STATE GEOLOGICAL SURVEY OF KANSAS

FRANKLIN D. MURPHY, M. D.,
Chancellor of the University, and ex officio Director of the Survey

FRANK C. FOLEY, Ph. D.,
State Geologist and Director

Division of Ground Water
V. C. FISHEL, B. S.,
Engineer in Charge

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GEOLOGY AND GROUND-WATER RESOURCES OF CLAY COUNTY, KANSAS

By KENNETH L. WALTERS and CHARLES K. BAYNE

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GEOLOGY AND GROUND-WATER RESOURCES OF CLAY COUNTY, KANSAS

By Kenneth L. Walters and Charles K. Bayne

ABSTRACT

This report describing the geography, geology, and ground-water resources of Clay County, in north-central Kansas, is based on hydrologic and geologic information obtained in the field during the fall of 1953 and the summer of 1954. The field data are given in tables; they include records of 143 wells, chemical analyses of water from 35 representative wells, logs of 28 test holes, and results of pumping (aquifer) tests. In addition, 110 holes were augered to determine the depth to water.

Clay County has an area of about 660 square miles and lies in the Great Plains and Central Lowlands physiographic provinces. Most of it is drained by Republican River; small areas are drained by Fancy Creek and Chapman Creek, which are not tributaries of Republican River. The normal annual precipitation at Clay Center is 27.92 inches, and the mean annual temperature is 55.1°F. Agriculture is the principal occupation in the county.

The rocks that crop out at the surface in Clay County are sedimentary and range in age from Permian to Recent. The oldest formation exposed in the county is the Barneston Limestone. The Dakota Formation, the youngest Cretaceous rock in the county, crops out over a large part of western and northern Clay County. The Permian and Cretaceous rocks are mantled in many places by unconsolidated continental deposits of fluviatile and eolian origin representing four stages of the Pleistocene Epoch.

The unconsolidated sand and gravel deposits of Pleistocene age form the principal aquifer in the county. These deposits are thickest and most extensive in the valley of Republican River. The Dakota Formation yields moderate quantities of water to wells in western and northern Clay County. The Barneston Limestone yields small to moderate quantities of water to wells in eastern Clay County. Ground water in the area is recharged principally from local precipitation; underflow from adjacent areas contributes significantly, however. Ground water is discharged mainly by seepage into streams and by transpiration by plants. All municipal and industrial water supplies and most domestic and stock supplies are obtained from wells. Irrigation from wells is practiced extensively in the valley of Republican River.

INTRODUCTION

Purpose and Scope of Investigation

A program of investigation of the ground-water resources of Kansas was begun in 1937 by the United States Geological Survey and the State Geological Survey of Kansas with the cooperation 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 of that part of Clay County that lies within the Republican

Valley was integrated with the program of the Interior Department for development of the Missouri River basin. The investigation upon which this report is based was begun in the fall of 1953 and field work was completed in the fall of 1955. It is similar to other investigations that have been completed or are being made in other counties in Kansas. The present status of investigations resulting from this program is shown in Figure 1.

Ground water is one of the principal natural resources of Clay County. Nearly all public, domestic, and industrial water supplies and many stock supplies are obtained from wells. Ground water is being used to some extent for irrigation, and recent interest in irrigation indicates that the use of ground water for this purpose probably will increase greatly in the future. Withdrawal at the present rate has not seriously depleted the ground-water supply or resulted in impairment of the quality of the water by encroachment of water of poor quality, but there is need for an adequate understanding of the quality and quantity of ground water available.

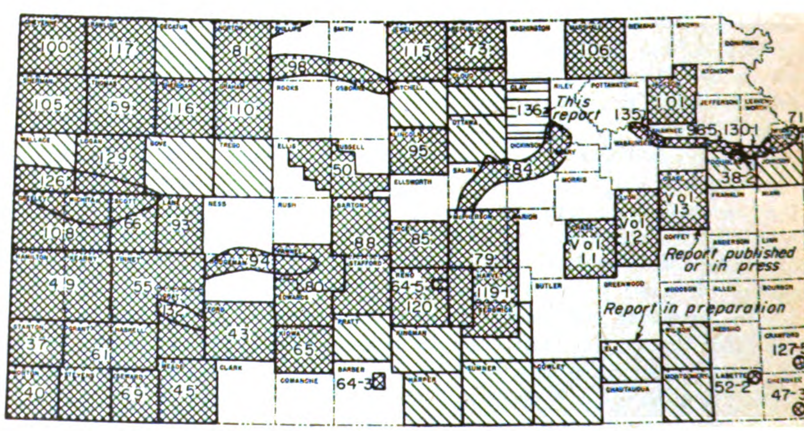

Fig. 1.—Index map of Kansas showing area discussed in this report and other areas for which ground-water reports have been published or are in preparation.

Location and Extent of Area

Clay County is in north-central Kansas, in the second tier of counties south of the Nebraska line and about 50 miles east of the center of the state. The county is bounded on the west by Ottawa and Cloud Counties, on the north by Washington County, on the east by Riley and Geary Counties, and on the south by Dickinson County; it has an area of 660 square miles.

Previous Investigations

The principal studies of the geology and ground-water resources of north-central Kansas that have a direct bearing on Clay County are cited below. Specific references are cited by author and date at appropriate places in the text; all are listed in the references at the end of the report.

The geology of the Upper Cretaceous rocks in Kansas was described by Logan (1897). Darton (1905) made reference to wells in north-central Kansas in a preliminary report on the geology and ground-water resources of the central Great Plains. Haworth (1913) prepared a report on well waters in Kansas in which he discussed the availability of ground water in the Republican River valley. Jewett (1941) prepared a report on the geology of Riley and Geary Counties; in the western part of these counties the geology is very similar to that in eastern Clay County. Plummer and Romary (1947) prepared a report on clay in Kansas in which they described the ceramic characteristics of the clays of the Dakota Formation in the area. Schoewe (1952) in a report on the coal resources of the Dakota Formation described coal reserves in the county. Frye and Leonard (1952) in a report on the Pleistocene geology of Kansas described unconsolidated deposits in the Republican River valley in Clay County.

Methods of Investigation

One month in the fall of 1953, four months in the summer of 1954, and one month in the fall of 1955 were spent in the field collecting the data upon which this report is based. The geology was mapped on aerial photographs from field observations and from stereoscopic study of the photographs. This information was transferred from the photographs to a base map modified from a map prepared by the Soil Conservation Service of the Department of Agriculture.

Data on the character of the water-bearing material, and on the depth, depth to water, and yield of 143 wells were collected (Table 10). Holes were augered with a power auger at 110 locations in order to gather both geologic and hydrologic information. Additional information on the material below the land surface was obtained by drilling 28 test holes with a hydraulic rotary drilling machine owned by the State Geological Survey of Kansas and operated by E. L. Reavis and William Gellinger. Logs of the test holes were prepared in the field, and the drill cuttings were studied microscopically in the laboratory. Altitudes at the surface of the wells and test holes were determined by a level party headed by Mr. Reavis using an alidade and plane table.

Several pumping (aquifer) tests were made to determine the hydraulic characteristics of the water-bearing deposits.

Thirty-three samples (two composite) of water from 35 wells and test holes were collected, and chemical analyses of the samples were made by Howard Stoltenberg, chemist in the Water and Sewage Laboratory of the Kansas State Board of Health (Table 3).

Well-Numbering System

In this report the wells, auger holes, and test holes are numbered according to their location as given by the General Land Office system of land classification. The component parts of a well number are the township number, range number, section number, and two or three lowercase letters that indicate respectively the quarter section, quarter-quarter section, and, if there are three, the quarter-quarter-quarter section in which the well is located. The lowercase letters are assigned to the quarter divisions in a counterclockwise direction, beginning in the northeast quarter of each section or subdivision. For example, well 6-1-2baa (Fig. 2) is in the NE¼ NE¼ NW¼ sec. 2, T. 6 S., R. 1 E. If there are two or more wells in the same quarter-quarter-quarter section they are numbered serially according to the order in which they were inventoried.

Acknowledgments

Appreciation is expressed to the many residents of Clay County who supplied information and aided in the collection of field data. Special acknowledgment is due the officials of the cities and industries who provided information about their water supplies. Acknowledgment is made also of information supplied by George Cox, driller, and E. H. Erickerman, irrigation-equipment supplier. F. Turner and H. Rhodes were very cooperative in permitting aquifer tests using their wells. Judge Walter O. Curtis of Clay Center was helpful in supplying information about some of the older wells in the area.

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 George S. Knapp, 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.

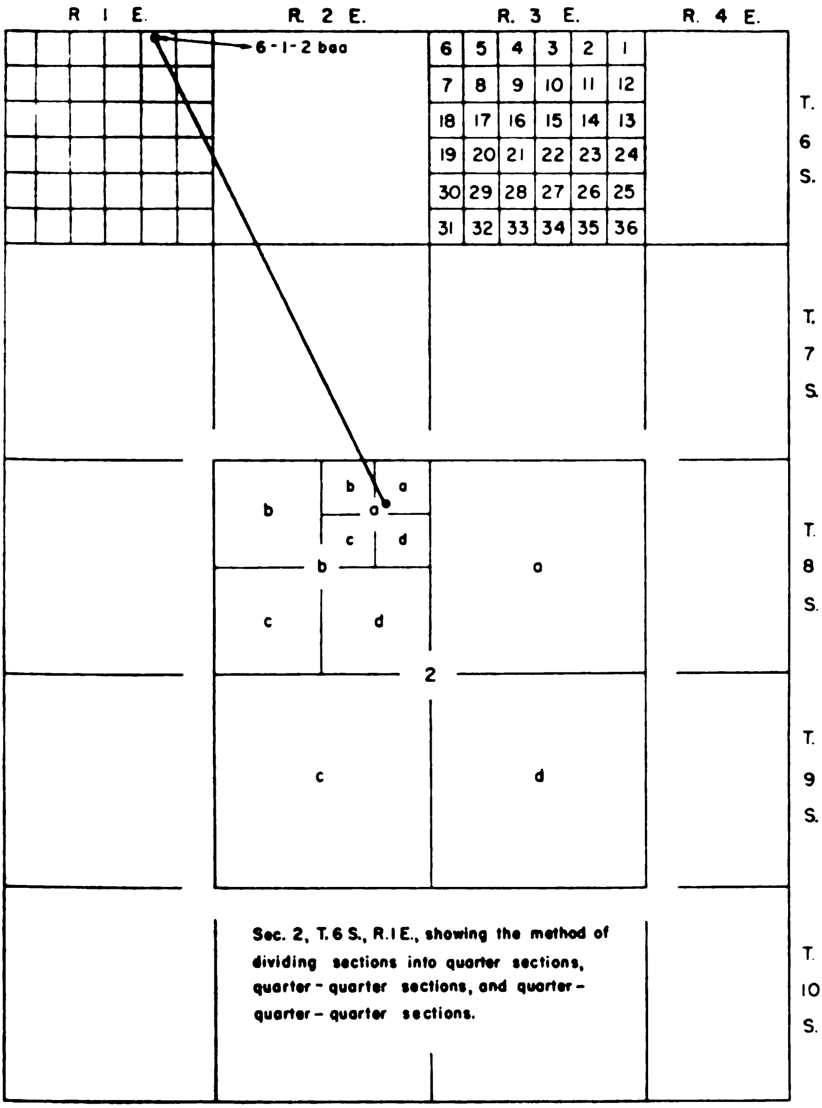

FIG. 2.—Map of Clay County illustrating well-numbering system used in this report.

GEOGRAPHY

Topography and Drainage

Schoewe (1949) placed the western part of Clay County in the Smoky Hills division of the Dissected High Plains section of the Great Plains physiographic province and the eastern part of the county in the Flint Hills Upland division of the Osage Plains section of the Central Lowlands physiographic province. The border between the two divisions roughly coincides with the contact between the Cretaceous (Dakota Formation) and Permian (Wellington Formation) rocks through the county. The topography is varied. In the western part of the county, areas underlain with Dakota Formation typically are gently rolling surfaces dotted with numerous mounds or buttes capped by sandstone. East of the outcrop of the Dakota Formation the topography is influenced by the thick shales of the Wellington Formation, which produce a gently rolling surface dissected by streams. Local relief is relatively small. The topography in the easternmost part of the county is dominated by the bedrock of the Chase Group. Here gently rolling uplands contrast with sharp breaks into the valley areas, and the relief is considerably greater than that to the west in the outcrop area of the Wellington Formation. The broad, flat terraces in the valley of Republican River are important for agriculture and ground water.

The highest points in Clay County (about 1,500 feet above sea level) are the hills formed by sandstone of the Dakota Formation a short distance northeast of Oak Hill, and the lowest point (altitude about 1,100 feet) is in the Republican River valley in the southeastern part of the county.

Approximately two-thirds of Clay County lies in the drainage basin of Republican River. The river enters the county near the northwest corner, flows southeastward across the county, and leaves the county a short distance north of the southeast corner. An area of about 50 square miles in northeastern Clay County drains into Fancy Creek and thence into Big Blue River. In southwestern Clay County an area of about 120 square miles drains into Chapman Creek and thence into Smoky Hill River.

Climate

The U. S. Weather Bureau has maintained precipitation and temperature gages at Clay Center since 1902. The normal annual precipitation at Clay Center is 27.92 inches. The annual precipitation and the cumulative departure from normal for the period of record are shown graphically in Figure 3. The precipitation has ranged from a low of 15.57 inches in 1934 to a high of 53.86 inches in 1951. About three-quarters of the precipitation falls during the 6-month period between April 1 and September 30, which is the period most favorable for growing crops. The normal monthly precipitation is shown graphically in Figure 4.

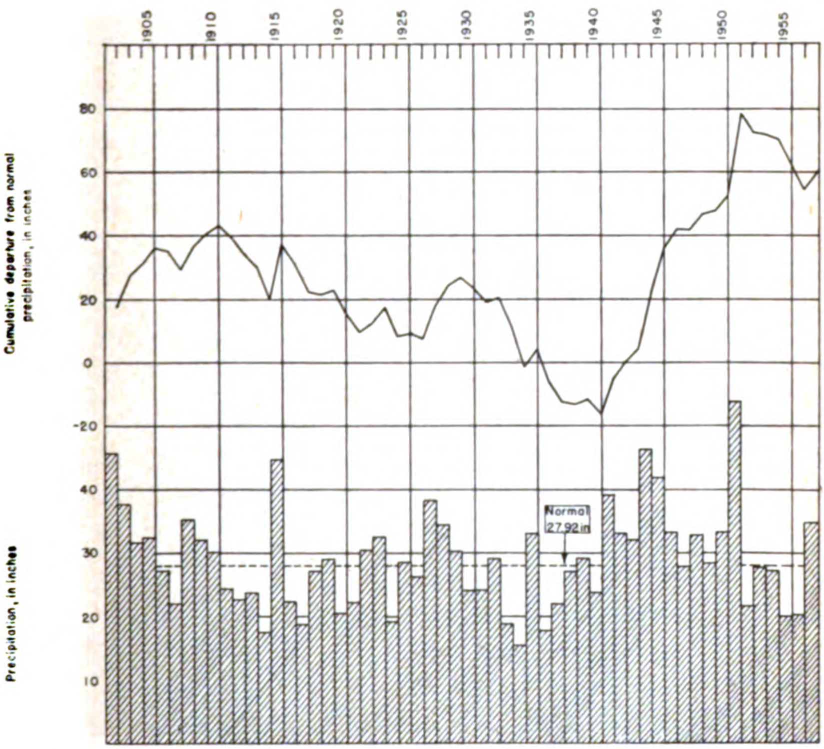

FIG. 3.—Annual precipitation and cumulative departure from normal precipitation at Clay Center.

The mean annual temperature at Clay Center is 55.1°F. The growing season in Clay County has ranged from 139 days to 213 days and averages 173 days. The earliest killing frost of record occurred on September 20, 1918; the latest, May 27, 1907.

POPULATION

According to the 1950 census, the population of Clay County was 11,697 and average density was 17.8 persons per square mile as compared with 23.1 per square mile for the entire state. The census records show that there has been a gradual decline in popu-

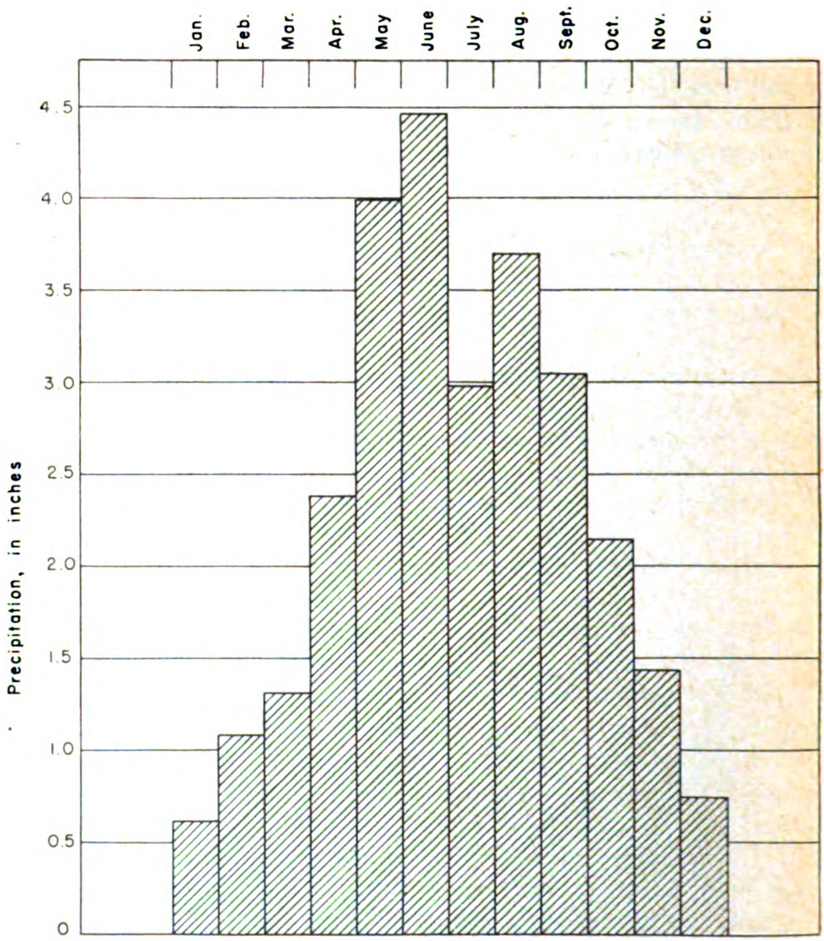

FIG. 4.—Normal monthly precipitation at Clay Center.

lation in the last 20 years, averaging about 140 persons a year. The urban population has remained about the same since the 1940 census, but the rural population has decreased. The principal cities and their population as shown by the 1950 census are as follows: Clay Center, 4,528; Clifton, 365; Green, 219; Longford, 178; Morganville, 278; Oak Hill, 92; Vining, 85; and Wakefield, 591.

