, 1,156.5 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Sangamonian and Illinoisan Stages		
Loveland and Crete Formations		
Silt, clayey, compact, tan	12	12
Silt, clayey, light gray green	6	18
Sand, fine to medium; contains some silt	2	20
Sand, fine to coarse, and some fine to medium gravel	8	28
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, hard, gray green, grading downward to blue gray,	2	30

33-3-27ddd.—Sample log of test hole in SE cor. sec. 27, T. 33 S., R. 3 E., 50 feet north and 8 feet west of center of road crossing; augered June 24, 1957; depth to water, 37.00 feet; altitude of land surface, 1,170.7 feet.

QUATERNARY—Pleistocene
Upper Pleistocene—Sangamonian and Illinoisan Stages
Loveland and Crete Formations

	Thickness, feet	Depth, feet
Silt, sandy, red brown	10	10
Sand, fine to medium, very silty	3	13
Silt, very sandy, brown	3	16
Silt, tan, and fine to coarse sand, some limestone gravel	4	20
Silt, tan; contains some fine to medium gravel	5	25
Silt, tan	6	31
Sand, fine, and tan silt	2	33
Sand, very fine, silty	3	36
Sand, medium, and fine arkosic gravel	12	48
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, light gray	1	49

* **33-3-28bbb.**—Sample log of test hole in NW cor. sec. 28, T. 33 S., R. 3 E., 53 feet east and 7 feet south of center of road crossing; drilled March 27, 1944; depth to water, 11.90 feet; altitude of land surface, 1,108.2 feet.

QUATERNARY—Pleistocene
Upper Pleistocene—Wisconsinan Stage
Terrace deposits

	Thickness, feet	Depth, feet
Sand, fine	10	10
Sand, fine to coarse, silt at 15 feet	8	18
Sand, fine to coarse, and much fine to medium gravel; some coarse gravel	12	30
Sand, fine to coarse, much fine to medium gravel and yellow silt	16	46
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, hard, dark gray	4	50

* **33-3-28dbc1.**—Sample log of test hole in SW NW SE sec. 28, T. 33 S., R. 3 E., on river bank at end of oil-field road; augered Aug. 16, 1956; depth to water, 17.40 feet; altitude of land surface, 1,111.0 feet.

QUATERNARY—Pleistocene
Upper Pleistocene—Wisconsinan Stage
Terrace deposits

	Thickness, feet	Depth, feet
Silt, sandy, black	5	5
Silt, tan	5	10
Sand, fine, silty, tan	5	15
Sand, fine to medium	5	20
Sand, coarse	15	35

* **33-3-29cca1.**—Sample log of test hole in NE SW SW sec. 29, T. 33 S., R. 3 E., along trail to north, 50 feet from river bank; augered Aug. 16, 1956; depth to water, 13.20 feet; altitude of land surface, 1,108.0 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Recent Stage		
Alluvium		
Silt, brown	5	5
Silt, sandy, brown	5	10
Sand, medium to coarse	5	15
Sand, coarse, and fine to coarse gravel	10	25
Sand, coarse, silty	15	40
Sand, coarse	1	41
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, gray	1	42

* **33-3-29ddd2.**—Sample log of test hole in SE cor. sec. 29, T. 33 S., R. 3 E., 50 feet west of corner in north road ditch; augered Aug. 15, 1956; depth to water, 22.10 feet; altitude of land surface, 1,113.1 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Wisconsinan Stage		
Terrace deposits		
Silt, sandy, fine, brown	5	5
Sand, fine	5	10
Sand, fine to medium	10	20
Sand, medium to coarse	10	30
Sand, coarse, and some fine to coarse gravel	26	56
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, gray	1	57

* **33-3-30aaa.**—Sample log of test hole in NE cor. sec. 30, T. 33 S., R. 3 E., 6 feet west and 15 feet south of center of "T" road; drilled March 30, 1944; depth to water, 4.41 feet; altitude of land surface, 1,098.7 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Wisconsinan Stage		
Terrace deposits		
Silt, dark gray	3	3
Silt, dark gray to buff	2	5
Sand, fine	5	10
Sand, fine to medium	10	20
Sand, fine to coarse	7.5	27.5
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, hard, light gray	2.5	30

* **33-3-31aaa.**—Sample log of test hole in NE cor. sec. 31, T. 33 S., R. 3 E., in west road ditch at south end of curve in road; augered Aug. 16, 1956; depth to water, 17.50 feet; altitude of land surface, 1,105.3 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Wisconsinan Stage		
Terrace deposits		
Silt, sandy, fine	7	7
Sand, fine	3	10
Sand, fine to medium	5	15
Sand, coarse, and some fine gravel	10	25
Sand, coarse, and fine to coarse, silty gravel	5	30
Sand, medium to coarse, very silty	10	40
Sand, medium to coarse	5	45
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, gray	1	46

* **33-3-31daa.**—Sample log of test hole in NE cor. NE SE sec. 31, T. 33 S., R. 3 E., 0.6 mile south of corner on west road shoulder; augered Aug. 16, 1956; depth to water, 10.80 feet; altitude of land surface, 1,102.2 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Wisconsinan Stage		
Terrace deposits		
Sand, fine	10	10
Sand, fine to medium	5	15
Sand, medium to coarse	15	30
Sand, medium to coarse, silty	14	44
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, gray	1	45

* **33-3-32daa.**—Sample log of test hole in NE cor. NE SE sec. 32, T. 33 S., R. 3 E., in west road ditch 20 feet south of ½-mile line; augered Aug. 16, 1956; depth to water, 21.90 feet; altitude of land surface, 1,111.0 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Wisconsinan Stage		
Terrace deposits		
Sand, fine, silty	5	5
Sand, fine	10	15
Sand, fine to medium	10	25
Sand, medium to coarse	15	40
Sand, coarse, and fine to coarse gravel	14	54
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, gray	1	55

* **33-3-33abb.**—Sample log of test hole in NW NW NE sec. 33, T. 33 S., R. 3 E., in south road ditch 0.4 mile west of corner; augered Aug. 15, 1956; depth to water, 15.10 feet; altitude of land surface, 1,117.1 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Wisconsinan Stage		
Terrace deposits		
Silt, black	5	5
Silt, clayey, black	5	10
Sand, fine to medium	10	20
Sand, medium to coarse, and some fine to coarse gravel	8	28

33-3-33add.—Sample log of test hole in SE cor. NE sec. 33, T. 33 S., R. 3 E., 10 feet west of center of road at ½-mile line; drilled March 23, 1944; altitude of land surface, 1,188.7 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Wisconsinan Stage		
Eolian deposits		
Silt, brown; contains much fine sand at 6 to 10 feet	10	10
Sand, fine, silty, brown	6	16
Lower Pleistocene—Yarmouthian and Kansan Stages		
Sappa and Grand Island Formations		
Sand, fine to coarse, and buff silt	11	27
Silt, gray	6	33
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, light gray	5	38

* **33-3-33dcc.**—Sample log of test hole in SW cor. SE sec. 33, T. 33 S., R. 3 E., 10 feet east and 10 feet north of center of road at ½-mile line; drilled March 23, 1944; depth to water, 9.55 feet; altitude of land surface, 1,104.6 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Wisconsinan Stage		
Terrace deposits		
Silt, dark gray	2	2
Silt, light gray	5	7
Sand and gravel, fine to coarse	10	17
Sand, fine to coarse, and fine to medium gravel	9	26
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, light gray	3	29

33-3-35ccc.—Sample log of test hole in SW cor. sec. 35, T. 33 S., R. 3 E., 10 feet north and 20 feet east of center of road crossing; augered June 24, 1957; dry hole; altitude of land surface, 1,192.5 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Wisconsinan Stage		
Eolian deposits		
Silt, black	2	2
Silt, red brown	4	6
Silt, tan	6	12
Silt, gray green	6	18
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, gray	1	19

33-4-5cbb.—Sample log of test hole in NW cor. SW sec. 5, T. 33 S., R. 4 E., on east road shoulder at ½-mile line; augered June 19, 1957; dry hole; altitude of land surface, 1,234.7 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Wisconsinan Stage		
Eolian deposits		
Silt, brown	5	5
Silt, reddish brown	5	10
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, gray	2	12

33-4-5ccc.—Sample log of test hole in SW cor. sec. 5, T. 33 S., R. 4 E., on east road shoulder 40 feet north of center of crossing; augered June 19, 1957; dry hole; altitude of land surface, 1,208.2 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Wisconsinan Stage		
Eolian deposits		
Silt, brown	5	5
Silt, gray	5	10
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, gray	2	12

33-4-7add.—Sample log of test hole in SE cor. NE sec. 7, T. 33 S., R. 4 E., 10 feet west of center of road at ½-mile line; drilled April 11, 1944; depth to water, 26.74 feet; altitude of land surface, 1,194.8 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Wisconsinan Stage		
Eolian deposits		
Silt, dark gray	2	2
Silt, greenish gray and tan	6	8

	Thickness, feet	Depth, feet
Lower Pleistocene—Yarmouthian and Kansan Stages		
Sappa and Grand Island Formations		
Silt, clayey, gray; contains much fine to medium sand	7	15
Sand, medium, slightly cemented at top, brown	13	28
Gravel, fine to coarse	2	30
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, gray green	1	31

33-4-14bbb.—Sample log of test hole in NW cor. sec. 14, T. 33 S., R. 4 E., on east road shoulder 50 feet south of corner; augered Aug. 27, 1958; depth to water, 11.20 feet; altitude of land surface, 1,109.6 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Wisconsinan Stage		
Terrace deposits		
Silt, dark red brown	5	5
Silt, tan brown	6	11
Sand, fine to medium, arkosic, and fine to coarse chert gravel	3	14
PERMIAN—Lower Permian Series		
Chase Group		
Doyle Shale		
Shale, gray	1	15

33-4-14bcc.—Sample log of test hole in SW cor. NW sec. 14, T. 33 S., R. 4 E., on east road shoulder 50 feet north of ½-mile line; augered Aug. 27, 1958; depth to water, 22.00 feet; altitude of land surface, 1,122.0 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Wisconsinan Stage		
Terrace deposits		
Silt, red brown	5	5
Silt, tan brown	5	10
Silt, tan	7	17
Silt, tan, and fine to coarse chert and arkosic gravel	5	22
PERMIAN—Lower Permian Series		
Chase Group		
Doyle Shale		
Shale, gray	1	23

* **33-4-17cbb.**—Sample log of test hole in NW cor. SW sec. 17, T. 33 S., R. 4 E., 135 feet north and 25 feet east of north end of culvert into school yard; drilled March 16, 1944; altitude of land surface, 1,162.1 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Sangamonian and Illinoisan Stages		
Loveland and Crete Formations		
Silt, dark gray brown	2	2
Silt, clayey, brown, grading downward to tan	10	12

	Thickness, feet	Depth, feet
Silt and clay, yellow tan to green gray; contains some nodular caliche	8	20
Silt, yellow tan; contains some fine sand	6	26
Sand, fine, and tan silt	4	30
Sand, fine to coarse, and some fine to medium gravel; contains some yellow-gray silt	10	40
Gravel, fine to coarse, and fine to coarse sand; contains some buff and yellow silt	11	51
PERMIAN—Lower Permian Series		
Chase Group		
Odell Shale		
Shale, hard, gray	2	53

33-4-18aaa.—Sample log of test hole in NE cor. sec. 18, T. 33 S., R. 4 E., 36 feet south and 9 feet west of center of crossroads; drilled April 12, 1944; depth to water, 34.14 feet; altitude of land surface, 1,171.5 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Sangamonian and Illinoisan Stages		
Loveland and Crete Formations		
Silt, tan	10	10
Silt, light tan	20	30
Silt, yellow gray; contains fine sand	10	40
Sand, fine to medium; some fine to medium gravel	10	50
Gravel, fine to medium, and fine to coarse sand; some coarse gravel	4	54
PERMIAN—Lower Permian Series		
Chase Group		
Odell Shale		
Shale, gray green	1	55

33-4-18abb.—Sample log of test hole in NW cor. NE sec. 18, T. 33 S., R. 4 E., 21 feet east and 5 feet south of center of road at ½-mile line; drilled April 12, 1944; depth to water, 26.69 feet; altitude of land surface, 1,165.0 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Sangamonian and Illinoisan Stages		
Loveland and Crete Formations		
Silt, dark gray	2	2
Silt, clayey, compact, gray	3	5
Silt, tan	5	10
Silt, clayey, gray brown to yellow gray	8	18
Silt, light tan	7	25
Silt, clayey, light gray contains fine to coarse sand	4	29
Sand, fine to medium; some fine to medium gravel and coarse sand	11	40
Gravel, fine to medium, and fine to coarse sand, much coarse gravel	10	50
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, light gray green	3	53

* **33-4-19aaa.**—Sample log of test hole in NE cor. sec. 19, T. 33 S., R. 4 E., 8 feet west and 63 feet south of center of crossing; drilled March 16, 1944; altitude of land surface, 1,151.9 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Sangamonian and Illinoisan Stages		
Loveland and Crete Formations		
Silt, dark gray brown	1.5	1.5
Clay, silty, gray, grading downward to light gray	6.5	8
Silt and clay, tan and light gray green; contains some fine sand at 18 to 19 feet	11	19
Sand, fine to coarse, and much fine to medium gravel	11	30
Gravel, fine and fine to coarse sand; much coarse to medium gravel at 37 to 40 feet	10	40
PERMIAN—Lower Permian Series		
Chase Group		
Odell Shale		
Shale, fossiliferous, hard, gray	2	42

33-4-19aab.—Drillers log of well 2 in NW NE NE sec. 19, T. 33 S., R. 4 E., 400 feet south of well 1; drilled by Layne-Western Co. for U. S. Army Air Force, Aug. 28, 1942; depth to water, 20.00 feet; altitude of land surface, 1,155.3 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Sangamonian and Illinoisan Stages		
Loveland and Crete Formations		
Clay, light brown to yellow tan	24.5	24.5
Sand, medium, and some clay	10	34.5
Sand, fine to medium; some fine gravel	6.5	41
Gravel, fine to medium; contains fine sand	2.5	43.5

33-4-19aac.—Drillers log of well 3 in SW NE NE sec. 19, T. 33 S., R. 4 E., 400 feet south of well 2; drilled by Layne-Western Co. for U. S. Army Air Force, Aug. 28, 1942; depth to water, 17.93 feet; altitude of land surface, 1,153.4 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Sangamonian and Illinoisan Stages		
Loveland and Crete Formations		
Clay	25	25
Sand and clay	10	35
Sand, fine to coarse, and some fine gravel	5	40
Gravel, fine to coarse, and fine to coarse sand	1	41

33-4-19adb2.—Drillers log of well 5 in NW SE NE sec. 19, T. 33 S., R. 4 E., 400 feet north of well 6; drilled by Layne-Western Co. for U. S. Army Air Force, Aug. 28, 1942; depth to water, 16.66 feet; altitude of land surface, 1,151.5 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Sangamonian and Illinoisan Stages		
Loveland and Crete Formations		
Silt	2	2
Clay, sandy	15.5	17.5
Sand, fine to medium	16.5	34
Sand, coarse	7	41

33-4-19add.—Sample log of test hole in SE cor. NE sec. 19, T. 33 S., R. 4 E., 24 feet west and 18 feet north of first tree south of road curve at ½-mile line; drilled March 17, 1944; altitude of land surface, 1,147.7 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Sagamonian and Illinoisan Stages		
Loveland and Crete Formations		
Silt, dark gray	1.5	1.5
Silt and clay, tan grading downward to buff	21	22.5
Clay, silty, blue gray and tan	3.5	26
Sand, fine to coarse, and some fine to coarse gravel	10.5	36.5
PERMIAN—Lower Permian Series		
Chase Group		
Odell Shale		
Shale, thin bedded, gray	1.5	38