TRANSPORTATION

Clay County has good transportation facilities. All but one of the cities are served by one or more railroads. Broughton, Clay Center, Morganville, Clifton, and Vining are served by a branch line of the Chicago, Rock Island and Pacific Railroad Company. Longford and Oak Hill are served by a branch line of the Atchison, Topeka and Santa Fe Railroad Company. Wakefield, Broughton, Clay Center, Idana, and Browndale are served by a branch line of the Union Pacific Railroad. The city of Green was formerly served by another branch line of the Union Pacific, but this line has been abandoned.

Clay County is served by a good state and national highway system. U. S. Highway 24 crosses the county from east to west through Clay Center. Kansas Highway 15 crosses the county from north to south, and Kansas Highway 9 crosses the northwestern part of the county from Kansas Highway 15 west through Clifton. Kansas Highway 82 crosses the southeastern part of the county from Kansas Highway 15 east through Wakefield. All state and federal highways are hard surfaced, as are many of the county highways. Most of the township roads are graded and many of them are all-weather roads.

Agriculture

Agriculture is the principal occupation in Clay County. About 85 percent of the land area in the county is used for agriculture, about one-third pasture and two-thirds cultivated. Wheat is the principal crop and is planted on about half the cultivated land.

The principal crops and the acres harvested in 1955 are as follows: Wheat, 94,000 acres; corn, 22,000 acres; alfalfa, 38,500 acres; sorghums, 21,700 acres; oats, 17,200 acres; and wild hay, 8,500 acres.

Ranking equally in value with grain and hay in the county is livestock products. In order of value these animal products are cattle, poultry and eggs, dairy products, and hogs. The value of livestock, poultry, milk, and eggs in 1955 was about $5,267,000, that of all grains and hay harvested was about $5,225,000 in 1955.

Mineral Resources

Construction Materials

Geologic materials that would be useful in construction projects include the alluvial deposits in the major stream valleys, sandstones and clays of the Dakota Formation, and Permian limestones in the eastern part of the county. For discussion these materials are classified according to use.

Concrete aggregate.—Aggregate for concrete consists of fragments of hard, durable minerals or rocks of sand and gravel size.

The constituent particles should be free from adherent coatings or particles that would interfere with the bonding of the cement and the aggregate. An almost unlimited quantity of sand and gravel is available from the alluvial deposits in the Republican River valley. Crushed limestone aggregate can be produced in large quantities from the Permian limestones in the eastern part of the county. Material for the manufacture of lightweight aggregate is available from the Dakota Formation and from thin deposits of the Kiowa Shale.

Road metal.—Road-surfacing material is available in large quantities from the sand and gravel in the alluvial deposits of the Republican River valley. Sandstone and iron-cemented sandstone of the Dakota Formation can be crushed for road metal and are used extensively in the western part of the county. Crushed limestone from the Permian beds is used extensively in the eastern part of the county.

Mineral filler.—Silts from loess deposits of the Sanborn Group and from terrace deposits in the Republican River valley are available and are used in large quantities for mineral filler in road-surfacing material in the county.

Structural stone.—Structural stone is any hard dense rock that can be quarried and cut to the desired size and shape. Materials that meet these requirements are found in the Cresswell Limestone member of the Winfield Limestone and the Fort Riley Limestone member of the Barneston Limestone. These limestones are found in the eastern part of the county, and many buildings in the area have been constructed from materials taken from small local quarries.

Agricultural Limestone

Limestone having a calcium carbonate equivalent of 80 percent or more and occurring in ledges sufficiently thick to allow economical quarrying is regarded as a potential source for agricultural limestone. In Clay County most of the limestones, especially the Cresswell Limestone member of the Winfield Limestone and the Fort Riley Limestone member of the Barneston Limestone, meet this requirement. Some zones in many of the shales contain enough calcium carbonate to be used for agricultural limestone.

Oil

Oil was discovered in the Wakefield pool in Clay County in 1928. The producing zone was the "Chat" at the top of the Mississippian rocks at a depth of 1,774 feet. After about 2 years the well was abandoned, but in 1951, production was resumed in this pool, and the Wakefield Northeast pool was discovered. In 1952, one well was added to each pool. No production figures are available for Clay County. Of 25 oil tests drilled in the county, 5 have produced some oil.

Gypsum

Gypsum is not produced commercially in Clay County, although there is a deposit in the NW¼ SW¼ sec. 19, T. 6 S., R. 4 E. Its areal extent is not known, but the geology and topography are such that the gypsum may extend over a considerable area. Unusually high sulfate content of water samples in the area probably indicates the presence of gypsum, though possibly not in commercial quantity. Test hole 6-4-19cb penetrated 13 feet of gypsum, including one seam of clean gypsum 8 feet thick. This deposit rests on the Herington Limestone member of the Nolans Limestone.

Ceramic Raw Materials

By Norman Plummer

Although there is no ceramic industry in Clay County at present, there is available an abundance of clay and shale suitable for use in the manufacture of structural brick and tile, fire brick, and pottery. The most important ceramic clay deposits are in the Dakota Formation, which is exposed in the western and northern parts of the county. Many of the clay deposits in the Dakota Formation fire to light colors ranging from ivory to buff. Most such clays are refractory and could be used for making Low Duty and Intermediate Duty fire brick as well as face brick and pottery. Other clays of the Dakota Formation fire to darker colors ranging from dark buff to deep red (Plummer and Romary, 1947).

Most of the Pleistocene loess deposits of the county are suitable for use in the manufacture of common brick, or as a flux for mixing with the more refractory clays. Such blends are especially suitable for the manufacture of sewer pipe (Frye, Plummer, Runnels, and Hladik, 1949).

Permian shale was at one time used in the manufacture of brick at a plant a short distance southeast of Clay Center. Although acceptable brick can be made from this material, it would be considered inferior in the light of modern standards of brickmaking, and because high-quality raw materials are available it probably would not be used.

The Kiowa Shale of Cretaceous Age, which underlies the Dakota Formation, is an excellent "bloating" shale from which a good grade of lightweight concrete aggregate could be produced.

TABLE 1.—*Generalized section of outcropping geologic rock units in Clay County*

System	Series	Stage	Group	Formation	Member	Thickness (feet)	Physical character	Water supply
Quaternary	Pleistocene	Recent		Dune sand		0–35	Fine to medium quartz sand, and some silt.	Above the water table, and does not yield water to wells in Clay County.
				Alluvium		0–70	Stream-deposited clay, silt, sand, and gravel. Generally graded, the coarser materials at the base.	Yields large quantities of water to wells in Clay County.
		Wisconsinan	Sanborn	Peoria		0–20	Wisconsinan terrace deposits and the Crete formation consist of stream-deposited beds of silt, clay, sand, and gravel. Loveland and Peoria formations consist of massive eolian deposits	Wisconsinan terrace deposits yield large quantities of water in Republican River valley and smaller amounts along tributary streams. Silt units yield little or no water to wells. Crete formation yields small to moderate quantities of water to wells in Clay County.
				Wisconsinan terrace deposits		0–70		
		Illinoian		Loveland		0–25		
				Crete		0–25		
		Kansan	Meade	Sappa		0–5	Gray clay and silt.	Does not yield water to wells in Clay County.
				Grand Island		0–10	Locally derived gravel.	Yields moderate amounts of water to wells in Clay County.
Cretaceous	Gulfian			Dakota Formation	Janssen Clay Terra Cotta Clay	0–165	Varicolored silty and sandy shale and massive sandstone beds.	Yields moderate amounts of water to wells in Clay County.
	Comanchean			Kiowa Shale		0–50	Dark fissile shale containing a few thin streaks of sand and silt.	Does not yield water to wells in Clay County.

Permian	Leonardian		Sumner	Wellington Formation		0-250	Chiefly gray shale; some red and green shale in lower part. Contains discontinuous beds of gypsum and impure limestone.	May yield small quantities of somewhat mineralized water to wells in Clay County.
	Wolfcampian		Chase	Nolans Limestone	Herington Ls. Paddock Shale Krider Ls.	18-23	Sandy and dolomitic yellowish-gray limestone and gray and red shale.	Yields small to moderate quantities of water to wells in Clay County.
				Odell Shale		20-24	Chiefly gray shale, varicolored in the upper part.	Does not yield water to wells in Clay County.
				Winfield Limestone	Cresswell Ls. Grant Shale Stovall Ls.	21-25	Massive fossiliferous upper limestone, gray and yellow-gray shale, and lower cherty limestone.	Yields small to moderate quantities of water to wells in Clay County.
				Doyle Shale	Gage Shale Towanda Ls. Holmesville Shale	65-70	Gray and varicolored shale and impure limestone.	May yield small quantities of water to wells in Clay County.
				Barneston Limestone	Fort Riley Ls. Oketo Shale Florence Ls.	75-85	Thick, massive limestone members separated by a thin shale member; lower limestone very cherty.	Yields moderate amounts of water to wells in Clay County.

GEOLOGY

Summary of Stratigraphy *

The areal geology of Clay County is shown on Plate 1. The rocks cropping out in the county are of sedimentary origin. The oldest rock exposed at the surface is the Barneston Limestone of the Chase Group, Wolfcampian Series, Permian System. It is exposed in the valley wall of Republican River in the vicinity of Wakefield. Successively younger Permian rocks are exposed west of the outcrop of the Barneston Limestone. The Wellington Formation, the youngest Permian formation in Clay County, is exposed in a wide belt extending across the county from north to south.

The Kiowa Shale is known to overlie the Wellington Formation in southwestern Clay County, but it is so poorly exposed that it is mapped with the Dakota. The Dakota Formation, the youngest Cretaceous rock unit in the county, crops out over a large part of western and northern Clay County.

Much of the upland area is blanketed by eolian silt or loess of Pleistocene age. Extensive Pleistocene alluvial deposits occur in the valleys.

A generalized section of the outcropping rock units of Clay County is given in Table 1. More detailed descriptions of these units are given in the section on rock units and their water-bearing characteristics.

Pre-Cenozoic Geologic History

Although exposed rocks in Clay County total only a few hundred feet in thickness, a great deal is known about the much thicker sequence of deeply buried rocks through the interpretation of deep tests for oil and gas. The geologic history during the Paleozoic Era, as it is discussed here, is based chiefly on reports by Jewett (1949) and by Lee, Leatherock, and Botinelly (1948).

Paleozoic Era

Clay County, like the rest of Kansas, is underlain by a basement complex of Precambrian crystalline rocks. The area that is now Clay County was invaded by the sea during Cambrian time, and remained an area of marine deposition during most of the Paleozoic Era. Rocks representing each of the systems of the Paleozoic Era are present, but leveling by erosion of certain beds indicates that the area was not always stable and was elevated above sea level

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

from time to time. Clay County is in the central part of the early Paleozoic North Kansas Basin and on the eastern flank of the late Paleozoic Salina Basin. Sedimentary rocks present under Clay County total about 3,000 feet in thickness.

Mesozoic Era

The Paleozoic Era was brought to a close by uplifting of the entire area by the end of Permian time. The area was above sea level and subjected to erosion throughout all of Triassic and Jurassic time. Erosion continued through Early Cretaceous time until the deposition of the Kiowa Shale during a brief invasion by the sea. As the sea retreated from the area, the Dakota Formation was deposited in shallow fresh water. The sea again invaded the area and marine deposition was resumed.

At the end of the Cretaceous Period an area far to the west was uplifted, forming the Rocky Mountains. The Mississippi Valley area also was uplifted at about the same time, resulting in a northwest regional dip of Cretaceous and older rocks in eastern and central Kansas.

Cenozoic Geologic History

Tertiary Period

After the withdrawal of the Cretaceous sea and the tilting of Cretaceous and older rocks, there was a long period of erosion. The Cretaceous rocks overlying the Dakota Formation were eroded from the area that is now Clay County. Late in the Tertiary Period (Pliocene Epoch) the area to the west of Clay County was receiving deposits of sand and gravel from the eroding Rocky Mountains. These sand and gravel deposits, the Ogallala Formation, may not have reached as far east as Clay County, but they are found in several scattered areas a few miles west of Clay County.

Quaternary Period—Pleistocene Epoch

The major events of the Pleistocene Epoch in this area were the establishment of new drainage lines and downcutting by existing streams, aggradation of the major streams, and the deposition of loess. The relation of the Pleistocene deposits is shown in Plate 3.

At the beginning of the Pleistocene Epoch, Clay County probably was drained by a system of small streams, none of whose headwaters were very far from the county. Climatic changes associated with the advance of the glacial ice fronts during the Pleistocene Epoch resulted in increased streamflow and downcutting by streams. There was little or no deposition along streams in Clay County during the first glacial stage, the Nebraskan. The second glacial stage, the Kansan, continued much as the Nebraskan stage had been. In early Illinoian time, the ancestral Republican River became blocked by ice or choked by sediments. The ancestral Republican River followed approximately the course of the present Republican River from its headwaters to the city of Republic in Republic County. From this point the ancestral river flowed northeastward into Nebraska (Lohman, in Fishel, 1948). After the damming of the ancestral Republican River in early Illinoian time, the impounded waters spilled over the lowest part of a divide between Republic and Scandia in Republic County, and the present course of Republican River was established from Republic to Junction City. Republican River and several smaller streams in Clay County have alternated since late Kansan time between periods of deposition and periods of downcutting, so that the valleys now contain terrace and alluvial deposits of Kansan, Illinoian, Wisconsinan, and Recent age.

During Recent time, sand has been carried from the flood plain of Republican River by the prevailing westerly winds and has been deposited in several places as sand dunes on the alluvium and Wisconsinan terraces.

GROUND WATER

Principles of Occurrence

The rocks and surficial deposits that form the crust of the earth are, in general, not solid throughout, but contain many open spaces, called voids or interstices, and it is in these spaces that water is found below the surface of the earth and from which it is recovered, in part, through springs and wells. 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 occurrence of ground water in any region, therefore, is determined by the geology of that region.

The interstices of rocks range in size from pores of microscopic dimensions to openings several inches or feet in width. These interstices can be divided into two classes, primary interstices and secondary interstices. The primary or original interstices were formed during the formation of the rocks. Secondary interstices were developed by the different processes that affected the rocks after deposition. In Clay County all the water-bearing rocks are sedimentary, and the openings that hold the water are either open pore spaces between the grains of rock (primary interstices) or joints and open bedding planes, which have resulted from deformation of the rocks, and openings caused by solution of the rocks. These are secondary interstices.

The amount of water that can be stored in any rock depends upon the porosity of that rock. Porosity is expressed quantitatively 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 that a rock can hold is determined by its porosity, but the rate at which it will yield water to wells is determined by its permeability. The permeability of a rock is its ability to transmit water under hydraulic gradient and is measured by the rate at which the 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 have a high porosity, but because the interstices are small and poorly connected, they transmit little or no water, and the rock may be regarded as virtually impervious. Rocks differ greatly in their degree of permeability, according to the number, size, and interconnection of their interstices.

Source

Ground water is the part of the water below the surface of the earth that supplies wells and springs. In Clay County, ground water is derived entirely from precipitation, in the form of rain or snow, that falls directly on the county or on nearby areas. Part of the precipitation that falls as rain or snow is carried away by surface runoff and is discharged by streams, a part of it may evaporate, and a part may be absorbed by vegetation and transpired into the atmosphere. The part that escapes runoff, evaporation, and transpiration percolates slowly downward through the soil and underlying strata until it reaches the water table, where it joins the body of ground water in the zone of saturation. After reaching the ground-water body the water percolates slowly through the rocks in directions 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 shallow.

Artesian Conditions

Artesian conditions may exist where a water-bearing bed is overlain by a relatively impermeable bed that dips from its outcrop area toward the discharge area. Water entering the water-bearing bed in the outcrop area percolates downward to the water table and moves downdip beneath the confining bed. The weight of the water at higher levels in the confined bed creates a hydrostatic pressure in the water reservoir. When the confining bed is penetrated the water will rise in the drill hole to a level equal to the hydrostatic head of the aquifer at the point of discharge. If the pressure in the aquifer is sufficient to lift the column of water above the top of the aquifer, artesian conditions exist. If the pressure in the aquifer is sufficient to lift the water above the land surface, the well will flow naturally. Such a well is called a flowing artesian well. Well 8-4-21ac flowed when drilled, but as the flow continued only a few days, a pump was installed. A flowing well was observed a few hundred yards west of the Clay County line, in the NE¼ sec. 13, T. 8 S., R. 1 W. Geologic and topographic conditions indicate that similar flowing wells could be drilled in an adjacent area in Clay County.

Although only one flowing well is known to have existed in the county, it is probable that artesian conditions exist locally over much of the county. In western Clay County the Dakota Formation contains lenticular sandstone bodies semiconfined beneath clay and shale, and much of the water is probably under some hydrostatic pressure. In eastern Clay County the rocks are a sequence of limestones and relatively impermeable shales. The limestones are in general the best aquifers, and local structures create hydrostatic head within the aquifers; although wells may not flow at the surface, in many of them the water rises above the aquifer.

The Water Table and Movement of Ground Water

The configuration and gradient of the water table and the direction of ground-water movement generally can be shown by constructing a water-table contour map. In Clay County, however, the water table is not everywhere continuous, so the water-table contours shown on Plate 2 cover only part of the areas discussed below. Clay County can be divided into three general areas on the basis of the occurrence and movement of ground water. The largest of these areas is that underlain by rocks of Permian age; it includes roughly the area east of a north-south line passing through the center of Range 2 East (Pl. 1). Although the largest, this area is probably the least important as a source of ground water, because it is underlain chiefly by shale. Water is derived principally from limestones but occurs also in appreciable quantity in solution channels in gypsum deposits in the lower shales of the Wellington Formation. The regional dip in this area is westward, and the water moves downdip from the recharge area that lies to the east.

The second largest ground-water area is that underlain by the Dakota Formation (Pl. 1). In this area water is obtained from sandstones in the lower part of the Dakota Formation. Water-table contours were drawn over a part of this area (Pl. 2), but in the areas where the Dakota Formation is thin it was not feasible to construct contours. Also, in many areas the water levels in the shallow wells did not fit the contour pattern of the water levels in deeper wells. The shallow water seemed to occupy a perched or semiperched position in relation to the rest of the Dakota Formation, and for this reason the shallow water levels were not used in constructing the water-table contours. The movement of ground water in this area is generally eastward toward the valley of Republican River.

The third and most important ground-water area in the county is the Republican River valley. Water is obtained from unconsolidated alluvial deposits, and large supplies are available for irrigation. The Republican River valley can be divided into two areas. One area is that part of the valley above Clay Center, where the Nolans Limestone crops out in the valley walls, and the second area is that part of the valley below the outcrop of the Nolans Limestone. In the upper area the valley is broad and flat and the contours cross the valley nearly at right angles to the river and valley walls, indicating that the river is neither gaining water from the ground-water reservoir nor losing water to it. The portion of the valley below the Nolans Limestone outcrop is narrower, and the water-table contours intersect the river at sharp angles, indicating that the river is draining the ground-water reservoir in this area.

Recharge

The addition of water to the zone of saturation is known as ground-water recharge. Ground-water recharge in Clay County occurs by infiltration from precipitation within the county, by percolation from influent streams, and by subsurface inflow from adjacent areas.

Recharge from Precipitation

The areas in Clay County that are most favorable to ground-water recharge are the small dune tracts near Clifton and Wakefield, where poor drainage and permeable soils tend to reduce runoff and induce infiltration. Next in importance is the valley area, which is relatively flat and is underlain by very permeable materials. Much water enters the ground-water reservoir in the outcrop area of the Dakota Formation where permeable sandstones are at or near the surface, although the steep slopes of this area tend to encourage runoff.

Percolation from Outside the Area

Most of the recharge in the area underlain by the Permian rocks necessarily penetrates through the more porous limestone beds in their outcrop areas and moves downdip to places where it is discharged. East of Clay County the lower part of the Barneston Limestone is cherty and fractured, and this area is probably the most important recharge area contributing water to the Permian rocks in Clay County.

Much water moves across the west county line of Clay County, through the Dakota Formation (Pl. 2). This water moves in a generally eastward direction to be discharged by seeps and springs and directly into the Republican River valley.

Seepage from Streams and Ponds

Much water is stored in ponds in Clay County. A large part of this water is lost through evaporation and transpiration and a part is used by livestock. The remainder seeps into the ground and becomes ground water. Under normal conditions the streams in Clay County contribute but little water to the ground-water reservoir, but when the stream stage is high a part of the water enters the stream bank as "bank storage". This process may become an important source of recharge in the future if large-scale development of irrigation in the valley area lowers the water table in these deposits and permits infiltration from the streams.

Discharge

Ground water is discharged in Clay County by evaporation and transpiration, by seeps and springs, by wells, and by percolation to areas outside the county.

Discharge by Evaporation and Transpiration

In the areas in Clay County where the water table is only a few feet below the surface, water may be evaporated from storage. This is especially true in the valley of Republican River and to a lesser extent along the steeper slopes of the upland area where the water table is relatively near the surface and where seeps and springs occur. Transpiration accounts for much discharge in areas where the water table can be reached by the roots of plants.

Discharge by Seeps and Springs

The water-table contours (Pl. 2) indicate that ground water in the outcrop area of the Dakota Formation moves toward Republican River or its tributaries. Many springs and seeps occur along the valley walls and steep slopes adjacent to tributary streams, and a considerable quantity of water is discharged from storage by this means. Springs occur along the outcrop of the Permian limestones in eastern Clay County where structural conditions are favorable. This water has moved downdip from the recharge area farther east and is discharged in considerable quantity.

Discharge by Wells

Although large quantities of water are discharged through wells in Clay County, it is probable that the discharge of water by wells is small in comparison with discharge by other means. With increased development of irrigation, discharge by wells will become a more important factor.

Recovery

Principles of Recovery

When water is standing in a well the head of the water in the aquifer outside the well is in equilibrium with that in the well. When water is withdrawn from a well a difference in head is created between the water inside the well and the water outside the well for some distance from the well. The water table in the vicinity of the well develops a cone of influence (Fig. 5), which is deepest at the wall of the well and extends some distance around the well. An increase in the pumping rate of the well produces a greater drawdown.

The specific capacity of a well is the rate of yield per unit of drawdown and is generally given in gallons a minute per foot of drawdown. Specific capacity is generally determined after the well has been pumped for a period long enough to stabilize the drawdown.

The character of the water-bearing material and the type of construction control the yield, drawdown, and specific capacity of a well. If the water-bearing material is coarse and well sorted it will readily yield large quantities of water to wells and have a minimum drawdown. If on the other hand the material is fine and poorly sorted, it will offer much resistance to the movement of water and

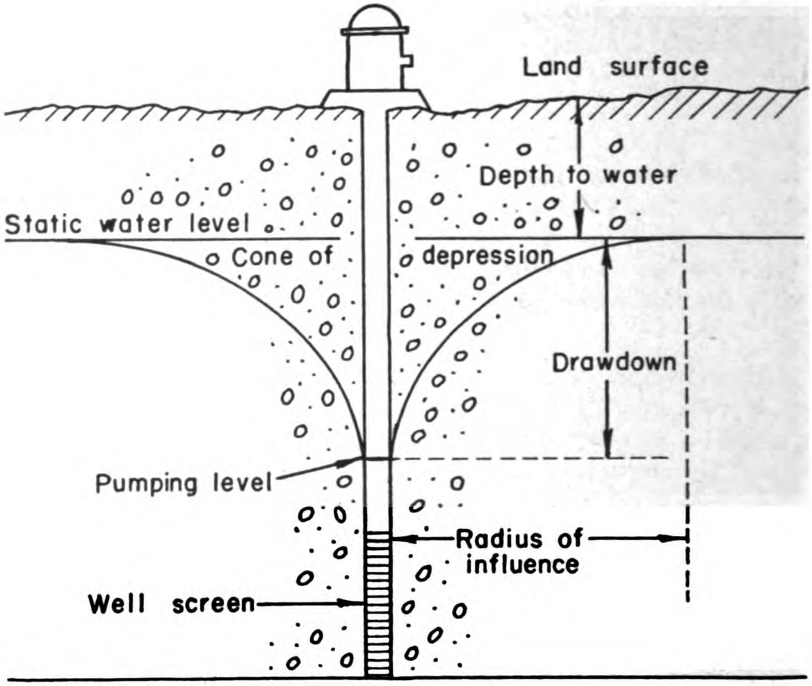

FIG. 5.—Diagrammatic section of well that is being pumped, showing drawdown, cone of depression, and radius of influence.

thereby yield less water and have a greater drawdown. All other things being equal, the drawdown of a well varies inversely with the permeability of the water-bearing material.

Types of Wells

Several different types of wells are used in Clay County for the recovery of ground water. Wells generally are classed according to the method of construction. The particular type of well used at any location depends on the geology of the area, the depth to water and thickness of the saturated material at the location, and the use for which the well is constructed.

Dug wells.—Dug wells are of large diameter, generally constructed with pick and shovel or other hand tools, and walled with stone, tile, or concrete. Such wells generally are constructed in areas where large supplies of ground water are not available, and the large hole is used as a storage reservoir, which provides water during periods of pumping and slowly fills when the pump is not running.

Driven wells.—Driven wells are constructed by driving a pipe, generally 1¼ to 2 inches in diameter and equipped with a screen, to a point below the water table. Such wells are pumped with some type of shallow-well pump. Most driven wells are in valley areas, for they are limited to areas where the water table is not much below 20 feet and where the deposits are unconsolidated. This type of well also is generally used when only small supplies of water are required.

Drilled wells.—Drilled wells are constructed by use of power-driven equipment to operate a percussion or rotary drill rig. This is the most common type of well in Clay County and is found in all types of material and in all localities. The depth of drilled wells is determined by the depth to the water table and the use for which the well is constructed. The use in turn may be limited by the quantity of water available. The diameter of drilled wells is generally dependent upon the use and desired quantity of water. Industrial, irrigation, and municipal wells require larger quantities of water and larger pumps and therefore require large-diameter holes to accommodate these pumps.

Utilization of Water

Ground water in Clay County is used chiefly for domestic, stock, and public supplies. Recent interest in irrigation in the valley areas in the county has caused an increase in the use of ground water for this purpose, and it is probable that there will be a considerable future increase. The quantity of water used for industrial purposes is small compared to that for other uses.

Domestic and Stock Supplies

Nearly all the domestic and stock supplies of water in rural areas and in small communities that do not have a public supply are obtained from privately owned wells. In the valley areas these supplies are obtained chiefly from drilled and driven wells. In the upland areas the water supplies are obtained from either dug or drilled wells. In several small areas underlain by shales of the Wellington Formation, there is a scarcity of wells and there are many abandoned farmsteads. A lack of dependable water supplies in these areas was a contributing factor in the abandoning of the farmsteads. In other areas the Wellington Formation yields water of good quality to wells.

Industrial Supplies

The quantity of water used for industrial purposes in Clay County is small in comparison with that for other uses. The Northern Natural Gas Company has four wells that yield water from terrace deposits in the Republican River valley in the NW¼ sec. 1, T. 6 S., R. 1 E. The wells are 50 feet deep, are equipped with turbine pumps, and pump an average of 325,000 gallons of ground water a day for cooling. In Clay Center, Swift and Company uses water from a well (8-3-8bb1) for cooling. This well is about 65 feet deep, is equipped with a turbine pump having a capacity of 120 gpm, and is pumped at an average rate of about 170,000 gpd. Well 8-3-8bc is owned by the Clay Center Coca Cola Bottling Company. This well is equipped with a jet pump having a capacity of about 50 gpm. The water is softened and the iron is removed. The average daily use is about 1,500 gallons.

Public Supplies

Seven cities in Clay County have public water supplies. These supplies are discussed in the following paragraphs.

Clay Center.—The Clay Center water supply is obtained from five wells drilled in the low terrace deposits in the Republican River valley. Three of these wells in Utility Park are 55 feet deep and the depth to water is about 22 feet. Well 8-3-8bb4 was tested for 8 hours at a rate of 850 gpm, and had a drawdown of 14 feet. Well 8-3-8bd in Dexter Park, which was drilled in the summer of 1954, yields water from terrace gravels. The well is 60 feet deep and the depth to water is about 29 feet. After the well was pumped 8 hours at a rate of 500 gpm, the drawdown was 4 feet. Well 8-3-8db, in the southeastern part of Clay Center, is a drilled well 58 feet deep and yields water from terrace gravels. In August 1954 the depth to water was 28 feet. All the wells are equipped with electric turbine pumps. The maximum capacity of the five wells is about 4 million gallons per day, and the average daily use is about 800,000 gallons. The water is chlorinated but receives no other treatment. The water is stored in an elevated steel tank having a capacity of 500,000 gallons. In addition to the five wells used for the public water supply, the city has four wells at the municipal power plant that provide water for cooling. These are drilled wells about 50 feet deep equipped with turbine pumps. The average daily pumpage from these wells is 1.7 million gallons.

Clifton.—The Clifton water supply is obtained from two wells (6-1-2bac1 and 6-1-2bac2) in the southwestern part of the city. The wells, which are equipped with turbine pumps, yield water from terrace deposits in the Republican River valley and are about 65 feet deep. The water level in August 1954 was about 30 feet. The drawdown in each of these wells is 7 feet at a pumping rate of 160 gpm. The maximum capacity of the two wells is about 360,000 gallons per day and the average daily use is 100,000 gallons. Hardness is reduced by pressure zeolite softeners and the water is chlorinated. A steel standpipe has a capacity of 90,000 gallons.

Green.—The Green municipal water supply is obtained from two wells (7-4-20ad and 7-4-21bc), which yield water from the Fort Riley Limestone member of the Barneston Limestone at depths of 170 and 190 feet respectively. The water is hard but receives no treatment. The capacity of the wells is about 30,000 gpd, and the average daily use is about 10,000 gallons. Water is pumped directly to an elevated concrete storage tank having a capacity of 60,000 gallons.

Idana.—The Idana water supply is obtained from one well (8-1-13ca) south of town in a creek valley. It yields water from terrace deposits along the edge of the valley. Average use at Idana is about 5,300 gpd. Storage capacity is 10,000 gallons in an underground steel tank.

Longford.—The Longford municipal water supply is obtained from two wells about half a mile west of the city. These wells (10-1-17dc1 and 10-1-17dc2) yield water from the Dakota Formation. The wells are 100 and 110 feet deep, respectively. The average daily pumpage is about 15,000 gallons. The water is chlorinated and delivered to the mains from an elevated concrete tank having a capacity of 60,000 gallons.

Morganville.—The Morganville water supply is obtained from two wells within the city limits. These wells (7-2-3cc and 7-2-4ddc) obtain water from terrace deposits in the Republican River valley. The wells are 53 and 57 feet deep, respectively, and are equipped with turbine pumps. Maximum daily yield is 160,000 gallons, and average daily pumpage is 30,000 gallons. The water is chlorinated and delivered to the mains from an elevated steel tank having a capacity of 50,000 gallons.

Wakefield.—The Wakefield water supply is obtained from two wells at the south edge of the city. These wells (10-4-5db1 and 10-4-5db2) obtain water from terrace deposits in the Republican River valley. The wells are 57 feet deep and are equipped with turbine pumps. The water levels in the wells were 34 feet below the surface in August 1954. After the wells are pumped for 24 hours at the rate of 100 gpm each, the drawdown is 2 feet. The yield of the wells as equipped is about 300,000 gpd, and average daily use is 80,000 gallons. The water is chlorinated and delivered to the mains from an elevated steel tank having a capacity of 30,000 gallons.

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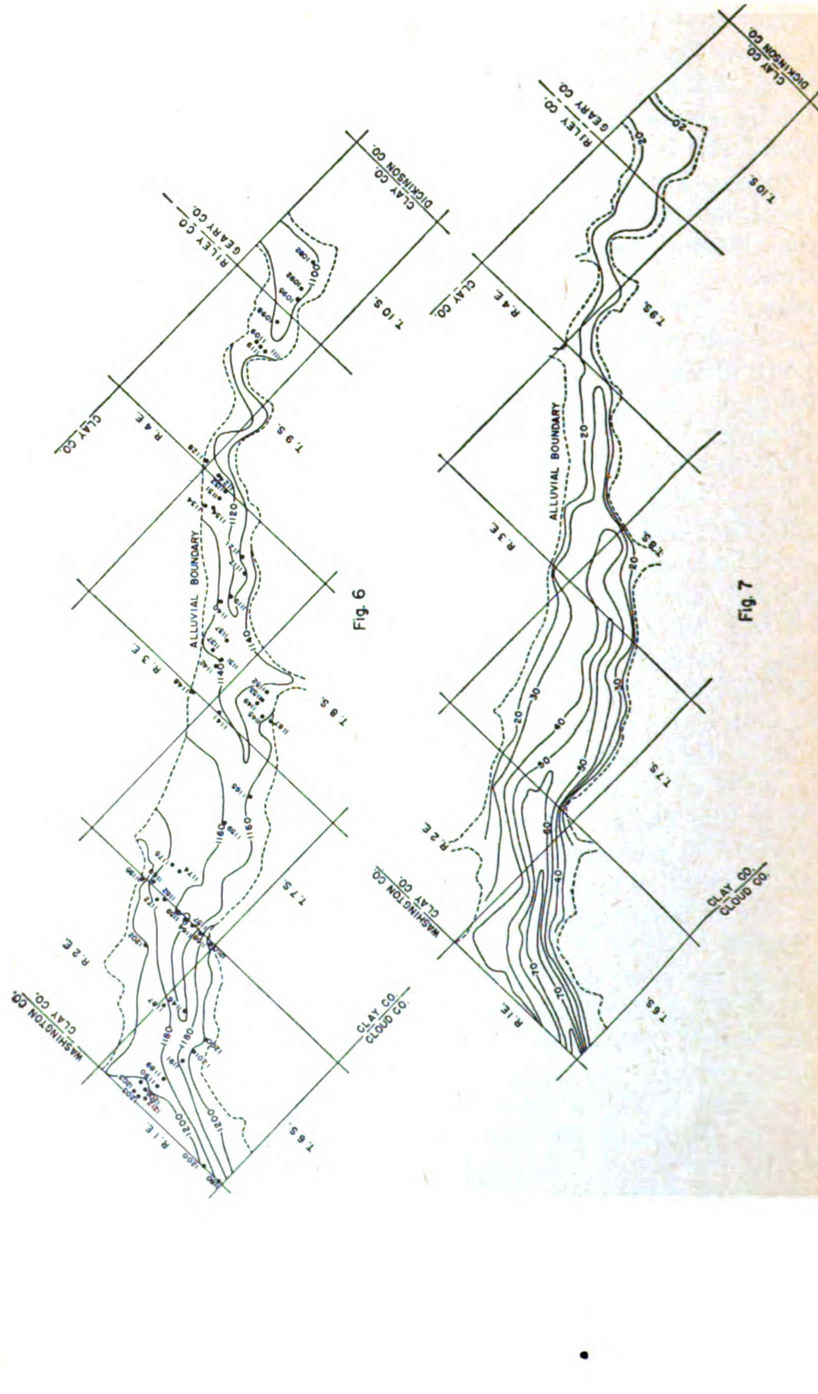

Fig. 6.—Configuration of bedrock surface in Republican River valley.
Fig. 7.—Thickness of saturated material in Republican River valley.

Irrigation Supplies

In the fall of 1954 six irrigation wells having a combined capacity of about 5,000 gpm were in operation in Clay County. Continued drought conditions during the growing season in 1955 intensified interest in irrigation, and by autumn 29 additional wells had been drilled, which had a combined capacity of about 21,000 gpm. In 1955 about 2,730 acre-feet of water was pumped for irrigation.

Four of the irrigation wells drilled in 1955 obtain water from the Barneston Limestone. The yields of these wells range from about 50 to 250 gpm. The other 25 wells obtain water from alluvial materials in the valley area. The yields of these wells range from 350 to 2,000 gpm.