33-4-19ddd.—Sample log of test hole in SE cor. sec. 19, T. 33 S., R. 4 E., 64 feet south and 3 feet east of center of culvert north of crossing; drilled March 17, 1944; altitude of land surface, 1,152.1 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Sagamonian and Illinoisan Stages		
Loveland and Crete Formations		
Silt, dark gray	2.5	2.5
Clay, silty, gray	5.5	8
Silt and clay, tan and gray	10	18
Sand, medium, and some fine to medium gravel	3	21
Sand, fine to coarse; much fine to medium gravel	19	40
PERMIAN—Lower Permian Series		
Chase Group		
Odell Shale		
Shale, hard, light gray and dark gray	4	44

33-4-21bcb.—Sample log of test hole in NW SW NW sec. 21, T. 33 S., R. 4 E., on east road shoulder 0.3 mile south of corner; augered June 19, 1957; depth to water, 24.50 feet; altitude of land surface, 1,160.3 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Sangamonian and Illinoisan Stages		
Loveland and Crete Formations		
Silt, brown	5	5
Silt, reddish brown	15	20
Silt, brown, some fine sand	25	45
Sand, fine to coarse, silty streaks	15	60
PERMIAN—Lower Permian Series		
Chase Group		
Odell Shale		
Shale, gray	1	61

33-4-21bdd.—Sample log of test hole in SE cor. NW sec. 21, T. 33 S., R. 4 E., in drive to west at ½-mile line; augered June 20, 1957; depth to water, 27.00 feet; altitude of land surface, 1,145.0 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Sangamonian and Illinoisan Stages		
Loveland and Crete Formations		
Silt, reddish brown	5	5
Silt, brown, some fine sand	5	10
Silt, brown	10	20
Silt, tan, some fine sand	12	32
Sand, fine to medium, very silty, tan	16	48
PERMIAN—Lower Permian Series		
Chase Group		
Odell Shale		
Shale, gray	1	49

** **33-4-21cdd.**—Sample log of test hole in SE cor. SW sec. 21, T. 33 S., R. 4 E., 138 feet west and 12 feet north of center of crossroad; augered April 17, 1944; depth to water, 17.72 feet; altitude of land surface, 1,138.3 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Sangamonian and Illinoisan Stages		
Loveland and Crete Formations		
Silt, dark gray to gray	4	4
Silt, clayey, greenish gray and tan	6	10
Silt, partly clayey, tan	10	20
Silt, clayey, light gray; contains some fine to coarse sand,	3	23
Gravel, fine to medium, and fine to coarse sand; some coarse gravel	7	30
Gravel, fine to coarse; contains much fine to coarse sand,	6	36
PERMIAN—Lower Permian Series		
Chase Group		
Doyle Shale		
Shale, hard, thin bedded, blue gray	4	40

33-4-22baa.—Sample log of test hole in NE cor. NW sec. 22, T. 33 S., R. 4 E., 50 feet south and 8 feet west of center of crossing; augered June 20, 1957; dry hole; altitude of land surface, 1,178.4 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Wisconsinan Stage		
Eolian deposits		
Silt, brown	10	10
Silt, brown, some very fine sand	6	16
Lower Pleistocene—Yarmouthian and Kansan Stages		
Sappa and Grand Island Formations		
Silt, buff to light gray, and fine to coarse sand	5	21
PERMIAN—Lower Permian Series		
Chase Group		
Doyle Shale		
Shale, gray	1	22

33-4-22caa.—Sample log of test hole in NE cor. SW sec. 22, T. 33 S., R. 4 E., on west road shoulder 100 feet south of ½-mile line; augered Aug. 27, 1958; depth to water, 31.60 feet; altitude of land surface, 1,153.0 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Sangamonian and Illinoisan Stages		
Loveland and Crete Formations		
Silt, red brown	5	5
Silt, brown	25	30
Silt, red brown	6	36
Sand, very fine to fine	9	45
Sand and gravel, fine to coarse	7	52
PERMIAN—Lower Permian Series		
Chase Group		
Doyle Shale		
Shale, gray	2	54

33-4-22ccc.—Sample log of test hole in SW cor. sec. 22, T. 33 S., R. 4 E., 39 feet east and 6 feet north of center of road at corner; drilled April 17, 1944; depth to water, 12.28 feet; altitude of land surface, 1,128.2 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Sangamonian and Illinoisan Stages		
Loveland and Crete Formations		
Silt, dark gray	2	2
Silt, clayey, compact, dark gray, grading downward to yellow gray	4	6
Silt, clayey, blocky, gray green and tan	10	16
Sand, medium; some fine gravel and coarse sand	4	20
Gravel, fine, and fine to coarse sand; some medium gravel,	7	27
PERMIAN—Lower Permian Series		
Chase Group		
Doyle Shale		
Shale, light blue gray	3	30

33-4-22cdd.—Sample log of test hole in SE cor. SW sec. 22, T. 33 S., R. 4 E., 33 feet west and 6 feet north of center of crossroad; drilled April 17, 1944; depth to water, 7.37 feet; altitude of land surface, 1,117.2 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Sangamonian and Illinoisan Stages		
Loveland and Crete Formations		
Silt, dark gray	3	3
Silt, clayey, gray brown, grading downward to light gray; contains some fine to coarse sand	5.5	8.5
Gravel, fine to very coarse, and fine to coarse sand; contains silt near base	5.5	14
PERMIAN—Lower Permian Series		
Chase Group		
Doyle Shale		
Shale, fissile, gray black	4	18

33-4-23aba.—Sample log of test hole in NE NW NE sec. 23, T. 33 S., R. 4 E., in drive to north about 100 yards west of bridge; augered June 20, 1957; depth to water, 25.30 feet; altitude of land surface, 1,107.9 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Wisconsinan Stage		
Terrace deposits		
Silt, black	10	10
Silt, brown, clayey	10	20
Silt, brown	5	25
Sand and gravel, fine to coarse (chert gravel)	15	40
Gravel (chert), fine to coarse, and tan silt	5	45
PERMIAN—Lower Permian Series		
Chase Group		
Barneston Limestone		
Limestone, white	1	46

33-4-23baa.—Sample log of test hole in NE NE NW sec. 23, T. 33 S., R. 4 E., 0.4 mile east of corner on south road shoulder; augered Aug. 27, 1958; depth to water, 14.60 feet; altitude of land surface, 1,109.5 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Wisconsinan Stage		
Terrace deposits		
Silt, dark brown	5	5
Silt, brown	3	8
Silt, tan brown	4	12
Silt, tan; contains much fine limestone gravel	3	15
PERMIAN—Lower Permian Series		
Chase Group		
Barneston Limestone		
Limestone, white	0.5	15.5

33-4-23bcc.—Sample log of test hole in SW cor. NW sec. 23, T. 33 S., R. 4 E., on east road shoulder 10 feet north of ½-mile line; augered Aug. 27, 1958; depth to water, 16.50 feet; altitude of land surface, 1,124.8 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Sangamonian and Illinoisan Stages		
Loveland and Crete Formations		
Silt, red brown	7	7
Silt, tan brown; contains some fine sand	4	11
Sand, fine to coarse, and red-brown silt	3	14
Gravel, fine to coarse (chert and arkosic), silty	3	17
PERMIAN—Lower Permian Series		
Chase Group		
Barneston Limestone		
Limestone, hard, white	0.5	17.5

33-4-23ccc1.—Sample log of test hole in SW cor. sec. 23, T. 33 S., R. 4 E., at NE cor. of intersection; augered June 20, 1957; depth to water, 8.50 feet; altitude of land surface, 1,117.1 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Sangamonian and Illinoisan Stages		
Loveland and Crete Formations		
Silt, reddish brown	5	5
Silt, brown; contains some fine sand	5	10
Silt, brown, and much fine to coarse sand	5	15
PERMIAN—Lower Permian Series		
Chase Group		
Doyle Shale		
Shale, gray	1	16

33-4-26acc.—Sample log of test hole in SW cor. NE sec. 26, T. 33 S., R. 4 E., in center of trail 200 feet east of center of sec.; augered Aug. 28, 1958; dry hole; altitude of land surface, 1,100.8 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Wisconsinan Stage		
Terrace deposits		
Silt, black	4	4
Silt, clayey, dark gray	4	8
PERMIAN—Lower Permian Series		
Chase Group		
Barneston Limestone		
Limestone, hard, white	0.2	8.2

33-4-26cbb.—Sample log of test hole in NW cor. SW sec. 26, T. 33 S., R. 4 E., 20 feet south of east-west road, in center of trail; augered Aug. 27, 1958; depth to water, 26.20 feet; altitude of land surface, 1,130.6 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Sangamonian and Illinoisan Stages		
Loveland and Crete Formations		
Silt, red brown	5	5
Silt, tan brown	11	16
Sand, fine, arkosic	2	18
Silt, gray; contains some fine sand	3	21
Sand, fine, arkosic	3	24
Sand, fine to coarse, and some fine arkosic gravel	6	30
Sand and gravel, fine to coarse, arkosic	3	33
PERMIAN—Lower Permian Series		
Chase Group		
Barneston Limestone		
Shale, gray	1	34

33-4-26daa.—Sample log of test hole in NE cor. SE sec. 26, T. 33 S., R. 4 E., on south side of trail at sec. line; augered Aug. 28, 1958; depth to water, 32.00 feet; altitude of land surface, 1,099.3 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Wisconsinan Stage		
Terrace deposits		
Silt, black	3	3
Silt, dark gray	12	15
Silt, tan gray	11	26
Silt, tan; contains some very fine sand	5	31
Silt, dark gray, and fine to coarse chert gravel	7	38
Silt, clayey, dark gray	3	41
PERMIAN—Lower Permian Series		
Chase Group		
Barneston Limestone		
Shale, gray	3	44

33-4-27bdd.—Sample log of test hole in SE cor. NW sec. 27, T. 33 S., R. 4 E., on west road shoulder 100 feet north of ½-mile line; augered June 20, 1957; depth to water, 28.50 feet; altitude of land surface, 1,114.2 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Sangamonian and Illinoisan Stages		
Loveland and Crete Formations		
Silt, black	6	6
Silt, brown	9	15
Silt, buff; contains some fine sand	10	25
Sand, fine to coarse, and some fine to medium gravel	12	37
PERMIAN—Lower Permian Series		
Chase Group		
Barneston Limestone		
Limestone, white	0.5	37.5

33-4-27cdd.—Sample log of test hole in SE cor. SW sec. 27, T. 33 S., R. 4 E., 100 feet north and 6 feet west of center of intersection; augered June 20, 1957; dry hole; altitude of land surface, 1,168.8 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Sangamonian and Illinoisan Stages		
Loveland and Crete Formations		
Silt, brown	5	5
Silt, reddish brown	5	10
Silt, reddish brown, some yellow mottling	15	25

33-4-28bda.—Sample log of test hole in NE SE NW sec. 28, T. 33 S., R. 4 E., in drive to west at top of hill 0.3 mile south of corner; augered June 20, 1957; depth to water, 28.40 feet; altitude of land surface, 1,153.0 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Sangamonian and Illinoisan Stages		
Loveland and Crete Formations		
Silt, brown	5	5
Silt, reddish brown	14	19

	Thickness, feet	Depth, feet
Silt, tan	11	30
Silt, tan brown, some sand and limestone gravel	5	35
Sand, fine to medium, silty	13	48
PERMIAN—Lower Permian Series		
Chase Group		
Doyle Shale		
Shale, limy, gray	0.5	48.5

33-4-28dcd.—Sample log of test hole in SE SW SE sec. 28, T. 33 S., R. 4 E., on north road shoulder 0.2 mile east of corner; augered June 20, 1957; dry hole; altitude of land surface, 1,206.0 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Wisconsinan Stage		
Eolian deposits		
Silt, dark brown	2	2
Silt, brown	3	5
Silt, tan	28	33
Lower Pleistocene—Yarmouthian and Kansan Stages		
Sappa and Grand Island Formations		
Silt, buff; contains some fine to medium sand	1	34
Sand, fine to coarse, and some limestone gravel	4	38
PERMIAN—Lower Permian Series		
Chase Group		
Winfield Limestone		
Limestone, white, hard	0.5	38.5

33-4-29aaa.—Sample log of test hole in NE cor. sec. 29, T. 33 S., R. 4 E., 111 feet south and 8 feet west of center of crossroad; drilled April 17, 1944; depth to water, 6.74 feet; altitude of land surface, 1,133.6 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Sangamonian and Illinoisan Stages		
Loveland and Crete Formations		
Silt, gray black to tan; contains some fine sand	4	4
Silt, tan	4	8
Silt, clayey, gray	5	13
Silt, gray white	2	15
Silt, fine to medium, and much gray silt	3	18
Gravel, fine to medium, and fine to coarse sand	2	20
Silt, gray white and blue gray; contains some fine gravel and fine to coarse sand	2	22
Gravel, fine to coarse; much fine to coarse, silty, yellow-buff sand	8	30
PERMIAN—Lower Permian Series		
Chase Group		
Doyle Shale		
Shale, thin bedded, light greenish gray	2	32

* **33-4-29abb.**—Sample log of test hole in NW cor. NE sec. 29, T. 33 S., R. 4 E., 24 feet east and 20 feet south of center of road at ½-mile line; drilled April 17, 1944; depth to water, 20.95 feet; altitude of land surface, 1,150.9 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Sangamonian and Illinoisan Stages		
Loveland and Crete Formations		
Silt, tan; contains fine to medium sand	18	18
Silt, yellow gray; contains some fine to coarse sand	2	20
Sand, fine to coarse, some fine gravel	10	30
Gravel, fine, and fine to coarse sand, some medium gravel, and yellow clay	10	40
Gravel, fine to medium, and fine to coarse sand; contains some coarse gravel	2	42
PERMIAN—Lower Permian Series		
Chase Group		
Doyle Shale		
Shale, hard, blue gray	1	43

33-4-29add.—Sample log of test hole in SE cor. NE sec. 29, T. 33 S., R. 4 E., on west road shoulder 10 feet north of ½-mile line; augered Aug. 25, 1958; depth to water, 29.80 feet; altitude of land surface, 1,158.5 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Sangamonian and Illinoisan Stages		
Loveland and Crete Formations		
Silt, black	4	4
Silt, brown	10	14
Silt, light tan to buff	2	16
Silt, brown	18	34
Sand, fine to very fine, silty	17	51
Sand, fine to coarse, and fine to medium gravel	8	59
PERMIAN—Lower Permian Series		
Chase Group		
Doyle Shale		
Shale, gray	1	60

33-4-29ccc.—Sample log of test hole in SW cor. sec. 29, T. 33 S., R. 4 E., 39 feet north and 9 feet east of center of crossroad; drilled March 18, 1944; depth to water, 37.22 feet; altitude of land surface, 1,175.2 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Sangamonian and Illinoisan Stages		
Loveland and Crete Formations		
Silt, partly clayey, tan	26	26
Clay, silty, gray	1	27
Silt, slightly clayey, dull tan	22	49
Sand, fine to medium, and some fine to medium, silty buff gravel	13	62
PERMIAN—Lower Permian Series		
Chase Group		
Winfield Limestone		
Limestone, hard	0.5	62.5

33-4-29cdd.—Sample log of test hole in SE cor. SW sec. 29, T. 33 S., R. 4 E., in field entrance 20 feet west of ⅛-mile line; augered Aug. 24, 1958; dry hole; altitude of land surface, 1,180.0 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Wisconsinan Stage		
Eolian deposits		
Silt, red brown	5	5
Silt, tan brown	20	25
Silt, tan	17	42
PERMIAN—Lower Permian Series		
Chase Group		
Odell Shale		
Shale, gray	1	43

33-4-30abb.—Sample log of test hole in NW cor. NE sec. 30, T. 33 S., R. 4 E., 48 feet west and 27 feet south of center of highway bridge; drilled April 18, 1944; depth to water, 7.80 feet; altitude of land surface, 1,142.6 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Sangamonian and Illinoisan Stages		
Loveland and Crete Formations		
Silt, gray black	4	4
Silt, clayey, gray	2	6
Silt, blocky, light gray green to yellow tan	2	8
Sand, fine to coarse, and some fine gravel and clay; contains some coarse gravel	12	20
Gravel, fine to medium, and fine to coarse sand; contains some coarse gravel	11	31
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, gray	4	35