Maps were prepared showing the configuration of the bedrock surface in the valley area (Fig. 6) and the water-table contours (Pl. 2). The water-table map was superposed over the bedrock map and a saturated-thickness map was prepared by connecting the points of equal thickness (Fig. 7). The bedrock contour map (Fig. 6) indicates that the pre-Pleistocene surface of the valley above Clay Center was a broad V-shaped valley in which the deeper part generally is near the center of the valley. Below Clay Center, where the limestones of Permian age cross the valley, the valley is also V shaped but is much narrower. The saturated-thickness map (Fig. 7) indicates that the thickest deposits of saturated material follow the deepest channels of the pre-Pleistocene surface shown in Figure 6, and the greatest thickness is in the northwest corner of the county, where the saturated materials are 80 feet thick. The thickness of these materials gradually decreases downstream to a point just west of Clay Center where the saturated material is only 40 feet thick, and below a point a short distance downstream from Clay Center the thickness of saturated materials is about 20 feet except in a very narrow channel cut in the pre-Pleistocene surface. The volume of saturated material in the valley area was determined from Figure 7, and by applying a specific yield of 20 percent the volume of water in storage was calculated. The volume of saturated material and volume of water in storage are given by townships in Table 2. Table 2 indicates that about 275,000 acre-feet of water is in storage west of the west line of Range 3 East and only about 45,000 acre-feet east of this line. The large amount of storage upstream from Clay Center in comparison with the small amount downstream is due to the great amount of alluvium upstream; the valley becomes narrower and shallower downstream because it is

TABLE 2.—*Volume of saturated water-bearing material in Republican River valley and volume of water in storage based on specific yield of 20 percent.*

Township	Acre-feet of saturated material	Acre-feet of water in storage
T. 6 S., R. 1 E.	560,000	110,000
T. 6 S., R. 2 E.	240,000	49,000
T. 7 S., R. 2 E.	510,000	100,000
T. 7 S., R. 3 E.	7,000	1,400
T. 8 S., R. 2 E.	100,000	20,000
T. 8 S., R. 3 E.	140,100	29,000
T. 9 S., R. 3 E.	13,000	2,600
T. 9 S., R. 4 E.	39,000	7,800
T. 10 S., R. 4 E.	32,000	6,400
Total	1,600,000	320,000

cut in the more resistant Permian limestones that cross the valley downstream, whereas upstream the less resistant Wellington and Dakota Formations form the bedrock underlying the valley area. The amount of water in storage (320,000 acre-feet) is equal to the quantity of water that would be pumped in 60 to 65 years at the 1955 rate of withdrawal for industrial and municipal use, which is about 5,000 acre-feet per year. This does not take into consideration any recharge to the valley during that period. The water-table contours indicate that water moves into the valley area, and although no quantitative data are available a considerable quantity of water must be contributed to the valley area in this way. Surface water is contributed to the valley through local drainage and through Republican River. Recent completion of reservoirs on Republican River in Colorado and Nebraska will aid in maintaining a minimum flow in the river. There seems to be no immediate danger of a serious depletion of ground water in storage in the Republican Valley, but a continued increase in the irrigation development will cause a lowering of the water table in the area and may diminish the streamflow during periods of heavy pumping.

CHEMICAL CHARACTER OF WATER

The chemical character of the ground water in Clay County is indicated by the analyses of 33 samples (2 composite) of water from 35 wells and test holes distributed as uniformly as practicable within the area and among the principal water-bearing formations (Table 3). A graphic representation of the chemical analyses of water from representative wells in the county is shown in Figures 8 and 9.

The depth given in Table 3 for the samples of water from test holes is the depth from which the sample was pumped. For all other samples of water the depth indicated is the total depth of the well. The samples of water were analyzed by Howard A. Stoltenberg, chemist, in the Water and Sewage Laboratory of the Kansas State Board of Health.

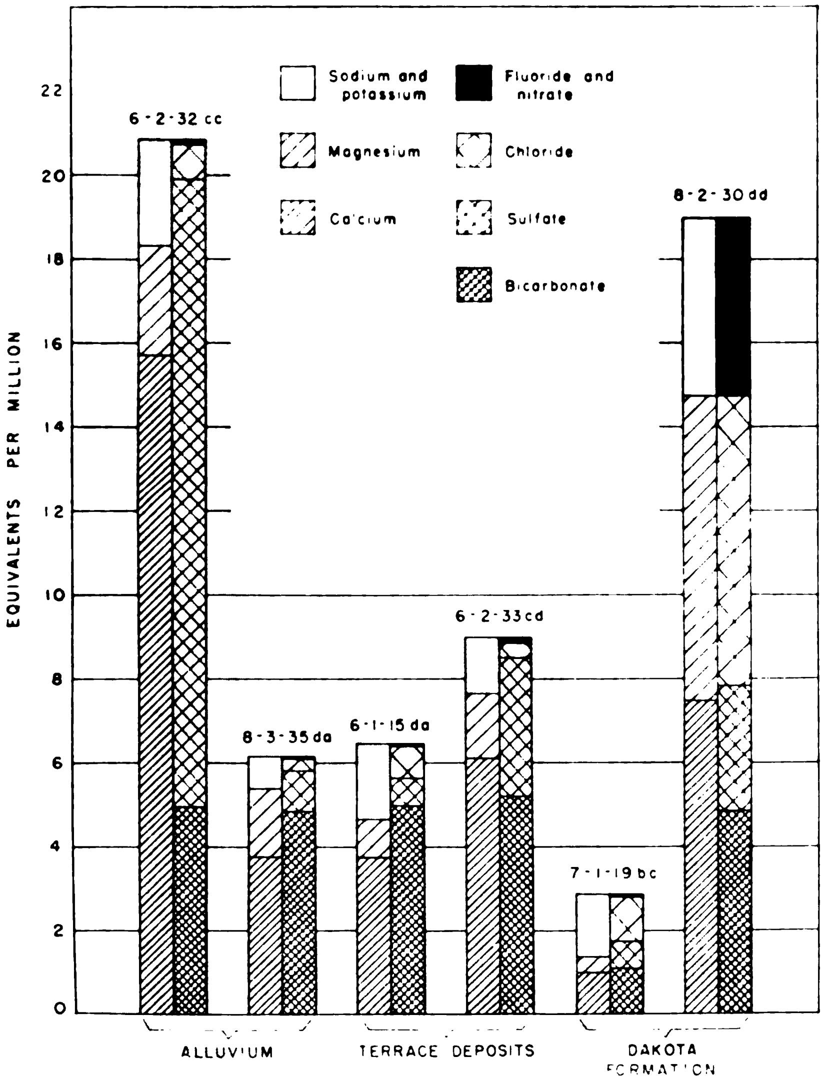

FIG. 8.—Graphic representation of chemical analyses of water from principal water-bearing formations in representative wells in Clay County.

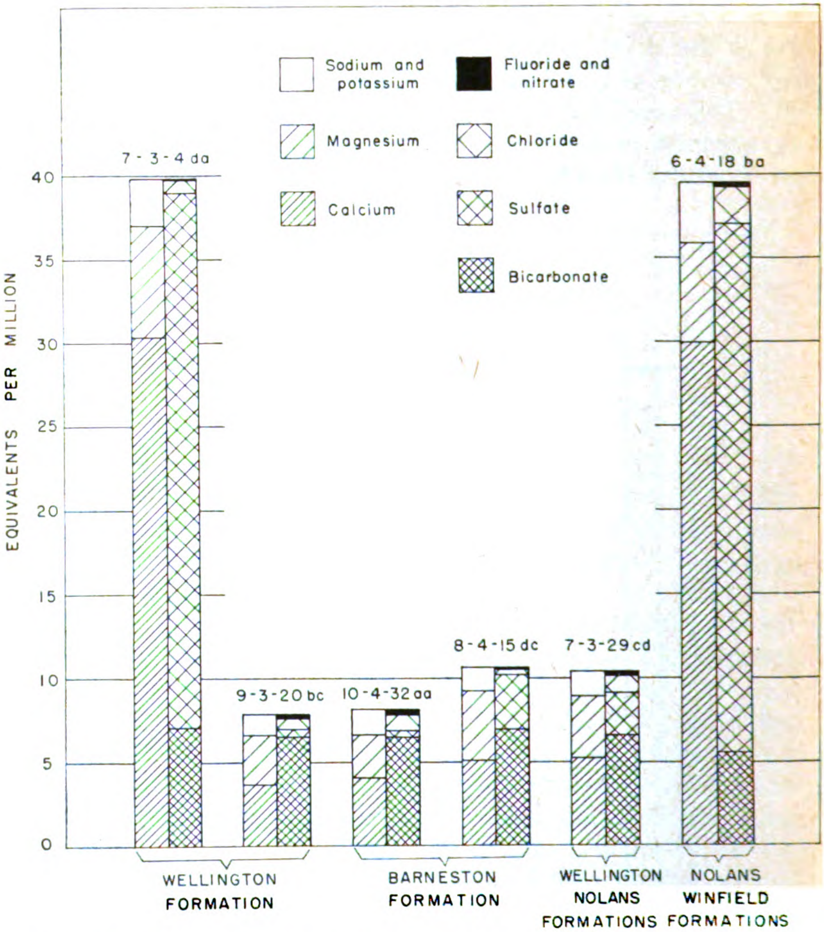

Fig. 9.—Graphic representation of chemical analyses of water from minor water-bearing formations in representative wells in Clay County.

Chemical Constituents in Relation to Use

The following discussion of the chemical constituents of ground water has been adapted from publications of the State Geological Survey of Kansas. The analyses of samples of water collected in Clay County are given in Table 3.

Dissolved solids.—The residue left after a natural water has evaporated consists of rock materials, but may include some organic material and water of crystallization. Waters containing less than 500 parts per million of dissolved solids generally are satisfactory for domestic use, except for difficulties resulting from hardness and, in some cases, excessive iron content or corrosiveness. Waters having more than 1,000 ppm are as a rule not satisfactory, for they are likely to contain enough of certain constituents to produce a noticeable taste or to make the water unsuitable in some other respect.

The concentration of dissolved solids was less than 500 ppm in 14 of the 33 samples of water collected in Clay County, ranged from 500 to 1,000 ppm in 14 samples, and was more than 1,000 ppm in 5 samples. The water sample having the lowest concentration of dissolved solids (58 ppm) was from a spring (9-2-30bb) in the Dakota Formation. The water sample having the highest concentration of dissolved solids (3,600 ppm) was from well 10-2-17cd1 in the Wisconsinan terrace deposits. This sample had a very high concentration of calcium and sulfate ions.

Hardness.—The hardness of water, which is the property of water that generally receives the most attention, is most commonly recognized by its effects when soap is used with water. Hard water is objectionable because it forms with soap a sticky, insoluble curd difficult to remove from containers and fabrics, and because it requires much soap to form a lather. Hard water forms scale in boilers and pipes, which reduces efficiency of heat transfer and may even result in boiler failure. Calcium and magnesium cause most of the hardness of ordinary water, and hence also the greater part of the scale in steam boilers and in other vessels in which water is heated or evaporated.

In addition to total hardness the table of analyses shows carbonate hardness and noncarbonate hardness. The carbonate hardness is that due to the presence of calcium and magnesium bicarbonates. It may be almost completely removed by boiling. This type of hardness has been called temporary hardness. The noncarbonate hardness is due to the presence of the sulfates or chlorides of calcium and magnesium and cannot be removed by boiling, and for this reason has sometimes been called permanent hardness. With reference to use with soap there is no difference between the carbonate and noncarbonate hardness.

Water having a hardness of less than 50 ppm is generally considered soft, and under ordinary circumstances treatment for removal of hardness is not necessary. Hardness between 50 and 150 ppm does not seriously interfere with the use of water for most purposes, but it does increase somewhat the consumption of soap, and its removal by a softening process is profitable for laundries and other industries using large quantities of soap. Hardness of more than 150 ppm can be noticed by most users, and if the hardness is 200

TABLE 3.—*Analyses of water from typical wells, springs, and test holes in Clay County*

Analyzed by H. A. Stoltenberg. Dissolved constituents given in parts per million [a]

Location	Depth, feet	Geologic source	Date of collection	Temperature (°F)	Dissolved solids	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na+K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Hardness as $CaCO_3$: Total	Hardness as $CaCO_3$: Carbonate	Hardness as $CaCO_3$: Noncarbonate
6-1-2bac1	65	Terrace deposits	7-20-45	58	345	24	0.61	70	12	37	290	40	16	0.3	1.5	224	224	0
6-1-2cc	56-61	Alluvium	6-17-54	58	373	28	3.8	88	13	29	345	26	18	0.3	0.9	273	273	0
6-1-15da	56-61	Terrace deposits	6-18-54	57	367	28	0.88	75	11	42	303	33	28	0.3	0.8	232	232	0
6-2-3ad	59	Dakota Formation	10-26-54	56	571	14	18	100	17	78	261	54	121	0.3	58	320	214	106
6-2-32ccc	60-65	Alluvium	6-23-54	56	1,320	18	4.1	315	32	57	300	721	30	0.6	2.3	918	246	672
6-2-33cd	56-61	Terrace deposits	6-24-54	....	525	23	1.2	122	19	30	317	160	13	0.4	1.7	382	260	122
6-4-18ba	77	Nolans and Winfield Limestones	10-26-54	56	2,530	10	11	601	71	83	349	1,510	77	0.8	1.5	1,790	286	1,500
6-4-33ad	103	Barneston Limestone	10-26-54	55	431	13	0.50	76	47	20	459	13	10	0.3	26	382	376	6
7-1-6bb	74-76	Dakota Formation	7- 8-54	....	502	9.5	....	89	27	53	337	134	20	0.4	3.2	333	276	57
7-1-15bcb	65	do	6- 9-54	57	853	8.2	4.9	145	23	106	262	54	171	0.2	217	456	215	241
7-1-19bc	50	do	3- 4-54	54	174	7.4	5.4	20	4.6	35	68	31	37	0.2	6.2	69	56	13
7-2-4ddc	57	Terrace deposits	11-24-53	....	514	....	0.18	122	24	28	354	140	16	0.3	6.6	403	290	113
7-3-4da	Spring	Wellington Formation	3- 1-54	57	2,540	17	0.42	608	83	60	432	1,530	25	0.8	1.5	1,860	354	1,500
7-3-29cd	77	Wellington Formation and Nolans Ls.	10-26-54	55	574	18	0.10	107	44	34	407	121	34	0.4	16	448	334	114
[b]7-4-20ad [b]7-4-21bc	190	Barneston Limestone	3- 2-54	....	835	15	0.23	143	67	39	368	311	49	0.6	26	632	302	330
7-4-32cc	195	Barneston Limestone	10-26-54	56	568	10	15	107	50	26	429	143	18	0.8	1.7	472	352	120

8-1-13ca	40	Terrace deposits	10-13-55	....	889	32	0.77	160	35	44	261	246	79	0.3	71	543	214	329
8-2-30dd	....	Dakota Formation	6- 9-54	56	1,140	9.4	3.2	151	88	97	295	146	244	0.6	261	738	242	496
8-3-8db	58	Terrace deposits	1-31-48	....	655	30	3.5	144	24	29	445	125	15	0.4	5.3	458	365	93
8-3-35da2	16-21	Alluvium	6-29-54	58	330	12	....	75	20	18	294	47	11	0.4	1.1	269	241	28
8-4-15dc	118	Barneston Limestone	10-26-54	56	580	13	9.0	102	51	32	427	157	13	0.6	1.3	464	350	114
9-2-30bb	Spring	Dakota Formation	10-27-54	57	58	11	0.23	7.4	1.8	7.6	29	4.9	7.0	0.2	3.6	26	24	2
9-3-1cc	93	Barneston Limestone	10-26-54	55	546	18	2.0	100	37	46	454	93	16	0.4	12	402	372	30
9-3-20bc	78	Wellington Formation	6- 9-54	56	401	11	1.9	75	36	26	404	18	20	0.2	16	335	331	4
9-3-23cc	99	Barneston Limestone	10-26-54	56	407	20	1.5	84	38	16	456	9.1	10	0.2	4.4	366	366	0
9-4-21aa	144	do.	10-26-54	55	371	16	0.26	76	23	32	383	14	14	0.2	6.6	284	284	0
9-4-32adc	31-36	Terrace deposits	7- 1-54	57	278	22	....	67	9.5	19	254	28	6.0	0.4	1.3	206	206	0
10-1-17dc	100	Dakota Formation	5-16-44	....	119	11	1.2	16	3.8	12	70	13	5.0	0.1	2.2	56	56	0
10-2-17cd	55	Terrace deposits	6- 9-54	56	3,600	22	29	549	198	292	371	2,170	178	0.9	1.9	2,180	304	1,880
10-2-23bb	65	Nolans Limestone	6- 9-54	57	476	9.4	1.5	73	31	64	387	46	54	0.2	8.4	310	310	0
10-3-13ba	107	Barneston Limestone	10-26-54	55	668	14	1.5	98	40	77	366	90	76	0.3	93	409	300	109
*10-4-5db1 *10-4-5db2	57	Terrace deposits	8-11-54	....	605	25	.04	109	28	40	371	56	43	0.2	62	387	304	83
10-4-32aa	134	Barneston Limestone	10-26-54	56	427	16	1.7	84	30	34	398	16	36	0.2	15	333	326	7

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.
* Composite sample from two wells.

ppm or more the water is commonly softened. Where municipal water supplies are softened, an attempt is generally made to reduce the hardness to about 80 to 100 ppm. Further softening of a public supply is deemed not worth the additional cost.

Of the 33 samples of water collected in Clay County only 3 samples had a hardness of less than 150 ppm, and these 3 samples were from the Dakota Formation. Six samples had a hardness of 150 to 300 ppm, and 24 samples had a hardness of more than 300 ppm. All but one of the samples collected from wells in Permian rocks had a hardness of more than 300 ppm.

Iron.—If the water contains much more than 0.3 ppm of iron, the excess may separate out and settle as a reddish sediment when exposed to air. Iron may be present in sufficient quantity to give a disagreeable taste or to stain cooking utensils; it may be removed by aeration and filtration, but some water requires additional treatment to remove the iron.

Water samples from the test holes in Clay County were pumped by the air-lift method, and the resulting aeration resulted in precipitation of much of the iron. These samples were not analyzed for iron. Only 6 of the 30 samples of water from Clay County that were analyzed for iron contained less than 0.3 ppm.

Fluoride.—The fluoride content of water used by children should be known, because fluoride in water has been shown to be associated with the dental defect known as mottled enamel. Mottled enamel may appear on the teeth of children who, during the formation of the permanent teeth, drink water containing excessive amounts of fluoride. According to standards promulgated by the U. S. Public Health Service (1946), water containing more than 1.5 ppm of fluoride should not be used by children. If water contains as much as 4 ppm of fluoride, 90 percent of the children habitually drinking it are likely to have mottled enamel. Concentrations of fluoride of about 1 to 1.5 ppm have been shown to be beneficial in reducing tooth decay, and fluoride is now being added to some municipal supplies to bring the concentration up to about 1 to 1.5 ppm. The water samples collected in Clay County had a fluoride content of less than 1 ppm.

Chloride.—Chloride is widely distributed in nature; it is an abundant constituent of sea water and oil-field brines and is dissolved from most rock materials. Chloride has little effect on the suitability of water for ordinary use unless there are enough chloride salts in solution to impart a salty taste or to cause the water to be corrosive. The removal of chloride from water is difficult and expensive.

Water containing chloride concentrations of less than 250 ppm is regarded as satisfactory for domestic uses. Concentrations of chloride salts giving a chloride content between 250 and 500 ppm may impart a slight salty taste, but the water may be used for drinking and for household uses if water of better quality is not available. Cattle have a fairly high tolerance for mineralized water. Although fresh water is preferable, it is reported that cattle can drink water having chloride content of 5,000 ppm.

All the samples of water from Clay County contained less than 250 ppm of chloride.