* **33-4-30add2.**—Sample log of test hole in SE cor. NE sec. 30, T. 33 S., R. 4 E., 30 feet north and 6 feet east of wooden culvert; drilled March 18, 1944; altitude of land surface, 1,160.4 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Sangamonian and Illinoisan Stages		
Loveland and Crete Formations		
Silt, clayey, dark gray	2	2
Clay, silty, light gray	3	5
Silt, clayey, blocky, tan	14	19
Silt, clayey, yellow tan	10	29
Sand, fine; contains some fine to medium gravel and coarse sand	11	40
Gravel, fine, and fine to coarse sand and gravel grading downward to coarse gravel and sand	7	47
PERMIAN—Lower Permian Series		
Chase Group		
Odell Shale		
Shale, hard, calcareous, yellow buff	2	49

33-4-31add.—Sample log of test hole in SE cor. NE sec. 31, T. 33 S., R. 4 E., on west road shoulder 20 feet north of ½-mile line; augered Aug. 24, 1958; dry hole; altitude of land surface, 1,218.0 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Wisconsinan Stage		
Eolian deposits		
Silt, tan	5	5
Silt, brown	18	23
Silt, gray	6	29
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, gray, and limestone	1.1	30.1

33-4-31baa.—Sample log of test hole in NE cor. NW sec. 31, T. 33 S., R. 4 E., on south road shoulder 100 feet west of ½-mile line; augered Aug. 24, 1958; depth to water, 20.70 feet; altitude of land surface, 1,160.2 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Sangamonian and Illinoisan Stages		
Loveland and Crete Formations		
Silt, black	3	3
Silt, tan	3	6
Silt, dark gray	9	15
Silt, buff	10	25
Sand, fine to coarse, silty	15	40
Sand, fine to coarse	9	49
PERMIAN—Lower Permian Series		
Chase Group		
Odell Shale		
Shale, gray, and limestone	1.5	50.5

33-4-31ddd.—Sample log of test hole in SE cor. sec. 31, T. 33 S., R. 4 E., on north road shoulder 50 feet west of center of crossing; augered Aug. 24, 1958; dry hole; altitude of land surface, 1,213.6 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Wisconsinan Stage		
Eolian deposits		
Silt, red brown	17	17
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, black	1	18
Shale, gray	2	20

33-4-33bbb.—Sample log of test hole in NW cor. sec. 33, T. 33 S., R. 4 E., 20 feet south of center of road to west and in center of trail to south; augered Aug. 25, 1958; dry hole; altitude of land surface, 1,196.8 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Wisconsinan Stage		
Eolian deposits		
Silt, tan brown	5	5
Silt, tan	5	10
Silt, brown	23	33
PERMIAN—Lower Permian Series		
Chase Group		
Odell Shale		
Shale, gray	1.5	34.5

33-4-35add.—Sample log of test hole in SE cor. NE sec. 35, T. 33 S., R. 4 E., on west road shoulder at ½-mile line; augered June 20, 1957; dry hole; altitude of land surface, 1,161.8 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Wisconsinan Stage		
Eolian deposits		
Silt, red brown	5	5
Lower Pleistocene—Yarmouthian and Kansan Stages		
Sappa and Grand Island Formations		
Sand, fine to coarse, very silty	5	10
Sand. fine to coarse	15	25
Sand, fine to coarse, and limestone gravel	5	30
PERMIAN—Lower Permian Series		
Chase Group		
Doyle Shale		
Shale, gray	2	32

34-3-3bbb.—Sample log of test hole in NW cor. sec. 3, T. 34 S., R. 3 E., 120 feet east and 6 feet south of center of crossing; augered June 23, 1957; dry hole; altitude of land surface, 1,174.5 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Wisconsinan Stage		
Eolian deposits		
Silt, brown	7	7
Silt, brown; contains some very fine sand	5	12
Sand, fine (dune)	10	22
Lower Pleistocene—Yarmouthian and Kansan Stages		
Sappa and Grand Island Formations		
Silt, tan; contains fine to medium sand	5	27
Silt, tan, and fine to medium, interbedded sand	8	35
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, gray, clayey	11	46

34-3-4aab.—Sample of log of test hole in NW NE NE sec. 4, T. 34 S., R. 3 E., 700 feet west of corner on south road shoulder; augered Aug. 17, 1956; dry hole.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Recent Stage		
Colluvium		
Silt, tan brown	6	6
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, soft, gray	4	10
Shale, gray, and white limestone streaks	5	15

* **34-3-4abb.**—Sample log of test hole in NW cor. NW NE sec. 4, T. 34 S., R. 3 E., on south road shoulder at ½-mile line; augered Aug. 17, 1956; depth to water, 11.70 feet; altitude of land surface, 1,102.0 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Wisconsinan Stage		
Terrace deposits		
Silt, red brown	4	4
Silt, brown	4	8
Sand and gravel, fine to coarse	18	26
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, gray	2	28

* **34-3-4dcc.**—Sample log of test hole in SW cor. SW SE sec. 4, T. 34 S., R. 3 E., in north ditch at ½-mile line; augered Sept. 2, 1956; depth to water, 16.70 feet; altitude of land surface, 1,097.0 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Wisconsinan Stage		
Terrace deposits		
Silt, tan	5	5
Silt, brown	2	7
Silt, gray; contains caliche nodules	1	8
Sand, fine to coarse, and fine gravel	7	15
Gravel, fine to coarse, and coarse sand	36	51
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, gray	1	52

* **34-3-5aab.**—Sample log of test hole in NW NE NE sec. 5, T. 34 S., R. 3 E., in south road ditch 700 feet west of corner; augered Aug. 17, 1956; depth to water, 11.00 feet; altitude of land surface, 1,095.9 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Wisconsinan Stage		
Terrace deposits		
Silt, sandy, fine, gray	3	3
Sand, fine to coarse	7	10
Sand and gravel, fine to coarse	32	42
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, gray	2	44

* **34-3-5add.**—Sample log of test hole in SE cor. NE sec. 5, T. 34 S., R. 3 E., 6 feet north and 30 feet west of fence-corner post; drilled March 23, 1944; altitude of land surface, 1,099.7 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Wisconsinan Stage		
Terrace deposits		
Sand, fine to coarse, and buff silt	4	4
Sand, fine to coarse, and some fine to coarse gravel	6	10
Gravel, fine to medium, and fine to coarse sand; some coarse gravel	33	43
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, blue gray	5	48

* **34-3-5bab.**—Sample log of test hole in NW cor. NE NW sec. 5, T. 34 S., R. 3 E., in south road ditch 0.3 mile east of corner; augered Aug. 18, 1956; depth to water, 9.35 feet; altitude of land surface, 1,098.0 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Wisconsinan Stage		
Terrace deposits		
Silt, sandy, black	2	2
Silt, very sandy, fine, brown	5	7
Silt, clayey, brown	4	11
Sand, fine, very silty, gray	5	16
Sand, medium to coarse, silty	6	22
Sand, fine to coarse, and fine, silty gravel	8	30
Sand and gravel, fine to coarse	16	46
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, gray	2	48

* **34-3-5bbb.**—Sample log of test hole in NW cor. sec. 5, T. 34 S., R. 3 E., in grass triangle where road turns east; augered Aug. 17, 1956; depth to water, 20.00 feet; altitude of land surface, 1,103.6 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Wisconsinan Stage		
Terrace deposits		
Silt, fine sandy, red brown	5	5
Silt, sandy, brown	5	10
Sand, fine	8	18
Sand and gravel, coarse to fine	12	30
Sand and gravel, coarse to fine, silty, gray	5	35
Sand and gravel, fine to coarse	9	44
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, gray	1	45

* **34-3-5caa.**—Sample log of test hole in NE cor. NE SW sec. 5, T. 34 S., R. 3 E., on west road shoulder 50 feet south of ½-mile line; augered Sept. 2, 1956; depth to water, 14.90 feet; altitude of land surface, 1,098.7 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Wisconsinan Stage		
Terrace deposits		
Silt, sandy, dark brown	3	3
Sand, fine	7	10
Sand and gravel, fine to coarse	10	20
Gravel, fine to coarse	23	43
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, gray	2	45

* **34-3-5dcc2.**—Sample log of test hole in SW cor. SE sec. 5, T. 34 S., R. 3 E., 60 feet east and 11 feet north of center of "T" road; drilled March 24, 1944; depth to water, 8.30 feet; altitude of land surface, 1,092.1 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Recent Stage		
Alluvium		
Silt, light gray	3	3
Gravel, fine to coarse, and much fine to coarse sand and gray silt	10	13
Sand, fine to coarse, and much fine to coarse gravel near bottom	7	20
Silt, sandy, light gray	6	26
Sand, fine to coarse, and much fine to medium gravel	12	38
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, light gray	5	43

* **34-3-8aaa.**—Sample log of test hole in NE cor. sec. 8, T. 34 S., R. 3 E., in south road ditch 30 feet west of corner; augered Sept. 2, 1956; depth to water, 13.40 feet; altitude of land surface, 1,090.0 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Wisconsinan Stage		
Terrace deposits		
Silt, very sandy, brown	6	6
Sand, fine	10	16
Sand, coarse	4	20
Gravel, fine to coarse	21	41
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, gray	2	43

* **34-3-8acc.**—Sample log of test hole in SW SW NE sec. 8, T. 34 S., R. 3 E., 600 feet east along trail toward river, 50 feet west of building; augered Sept. 2, 1956; depth to water, 9.30 feet; altitude of land surface, 1,089.4 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Recent Stage		
Alluvium		
Sand, fine	10	10
Sand and gravel, fine to coarse	15	25
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, gray, soft	5	30

* **34-3-8baa.**—Sample log of test hole in NE NE NW sec. 8, T. 34 S., R. 3 E., at end of curve in road in south ditch; augered Sept. 2, 1956; depth to water, 8.00 feet; altitude of land surface, 1,088.8 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Recent Stage		
Alluvium		
Silt, sandy, fine, gray	5	5
Sand, fine	5	10
Sand and gravel, fine to coarse	25	35
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, gray	1	36

34-3-8bcb.—Sample log of test hole in NW cor. SW NW sec. 8, T. 34 S., R. 3 E., 0.05 mile west of river bridge; drilled March 24, 1944; altitude of land surface, 1,092.4 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Recent Stage		
Alluvium		
Silt, dark gray to buff; contains some fine to coarse sand,	3	3
Gravel, fine to medium, and fine to coarse cemented sand,	0.5	3.5
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, light gray to buff	6.5	10

* **34-3-8cdd.**—Sample log of test hole in SE cor. SE SW sec. 8, T. 34 S., R. 3 E., in north road ditch at ½-mile line; augered Sept. 2, 1956; depth to water, 10.70 feet; altitude of land surface, 1,091.9 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Wisconsinan Stage		
Terrace deposits		
Silt, red brown	5	5
Silt, clayey, black	5	10
Sand, fine	7	17
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, gray	2	19

34-3-10aaa.—Sample log of test hole in NE cor. sec. 10, T. 34 S., R. 3 E., on curve at corner 20 feet north of metering station; augered June 23, 1957; depth to water, 34.50 feet; altitude of land surface, 1,174.5 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Wisconsinan Stage		
Eolian deposits		
Silt, clayey, brown	3	3
Silt, fine sandy, light brown	4	7
Silt, fine sandy, very dark brown	9	16
Lower Pleistocene—Yarmouthian and Kansan Stages		
Sappa and Grand Island Formations		
Silt, light tan brown	2	18
Sand, fine to medium	3	21
Silt, light tan	2	23
Silt, brown; some very fine sand	3	26
Silt, buff	11	37
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, gray	1	38

34-3-10bbb.—Sample log of test hole in NW cor. sec. 10, T. 34 S., R. 3 E., 120 feet east and 8 feet south of center of road crossing; augered June 23, 1957; depth to water, 8.10 feet; altitude of land surface, 1,106.3 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Wisconsinan Stage		
Terrace deposits		
Silt, very sandy, black	3	3
Silt, brown	4	7
Silt, tan	4	11
Sand, fine to coarse, silty	8	19
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, gray	0.5	19.5

34-3-10ddd.—Sample log of test hole in SE cor. sec. 10, T. 34 S., R. 3 E., 150 feet west and 8 feet north of center of crossing; augered June 22, 1957; depth to water, 19.50 feet; altitude of land surface, 1,169.7 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Wisconsinan Stage		
Eolian deposits		
Silt, brown	5	5
Silt, clayey, brown mottled gray	2	7
Sand, fine to very fine (dune)	1	8
Lower Pleistocene—Yarmouthian and Kansan Stages		
Sappa and Grand Island Formations		
Silt, tan, very sandy, coarse to fine	4	12
Sand, fine to medium	7	19
Sand, fine to medium, and buff silt	5	24
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, gray blue	4	28

34-3-14aaa.—Sample log of test hole in NE cor. sec. 14, T. 34 S., R. 3 E., 120 feet west and 8 feet south of center of road crossing; augered June 22, 1957; depth to water, 21.40 feet; altitude of land surface, 1,146.3 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Wisconsinan Stage		
Eolian deposits		
Silt, tan brown; contains some fine sand	2	2
Silt, light brown; contains much fine sand	3	5
Sand, fine (dune)	5	10
Lower Pleistocene—Yarmouthian and Kansan Stages		
Sappa and Grand Island Formations		
Silt, fine, sandy, buff	10	20
Silt, buff; contains much fine to coarse sand	9	29

PERMIAN—Middle Permian Series
Sumner Group
Wellington Formation

	Thickness, feet	Depth, feet
Shale, blue gray	7	36

*** 34-3-15bbb.**—Sample log of test hole in NW cor. sec. 15, T. 34 S., R. 3 E., on south road shoulder 150 feet west of railroad; augered June 22, 1957; depth to water, 7.50 feet; altitude of land surface, 1,087.3 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Wisconsinan Stage		
Terrace deposits		
Silt, black; contains fine sand	2	2
Silt, sandy, red brown	8	10
Sand, fine to medium, silty	6	16
Sand, fine to coarse, some fine gravel	16	32
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, gray	1	33

*** 34-3-15cdd.**—Sample log of test hole in SE cor. SW sec. 15, T. 34 S., R. 3 E., 15 feet north and 15 feet west of center of crossing; augered June 22, 1957; depth to water, 6.00 feet; altitude of land surface, 1,080.1 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Recent Stage		
Alluvium		
Sand, fine, silty	5	5
Sand, fine to medium	5	10
Sand and gravel, fine to coarse	33	43
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, gray	1	44

*** 34-3-16bbb.**—Sample log of test hole in NW cor. sec. 16, T. 34 S., R. 3 E., on east road shoulder at north end of hedgerow; augered Sept. 2, 1956; depth to water, 14.60 feet; altitude of land surface, 1,087.0 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Wisconsinan Stage		
Terrace deposits		
Silt, hard, red brown	3	3
Sand, very fine	6	9
Sand and gravel, fine to coarse	3	12
Gravel, fine to coarse	24	36
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, gray	1	37

34-3-17ccc.—Sample log of test hole in SW cor. sec. 17, T. 34 S., R. 3 E., on north road shoulder 50 feet east of center of crossing; augered Aug. 23, 1958; dry hole; altitude of land surface, 1,134.6 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Wisconsinan Stage		
Eolian deposits		
Silt, clayey, dark brown	4	4
Silt, brown	7	11
Silt, tan	1	12
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, gray	2	14

34-3-17ddd.—Sample log of test hole in SE cor. sec. 17, T. 34 S., R. 3 E., on north road shoulder 50 feet west of center of crossing; augered Aug. 23, 1958; dry hole; altitude of land surface, 1,148.1 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Wisconsinan Stage		
Eolian deposits		
Silt, brown	3	3
Silt, tan brown	13	16
Silt, tan; contains some limestone gravel at base	6	22
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, gray	2	24

34-3-18bcc.—Sample log of test hole in SW cor. NW sec. 18, T. 34 S., R. 3 E., 25 feet north and 8 feet east of center of road at ½-mile line; drilled March 24, 1944; dry hole; altitude of land surface, 1,105.6 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Wisconsinan Stage		
Eolian deposits		
Silt, dark gray	3	3
Silt, brown; contains some fine sand	3	6
Silt, clayey, buff	10	16
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, soft, gray	3	19

34-3-19bbb.—Sample log of test hole in NW cor. sec. 19, T. 34 S., R. 3 E., on south road shoulder 50 feet east of center of crossing; augered Aug. 23, 1958; dry hole; altitude of land surface, 1,140.1 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Wisconsinan Stage		
Eolian deposits		
Silt, gray	5	5
Silt, tan brown	2	7
Silt, tan	1	8
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, gray	2	10

34-3-23baa.—Sample log of test hole in NE cor. NW sec. 23, T. 34 S., R. 3 E., 70 feet south and 6 feet west of center of crossing; augered June 22, 1957; depth to water, 9.60 feet; altitude of land surface, 1,171.1 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Wisconsinan Stage		
Eolian deposits		
Silt, black; contains much fine sand	5	5
Sand fine (dune), silty	5	10
Lower Pleistocene—Yarmouthian and Kansan Stages		
Sappa and Grand Island Formations		
Sand, fine to coarse; contains much gray silt	5	15
Sand, fine to coarse	15	30
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, gray	3	33

** **34-3-23cbb.**—Sample log of test hole in NW cor. SW sec. 23, T. 34 S., R. 3 E., 8 feet east and 24 feet north of tree at fence corner; drilled April 20, 1944; depth to water, 6.62 feet; altitude of land surface, 1,075.4 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Recent Stage		
Alluvium		
Sand, fine to medium; contains some dark-gray silt	5	5
Sand, fine to coarse; contains some fine to coarse gravel	5	10
Gravel, fine to medium, and fine to coarse sand; some coarse gravel	10	20
Gravel, fine to coarse, and some fine to coarse sand	10	30
Gravel, fine to medium; some coarse gravel and coarse to fine sand	10.5	40.5
PERMIAN—Lower Permian Series		
Chase Group		
Odell Shale		
Shale, yellow buff grading downward to blue gray	5.5	46

* **34-3-23ccc.**—Sample log of test hole in SW cor. sec. 23, T. 34 S., R. 3 E., 200 feet east and 6 feet north of center of crossing; augered June 5, 1957; depth to water, 9.10 feet; altitude of land surface, 1,082.7 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Wisconsinan Stage		
Terrace deposits		
Silt, tan brown	4	4
Silt, black, some fine sand	2	6
Silt, very sandy, fine, tan	3	9
Sand, fine, silty	3	12
Sand, fine to coarse, some fine gravel	16	28
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, gray	1	29

34-3-23dba.—Sample log of test hole in NE NW SE sec. 23, T. 34 S., R. 3 E., on south road shoulder ¼-mile west of corner; augered June 23, 1957; depth to water, 30.00 feet; altitude of land surface, 1,141.4 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Recent and Wisconsinan Stages		
Eolian deposits		
Sand, fine	4	4
Silt, reddish brown; contains fine sand	3	7
Sand, fine to medium (dune)	9	16
Lower Pleistocene—Yarmouthian and Kansan Stages		
Sappa and Grand Island Formations		
Sand, fine to coarse, silty	14	30
Sand, fine to coarse, very silty, buff	11	41
PERMIAN—Lower Permian Series		
Chase Group		
Nolans Limestone		
Shale, gray	2	43
Limestone, hard, white	0.5	43.5

34-3-25caa.—Sample log of test hole in NE NE SW sec. 25, T. 34 S., R. 3 E., 200 feet south of Chestnut Ave. on first road west of railroad; augered June 7, 1957; depth to water, 4.80 feet; altitude of land surface, 1,067.1 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Wisconsinan Stage		
Terrace deposits		
Silt, sandy, black	5	5
Sand, fine, very silty	5	10
PERMIAN—Lower Permian Series		
Chase Group		
Nolans Limestone		
Limestone, hard, white	0.5	10.5

* **34-3-26add.**—Sample log of test hole in SE SE NE sec. 26, T. 34 S., R. 3 E., on north road shoulder 500 feet west of river bridge; augered June 7, 1957; depth to water, 6.40 feet; altitude of land surface, 1,072.2 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Recent Stage		
Alluvium		
Silt, sandy, black	5	5
Sand, fine	5	10
Sand, fine to medium	10	20
Sand and gravel, fine to coarse	16	36
PERMIAN—Lower Permian Series		
Chase Group		
Nolans Limestone		
Limestone, hard, white	1	37

* **34-3-26bab.**—Sample log of test hole in NW NE NW sec. 26, T. 34 S., R. 3 E., in center of trail to east, 50 feet east of road leading south; augered June 6, 1957; depth to water, 8.30 feet; altitude of land surface, 1,073.2 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Wisconsinan Stage		
Terrace deposits		
Sand, fine, silty	6	6
Sand, fine	4	10
Sand and gravel, fine to coarse	34	44
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, blue gray	1	45

* **34-3-26bdc.**—Sample log of test hole in SW SE NW sec. 26, T. 34 S., R. 3 E., on west shoulder of diagonal road 600 feet NW of Chestnut Ave.; augered June 6, 1957; depth to water, 5.30 feet; altitude of land surface, 1,073.3 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Wisconsinan Stage		
Terrace deposits		
Silt, sandy, fine, black	4	4
Sand, fine	10	14
Sand, fine to coarse, and some fine gravel	6	20
Sand and gravel, fine to coarse	19	39
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, gray green	1	40

34-3-28aaa.—Sample log of test hole in NE cor. sec. 28, T. 34 S., R. 3 E., 60 feet west and 8 feet south of center of crossing; augered June 5, 1957; dry hole; altitude of land surface, 1,122.0 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Wisconsinan Stage		
Eolian deposits		
Silt, brown, some sand and gravel near base	5	5
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, soft (weathered), gray	5	10
Shale, gray green	5	15

34-3-28ddd.—Sample log of test hole in SE cor. sec. 28, T. 34 S., R. 3 E., 100 feet north and 6 feet west of center of crossing; augered June 5, 1957; dry hole; altitude of land surface, 1,148.1 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Wisconsinan Stage		
Eolian deposits		
Silt, black	2	2
Silt, red brown	7	9
Silt, tan	4	13
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, weathered, gray	3	16
Shale, gray green	2	18
Limestone, hard, white	0.5	18.5

34-3-29aaa.—Sample log of test hole in NE cor. sec. 29, T. 34 S., R. 3 E., on south road shoulder 70 feet west of center of crossing; augered Aug. 22, 1958; dry hole; altitude of land surface, 1,138.9 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Wisconsinan Stage		
Eolian deposits		
Silt, red brown	4	4
Silt, tan brown	5	9
Silt, tan	9	18
Lower Pleistocene—Yarmouthian and Kansan Stages		
Sappa and Grand Island Formations		
Silt, buff; contains small caliche nodules	8	26
Silt, tan buff; contains much fine to coarse sand	2	28
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, gray	0.5	28.5

34-3-29bbb.—Sample log of test hole in NW cor. sec. 29, T. 34 S., R. 3 E., on south road shoulder 50 feet east of center of crossing; augered Aug. 22, 1958; depth to water, 28.00 feet; altitude of land surface, 1,143.3 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Wisconsinan Stage		
Eolian deposits		
Silt, dark brown	6	6
Silt, brown	5	11
Silt, tan	6	17
Silt, tan; contains some very fine sand	10	27
Lower Pleistocene—Yarmouthian and Kansan Stages		
Sappa and Grand Island Formations		
Silt, gray; contains some sand	3	30
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, gray	3	33

34-3-29ccc.—Sample log of test hole in SW cor. sec. 29, T. 34 S., R. 3 E., 250 feet north of center of highway on east road shoulder; augered Aug. 22, 1958; dry hole; altitude of land surface, 1,166.1 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Wisconsinan Stage		
Eolian deposits		
Silt, red brown	5	5
Silt, reddish tan	3	8
Lower Pleistocene—Yarmouthian and Kansan Stages		
Sappa and Grand Island Formations		
Silt, buff; contains small caliche nodules	5	13
Silt, buff	17	30
Silt, buff; contains some fine to coarse sand	10	40
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, gray	2	42

34-3-30bbb.—Sample log of test hole in NW cor. sec. 30, T. 34 S., R. 3 E., on south road shoulder 50 feet east of center of road; augered Aug. 23, 1958; dry hole; altitude of land surface, 1,172.1 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Wisconsinan Stage		
Eolian deposits		
Silt, black	2	2
Silt, brown	10	12
Silt, red brown	5	17
Lower Pleistocene—Yarmouthian and Kansan Stages		
Sappa and Grand Island Formations		
Silt, gray buff, clayey; contains small caliche nodules	4	21
Clay, buff	2	23
Silt, gray	1	24

	Thickness, feet	Depth, feet
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, gray	1	25

34-3-31bbb.—Sample log of test hole in NW cor. sec. 31, T. 34 S., R. 3 E., on east road shoulder 70 feet south of center of highway; augered Aug. 22, 1958; depth to water, 32.00 feet; altitude of land surface, 1,190.7 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Wisconsinan Stage		
Eolian deposits		
Silt, dark brown	6	6
Silt, dark gray	3	9
Silt, brown	8	17
Silt, tan	8	25
Lower Pleistocene—Yarmouthian and Kansan Stages		
Sappa and Grand Island Formations		
Silt, clayey, buff	6	31
Silt, clayey, buff; contains some fine sand	11	42
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, gray	2	44

34-3-34ccc.—Sample log of test hole in SW cor. sec. 34, T. 34 S., R. 3 E., on north road shoulder 50 feet east of stop sign; augered June 5, 1957; depth to water, 9.20 feet; altitude of land surface, 1,136.7 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Wisconsinan Stage		
Eolian deposits		
Silt, brown	5	5
Silt, tan	4	9
Clay, green	2	11
Silt, tan; some fine sand at bottom	3	14
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, gray	2	16

34-3-34ddd.—Sample log of test hole in SE cor. sec. 34, T. 34 S., R. 3 E., 50 feet west and 8 feet north of center of road crossing; augered Aug. 21, 1958; dry hole; altitude of land surface, 1,129.5 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Wisconsinan Stage		
Eolian deposits		
Silt, dark brown	4	4
Silt, tan brown	13	17

	Thickness, feet	Depth, feet
Lower Pleistocene—Yarmouthian and Kansan Stages		
Sappa and Grand Island Formations		
Silt, gray; contains some fine to coarse sand	4	21
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, gray	1	22

* **34-3-35aab.**—Sample log of test hole in NW cor. NE NE sec. 35, T. 34 S., R. 3 E., 100 feet south of highway, between sand pit and railroad; augered June 7, 1957; depth to water, 5.40 feet; altitude of land surface, 1,069.9 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Wisconsinan Stage		
Terrace deposits		
Silt, sandy, dark brown	6	6
Sand, fine, silty	2	8
Sand, fine to medium	3	11
Sand and gravel, fine to coarse	26	37
PERMIAN—Lower Permian Series		
Chase Group		
Nolans Limestone		
Limestone, hard, white	0.5	37.5

***34-3-36bab.**—Sample log of test hole in NW NE NW sec. 36, T. 34 S., R. 3 E., in south ditch 400 feet west of city limit sign; drilled June 7, 1957; depth to water, 9.40 feet; altitude of land surface, 1,073.0 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Wisconsinan Stage		
Terrace deposits		
Sand, fine, silty, black (crude oil stain)	5	5
Sand, fine	5	10
Sand, fine to coarse	13	23
Sand and gravel, fine to coarse	4	27
PERMIAN—Lower Permian Series		
Chase Group		
Nolans Limestone		
Limestone, hard, white	0.5	27.5

34-4-6abb.—Sample log of test hole in NW cor. NE sec. 6, T. 34 S., R. 4 E., 250 feet east of roalroad, on south shoulder of road; augered Aug. 24, 1958; depth to water, 24.50 feet; altitude of land surface, 1,191.8 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Wisconsinan Stage		
Eolian deposits		
Silt, red brown	10	10
Silt, brown	10	20
Silt, gray	8	28

Permian—Lower Permian Series
Chase Group
Odell Shale

	Thickness, feet	Depth, feet
Shale, gray	2	30

34-4-11bba.—Sample log of test hole in NE NW NW sec. 11, T. 34 S., R. 4 E., on south road shoulder 500 feet east of river bridge; augered Aug. 28, 1958; depth to water, 21.50 feet; altitude of land surface, 1,076.6 feet.

	Thickness, feet	Depth, feet
Quaternary—Pleistocene		
Upper Pleistocene—Wisconsinan Stage		
Terrace deposits		
Silt, black	6	6
Silt, tan brown	6	12
Silt, tan; contains some fine to coarse chert gravel	4	16
Silt, tan; contains fine to coarse sand	3	19
Silt, black, and coarse chert gravel	20.5	39.5
Permian—Lower Permian Series		
Chase Group		
Barneston Limestone		
Limestone	0.5	40

34-4-15aaa.—Sample log of test hole in NE cor. sec. 15, T. 34 S., R. 4 E., on south road shoulder 100 feet west of center of road crossing; augered Aug. 28, 1958; dry hole; altitude of land surface, 1,103.3 feet.

	Thickness, feet	Depth, feet
Quaternary—Pleistocene		
Upper Pleistocene—Sangamonian and Illinoisan Stages		
Loveland and Crete Formations		
Silt, dark brown	5	5
Silt, brown	6	11
Silt, tan	8	19
Silt, tan; contains much fine sand	4	23
Permian—Lower Permian Series		
Chase Group		
Barneston Limestone		
Limestone, hard, white	0.5	23.5

34-4-15abb.—Sample log of test hole in NW cor. NE sec. 15, T. 34 S., R. 4 E., on south road shoulder 200 feet east of ½-mile line; augered Aug. 28, 1958; dry hole; altitude of land surface, 1,111.3 feet.