Nitrate.—The use of water containing an excessive amount of nitrate in the preparation of a baby's formula can cause cyanosis (blue baby), or oxygen starvation. Some authorities advocate that water containing more than 45 ppm of nitrate should not be used in formula preparation for infant feeding. Water containing 90 ppm of nitrate is generally considered dangerous to infants, and water containing 150 ppm may cause severe cyanosis. Cyanosis is not produced in adults and older children by the concentration of nitrate found in drinking water. Boiling of water containing excessive nitrate does not render it safe for use by infants; therefore, only water that is known to be free from excessive nitrate should be used for preparing baby formulas.

The nitrate content of the water from some wells is somewhat seasonal, being highest in the winter and lowest in the summer (Metzler and Stoltenberg, 1950). Of the 33 water samples for which analyses are given in Table 3, 27 contained less than 45 ppm of nitrate, 3 contained 45 to 90 ppm, 1 contained 90 to 150 ppm, and 2 contained more than 150 ppm of nitrate.

Sulfate.—Sulfate in ground water is derived principally from gypsum (calcium sulfate), and from the oxidation of pyrite (iron sulfide). Magnesium sulfate (Epsom salt) and sodium sulfate (Glauber's salt), if present in sufficient quantity, will impart a bitter taste to the water and may have a laxative effect upon persons who are not accustomed to drinking it.

Of 33 samples of water from Clay County that were analyzed for sulfate, 14 contained less than 50 ppm, 13 contained 51 to 200 ppm, and 6 contained more than 200 ppm.

Chemical Constituents in Relation to Irrigation

This discussion of the suitability of water for irrigation is adapted from Agriculture Handbook 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. Irrigation practices, drainage conditions, and quality of irrigation water all are involved in salinity and alkali control. Soil that was originally nonsaline and nonalkali may become unproductive if excessive soluble salts or exchangeable sodium are allowed to accumulate because of improper irrigation and soil-management practices or inadequate drainage.

In areas of sufficient rainfall and ideal soil conditions the soluble salts originally present in the soil or added to the soil with water are carried downward by the water and ultimately reach the water table. This process of dissolving and transporting soluble salts by the downward movement of water through the soil is called leaching. If the amount of water applied to the soil is not in excess of the amount needed by plants, there will be no downward percolation of water below the root zone, and mineral matter will accumulate at that level. Likewise, impermeable soil zones near the surface can retard the downward movement of water, resulting in waterlogging of the soil and in deposition of salts. Unless drainage is adequate, attempts at leaching may not be successful, because leaching requires the free passage of water through and away from the root zone.

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, potassium, and sodium); (3) concentration of boron or other elements that may be toxic; and (4) under some conditions, the bicarbonate concentration as related to the concentration of calcium plus magnesium.

For diagnosis and classification of irrigation water, the total concentration of soluble salts can be adequately expressed in terms of electrical conductivity. Electrical conductivity is the measure of the ability of the inorganic salts in solution to conduct an electric current, and is usually expressed in terms of micromhos per centimeter at 25° C. The electrical conductivity can be determined accurately in the laboratory, or an approximation of the electrical conductivity may be obtained by multiplying the total equivalents per million of calcium, sodium, magnesium, and potassium by 100, or by dividing the total dissolved solids in parts per million by a factor. which in this area is about 0.64. Table 4 gives the factors for converting parts per million to equivalents per million. In general.

waters having an electrical conductivity less than 750 micromhos per centimeter are satisfactory for irrigation insofar as salt content is concerned, although salt-sensitive crops such as strawberries, green beans, and red clover may be adversely affected by irrigation water having an electrical conductivity in the range of 250 to 750 micromhos per centimeter. Waters in the range of 750 to 2,250 micromhos per centimeter are widely used, and satisfactory crop

TABLE 4.—*Factors for converting parts per million of mineral constituents to equivalents per million.*[1]

Cation	Conversion factor	Anion	Conversion factor
Ca^{++}	0.0499	HCO_3^-	0.0164
Mg^{++}	.0822	SO_4^{--}	.0208
Na^+	.0435	Cl^-	.0281
		NO_3^-	.0161
		F^-	.0526

1. Equivalents per million equals parts per million multiplied by conversion factor. For example, 487 ppm of calcium × 0.0499 = 24.3 epm.

growth is obtained under good management and favorable drainage conditions, but saline conditions will develop if leaching and drainage are inadequate. Use of waters having a conductivity greater than 2,250 micromhos per centimeter is the exception, and very few instances can be cited where such waters have been used successfully.

In the past the relative proportion of sodium to other cations in irrigation water has been expressed simply as the percentage of sodium, generally called "percent sodium". According to the U. S. Department of Agriculture, however, the sodium-adsorption ratio (SAR), used to express the relative activity of sodium ions in exchange reactions with soil, is a much better measure of 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 be determined also by use of the nomogram shown in Figure 10. In using the nomogram to determine the sodium-adsorption ratio of a water, the concentration of sodium expressed in equivalents per million is plotted on the left scale (A),

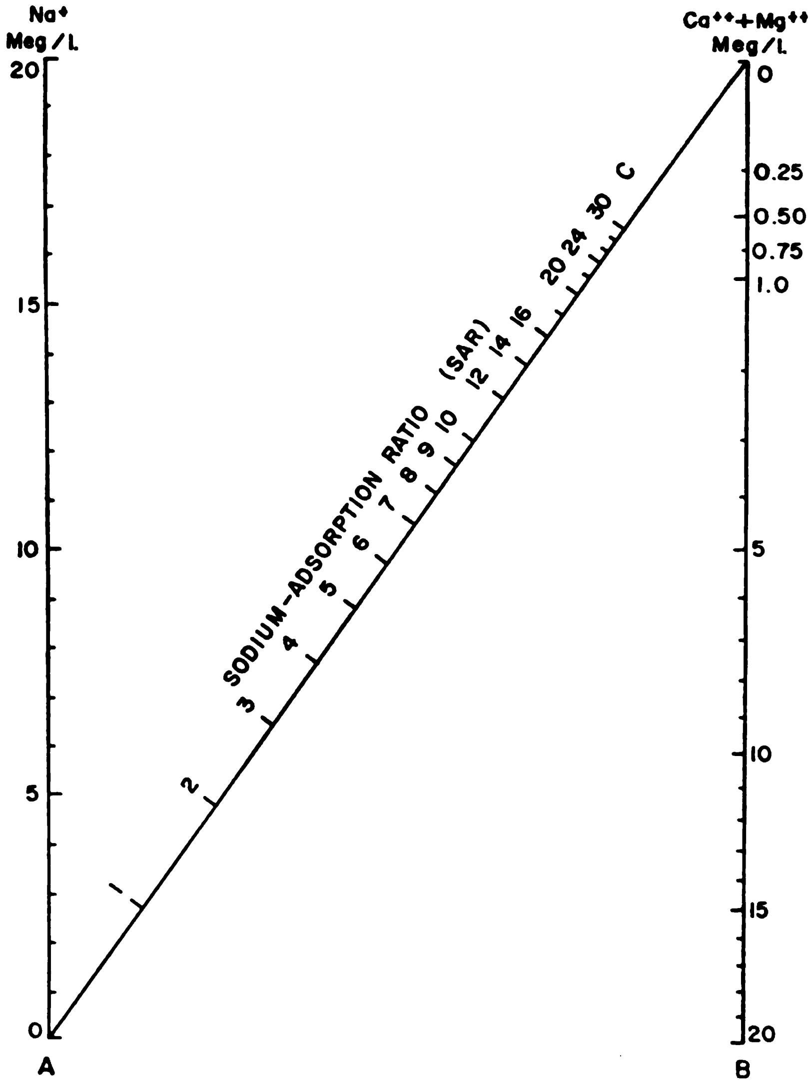

FIG. 10.—**Nomogram for determining sodium-adsorption ratio of irrigation water.**

and the concentration of calcium plus magnesium expressed in equivalents per million is plotted on the right scale (B). The point at which a line connecting these two points intersects the sodium-adsorption-ratio scale (C) 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 11. Low-sodium water (S1) can be used for irrigation on almost all soils with little danger of the development of harmful levels of exchangeable sodium. Medium-sodium water

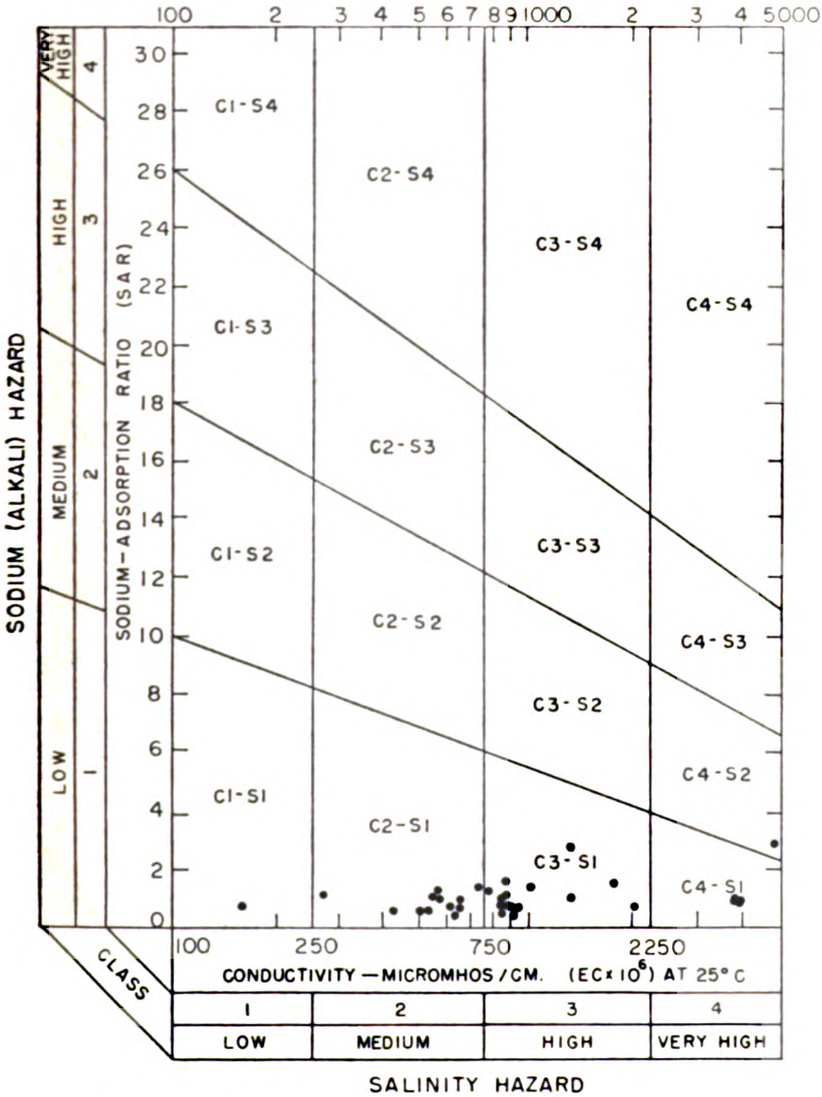

FIG. 11.—Diagram showing classification of water in Clay County for irrigation use.

(S2) will present an appreciable sodium hazard in certain fine-textured soils, especially under low-leaching conditions. This water may be safely used on coarse-textured or organic soils having good permeability. High-sodium water (S3) may produce harmful levels of exchangeable sodium in most soils and will require special soil management such as good drainage, high leaching, and additions of organic matter. Very high sodium water (S4) is generally unsatisfactory for irrigation unless special action is taken, such as addition of gypsum to the soil.

Low-salinity water (C1) can be used for irrigation of most crops on most soils with little likelihood that soil salinity will develop. Medium-salinity water (C2) can be used if a moderate amount of leaching occurs. Crops having moderate salt tolerances, such as potatoes, corn, wheat, oats, and alfalfa, can be irrigated with (C2) water without special practices. High-salinity water (C3) cannot be used on soils with restricted drainage. Very high salinity water (C4) can be used only on certain crops and then only if special practices are followed.

Boron is essential to normal plant growth, but the quantity required is very small. Crops vary greatly in their boron tolerances, but in general it may be said that the ordinary field crops common to Kansas are not adversely affected by boron concentrations of less than 1 ppm.

Prolonged use, under adverse conditions, of water having a high concentration of bicarbonate could have an undesirable effect upon the soil texture and plant growth.

Water samples (1 composite) from 33 wells and test holes are classified on Figure 11 to show the suitability of the water for irrigation use. The wells or test holes corresponding to points shown in Figure 11 are given in Table 5. Of 32 samples of water from Clay County, 2 are of low alkali hazard and low salinity hazard and are very good irrigation waters; 7 analyses indicate a low alkali hazard and medium salinity hazard, and the waters are satisfactory for irrigation of most crops grown in Clay County; 20 samples represent water of low alkali hazard but high salinity hazard, but as most of these samples fall within the lower part of the high-salinity area, only moderate precautionary measures would be necessary. Three samples were of low or medium alkali hazard but very high salinity hazard, and such waters are unfit for irrigation use. In general, the aquifers in Clay County that produce water that is unfit for irrigation do not produce large enough quantities to be considered for irrigation.

TABLE 5.—*Sodium-adsorption ratios (SAR), conductivity (C), and class of water for irrigation for wells plotted on Figure 11.*

Well number	SAR	C	Class	number	SAR	C	Class
6-1-2bac1....	1.07	537	S1-C2	8-1-13ca..	0.82	1,370	S1-C3
6-1-2cc......	.75	563	S1-C2	8-2-30dd..	1.56	1,780	S1-C3
6-1-15da....	1.21	573	S1-C2	8-3-8db...	.59	900	S1-C3
6-2-3ad.....	1.80	892	S1-C3	8-3-35da$_2$	.47	515	S1-C2
6-2-32ccc....	.78	2,070	S1-C3	8-4-15dc..	.65	906	S1-C3
6-2-33cd.....	.62	820	S1-C3	9-2-30bb..	.65	90	S1-C1
6-4-18ba.....	.85	3,950	S1-C4	9-3-1cc...	1.00	853	S1-C3
6-4-33ad.....	.44	673	S1-C2	9-3-20bc..	.61	626	S1-C2
7-1-6bb......	1.26	784	S1-C3	9-3-23cc...	.37	635	S1-C2
7-1-15bcb....	2.16	1,330	S1-C3	9-4-21aa..	.83	579	S1-C2
7-1-19bc.....	1.8	272	S1-C2	9-4-32adc	.58	434	S1-C2
7-2-4ddc.....	.60	803	S1-C3	10-1-17dc$_1$	.70	186	S1-C1
7-3-4da......	.60	3,970	S1-C4	10-2-17cd$_1$	2.72	5,620	S2-C4
7-3-29cd.....	.69	896	S1-C3	10-2-23bb..	1.58	743	S1-C2
*7-4-(20ad-21bc)	.68	926	S1-C3	10-3-13ba..	1.65	1,040	S1-C3
7-4-32cc.....	.52	887	S1-C3	10-4-32aa..	.75	667	S1-C2

* Composite sample from wells 7-4-20ad and 7-4-21bc.

HYDROLOGIC PROPERTIES OF WATER-BEARING MATERIALS

The quantity of water that a water-bearing formation will yield to wells depends upon the hydrologic properties of the material from which the wells produce. The two hydrologic properties of greatest significance are the coefficients of transmissibility (T) and storage (S) and are used in making quantitative estimates of water available in an aquifer and of future water-level decline that will result from continued pumping. Controlled aquifer tests in the field provide the data required to compute these coefficients.

The coefficient of transmissibility (T) may be defined as the number of gallons of water at the prevailing temperature that will move in 1 day through a vertical strip of the aquifer 1 foot wide, having a height equal to the full thickness of the aquifer, under a hydraulic gradient of 1 foot per foot, or it is the number of gallons of water that will move in 1 day through a cross-sectional area equal to the saturated thickness of the aquifer and 1 mile wide under a hydraulic gradient of 1 foot per mile. The coefficient of storage (S) may be defined as the change in volume of water stored per unit surface area of aquifer per unit change in head. Under water-table conditions the coefficient of storage (S) is practically the same as the specific yield of the aquifer.

The coefficient of permeability (P) of an aquifer is the discharge per unit of area per unit of hydraulic gradient. It may be measured in terms of the number of gallons of water a day, at 60° F., conducted laterally through each mile of aquifer under investigation (measured at right angles to the direction of flow) for each foot of thickness of the aquifer, and for each foot per mile of hydraulic gradient. The field coefficient of permeability (P_f) is the same except that it is measured at the prevailing temperatures of the water rather than at 60° F. The coefficient of permeability may be expressed by the formula $P_f = \frac{T}{m}$ where P_f is the field coefficient of permeability, T is the coefficient of transmissibility, and m is the thickness of the aquifer, in feet.

Aquifer-Test Determination of Transmissibility and Permeability

The coefficients of transmissibility and permeability of the alluvium and terrace deposits in the Republican River valley in the vicinity of Clifton were determined by an aquifer test using well 6-1-2ac owned by Mr. F. Turner and operated by Mr. H. Rhodes. Values for the coefficient of transmissibility (T), storage (S), and permeability (P) were computed from the aquifer-test data by formulas developed by C. V. Theis and C. E. Jacob.

Theis Recovery Method of Determining Transmissibility

The recovery method of computing transmissibility (T) developed by Theis (1935) utilizes a series of measurements of the water level in a well after a period of pumping.

The Theis recovery formula is expressed as: $T = \frac{264Q \log_{10} t/t'}{s'}$

in which T is the coefficient of transmissibility, in gallons per day per foot, Q is the pumping rate, in gallons a minute, t is the time since pumping started, in minutes, t′ is the time since pumping stopped, in minutes, and s′ is the residual drawdown in the pumped well, in feet, at time t′.

The residual drawdown (s′) is computed by subtracting the static-water-level measurement from the depth-to-water measurements at time t′ after pumping ceases.

The proper ratio of $\log_{10} t/t'$ to s′ is determined graphically by plotting $\log_{10} t/t'$ on the logarithmic coordinate and s′ on the arithmetic coordinate of semilogarithmic paper. If $\log_{10} t/t'$ is taken over one log cycle it will become unity. The formula may then be expressed as $T = \frac{264Q}{\Delta s}$, where Δs is the difference in drawdown over one log cycle. In practice, water levels at time t′ may be plotted and the residual drawdown need not be computed. Because the value of T is directly related to the slope of the line formed by plotting water level against t/t′, the selection of the proper points on the plot to determine Δs is very important. Theoretically, the relation s′ to t/t′ should plot as a straight line that passes through the point where residual drawdown is 0 and where t/t′ approaches unity. In unconsolidated deposits this is not always true, as the observed line is nearly always a curve and seldom passes through the point of origin. Generally the early points on the recovery curve are erratic and do not fall in a straight line. This may be due in part to head loss in the well or to the surge of the column of water, which falls back into the well after the pump is shut off. For this reason it would seem that the points on the curve corresponding to the late part of the recovery period would be the most reliable and should be used in determining Δs. For many aquifer tests the recovery data will not plot on a line that passes through the point where $s' = 0$ and will not plot in a straight line in the latter part of the recovery period, and it is difficult to establish a line that will determine Δs. If the latest data where t/t′ approaches 1 do not fall on a straight line, they should not be used. If the earlier points fall on a straight line they should be used, but if there is an appreciable curve to the line almost any value can be obtained for Δs, and hence the value of T can be considerably in error.