	Thickness, feet	Depth, feet
Quaternary—Pleistocene		
Upper Pleistocene—Sangamonian and Illinoisan Stages		
Loveland and Crete Formations		
Silt, dark brown, sandy	6	6
Silt, tan	19	25
Silt, tan; contains much fine arkosic sand	7	32
Silt, tan; contains fine sand and limestone gravel	6	38
Permian—Lower Permian Series		
Chase Group		
Barneston Limestone		
Limestone, white	0.5	38.5

34-4-15bbb.—Sample log of test hole in NW cor. sec. 15, T. 34 S., R. 4 E., on east road shoulder 100 feet south of center of road crossing; augered Aug. 28, 1958; dry hole; altitude of land surface, 1,095.9 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Sangamonian and Illinoisan Stages		
Loveland and Crete Formations		
Silt, dark brown	3	3
Silt, brown	13	16
Silt, brown, and fine to medium arkosic sand	5	21
Gravel, fine to coarse, and fine to coarse, cherty and arkosic sand	6	27
PERMIAN—Lower Permian Series		
Chase Group		
Doyle Shale		
Shale, gray buff	2	29

34-4-15dcc.—Sample log of test hole in SW cor. SE sec. 15, T. 34 S., R. 4 E., on north road shoulder at ¼-mile line; augered June 21, 1957; dry hole; altitude of land surface, 1,176.8 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Lower Pleistocene—Yarmouthian and Kansan Stages		
Sappa and Grand Island Formations		
Silt, red brown	5	5
Silt, clayey, brown	2	7
Silt, brown; contains much fine to coarse sand	3	10
PERMIAN—Lower Permian Series		
Chase Group		
Odell Shale		
Shale, limy, gray	2	12

34-4-15ddd.—Sample log of test hole in SE cor. sec. 15, T. 34 S., R. 4 E., on north road shoulder 20 feet west of center of crossing; augered June 21, 1957; dry hole; altitude of land surface, 1,181.6 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Wisconsinan Stage		
Eolian deposits		
Silt, brown	5	5
PERMIAN—Lower Permian Series		
Chase Group		
Odell Shale		
Shale, gray	5	10

34-4-16abb.—Sample log of test hole in NW cor. NE sec. 16, T. 34 S., R. 4 E., on east road shoulder 150 feet south of corner; augered Aug. 28, 1958; dry hole; altitude of land surface, 1,103.2 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Sangamonian and Illinoisan Stages		
Loveland and Crete Formations		
Silt, dark brown	2	2
Silt, brown	28	30

	Thickness, feet	Depth, feet
Silt, tan	5	35
Silt, tan; contains much fine arkosic sand and some fine to coarse chert gravel	7	42
PERMIAN—Lower Permian Series		
Chase Group		
Doyle Shale		
Shale, gray	1	43

34-4-16acc.—Sample log of test hole in SW cor. NE sec. 16, T. 34 S., R. 4 E., on east road shoulder 20 feet north of ½-mile line; augered Aug. 27, 1958; dry hole; altitude of land surface, 1,108.4 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Sangamonian and Illinoisan Stages		
Crete and Loveland Formations		
Silt, clayey, dark brown	6	6
Silt, tan brown	14	20
Silt, tan	15	35
Silt, tan; and coarse to fine arkosic sand and fine chert gravel	6	41
Silt, tan, and fine to coarse sand and gravel, arkosic and chert	5	46
PERMIAN—Lower Permian Series		
Chase Group		
Doyle Shale		
Limestone, white	0.2	46.2

34-4-16cdd.—Sample log of test hole in SE cor. SW sec. 16, T. 34 S., R. 4 E., in center of "T" intersection; augered June 21, 1957; dry hole; altitude of land surface, 1,130.4 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Lower Pleistocene—Yarmouthian and Kansan Stages		
Sappa and Grand Island Formations		
Silt and sand, fine to coarse, some fine gravel	3	3
Silt, brown	2	5
Silt, sandy, fine, reddish brown	2	7
PERMIAN—Lower Permian Series		
Chase Group		
Winfield Limestone		
Limestone, hard, white	1	8

34-4-17bcc.—Sample log of test hole in SW cor. NW sec. 17, T. 34 S., R. 4 E., on east road shoulder 400 feet south of bridge; augered June 22, 1957; altitude of land surface, 1,068.7 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Wisconsinan Stage		
Terrace deposits		
Sand and fine to coarse chert gravel	10	10
Sand, fine to coarse, and fine chert gravel	10	20
Chert gravel, fine to coarse, some sand	15	35

PERMIAN—Lower Permian Series
Chase Group
Doyle Shale

	Thickness, feet	Depth, feet
Shale, gray	1	36

34-4-19bcc.—Sample log of test hole in SW cor. NW sec. 19, T. 34 S., R. 4 E., 45 feet south of SE cor. of stone wall on east side of U. S. Highway 77; drilled April 18, 1944; depth to water, 9.70 feet; altitude of land surface, 1,088.7 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Sangamonian and Illinoisan Stages		
Loveland and Crete Formations		
Sand, fine to medium, and dark-gray silt	4	4
Sand, fine to medium; some fine silty gravel	6.5	10.5
PERMIAN—Lower Permian Series		
Chase Group		
Doyle Shale		
Shale, hard, gray	2.5	13
Shale, very hard, calcareous, buff	4	17

34-4-20bcc.—Sample log of test hole in SW cor. NW sec. 20, T. 34 S., R. 4 E., in NE cor. of intersection; augered June 22, 1957; depth to water, 19.00 feet; altitude of land surface, 1,072.8 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Wisconsinan Stage		
Terrace deposits		
Silt, black	5	5
Silt, brown	10	15
Silt, brown; some coarse chert gravel	5	20
Silt, sandy, fine, gray	10	30
Silt, sandy, gray, and coarse chert gravel	10	40
Silt, gray, and coarse to fine sand and chert gravel	10	50
PERMIAN—Lower Permian Series		
Chase Group		
Doyle Shale		
Shale, gray	1	51

* **34-4-20cab.**—Sample log of test hole in NW NE SW sec. 20, T. 34 S., R. 4 E., 50 feet south of center of road and 50 feet east of house; augered June 12, 1957; depth to water, 15.40 feet; altitude of land surface, 1,067.9 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Wisconsinan Stage		
Terrace deposits		
Silt, red brown	5	5
Silt, brown	15	20
Silt and sand, fine, and coarse chert gravel	23	43
PERMIAN—Lower Permian Series		
Chase Group		
Doyle Shale		
Shale, gray	0.5	43.5

34-4-21bba.—Sample log of test hole in NE NW NW sec. 21, T. 34 S., R. 4 E., on south road shoulder 0.2 mile east of corner; augered Aug. 27, 1958; dry hole; altitude of land surface, 1,134.0 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Wisconsinan Stage		
Eolian deposits		
Silt, brown	10	10
Silt, brown, and some fine sand	2	12
PERMIAN—Lower Permian Series		
Chase Group		
Barneston Limestone		
Limestone, hard, white	0.3	12.3

34-4-21ccc.—Sample log of test hole in SW cor. sec. 21, T. 34 S., R. 4 E., on east road shoulder 100 feet north of corner; augered Aug. 27, 1958; dry hole; altitude of land surface, 1,121.2 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Wisconsinan Stage		
Eolian deposits		
Silt, tan; contains some very fine sand	3	3
Silt, gray buff	4	7
PERMIAN—Lower Permian Series		
Chase Group		
Odell Shale		
Shale, soft, gray	1	8
Shale, blue gray	2	10

34-4-22bab.—Sample log of test hole in NW NE NW sec. 22, T. 34 S., R. 4 E., 0.3 mile east of corner, on south road shoulder; augered Aug. 27, 1958; dry hole; altitude of land surface, 1,184.9 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Wisconsinan Stage		
Eolian deposits		
Silt, brown	5	5
Silt, tan	3	8
Silt, buff	4	12
Silt, tan	11	23
PERMIAN—Lower Permian Series		
Chase Group		
Winfield Limestone		
Limestone, hard, white	0.2	23.2

34-4-22bbb.—Sample log of test hole in NW cor. sec. 22, T. 34 S., R. 4 E., in SE cor. of intersection; augered June 21, 1957; dry hole; altitude of land surface, 1,142.5 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Lower Pleistocene—Yarmouthian and Kansan Stages		
Sappa and Grand Island Formations		
Sand, fine to coarse, silty, red	5	5
Silt, fine, very sandy, tan	4	9
Sand, fine to coarse, very silty, tan	4	13
PERMIAN—Lower Permian Series		
Chase Group		
Winfield Limestone		
Limestone, hard, white	0.2	13.2

34-4-28aaa.—Sample log of test hole in NE cor. sec. 28, T. 34 S., R. 4 E., on west road shoulder 75 feet south of corner; augered Aug. 27, 1958; dry hole; altitude of land surface, 1,162.5 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Wisconsinan Stage		
Eolian deposits		
Silt, tan brown	5	5
Silt, tan	5	10
Silt, clayey, tan gray	5	15
PERMIAN—Lower Permian Series		
Chase Group		
Odell Shale		
Shale, gray, and white limestone	0.3	15.3

34-4-28abb.—Sample log of test hole in NW cor. NE sec. 28, T. 34 S., R. 4 E., on south road shoulder at ½-mile line; augered Aug. 27, 1958; depth to water, 31.00 feet; altitude of land surface, 1,171.4 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Wisconsinan Stage		
Eolian deposits		
Silt, dark brown; contains some fine sand	3	3
Silt, tan brown; contains some fine sand	3	6
Silt, tan brown	9	15
Lower Pleistocene—Yarmouthian and Kansan Stages		
Sappa and Grand Island Formations		
Silt, gray buff	2	17
Silt, buff; contains much arkosic sand	9	26
Sand, fine to coarse, silty	5	31
Sand and gravel, arkosic, fine to coarse	11	42
PERMIAN—Lower Permian Series		
Chase Group		
Odell Shale		
Shale, gray	1	43

34-4-28dcc.—Sample log of test hole in SW SW SE sec. 28, T. 34 S., R. 4 E., on north side of highway about 150 feet west of bridge; augered June 22, 1957; altitude of land surface, 1,121.4 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Sangamonian and Illinoisan Stages		
Loveland and Crete Formations		
Sand, fine, brown	10	10
Sand, fine, red	5	15
Silt, brown; contains fine sand	25	40
Silt, tan; contains some fine to coarse sand	5	45
Silt, brown	10	55
Sand, fine to coarse, silty	13	68
PERMIAN—Lower Permian Series		
Chase Group		
Doyle Shale		
Shale, gray	1	69

34-4-28ddd.—Sample log of test hole in SE cor. sec. 28, T. 34 S., R. 4 E., in NW cor. of intersection; augered June 22, 1957; depth to water, 28.50 feet; altitude of land surface, 1,091.2 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Sangamonian and Illinoisan Stages		
Loveland and Crete Formations		
Silt, sandy, brown	5	5
Sand, fine	5	10
Silt, sandy, brown	5	15
Silt, red; contains much fine sand	3	18
Silt, clayey, red	2	20
Silt, sandy, tan	5	25
Sand, fine to coarse, silty	5	30
Sand, fine to coarse	8.5	38.5
PERMIAN—Lower Permian Series		
Chase Group		
Doyle Shale		
Shale, gray	0.5	39

34-4-29bcc.—Sample log of test hole in SW SW NW sec. 29, T. 34 S., R. 4 E., 20 feet east of river bank 200 feet north of east end of bridge; augered June 12, 1957; depth to water, 9.20 feet; altitude of land surface, 1,061.5 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Recent Stage		
Colluvium		
Silt, black	5	5
Silt, brown	10	15
Silt, black, some fine sand	5	20
PERMIAN—Lower Permian Series		
Chase Group		
Winfield Limestone		
Limestone, white	0.5	20.5

* **34-4-30adc.**—Sample log of test hole in SW SE NE sec. 30, T. 34 S., R. 4 E., 300 feet east of dike on Chestnut Ave. in drive 30 feet north of road; augered June 12, 1957; depth to water, 10.00 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Wisconsinan Stage		
Terrace deposits		
Silt, black	5	5
Silt, brown	7	12
Silt, dark brown	6	18
Chert gravel, coarse, and fine to coarse sand	24	42
PERMIAN—Lower Permian Series		
Chase Group		
Doyle Shale		
Shale, gray	0.5	42.5

* **34-4-31aba.**—Sample log of test hole in NE NW NE sec. 31, T. 34 S., R. 4 E., south of highway and east of dike at gate; augered June 11, 1957; depth to water, 11.50 feet; altitude of land surface, 1,061.6 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Wisconsinan Stage		
Terrace deposits		
Silt, black	5	5
Silt, sandy, brown	5	10
Silt and fine sand (locally derived)	5	15
Gravel, coarse (chert)	10	25
PERMIAN—Lower Permian Series		
Chase Group		
Doyle Shale		
Shale, soft, gray	5	30

** **35-3-1aaa.**—Sample log of test hole in NE cor. sec. 1, T. 35 S., R. 3 E., in City Park 120 feet west of Summit Street, west of gas-metering station; augered June 8, 1957; depth to water, 7.90 feet; altitude of land surface, 1,066.1 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Wisconsinan Stage		
Terrace deposits		
Silt, black	2	2
Sand, fine, silty	2	4
Sand, fine to coarse	11	15
Sand and gravel, fine to coarse	35	50
PERMIAN—Lower Permian Series		
Chase Group		
Nolans Limestone		
Limestone, hard, white	0.5	50.5

35-3-1ccc.—Sample log of test hole in SW cor. sec. 1, T. 35 S., R. 3 E., 6 feet east and 50 feet north of center of road crossing; augered Aug. 21, 1958; dry hole; altitude of land surface, 1,122.9 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Wisconsinan Stage		
Eolian deposits		
Silt, red brown	6	6
Silt, tan brown	7	13
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, gray, and white limestone streaks	2	15

35-3-2aaa.—Sample log of test hole in NE cor. sec. 2, T. 35 S., R. 3 E., 30 feet west and 16 feet south of center of road crossing; augered Aug. 21, 1958; dry hole; altitude of land surface, 1,119.6 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Wisconsinan Stage		
Eolian deposits		
Silt, reddish brown	6	6
Silt, tan brown	11	17
Silt, tan	2	19
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, gray, and limestone streaks	2	21

35-3-2ccc.—Sample log of test hole in SW cor. sec. 2, T. 35 S., R. 3 E., in center of triangle formed by road curve; augered Aug. 21, 1958; dry hole; altitude of land surface, 1,138.9 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Wisconsinan Stage		
Eolian deposits		
Silt, gray	7	7
Silt, buff	5	12
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, gray, and white limestone	2.1	14.1

35-3-4bbb.—Sample log of test hole in NW cor. sec. 4, T. 35 S., R. 3 E., 6 feet south and 50 feet east of center of road crossing; augered Aug. 21, 1958; altitude of land surface, 1,166.7 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Wisconsinan Stage		
Eolian deposits		
Silt, dark brown	6	6
Silt, red brown	2	8

	Thickness, feet	Depth, feet
Lower Pleistocene—Yarmouthian and Kansan Stages		
Sappa and Grand Island Formations		
Sand, fine to coarse, very silty, brown	4	12
Silt, tan to buff	5	17
Silt, buff; contains fine sand	9	26
Silt, gray	3	29
Sand, fine to coarse; contains silt stringers	4	33
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, gray	2	35

35-3-5bbb.—Sample log of test hole in NW cor. sec. 5, T. 35 S., R. 3 E., in south road ditch 50 feet east of road crossing; augered Aug. 21, 1958; depth to water, 33.50 feet; altitude of land surface, 1,161.9 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Wisconsinan Stage		
Eolian deposits		
Silt, brown	4	4
Silt, reddish brown	12	16
Lower Pleistocene—Yarmouthian and Kansan Stages		
Sappa and Grand Island Formations		
Silt, gray to buff	5	21
Silt, brown; some fine to coarse sand	16	37
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, gray	1	38

35-3-6bbb.—Sample log of test hole in NW cor. sec. 6, T. 35 S., R. 3 E., 40 feet east and 16 feet south of center of road crossing; augered Aug. 21, 1958; depth to water, 32.00 feet; altitude of land surface, 1,209.5 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Wisconsinan Stage		
Eolian deposits		
Silt, brown	5	5
Silt, reddish brown	6	11
Lower Pleistocene—Yarmouthian and Kansan Stages		
Sappa and Grand Island Formations		
Silt, tan; contains some fine to coarse sand	5	16
Silt, gray, and much fine to coarse sand	10	26
Sand, fine to coarse, and fine to coarse gravel	7	33
Clay, tan	3	36
Clay, gray to buff; contains some fine sand	14	50
Clay and sand interbedded	14	64
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, soft, gray	6	70

35-3-6ccc.—Sample log of test hole in SW cor. sec. 6, T. 35 S., R. 3 E., 6 feet east and 50 feet north of center of road crossing; augered Aug. 18, 1958; altitude of land surface, 1,192.0 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Wisconsinan Stage		
Eolian deposits		
Silt, dark gray	5	5
Silt, brown	5	10
Silt, tan	10	20
Lower Pleistocene—Yarmouthian and Kansan Stages		
Sappa and Grand Island Formations		
Silt, buff; contains fine to medium sand	15	35
Silt, tan	5	40
Silt, tan and buff	5	45
Silt, buff	5	50
Silt, tan, and fine to coarse sand	5	55
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, gray	1	56

35-3-6ddd.—Sample log of test hole in SE cor. sec. 6, T. 35 S., R. 3 E., 50 feet west and 12 feet north of center of road crossing; augered Aug. 21, 1958; depth to water, 37.00 feet; altitude of land surface, 1,192.3 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Wisconsinan Stage		
Eolian deposits		
Silt, black	5	5
Silt, brown	10	15
Silt, reddish brown	5	20
Lower Pleistocene—Yarmouthian and Kansan Stages		
Sappa and Grand Island Formations		
Silt, tan, and fine to coarse gravel, some sand	15	35
Sand, fine to coarse, silty	5	40
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, gray green	2	42

35-3-7ccc.—Sample log of test hole in SW cor. sec. 7, T. 35 S., R. 3 E., 100 feet north and 6 feet east of center of crossing; augered June 5, 1957; depth to water, 12.70 feet; altitude of land surface, 1,176.8 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Recent Stage		
Colluvium		
Silt, sandy, brown	5	5
Silt, gray, some imbedded fine gravel	5	10