Straight-line Graphical Method of Determining Transmissibility and Storage Coefficient

The Theis (1935) nonequilibrium formula requires the use of a "type curve" on which the test-data curve is superimposed to determine the coefficients of transmissibility and storage. Cooper and Jacob (1946) devised a straight-line graphical method that does not require the type curve to accomplish the same purposes. In this method the data are plotted on semilogarithmic paper, on which the plotted points should fall in a straight line. Three equations were devised for determination of coefficients of transmissibility and storage by a distance-drawdown graph, a time-drawdown graph, and a composite graph. In the distance-drawdown graph, drawdown is plotted on the arithmetic scale and distance of observation wells in feet from the pumped well is plotted on the logarithmic scale. The formulas for coefficients of transmissibility and storage are:

$$T = \frac{264\,Q}{\Delta s} \text{ and } S = \frac{0.3\,Tt}{r_0^2}.$$

In the time-drawdown graph, drawdown is plotted on the arithmetic scale and time in days is plotted on the logarithmic scale. The formulas for coefficients of transmissibility and storage are:

$$T = \frac{264\,Q}{\Delta s} \text{ and } S = \frac{0.3Tt_o}{r^2}.$$

In the composite drawdown graph, drawdown is plotted on the arithmetic scale and the value t/r^2 is plotted on the logarithmic scale. In this method the plots of all observation wells should fall in a straight line. The formulas for coefficients of transmissibility and storage are:

$$T = \frac{264\,Q}{\Delta s} \text{ and } S = 0.3T \times (t/r^2)_o.$$

In the above formulas, the symbols are:

T = coefficient of transmissibility, in gallons per day per foot
S = coefficient of storage
Q = rate of discharge of pumped well, in gallons per minute
Δs = drawdown over one log cycle
t = time since pumping started, in days
r = distance from pumped well, in feet
t_o = value of t where drawdown = 0
r_o = value of r where drawdown = 0
$(t/r^2)_o$ = value of t/r^2 where drawdown = 0

Turner Aquifer Test

An aquifer test was made in the fall of 1955 in which well 6-1-2ac was used. This well yields water from late Wisconsinan terrace deposits in the valley of Republican River. The well is of gravel-wall construction and is 18 inches in diameter and 70 feet deep. Three observation wells, a, b, and c, were drilled in a line at distances of 25, 50, and 100 feet respectively from the pumped well. The well was pumped at a rate of 800 gpm from 9:25 a. m. until 9:55 a. m., when pumping stopped for a period of 45 minutes, owing to a power failure. Pumping was resumed at 10:40 a. m. and continued until 1:13 p. m. Water-level measurements made during the pumping period and values for t are given in Table 6.

In Figure 12 the depth-to-water measurements in the pumped well are plotted against time since pumping started. A line drawn

TABLE 6.—*Water-level measurements made during pumping and recovery periods in well 6-1-2ac, and values for (t).*

Time	Time since pumping started, t, in minutes	Depth to water, in feet
9:20 a.m.	Static water level	22.21
9:25	Pumping started	
9:25:20	0.3	31.35
9:25:45	.75	32.87
9:26:15	1.25	33.55
9:26:45	1.75	33.99
9:27:15	2.25	34.17
9:28	3	34.44
9:29	4	34.77
9:29:30	4.5	34.86
9:30	5	34.95
9:30.30	5.5	35.04
9:31	6	35.11
9:31:30	6.5	35.19
9:32	7	35.26
9:32:30	7.5	35.32
9:33	8	35.36
9:33:30	8.5	35.42
9:34	9	35.48
9:34:30	9.5	35.52
9:35	10	35.57
9:36	11	35.67
9:37	12	35.78
9:38	13	35.83
9:39	14	35.89
9:40	15	35.95
9:45	20	36.15
9:50	25	36.47
9:55	Pump off (power failure)	
10:39		22.98
10:40	Pumping started	
10:40:30	75.5	33.87
10:41	76	34.77
10:41:30	76.5	35.16
10:42	77	35.42
10:42:30	77.5	35.67
10:43	78	35.81
10:44	79	36.00
10:44:30	79.5	36.10
10:45	80	36.20
10:45:30	80.5	36.29
10:46	81	36.38
10:46:30	81.5	36.44
10:47	82	36.52

TABLE 6.—*Water-level measurements made during pumping and recovery periods in well 6-1-2ac, and values for (t).—Continued.*

Time	Time since pumping started, t, in minutes	Depth to water, in feet
10:47:30 a.m.	82.5	36.57
10:48	83	36.66
10:48:30	83.5	36.70
10:49	84	36.74
10:49:30	84.5	36.78
10:50	85	36.83
10:50:30	85.5	36.87
10:51	86	36.90
10:51:30	86.5	36.93
10:52	87	36.95
10:52:30	87.5	36.97
10:53	88	37.00
10:53:30	88.5	37.01
10:54	89	37.03
10:54:30	89.5	37.06
10:55	90	37.09
10:57	92	37.16
10:59	94	37.23
11:02	97	37.35
11:05	100	37.48
11:10 a.m.	105	37.61
11:15	110	37.78
11:20	115	37.90
11:25	120	38.00
11:30	125	38.13
11:35	130	38.22
11:40	135	38.30
11:50	140	38.48
12:00 noon	155	38.55
12:10 p.m.	165	38.60
12:20	175	38.67
12:30	185	38.81
12:40	195	38.86
12:50	205	38.90
1:00	215	38.94
1:10	225	38.96
1:13	228 Pump off	....
1:14	229	26.83
1:15	230	26.38
1:16	231	26.17
1:17	232	26.01
1:18	233	25.90
1:19	234	25.80
1:20	235	25.71
1:21	236	25.63

TABLE 6.—*Water-level measurements made during pumping and recovery periods in well 6-1-2ac, and values for (t).—Concluded.*

Time	Time since pumping started, t, in minutes	Depth to water, in feet
1:22 p.m.	237	25.57
1:23	238	25.49
1:24	239	25.44
1:25	240	25.39
1:26	241	25.35
1:28	243	25.26
1:30	245	25.16
1:32	247	25.09
1:34	249	25.02
1:36	251	24.95
1:38	253	24.90
1:41	256	24.80
1:44	259	24.74
1:47	262	24.66
1:50	265	24.58
1:54	269	24.52
1:58	273	24.45
2:02	277	24.38
2:06	281	24.32
2:10	285	24.24
2:15	290	24.15
2:21	296	24.09
2:28	303	24.01
2:35	310	23.98
2:45	320	23.91
2:55	330	23.81
3:05	340	23.74
3:15	350	23.66
3:25	360	23.60
3:35	370	23.54
3:50	385	23.46
4:05	400	23.40
4:20	415	23.32

through these points gives a value for Δs of 2.18. Applying the Cooper-Jacob formula, $T = \frac{(264)\ (800)}{2.18} = 97{,}000$ gpd per foot.

The saturated thickness is 43 feet, and from the relation $P = \frac{T}{m}$, $P = 2{,}250$. The pumped well had a drawdown of 17 feet while pumping 800 gpm; hence the specific capacity of the well was 47 gpm per foot of drawdown.

Depth-to-water measurements were made in observation wells a, b, and c during the test and are shown in Tables 7, 8, and 9.

Early in the test it was evident that observation well a was not responding to pumping as it should. The water-level measurements in Tables 7 and 8 indicate that the water level in observation well a was drawing down less than that in observation well b throughout the test. This was probably due to the lenticular nature of the aquifer rather than to any defect in the observation well, as tests made during the power failure indicated that the observation wells were open and functioning normally.

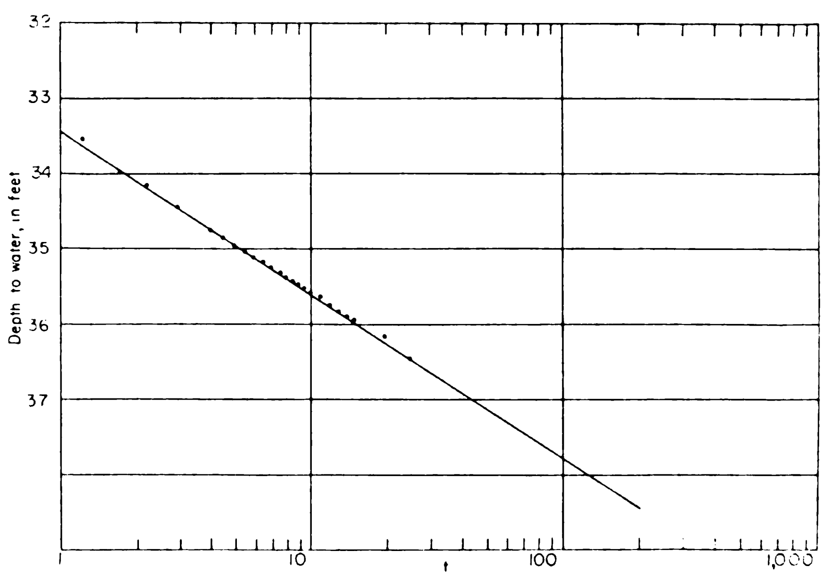

Fig. 12.—Depth to water in well 6-1-2ac plotted against time since pumping started.

TABLE 7.—*Water-level measurements in observation well a, 25 feet from pumped well 6-1-2ac.*

Time	Time since pumping started, t, in minutes	Depth to water, in feet
9:20 a.m.	Static water level	23.40
9:25	Pumping started	....
9:26	1	24.31
9:27	2	24.69
9:29	4	25.05
9:30	5	25.23
9:32	7	25.56
9:34	9	25.72
9:36	11	25.93
9:38	13	26.08
9:40	15	26.23
9:42	17	26.33
9:44	19	26.47
9:46	21	26.60
9:48	23	26.69
9:50	25	26.78
9:53	28	26.98
9:55	Pumping stopped	....
10:38	....	24.24
10:40	Pumping started	....
10:41	1	25.12
10:42	2	25.37
10:43	3	25.75
10:44	4	25.84
10:47	7	26.05
10:49	9	26.30
10:51	11	26.50
10:53	13	26.67
10:55	15	26.84
10:57	17	26.98
11:00	20	27.10
11:05	25	27.26
11:10	30	27.48
11:15	35	27.68
11:20	40	27.86
11:25	45	27.99
11:30	50	28.13
11:35	55	28.24
11:40	60	28.32
11:45	65	28.42
11:50	70	28.50

TABLE 7.—*Water-level measurements in observation well a, 25 feet from pumped well 6-1-2ac.—Concluded.*

Time	Time since pumping started, t, in minutes	Depth to water, in feet
11:55 a.m.	75	28.58
12:00	80	28.64
12:10 p.m.	90	28.69
12:20	100	28.80
12:30	110	28.89
12:40	120	28.98
12:50	130	29.03
1:00	140	29.09
1:10	150	29.15

Table 8.—*Water-level measurements in observation well b, 50 feet from pumped well 6-1-2ac.*

Time	Time since pumping started, t, in minutes		Depth to water, in feet
9:20 a.m.	Static water level		23.34
9:25	Pumping started		....
9:26:30	1.5		26.63
9:27:30	2.5		27.12
9:28:15	3.25		27.32
9:29			27.48
9:30	5		27.61
9:31	6		27.71
9:32	7		27.82
9:33	8		27.90
9:34	9		27.98
9:35	10		28.04
9:36	11		28.11
9:38	13		28.19
9:40	15		28.34
9:42	17		28.43
9:44	19		28.51
9:46	21		28.59
9:48	23		28.67
9:50	25		28.75
9:53	28		28.84
9:54	Pumping stopped		....
10:38	....		24.00
10:40	Pumping started		....
10:41:30	1.5	76.5	27.48
10:43	3	78	27.98
10:44	4	79	28.22
10:45	5	80	28.36
10:46	6	81	28.47
10:48	8	83	28.84
10:50	10	85	28.89
10:52	12	87	28.90
10:55	15	90	29.04
10:58	18	93	29.15
11:00	20	95	29.23
11:05	25	100	29.38
11:10	30	105	29.51
11:15	35	110	29.66
11:20	40	115	29.77
11:25	45	120	29.85
11:30	50	125	29.95

TABLE 8.—*Water-level measurements in observation well b, 50 feet from pumped well 6-1-2ac.—Concluded*

Time	Time since pumping started, t, in minutes		Depth to water, in feet
11:40 a.m.	60	135	30.11
11:50	70	145	30.23
12:00 noon	80	155	30.33
12:10 p.m.	90	165	30.45
12:20	100	175	30.54
12:30	110	185	30.63
12:40	120	195	30.69
12:50	130	205	30.73
1:00	140	215	30.79

TABLE 9.—*Water-level measurements in observation well c, 100 feet from pumped well 6-1-2ac.*

Time	Time since pumping started, t, in minutes	Depth to water, in feet
9:20 a.m.	Static water level	23.53
9:25	Pumping started	....
9:26	1	23.57
9:27	2	23.64
9:28	3	23.73
9:29	4	23.81
9:30	5	23.88
9:31	6	23.97
9:32	7	24.04
9:33	8	24.12
9:34	9	24.18
9:35	10	24.24
9:36	11	24.31
9:37	12	24.38
9:38	13	24.44
9:39	14	24.50
9:40	15	24.56
9:42	17	24.66
9:44	19	24.78
9:46	21	24.90
9:48	23	25.00
9:50	25	25.09
9:53	28	25.21
9:54	Pumping stopped	....
10:38	....	24.37
10:40	Pumping started	....
10:41	1	24.39
10:42	2	24.45
10:43	3	24.52
10:44	4	24.58
10:45	5	24.66
10:46	6	24.73
10:47	7	24.79
10:48	8	24.86
10:49	9	24.93
10:50	10	24.99
10:52	12	25.10
10:54	14	25.21
10:56	16	25.23
10:58	18	25.42
11:00	20	25.51
11:03	23	25.63
11:06	26	25.76
11:09	29	25.86

TABLE 9.—*Water-level measurements in observation well c, 100 feet from pumped well 6-1-2ac* —*Continued.*

Time	Time since pumping started, t, in minutes	Depth to water, in feet
11:12 a.m.	32	26.00
11:15	35	26.09
11:20	40	26.25
11:25	45	26.38
11:30	50	26.52
11:35	55	26.62
11:40	60	26.71
11:45	65	26.94
11:50	70	26.95
11:55	75	27.02
12:00 noon	80	27.07
12:10 p.m.	90	27.20
12:20	100	27.30
12:30	110	27.43
12:40	120	27.49
12:50	130	27.57
1:00	140	27.59
1:10	150	27.67
1:13	Pumping stopped	....
1:14	1	27.62
1:15	2	27.58
1:16	3	27.53
1:17	4	27.45
1:18	5	27.42
1:19	6	27.39
1:20	7	27.29
1:21	8	27.28
1:22	9	27.22
1:23	10	27.17
1:24	11	27.13
1:25	12	27.09
1:26	13	27.05
1:27	14	27.01
1:28	15	26.97
1:29	16	26.93
1:30	17	26.88
1:31	18	26.86
1:32	19	26.83
1:33	20	26.78
1:34	21	26.76
1:35	22	26.73
1:36	23	26.69
1:37	24	26.67
1:38	25	26.64
1:40	27	26.58

TABLE 9.—*Water-level measurements in observation well c, 100 feet from pumped well 6-1-2ac.*—*Concluded.*

Time	Time since pumping stopped, t, in minutes	Depth to water, in feet
1:45 p.m.	32	26.45
1:50	37	26.34
1:55	42	26.23
2:00	47	26.14
2:05	52	26.05
2:10	57	25.97
2:15	62	25.89
2:20	67	25.82
2:25	72	25.75
2:30	77	25.69
2:40	87	25.58
2:50	97	25.49
3:00	107	25.39
3:10	117	25.31
3:20	127	25.23
3:31	138	25.14
3:45	152	25.05
4:00	167	25.00
4:15	182	24.88

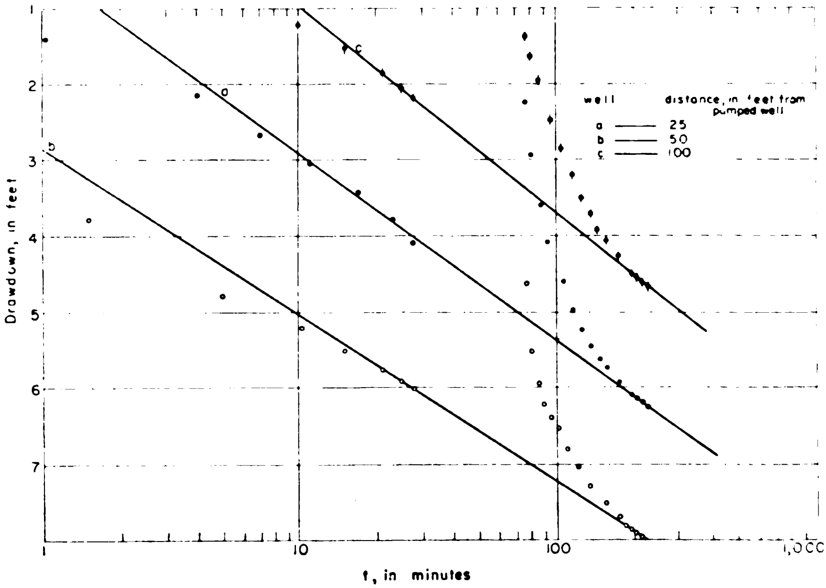

FIG. 13.—**Drawdown in observation wells a, b, and c plotted against time since pumping started, during test using well 6-1-2ac.**

The drawdowns in observation wells a, b, and c are plotted against the time since pumping started (Fig. 13). Lines through the latest points prior to the power failure pass through the latest points in the test in all the plots. Applying the Cooper-Jacob formula, values for the coefficient of transmissibility from the fluctuations in observation wells a, b, and c are 87,000, 97,000, and 79,000 gpd per foot respectively. The storage coefficient, from measurements in wells a and c, was 0.03 and 0.02, respectively, indicating water-table conditions.

A line through the latest points in the recovery curve for well c (Fig. 14) gives a value for $s = 2.17$. Applying the formula

$$T = \frac{(264)\ (800)}{2.17}$$

gives a result of 97,000 gpd/per foot.

Summary.—The values of T obtained from the aquifer test using well 6-1-2ac ranged from 79,000 to 97,000 gpd per foot. The lowest value was 79,000 gpd per foot from observation well a and the highest value, 97,000 gpd per foot, from the pumped well, observation well b, and the recovery curve for observation well c. The test is not conclusive, but 90,000 gpd per foot is probably about the cor-

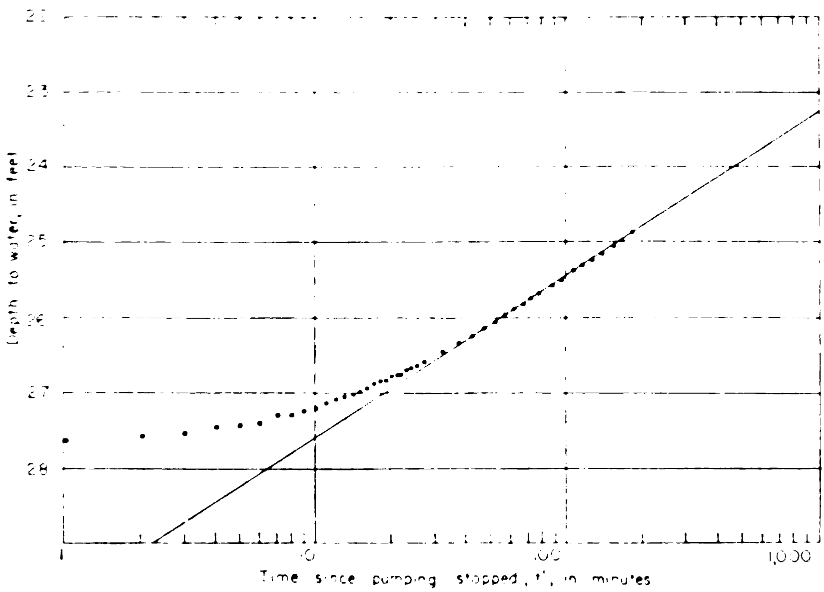

FIG. 14.—Depth to water in observation well c plotted against time since pumping stopped, during test using well 6-1-2ac.

rect value of T in the area of the well. The test shows that the aquifer is not homogeneous and that conditions are variable within short distances. The values for S are too small to have any significance, because of the shortness of the period of pumping.

ROCK UNITS AND THEIR WATER-BEARING PROPERTIES

PERMIAN SYSTEM

Wolfcampian Series—Chase Group

Barneston Limestone

In Clay County the Barneston Limestone crops out in the vicinity of Wakefield in the valley walls of Republican River and its tributaries. The Barneston Limestone contains the thickest and most resistant limestone beds in the county, and in the area to the east it is one of the principal scarp-forming rocks of the Flint Hills. In Clay County the Barneston Limestone occupies a fairly low topographic position and does not form a prominent scarp. The members of the Barneston Limestone, in ascending order, are the Florence Limestone, the Oketo Shale, and the Fort Riley Limestone members.

The Florence Limestone member is very easily recognized in Clay County because it is the only rock unit more than a few feet thick that contains a preponderance of chert or flint. The member is primarily a series of beds of limestone and beds of chert. The chert beds are generally of about the same thickness as the limestone beds. At most places a very dark gray or black impure limestone bed about 2 feet thick forms the base of the Florence Limestone member, and a persistent shale bed about 2 feet thick occurs in the upper part of the member. The Florence contains abundant fossils of many varieties. The thickness of the member ranges from 35 to 40 feet.

In Clay County the Oketo Shale member averages about 5 feet in thickness. It is composed chiefly of fossiliferous hard gray calcareous shale.

The lower few feet of the Fort Riley Limestone member is composed chiefly of thin-bedded yellow limestone. The limestone beds are overlain by a few feet of gray shale, which is easily confused with the underlying Oketo Shale member unless the Florence Limestone member is exposed also. Next above this shale bed is a massive bed of yellow limestone about 5 feet thick. This bed, which weathers to a pitted surface, is the rimrock, characteristic of nearly all exposures of the Fort Riley Limestone member (Pl. 4A). The rimrock bed is overlain by 15 to 20 feet of thin-bedded sandy yellow limestone and thin calcareous shale beds. In some exposures, a massive bed that has much the same appearance as the rimrock occurs in the upper part of the member. The average thickness of the member is about 35 feet.

Both the Florence and Fort Riley Limestone members are important aquifers in Clay County, but the Oketo Shale member does not yield appreciable quantities of water. A properly constructed well that penetrates the entire thickness of the Barneston Limestone may produce as much as 350 gpm.

In areas where the Barneston Limestone is deeply buried it may yield water that is too mineralized for domestic use. Several wells are known to obtain water of satisfactory quality from the Barneston Limestone at a depth of almost 200 feet, however.

Doyle Shale

The Doyle Shale is composed of two shale members separated by a limestone member—in ascending order, the Holmesville Shale, the Towanda Limestone, and the Gage Shale members.

A

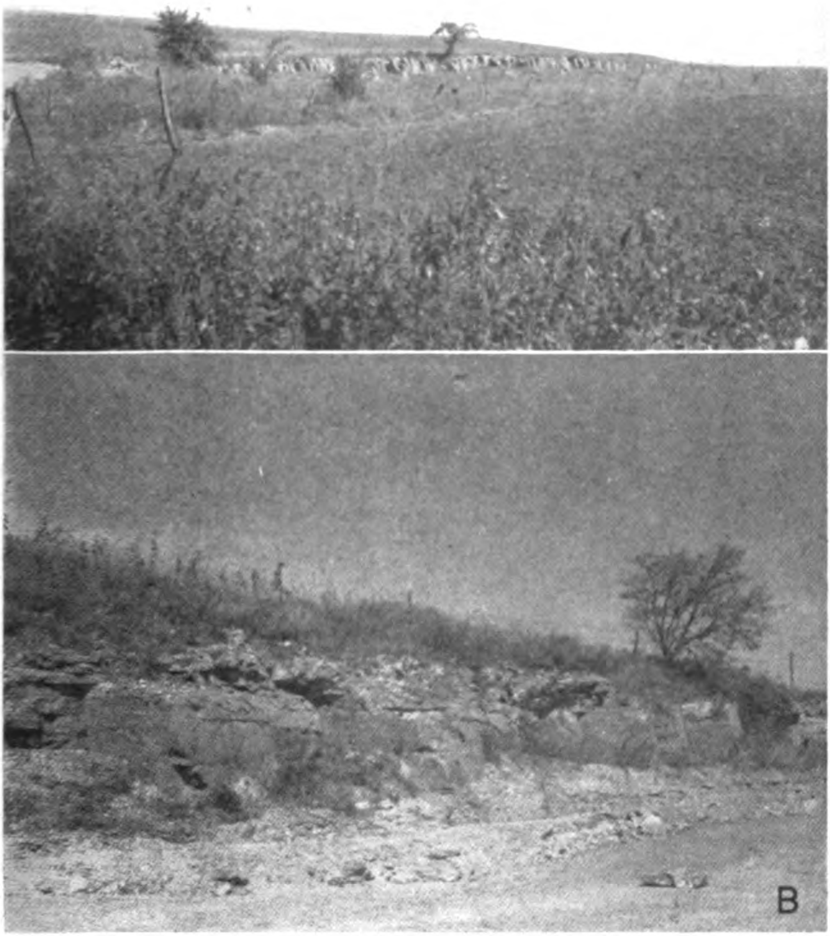

Plate 4. **A,** Rimrock formed by Fort Riley Limestone member, SE¼ NE¼ sec. 27, T. 9 S., R. 4 E.; **B,** Exposure of Winfield Limestone, SE¼ NE¼ sec 19, T. 10 S., R. 4 E.

The Holmesville Shale member consists of 20 to 25 feet of varicolored calcareous shale. Calcite veinlets and thin impure limestone beds are present in the lower few feet of the member in most places.

The Towanda Limestone member is composed chiefly of platy and nodular beds of gray to yellow limestone. In most weathered exposures the member has a very broken and deformed appearance, and the upper limestone beds may be limonite stained and may contain many calcite veinlets. The average thickness of the Towanda Limestone member is about 10 feet.

The Gage Shale member, which in Clay County has an average thickness of about 35 feet, is composed of a lower unfossiliferous varicolored shale and an upper very fossiliferous gray and yellow shale.

The Doyle Shale is not an important aquifer in Clay County, but locally the Towanda Limestone member may yield as much as 5 gpm to properly constructed wells.

Winfield Limestone

The members of the Winfield Limestone, in ascending order, are the Stovall Limestone, the Grant Shale, and the Cresswell Limestone members.

The Stovall Limestone member consists of a single bed of gray to tan hard cherty limestone about 1 foot thick. It is nonresistant to weathering and is not well exposed in many places. Echinoid spines are the most common fossils in the Stovall. It is easily recognized by its uniform thickness and chert content.

The Grant Shale member has a uniform thickness of about 10 feet in Clay County. It is composed chiefly of tan and gray shale but includes some darker shale in the upper part. It contains many fossil brachiopods, and many quartz geodes are present in the upper part.

The Cresswell Limestone member now includes all the sequence of rocks that in some earlier reports was divided into the Cresswell Limestone member and the Luta Limestone member. The Cresswell Limestone member as now defined consists of a lower massive bed of yellow limestone, containing numerous echinoid spines and other fossils and characterized by pinkish-brown splotches on weathered surfaces, and an upper thin-bedded to concretionary sequence of limestone and shale (Pl. 4B). The thickness of the Cresswell Limestone member in Clay County is about 13 feet.

The Winfield Limestone yields water in quantities sufficient for most domestic and stock supplies, and where the formation is not deeply buried, the water is of good quality.

Odell Shale

The Odell Shale in Clay County consists of about 23 feet of shale. The lower few feet of the shale is principally yellow, and the middle and upper parts of it are mostly red and more calcareous than the lower part.

The Odell Shale does not yield water to wells in Clay County.

Nolans Limestone

The Nolans Limestone includes, in ascending order, the Krider Limestone, Paddock Shale, and Herington Limestone members. The thickness of the formation in Clay County ranges from 18 to 23 feet.

The Krider Limestone member consists of one bed of limestone or of two beds separated by a thin shale bed. The total thickness of the Krider Limestone member is not known to exceed 2 feet. In most places the limestone portion of the member is yellow sandy-appearing nodular limestone containing many fossil brachiopods and pelecypods.

The Paddock Shale member consists of 11 to 13 feet of gray fossiliferous shale.

The Herington Limestone member is the most conspicuous part of the Nolans Limestone. Although it is not as resistant to weathering as the Cresswell Limestone member of the Winfield Limestone, the Herington does form an escarpment in favorable topographic situations. In most places the member consists of 6 to 8 feet of yellow to brown, pelecypod-bearing limestone. The upper part is almost everywhere more massive than the lower part of the member (Pl. 5A).

The Nolans Limestone is not a good aquifer in Clay County. The Krider Limestone and Paddock Shale members are not known to yield water. Under favorable conditions the Herington Limestone member might yield some water to domestic and stock wells.

Leonardian Series—Sumner Group

Wellington Formation

The Wellington Formation is not well exposed in Clay County, hence can be described only from observations in other areas and from the interpretation of well logs.

The lower part of the Wellington Formation in Clay County consists chiefly of greenish-gray and red clay shale. Locally, a massive

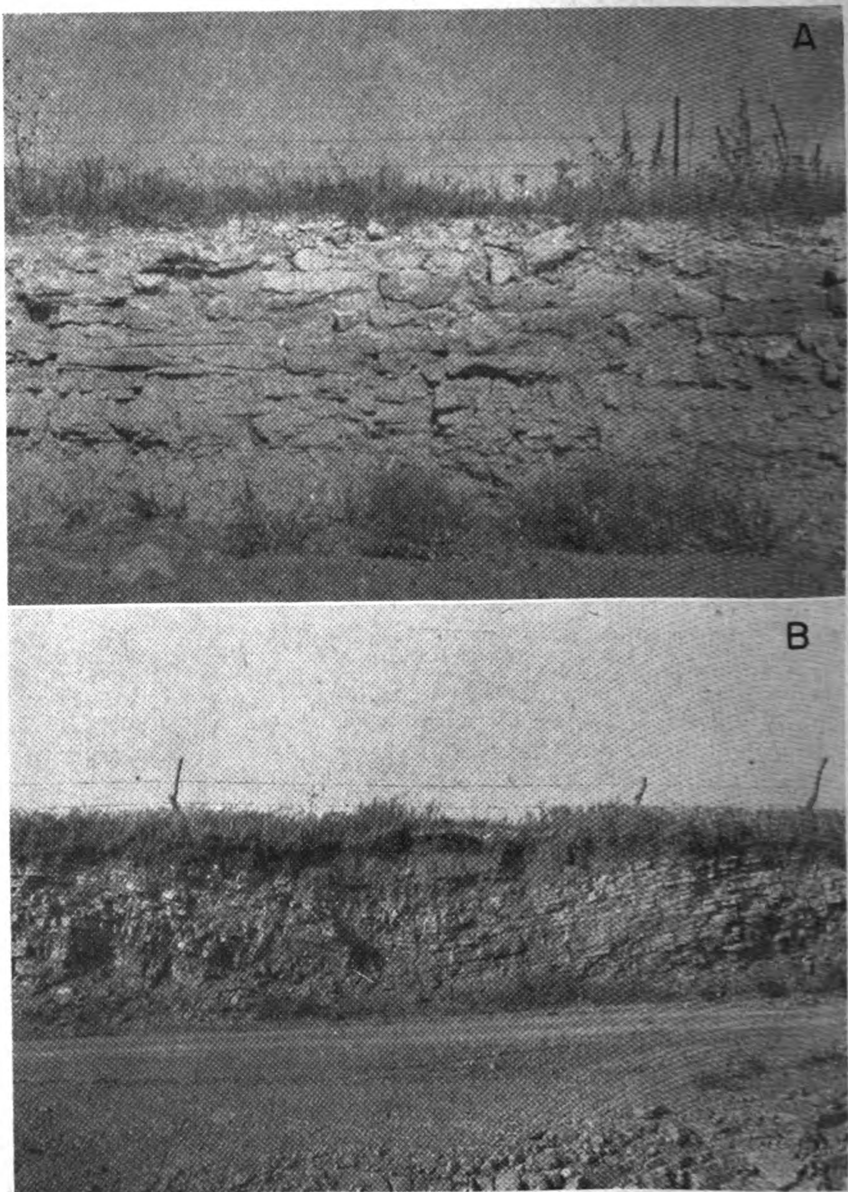

PLATE 5. **A**, Herington Limestone member exposed in road cut, NW¼ sec. 9, T. 9 S., R. 3 E.; **B**, Hollenberg Limestone member in NW¼ sec. 32, T. 6 S., R. 4 E.

bed of gypsum forms the base of the formation in contact with the Herington Limestone member of the Nolans Limestone. This massive bed of gypsum is well exposed in the southwest bank of a creek about 100 feet east and 300 feet south of the center of the west line of sec. 19, T. 6 S., R. 4 E.

A bed of impure dolomitic limestone, the Hollenberg Limestone member, lies about 40 feet above the base of the Wellington Formation in the northern part of the county. In the area southwest of Broughton the sequence between the Herington Limestone member and the Hollenberg Limestone member may be as thin as 20 feet. The Hollenberg is typically a succession of light-yellow earthy limestone and shale beds, each of which is about 3 to 5 inches thick. In almost every observed exposure in Clay County, the Hollenberg is deformed by many small anticlines and synclines (Pl. 5B) having an amplitude of only a few feet and a distance between crests of about 20 feet. Small-scale faulting also is very common in exposures of the Hollenberg (Pl. 6A). The thickness of the Hollenberg ranges from slightly less than 1 foot to 5 feet.

That part of the Wellington Formation that overlies the Hollenberg Limestone member in Clay County is in general darker than that below. At several widely scattered points a thin discontinuous bed of dark-gray to black chert was found about 12 to 15 feet above the Hollenberg Limestone member. The Hutchinson Salt member, which occurs in the middle part of the formation farther southwest, does not underlie any of Clay County. The greatest thickness of Wellington Formation underlying Clay County is not known, but probably is about 250 feet.

The Wellington Formation yields only very small quantities of water of poor quality to wells in Clay County. One spring (7-3-4da) discharges about 200 gpm of mineralized water from the Wellington Formation.

Cretaceous System

Comanchean Series

Kiowa Shale

The base of the Cretaceous rocks is marked by a major unconformity indicated by a cobble zone. The cobbles consist of quartzite, chert, igneous rock, and many types of metamorphic rocks. At many places in Clay County the Dakota Formation rests on the Wellington Formation, the cobble zone being incorporated in the base of the Dakota Formation, and the Kiowa Shale is absent. At a few localities in southern Clay County a dark clay shale resem-

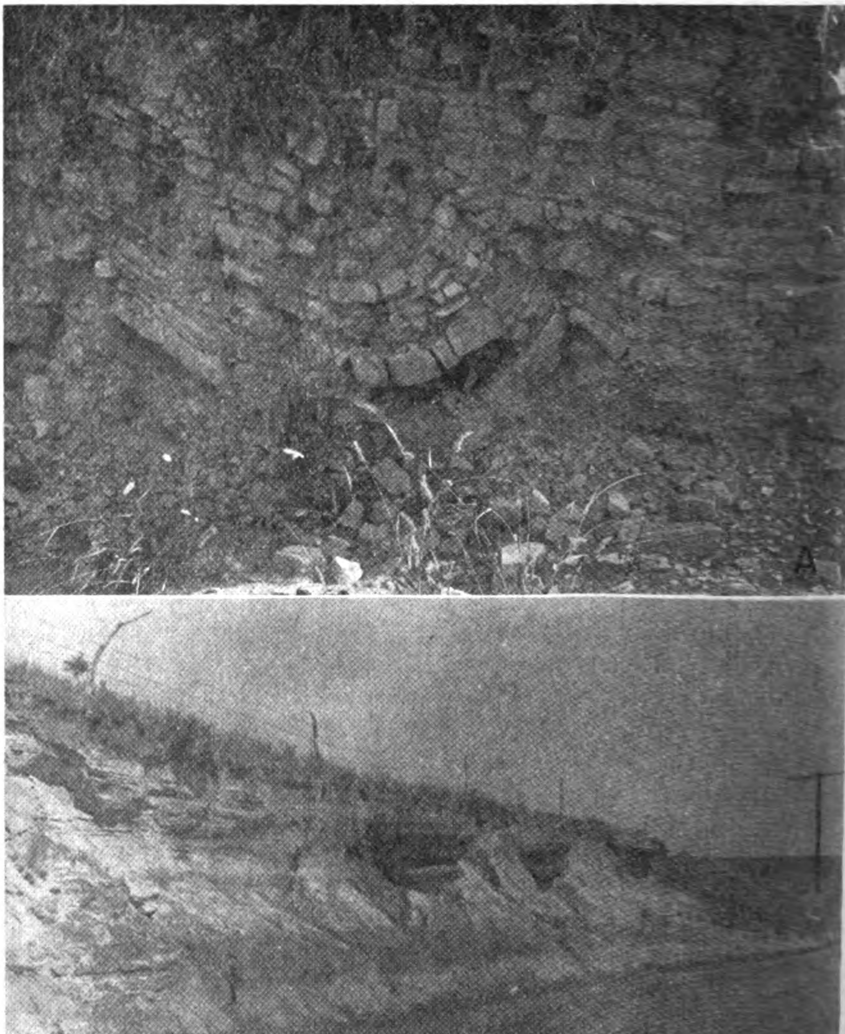

PLATE 6. **A, Faulting in Hollenberg Limestone member in NW¼ sec. 32, T. 6 S., R. 4 E.; B, Concretions in Dakota Formation, NE¼ sec. 17, T. 10 S., R. 1 E.**

bling the Kiowa crops out at about the contact between the Permian and Cretaceous, but at these localities the cobble zone is not noticeably present at the base of the shale, and the age of the shale is not known. Because the Kiowa Shale was not definitely recognized in Clay County and because of the similarity of their water-bearing characteristics to those of the Wellington Formation, these deposits are included with the Wellington Formation, and the Kiowa Shale is not shown on the geologic map.