	Thickness, feet	Depth, feet
Lower Pleistocene—Yarmouthian and Kansan Stages		
Sappa and Grand Island Formations		
Silt, buff	5	15
Silt, tan, and fine to coarse interbedded sand	5	20
Silt, buff	5	25
Sand, fine to coarse, silty, buff	10	35
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, blue gray	1	36

35-3-8aaa.—Sample log of test hole in NE cor. sec. 8, T. 35 S., R. 3 E., 30 feet west and 8 feet south of center of road crossing; augered Aug. 21, 1958; depth to water, 28.50 feet; altitude of land surface, 1,185.2 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Wisconsinan Stage		
Eolian deposits		
Silt, black	2	2
Silt, reddish brown	10	12
Lower Pleistocene—Yarmouthian and Kansan Stages		
Sappa and Grand Island Formations		
Silt, red brown to tan, clayey	8	20
Silt, tan	10	30
Silt, clayey, red brown	10	40
Silt, fine sandy, red brown	6	46
Sand, fine to coarse; some fine to coarse silty gravel	17	63
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, weathered, gray	7	70

35-3-9aaa.—Sample log of test hole in NE cor. sec. 9, T. 35 S., R. 3 E., 75 feet west and 8 feet south of center of crossing; augered June 5, 1957; depth to water, 33.60 feet; altitude of land surface, 1,176.6 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Wisconsinan Stage		
Eolian deposits		
Silt, red brown	5	5
Silt, brown	2	7
Lower Pleistocene—Yarmouthian and Kansan Stages		
Sappa and Grand Island Formations		
Sand and gravel, fine to coarse, much buff silt	11	18
Silt, tan to buff, some fine sand	3	21
Silt, gray	17	38
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, gray green	3	41

35-3-12ccc.—Sample log of test hole in SW cor. sec. 12, T. 35 S., R. 3 E., 75 feet north and 8 feet east of center of crossing; augered June 4, 1957; dry hole; altitude of land surface, 1,164.4 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Wisconsinan Stage		
Eolian deposits		
Silt, tan brown	3	3
Silt, tan, and limestone pebbles	2	5
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, gray	3	8

35-3-13ccc.—Sample log of test hole in SW cor. sec. 13, T. 35 S., R. 3 E., 100 feet north and 10 feet east of center of road crossing; augered Aug. 18, 1958; dry hole; altitude of land surface, 1,178.4 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Wisconsinan Stage		
Eolian deposits		
Silt, brown	5	5
Silt, tan	10	15
Lower Pleistocene—Yarmouthian and Kansan Stages		
Sappa and Grand Island Formations		
Silt, gray, and fine to medium sand	5	20
Sand and gravel, fine to coarse, very silty	6	26
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, gray	4	30

35-3-14bbb.—Sample log of test hole in NW cor. sec. 14, T. 35 S., R. 3 E., 125 feet south and 5 feet east of center of crossing; augered June 4, 1957; altitude of land surface, 1,1[illegible] feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Wisconsinan Stage		
Eolian deposits		
Silt, black	2	2
Silt, brown	3	5
Silt, tan	5	10
Lower Pleistocene—Yarmouthian and Kansan Stages		
Sappa and Grand Island Formations		
Silt, fine sandy, buff	5	15
Silt, sandy, buff	20	35
Silt, buff, and fine to coarse sand streaks	23	58
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, gray to blue gray	[illegible]	[illegible]

35-3-14ccc.—Sample log of test hole in SW cor. sec. 14, T. 35 S., R. 3 E., 100 feet north and 10 feet east of center of road crossing; augered Aug. 18, 1958; depth to water, 30.00 feet; altitude of land surface, 1,160.7 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Wisconsinan Stage		
Eolian deposits		
Silt, brown	5	5
Silt, red brown	20	25
Lower Pleistocene—Yarmouthian and Kansan Stages		
Sappa and Grand Island Formations		
Silt, light tan	13	38
Sand, fine, and buff silt	5	43
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale and limestone	1	44

35-3-15bbb.—Sample log of test hole in NW cor. sec. 15, T. 35 S., R. 3 E., 75 feet south and 6 feet east of center of crossing; augered June 4, 1957; depth to water, 31.70 feet; altitude of land surface, 1,168.0 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Wisconsinan Stage		
Eolian deposits		
Silt, black	2	2
Silt, brown	7	9
Silt, tan	6	15
Lower Pleistocene—Yarmouthian and Kansan Stages		
Sappa and Grand Island Formations		
Silt, red brown	8	23
Silt, buff; contains some coarse gravel	3	26
Sand and gravel, fine to coarse, silty, buff; gravel is both local and arkosic	9	35
Silt, buff, and some fine gravel	12	47
Silt, buff, and fine to coarse interbedded sand	18	65
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, blue gray	2	67

35-3-15ccc.—Sample log of test hole in SW cor. sec. 15, T. 35 S., R. 3 E., 75 feet north and 6 feet east of center of crossing; augered June 5, 1957; depth to water, 5.00 feet; altitude of land surface, 1,147.4 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Wisconsinan Stage		
Eolian deposits		
Silt, brown	10	10
Silt, clayey, tan	5	15

	Thickness, feet	Depth, feet
Lower Pleistocene—Yarmouthian and Kansan Stages		
Sappa and Grand Island Formations		
Silt, light gray	15	30
Silt, gray, and interbedded sand	5	35
Permian—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, blue gray	1	36
Limestone, hard, white	0.5	36.5

35-3-17aaa.—Sample log of test hole in NE cor. sec. 17, T. 35 S., R. 3 E., 75 feet west and 8 feet south of center of crossing; augered June 4, 1957; depth to water, 81.50 feet; altitude of land surface, 1,173.2 feet.

	Thickness, feet	Depth, feet
Quaternary—Pleistocene		
Upper Pleistocene—Wisconsinan Stage		
Eolian deposits		
Silt, black	2	2
Silt, gray	6	8
Silt, fine sandy, gray	4	12
Silt, tan	18	30
Lower Pleistocene—Yarmouthian and Kansan Stages		
Sappa and Grand Island Formations		
Silt, sandy, fine, tan	10	40
Silt, sandy, fine, buff	4	44
Silt, light gray, contains much fine to coarse sand	21	65
Permian—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, light blue gray	2	67

35-3-17ddd.—Sample log of test hole in SE cor. sec. 17, T. 35 S., R. 3 E., 50 feet west and 8 feet north of center of road crossing; augered Aug. 18, 1958; depth to water, [illegible] feet; altitude of land surface, 1,158.6 feet.

	Thickness, feet	Depth, feet
Quaternary—Pleistocene		
Upper Pleistocene—Wisconsinan Stage		
Eolian deposits		
Silt, black	5	5
Silt, brown	15	20
Lower Pleistocene—Yarmouthian and Kansan Stages		
Sappa and Grand Island Formations		
Silt, light tan, contains much fine sand	5	25
Sand, fine to coarse, and tan silt	5	30
Permian—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, gray green	3	33

35-3-18aaa.—Sample log of test hole in NE cor. sec. 18, T. 35 S., R. 3 E., 50 feet west and 8 feet south of center of crossing; augered June 4, 1957; depth to water, 34.30 feet; altitude of land surface, 1,185.9 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Wisconsinan Stage		
Eolian deposits		
Silt, black	3	3
Silt, red brown	17	20
Lower Pleistocene—Yarmouthian and Kansan Stages		
Sappa and Grand Island Formations		
Silt, buff, and interbedded fine sand	3	23
Sand, fine to medium, silty, buff	17	40
Silt, gray, and interbedded fine to coarse sand	17	57
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, blue gray	1	58

35-3-18ccc.—Sample log of test hole in SW cor. sec. 18, T. 35 S., R. 3 E., 10 feet north and 50 feet east of center of road crossing; augered Aug. 18, 1958; depth to water, 24.40 feet; altitude of land surface, 1,185.5 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Wisconsinan Stage		
Eolian deposits		
Silt, black	5	5
Silt, brown to tan brown	20	25
Lower Pleistocene—Yarmouthian and Kansan Stages		
Sappa and Grand Island Formations		
Silt, gray; contains fine sand	10	35
Silt, tan	5	40
Sand, fine, and tan silt	10	50
PERMIAN—Middle Permian Series		
Sumner Group		
Wellington Formation		
Shale, gray	3	53

35-3-18ddd.—Sample log of test hole in SE cor. sec. 18, T. 35 S., R. 3 E., 8 feet north and 50 feet west of center of crossing; augered Aug. 18, 1958; dry hole; altitude of land surface, 1,178.1 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Wisconsinan Stage		
Eolian deposits		
Silt, brown	5	5
Silt, red brown	10	15
Silt, gray green	5	20

** **35-4-2add.**—Sample log of test hole in SE cor. NE sec. 2, T. 35 S., R. 4 E., 12 feet west and 21 feet south of east gate post; drilled April 18, 1944; depth to water, 5.29 feet; altitude of land surface, 1,049.5 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Recent Stage		
Alluvium		
Sand, fine to medium, and light-brown silt	5	5
Sand, fine to coarse; some fine to coarse gravel	5	10
Gravel, fine to medium, and fine to coarse sand	20	30
Gravel, very coarse, and fine to coarse sand	14	44
PERMIAN—Lower Permian Series		
Chase Group		
Matfield Shale		
Shale, red brown	6	50

* **35-4-3ada.**—Sample log of test hole in NE SE NE sec. 3, T. 35 S., R. 4 E., 200 feet west of curve on south shoulder of road; augered June 9, 1957; depth to water, 6.10 feet; altitude of land surface, 1,041.8 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Wisconsinan Stage		
Terrace deposits		
Sand, fine	10	10
Sand, fine to coarse	8	18
Sand and gravel, fine to coarse; some gravel at 18 to 22 feet, derived from Permian rocks	19	37
PERMIAN—Lower Permian Series		
Chase Group		
Doyle Shale		
Shale, gray	1	38

* **35-4-4aad.**—Sample log of test hole in SE cor. NE NE sec. 4, T. 35 S., R. 4 E., 60 feet north and 5 feet west of center of crossing; augered June 9, 1957; depth to water, 14.70 feet; altitude of land surface, 1,055.3 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Wisconsinan Stage		
Terrace deposits		
Silt, black	6	6
Silt, sandy, fine, tan	2	8
Sand, fine	5	13
Sand and gravel, fine to coarse	9	22
PERMIAN—Lower Permian Series		
Chase Group		
Doyle Shale		
Limestone, hard, blue white	0.5	22.5

* **35-4-5abb.**—Sample log of test hole in NW cor. NW NE sec. 5, T. 35 S., R. 4 E., on east road shoulder 100 feet north of curve in road; augered June 11, 1957; depth to water, 8.40 feet; altitude of land surface, 1,048.8 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Recent Stage		
Alluvium		
Sand, fine to medium	21	21
Sand and gravel, fine to coarse	21	42
PERMIAN—Lower Permian Series		
Chase Group		
Doyle Shale		
Shale, gray	2	44

* **35-4-5daa.**—Sample log of test hole in NE cor. NE SE sec. 5, T. 35 S., R. 4 E., on south road shoulder at entrance to field; augered June 8, 1957; depth to water, 6.40 feet; altitude of land surface, 1,054.0 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Wisconsinan Stage		
Terrace deposits		
Sand, fine, silty, black	5	5
Sand, fine to coarse	7	12
Sand and gravel, fine to coarse	16	28
PERMIAN—Lower Permian Series		
Chase Group		
Doyle Shale		
Shale, gray to buff	2	30

35-4-11aaa.—Sample log of test hole in NE cor. sec. 11, T. 35 S., R. 4 E., on south road shoulder 50 feet west of corner; augered Aug. 24, 1958; depth to water, 31.20 feet; altitude of land surface, 1,061.1 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Wisconsinan Stage		
Eolian deposits		
Silt, black; contains very fine sand	3	3
Silt, brown; contains very fine sand	3	6
Silt, brown	10	16
Sand, fine (dune), silty	9	25
Sand, fine	7	32
PERMIAN—Lower Permian Series		
Chase Group		
Barneston Limestone		
Limestone, hard, white	0.5	32.5

35-4-11add.—Sample log of test hole in SE cor. NE sec. 11, T. 35 S., R. 4 E., on west road shoulder 30 feet north of ½-mile line; augered Aug. 24, 1958; dry hole; altitude of land surface, 1,108.0 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Wisconsinan Stage		
Eolian deposits		
Silt, dark brown	6	6
Silt, clayey, tan brown; contains some small caliche nodules	2	8
Silt, buff; contains small caliche nodules	4	12
Silt, gray	4	16
PERMIAN—Lower Permian Series		
Chase Group		
Doyle Shale		
Shale, gray	4	20

35-4-11baa.—Sample log of test hole in NE cor. NW sec. 11, T. 35 S., R. 4 E., on south road shoulder 250 feet west of ½-mile line; augered Aug. 24, 1958; dry hole; altitude of land surface, 1,113.1 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Wisconsinan Stage		
Eolian deposits		
Sand, very fine; contains much silt	3	3
Sand, very fine	5	8
Silt, dark brown	5	13
Silt, brown	14	27
PERMIAN—Lower Permian Series		
Chase Group		
Doyle Shale		
Shale, gray	2.5	29.5
Limestone, white	0.3	29.8

35-4-13aab.—Sample log of test hole in NW NE NE sec. 13, T. 35 S., R. 4 E., on south road shoulder 100 feet west of house; augered June 10, 1957; dry hole; altitude of land surface, 1,036.0 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Wisconsinan Stage		
Eolian deposits		
Silt, dark brown	3	3
Silt, brown	7	10
Silt, brown, some very fine sand near bottom	24	34
PERMIAN—Lower Permian Series		
Chase Group		
Doyle Shale		
Shale, gray	1	35

35-4-13ddc.—Sample log of test hole in SW cor. SE SE sec. 13, T. 35 S., R. 4 E., 100 feet north of creek crossing; augered June 10, 1957; depth to water, 7.20 feet; altitude of land surface, 1,075.5 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Wisconsinan Stage		
Terrace deposits		
Silt, black	5	5
Silt, brown	5	10
Sand, fine to coarse, very silty	6	16
PERMIAN—Lower Permian Series		
Chase Group		
Barneston Limestone		
Limestone, white	1	17

* **35-5-18bbb.**—Sample log of test hole in NW cor. sec. 18, T. 35 S., R. 5 E., on south shoulder of road 30 feet from river bank; augered June 9, 1957; depth to water. 6.00 feet; altitude of land surface, 1,024.6 feet.

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Upper Pleistocene—Wisconsinan Stage		
Terrace deposits		
Silt, sandy, red brown	5	5
Sand, fine	10	15
PERMIAN—Lower Permian Series		
Chase Group		
Barneston Limestone		
Limestone, hard, white	0.5	15.5

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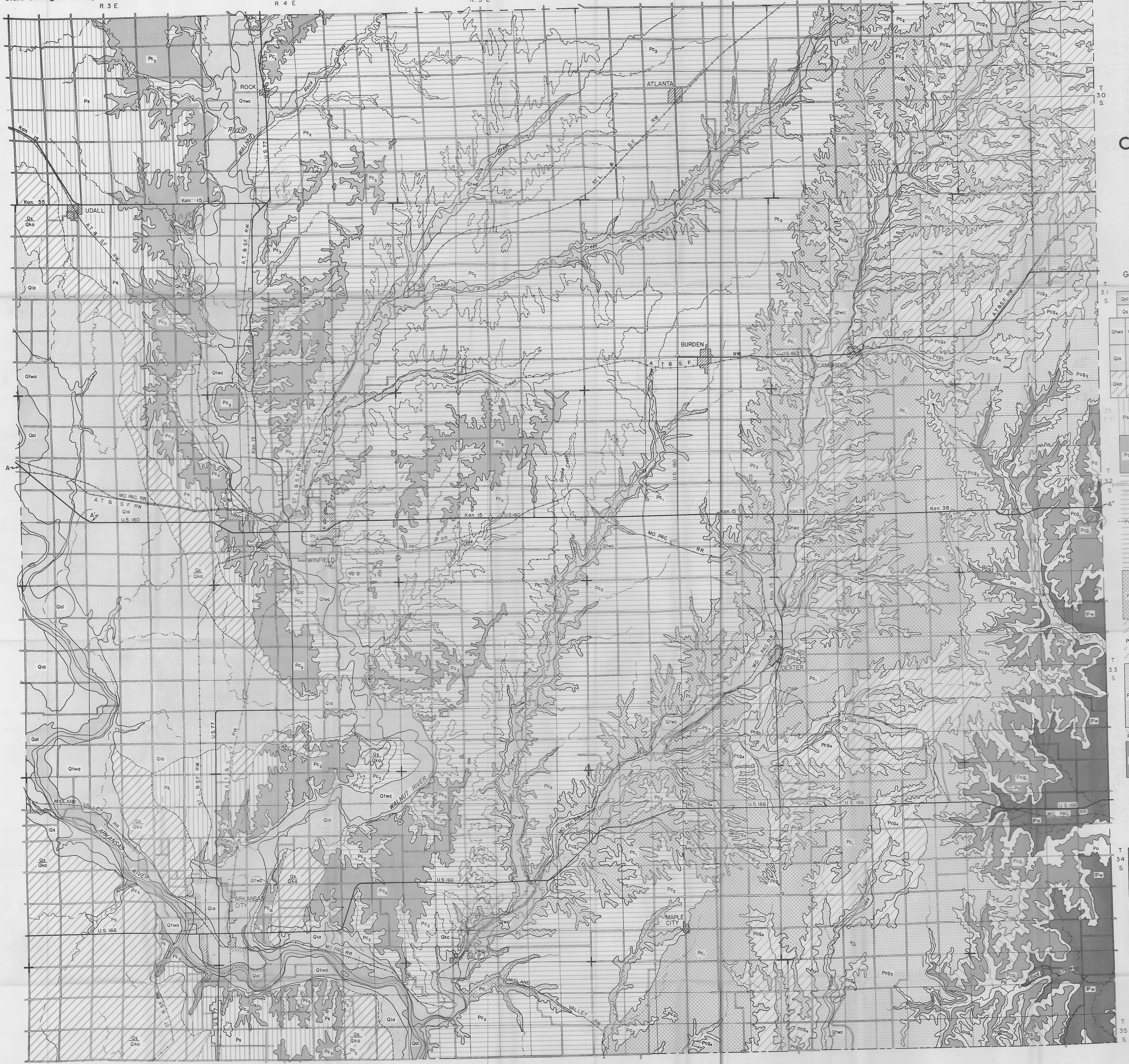
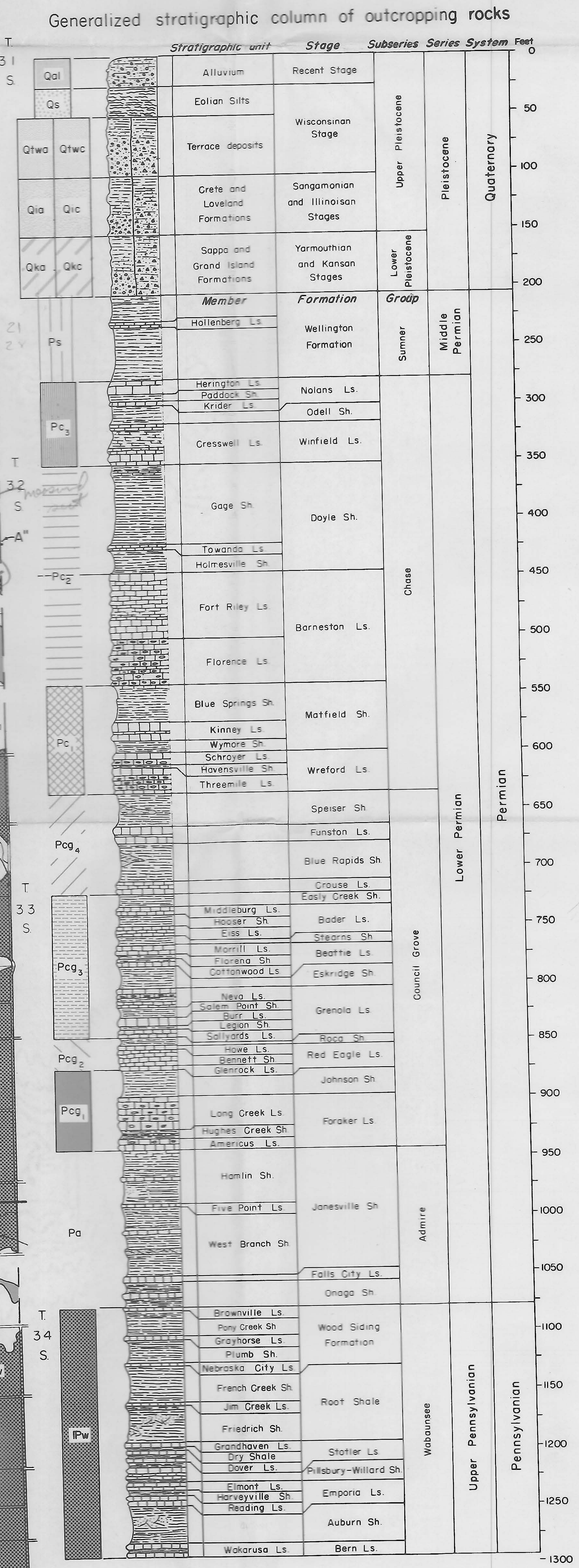
AREAL GEOLOGY OF COWLEY COUNTY, KANSAS

by Charles K. Bayne
1958



Generalized stratigraphic column of outcropping rocks



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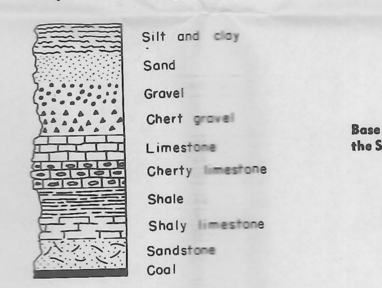
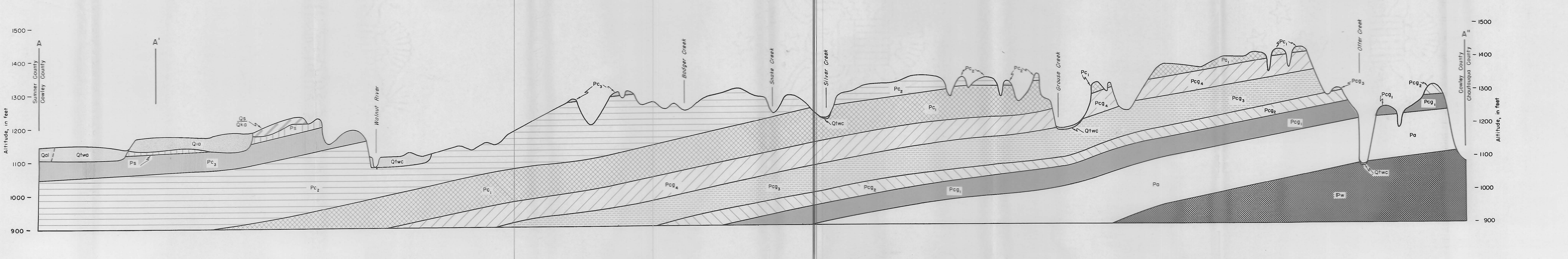
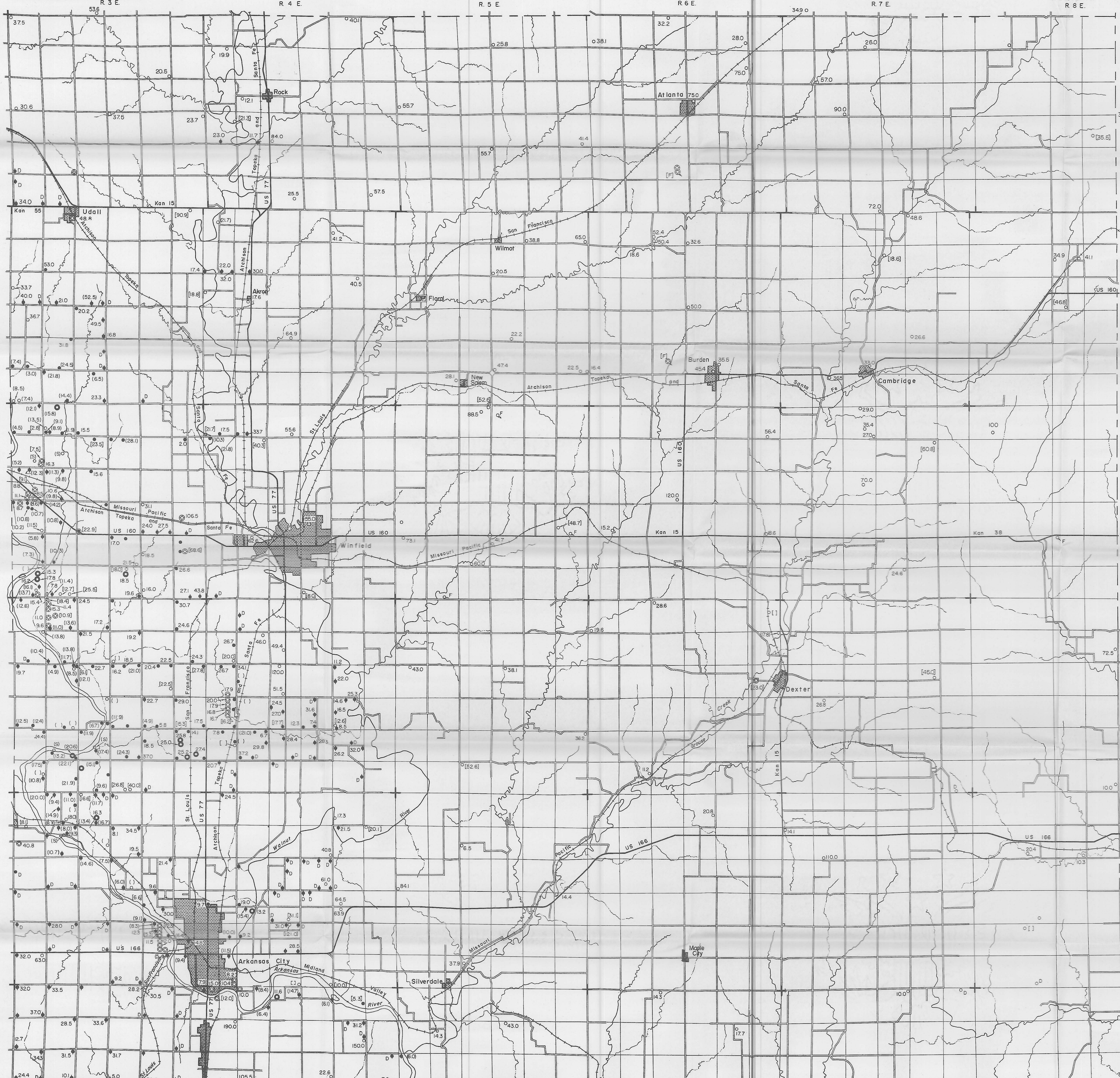


Base compiled from maps prepared by the Soil Conservation Service





MAP OF COWLEY COUNTY, KANSAS

SHOWING LOCATION OF WELLS, SPRINGS, TEST HOLES AND AUGER HOLES FOR WHICH RECORDS ARE GIVEN

by Charles K. Bayne
1958

EXPLANATION

- ○ Domestic or stock well
- ● Drilled test hole
- ♦ Auger hole
- ○ Spring F flowing
- Irrigation well
- Public supply well
- Public supply spring
- Industrial well
- Observation well
- ●60 Number indicates depth to water
- [ ] Complete analysis given in Table 6
- ( ) Partial analysis given in Table 7
- S Surface water sampling point
- D Dry hole

0 1 2 3 4
Scale in miles

Base compiled from maps prepared by the Soil Conservation Service

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Plate 3

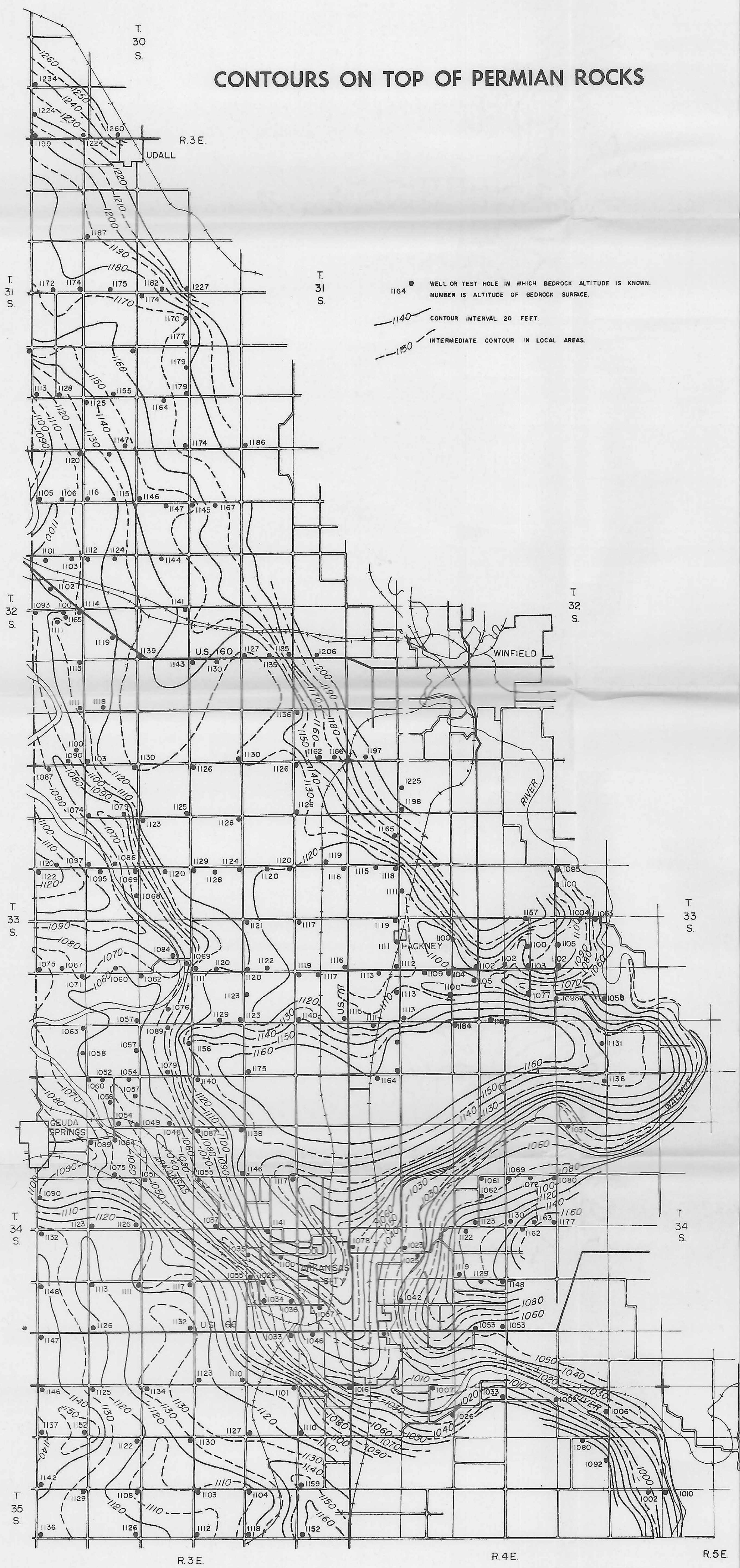
MAPS OF A PART OF COWLEY COUNTY, KANSAS

SHOWING BEDROCK CONTOURS, WATER-TABLE CONTOURS, AND SATURATED THICKNESS OF PLEISTOCENE DEPOSITS

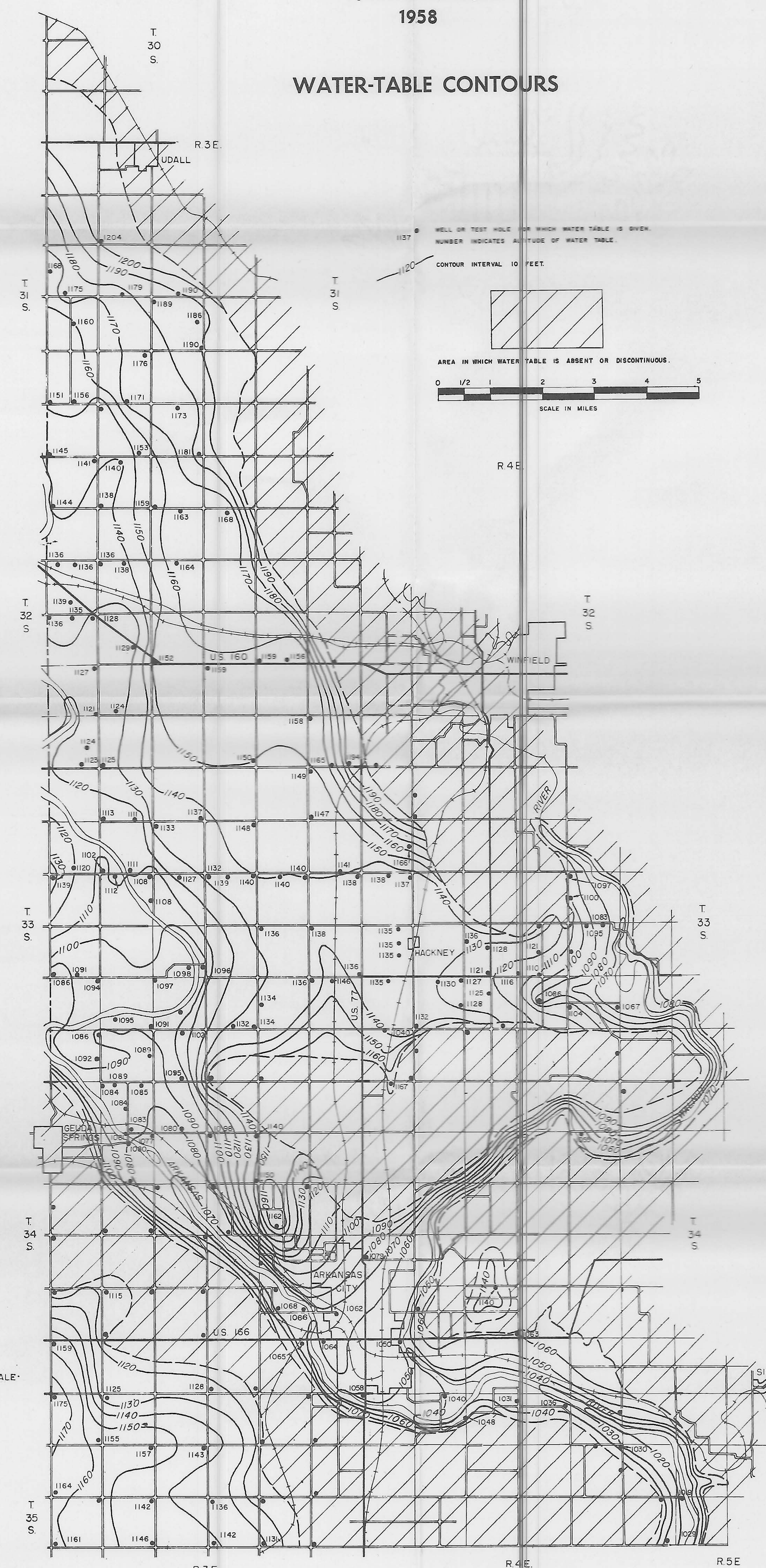
by Charles K. Bayne

1958

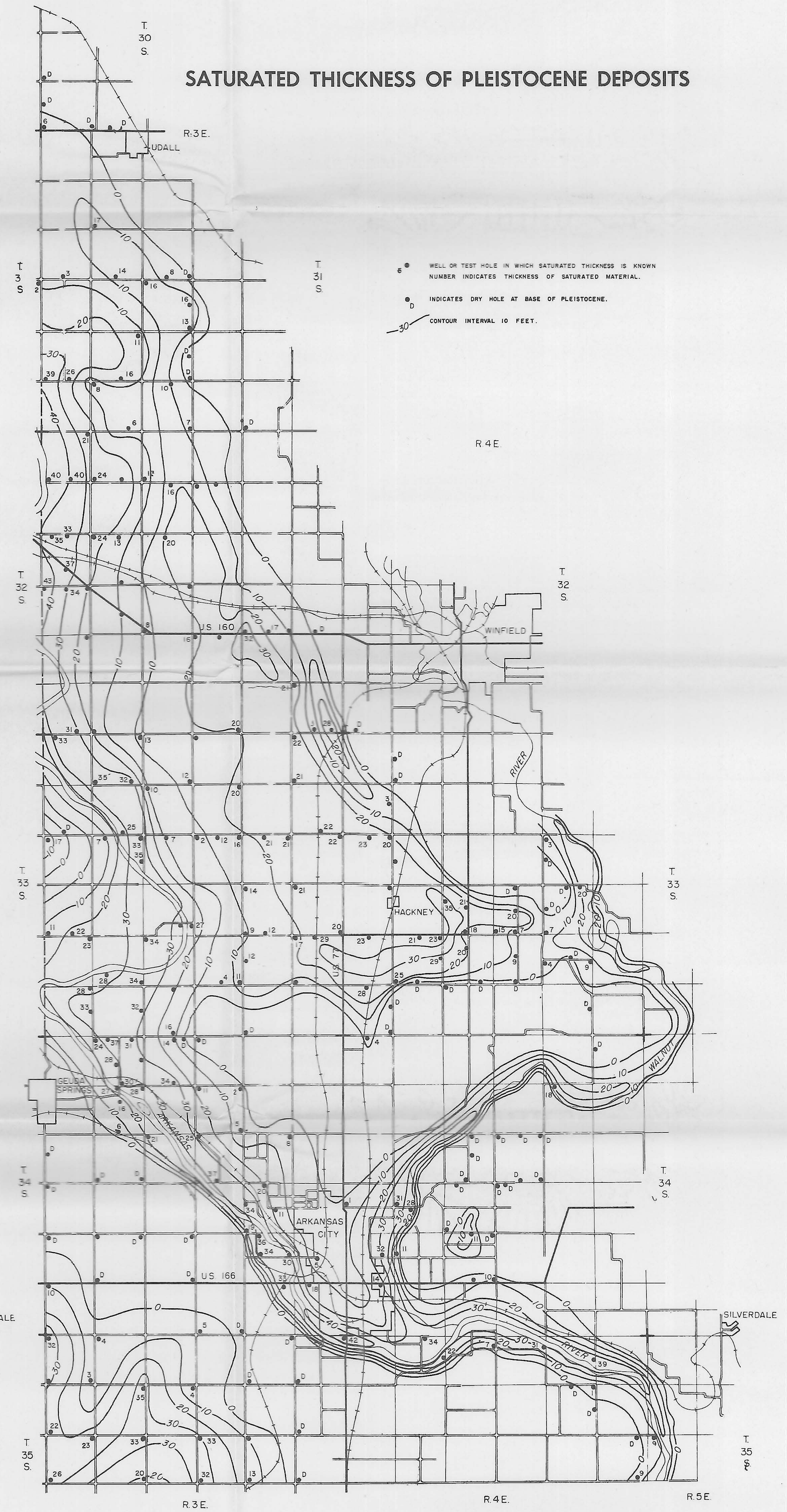
CONTOURS ON TOP OF PERMIAN ROCKS



WATER-TABLE CONTOURS



SATURATED THICKNESS OF PLEISTOCENE DEPOSITS



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GEOLOGIC SECTIONS IN COWLEY COUNTY, KANSAS

by Charles K. Bayne

1958

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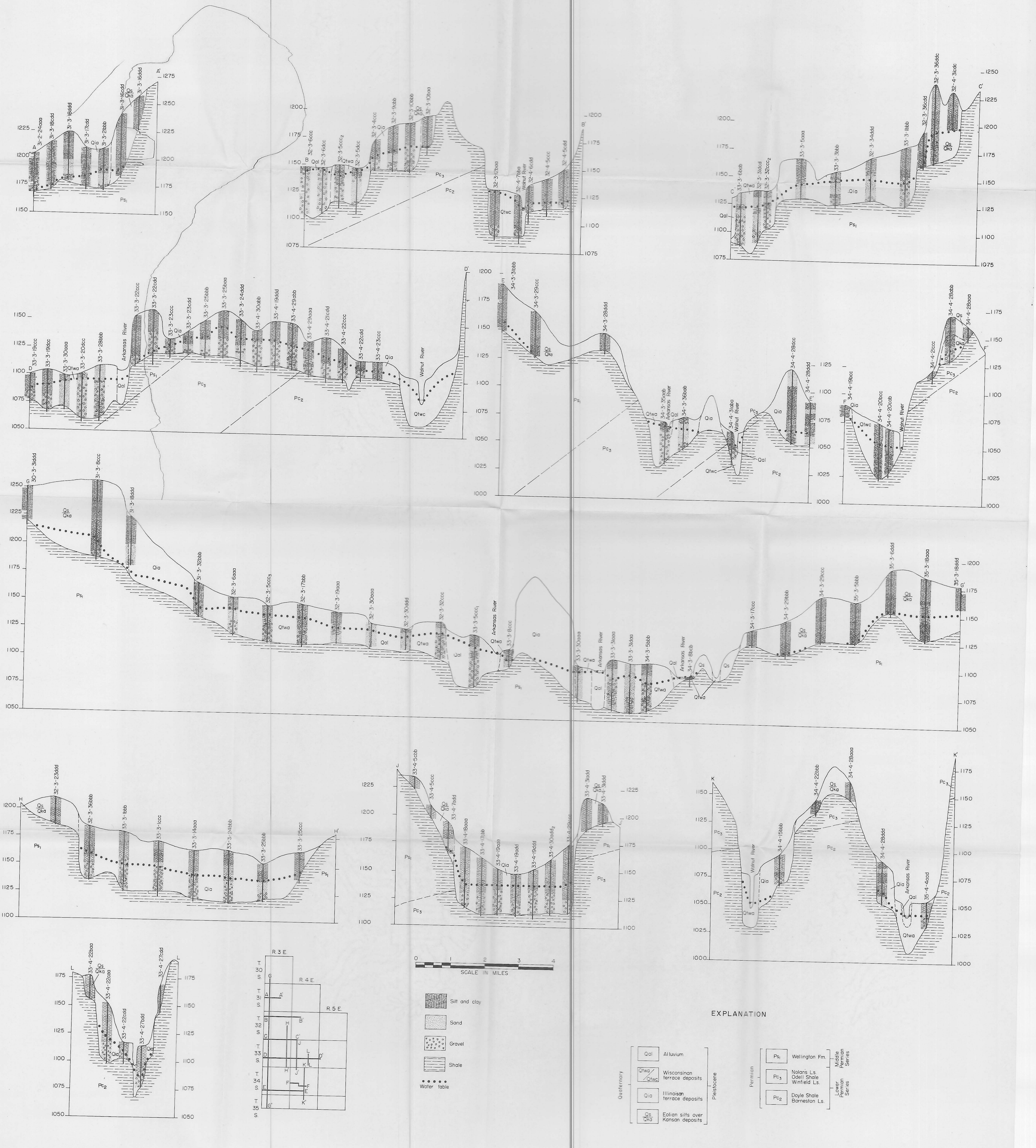

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STRUCTURE CONTOURS OF TOP OF DOUGLAS GROUP IN COWLEY COUNTY

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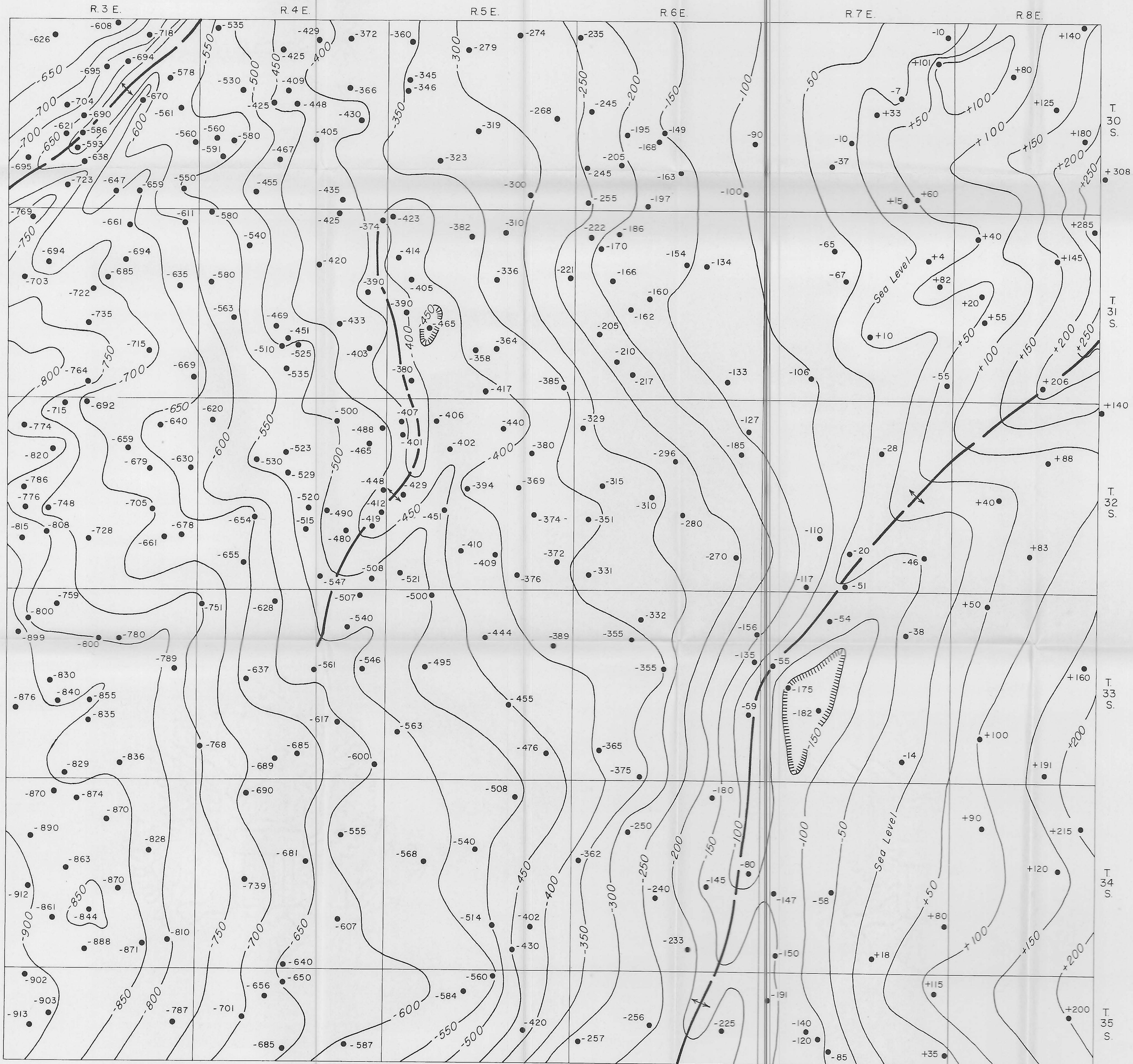

EXPLANATION

• Well penetrating Douglas rocks

Contour interval 50 feet

Datum mean sea level

+90, -40 Altitude above or below sea level

0 1 2 3 4 5 6
Scale in miles

Axis of anticline

MAP OF ARKANSAS VALLEY AREA

showing location and depth of test holes,
and chloride content of water samples

by
Charles K. Bayne
1960

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of Kansas

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Plate 6