Gulfian Series—Colorado Group

Dakota Formation

The Dakota Formation in Kansas consists of two members, the lower Terra Cotta Clay member and the upper Janssen Clay member. The Dakota Formation popularly is believed to consist chiefly of sandstone, but as the member names indicate, clay is the dominant material in most of Kansas. The formation consists entirely of continental or near-shore deposits. Study of surface exposures and test-hole cuttings shows that the formation consists principally of clay of various colors but contains discontinuous beds and lenses of sandstone and siltstone. Minor amounts of pyrite, limonite, hematite, and siderite as concretions (Pl. 6B), thin beds of lignite, and small lenses of quartzitic sandstone are scattered throughout the formation.

In the subsurface most of the sandstone is light gray, but upon being exposed to weathering it becomes yellow, dark brown, or almost red. Some of the sandstone beds are very resistant to weathering and form bold outcrops.

The Dakota Formation is the youngest Cretaceous formation exposed in Clay County, and where it occurs its top is an erosional surface. The thickness of the Dakota Formation in Clay County ranges from a featheredge to about 165 feet.

The Dakota Formation is one of the principal aquifers in Clay County. The water is generally of good quality. Few wells in Clay County that obtain water from the Dakota Formation yield more than 30 gpm, but it is likely that test drilling in some areas might locate a sufficient thickness of sandstone to yield as much as 100 gpm. Water in the Dakota Formation is under artesian pressure in most parts of Clay County. No flowing wells were observed in the county, but a well flowing from the Dakota Formation is located a few feet west of the county line in Cloud County. Chemical analyses of water from the Dakota Formation are shown in Table 3 and in Figure 8.

Quaternary System

Pleistocene Series

Pleistocene deposits of Nebraskan age possibly are present in Clay County but are unimportant quantitatively. During the first stage of the Pleistocene Epoch there were probably no well-established lines of through drainage, and erosion was the dominant process. Remnants of conglomerate (Pl. 7A), which are exposed in several places in northeastern and south-central Clay County, probably were deposited during Nebraskan or early Kansan time. The conglomerate contains pebbles and fragments of sandstone and limestone derived from Cretaceous rocks and is overlain by loess of Illinoian and Wisconsinan age. These deposits are not known to exceed 4 feet in thickness, and because they cover a very small area they are not shown on the geologic map.

Kansan Stage

A few feet of locally derived gravel of probable Kansan age underlies the alluvium of Republican River upstream from Clay Center. Although Republican River did not flow through Clay County during Kansan time, a stream whose headwaters were in the drainage area of what is now White Rock Creek in Jewell County probably flowed where Republican River now has its course through Clay County. In most places this deposit of limestone and sandstone gravel (Grand Island Formation) is 6 to 10 feet thick and in some places is overlain by a few feet of clay of the Sappa Formation.

The water in the basal gravels has about the same quality as that in the overlying Recent alluvium. The Kansan gravel deposits are made up of more angular particles than other valley-fill deposits in the county and probably do not yield as much water as an equal thickness of younger gravel. They do add considerably to the total yield of wells in northwestern Clay County, however.

Illinoian Stage

Terrace deposits.—Deposits of Illinoian age in Clay County are represented by the Crete Formation along Republican River and its major tributaries. The Crete Formation in Clay County is in the form of terrace deposits and consists chiefly of silt and clay contain-

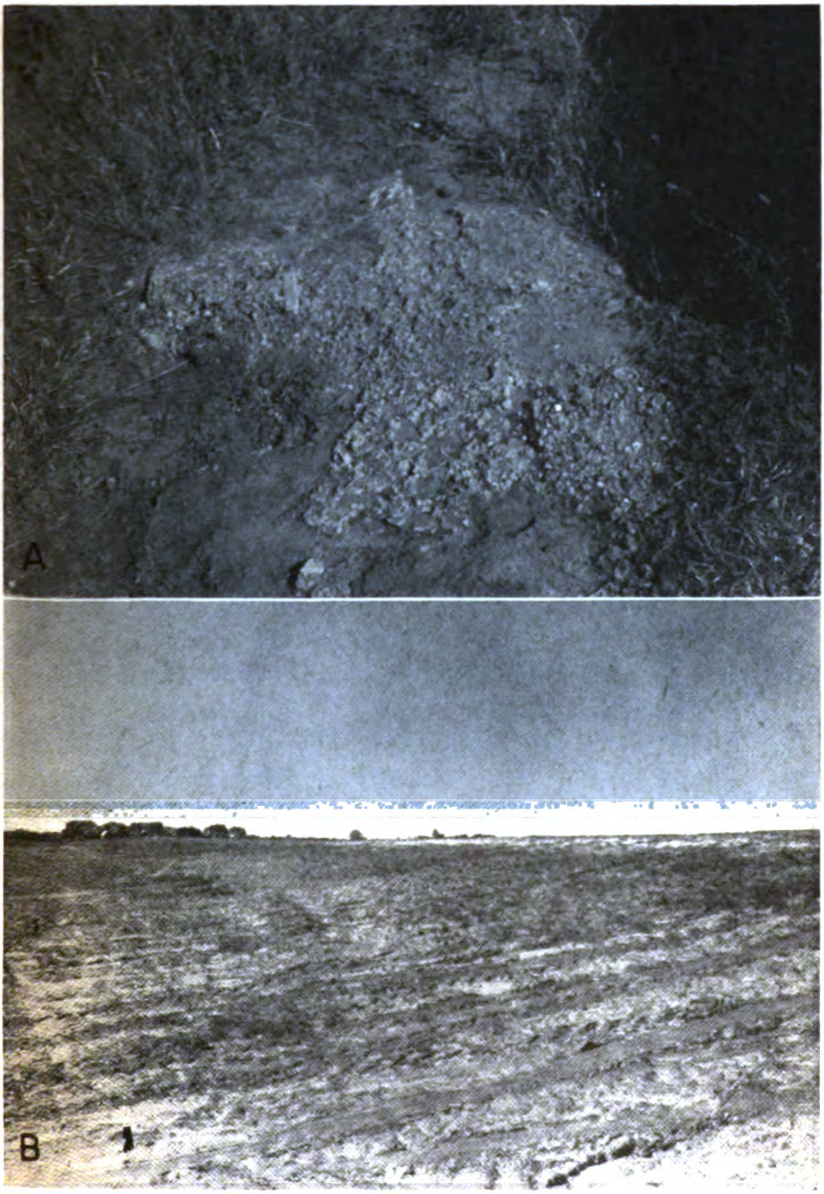

Plate 7. **A,** Exposure of Pleistocene conglomerate, center south side sec. 10, T. 10 S., R. 2 E.; **B,** Prominent scarp formed by Wisconsinan terrace, NE¼ sec. 2, T. 6 S., R. 1 E.

ing minor amounts of sand and gravel. Nearly all the deposits of the Crete Formation in Clay County are blanketed by a thick covering of Peoria loess, and are not shown on the geologic map. The upper surface of the Crete Formation at most places in Clay County is about 30 to 40 feet above flood plain level.

The Crete Formation in Clay County is generally only partly saturated; however, a bed of locally derived gravel, which is present in many places at the base of the formation, is generally saturated and yields small to moderate supplies of water.

Eolian deposits.—Much of the upland area of Clay County as well as the Crete Formation is blanketed with wind-deposited silt commonly known as loess. All the loess in Clay County is included in the Sanborn Group, but only the oldest silt formation, the Loveland Formation, is of Illinoian age. In fresh exposures the Loveland consists of reddish-yellow silt and clay. Most deposits in Clay County are only a few feet thick, and at some localities they are entirely contained within the Sangamon soil, which was developed on the Loveland during the interglacial period between the Illinoian and Wisconsinan glaciers. The Loveland Formation is above the water table and does not yield water to wells.

Wisconsinan Stage

Terrace deposits.—Deposits of sand, gravel, and clay locally almost 70 feet thick were laid down along Republican River and other major streams during Wisconsinan time. The streams have subsequently cut to a lower level and these alluvial deposits now form low terraces above the flood plain. These terraces were mapped solely on the basis of topographic expression and probably include both early and late Wisconsinan deposits (Pl. 1).

The Wisconsinan terrace deposits along Chapman Creek and the streams tributary to Republican River are composed chiefly of silt and clay but contain minor amounts of locally derived sand and gravel in the lower part. These deposits yield small to moderate quantities of water to wells, adequate only for domestic or stock use.

The Wisconsinan terrace deposits of Republican River in Clay County are composed almost entirely of arkosic sand and gravel, with the exception of the upper 15 to 20 feet, which in most places is silt and clay. No evidence of a continuous clay bed at the base of the Wisconsinan terrace deposits such as occurs near Concordia, in Cloud County, was found in Clay County. The Wisconsinan terrace deposits lack the hummocky topography typical of the Recent alluvium, and the upper surface of the terrace deposits lies about 12 feet above the upper surface of the alluvium (Pl. 7B). In the area northwest of Clay Center, the Wisconsinan terrace deposits along Republican River yield large quantities of water to wells. Downstream from Clay Center, where the valley is cut through more resistant rocks, the terrace deposits are thinner and more restricted laterally, and the available supply of ground water is somewhat less than in the valley upstream from Clay Center. Water from the Wisconsinan terrace deposits in Clay County is hard but otherwise satisfactory for most uses.

Eolian deposits.—Large areas of Clay County are mantled by deposits of loess, or wind-deposited silt, of Wisconsinan age. This silt of the Peoria Formation is contemporaneous with or older than the Wisconsinan terrace deposits. The silt of the Peoria Formation is gray buff and in most places is separated from the underlying reddish-yellow silt of the Loveland Formation by the Sangamon soil. The silt of the Peoria Formation, like all silts, has low permeability and retards the downward movement of rain water, and thus hinders recharge in the upland areas of Clay County. The Peoria Formation lies above the water table and does not yield water to wells.

Recent Stage

Alluvium.—Most of the streams of Clay County traverse flood plains underlain by alluvium of Recent age. The alluvium consists predominantly of sand and gravel but includes some silt and clay. The upper surface of the alluvium is characteristically very hummocky and in most places lies about 12 feet lower than the upper surface of the Wisconsinan terraces. Much of the alluvium is covered by water during major floods; it is subjected to erosion in some places, but in other places a small amount of additional material is added. The composition of the alluvium is nearly the same as that of the Wisconsinan terrace deposits, but as the alluvium is somewhat thicker and generally has a greater percentage of saturation, somewhat larger yields of water are obtained from wells in the alluvium.

The quality of the water in the alluvium of Republican River in Clay County is about the same as that of the water in the Wisconsinan terrace deposits. The water is hard but not strongly mineralized.

Dune sand.—In an area west of Vining, an area north of Wakefield, and in several smaller areas along Republican River, the wind has piled up sand from the channel and flood plain to form dunes. These dunes are still active in spots, and very little soil has developed on them. The dune areas are composed of many sand hills or dunes interspersed with undrained depressions. The dunes are above the water table and do not yield water to wells, but because of their permeability and lack of drainage they form important recharge facilities for the underlying alluvium and terrace deposits.

RECORDS OF WELLS

Records of 143 wells, 28 test holes, and 110 auger holes in Clay County are given in Table 10. All information classed as reported was obtained from the owner or tenant. Reported depths of wells are given in feet; measured depths are in feet and tenths. Reported depths to water level are given in feet; measured depths to water level are given in feet, tenths, and hundredths. The well-numbering system used in this table is explained on page 12.

TABLE 10.—*Records of wells, springs, and test holes in Clay County*

Well number	Location	Owner or tenant	Type of well (1)	Depth of well, feet (2)	Diameter of well, inches	Type of casing (3)	Principal water-bearing bed: Character of material	Principal water-bearing bed: Geologic source	Method of lift (4)	Use of water (5)	Measuring point: Description	Measuring point: Distance above land surface, feet	Measuring point: Height above mean sea level, feet	Depth to water level below land surface, feet (6)	Date of measurement	REMARKS (Yield given in gallons a minute; drawdown in feet)
	T. 6 S., R. 1 E.															
6-1-1ba	NE NW sec. 1	U. S. Geol. Survey	A	29.0	4	N	Sand	Terrace deposits	N	N	Land surface	0.0	1266.6	22.70	4-16-54	Did not reach bedrock.
6-1-1bc	SW NW sec. 1	Northern Natural Gas Co.	D	50	16	S	Sand and gravel	do	T, E	Ind.	do	0.0	1264.0	22	....	Four wells; one symbol on Pl. 2
6-1-2ac	SW NE sec. 2	F. Turner	D	70.0	18	GI	do	do	T, T	I	Hole in pump base	0.2	1265.4	22.01	10-12-55	Aquifer test run 10-12-25.
6-1-2baa	NE NW sec. 2	U. S. Geol. Survey	A	29.0	4	N	do	do	N	N	Land surface	0.0	1269.1	25.00	4-16-54	Did not reach bedrock.
*6-1-2bac1	NE NW sec. 2	City of Clifton	D	65.0	12	S	do	do	T, E	P	do	0.0	1268.4	21	4- 5-49	Drillers log of nearby test hole is given.
6-1-2bac2	NE NW sec. 2	do	D	66	12	S	do	do	T, E	P	do	0.0	1267.9	....	....	
6-1-2bac3	NE NW sec. 2	do	D	62	4	N	do	do	N	N	do	0.0	....	21	....	Test hole drilled by Layne Western.
6-1-2bb	NW NW sec. 2	U. S. Geol. Survey	D	70	4	N	do	do	N	N	do	0.0	1272.0	....	6-17-54	Test hole.
6-1-2bc	SW NW sec. 2	C. Nelson	D	56.5	18	GI	do	do	T, T	I	Hole in pump base	2.0	1261.6	10.17	10-25-55	Drilled in 1955. Not used that season.
*6-1-2cc	SW SW sec. 2	U. S. Geol. Survey	D	70	4	N	do	Alluvium	N	N	Land surface	0.0	1256.8	7.10	6-18-54	Test hole.
6-1-2dba	NW SE sec. 2	C. Anderson	D	60.4	18	GI	do	Terrace deposits	T, T	I	Hole in pump base	0.2	1264.5	23.07	10-25-55	
6-1-3aa	NE NE sec. 3	U. S. Geol. Survey	A	29.0	4	N	Sand	do	N	N	Land surface	0.0	1269.9	24.50	4-16-54	Did not reach bedrock.
6-1-3abb	NW NE sec. 3	do	A	29.0	4	N	do	do	N	N	do	0.0	1270.8	18.00	4-16-54	do
6-1-3ad	SE NE sec. 3	do	A	14.0	4	N	do	do	N	N	do	0.0	1260.9	10.70	4-16-54	do
6-1-3ddd	SE SE sec. 3	do	A	9.0	4	N	do	Alluvium	N	N	do	0.0	1256.8	7.20	4-16-54	do
6-1-4aaa	NE NE sec. 4	do	A	34.0	4	N	Sand and gravel	Terrace deposits	N	N	do	0.0	1272.1	19.20	4-15-54	do
6-1-4abb	NW NE sec. 4	do	A	24.0	4	N	Sand	do	N	N	do	0.0	1271.8	20.70	4-15-54	do
6-1-4bb	NW NW sec. 4	do	A	24.0	4	N	do	do	N	N	do	0.0	1272.7	19.10	4-15-54	do

6-1-5abb	NW NE sec. 5	do	A	24.0	4	N	Sand and gravel	do	N	N	do	0.0	1275.2	18.80	4-15-54	do
6-1-6aaa	NE NE sec. 6	do	A	19.0	4	N	do	do	N	N	do	0.0	1270.2	14.70	4-15-54	do
6-1-6abb	NW NE sec. 6	do	A	19.0	4	N	Sand	do	N	N	do	0.0	1272.2	13.00	4-15-54	do
6-1-10add	SE NE sec. 10	do	A	14.0	4	N	do	Alluvium	N	N	do	0.0	1258.3	10.20	4-16-54	do
6-1-11bc	SW NW sec. 11	do	D	70	4	N	do	do	N	N	do	0.0	1258.3			Test hole.
6-1-14bb	NW NW sec. 14	do	D	77	4	N	do	do	N	N	do	0.0	1267.0			do
6-1-15aa	NE NE sec. 15	do	A	39.0	4	N	do	Terrace deposits	N	N	do	0.0	1267.0	27.60	4-16-54	do
6-1-15add	SE NE sec. 15	do	A	30.0	4	N	do	do	N	N	do	0.0	1261.2	27.10	4-16-54	do
*6-1-15da	NE SE sec. 15	do	D	63	4	N	do	do	N	N	do	0.0	1261.2	22.00	6-18-54	do
6-1-15dd	SE SE sec. 15	do	A	29.0	4	N	do	do	N	N	do	0.0	1261.3	23.40	4-16-54	do
6-1-16dd	SE SE sec. 16	School District	D	86.1	5	GI	Sandstone	Dakota Formation	Cy, H	D	Base of pump	0.2	1339.6	52.69	9-3-54	
6-1-17cb	NW SW sec. 17	J. O. Lewis	D	53.2	6	GI	do	do	Cy, W	S	do	1.0	1304.2	28.35	9-2-54	
6-1-22aad	NE NE sec. 22	U. S. Geol. Survey	D	63.5	4	N	Sand and gravel	Terrace deposits	N	N	Land surface	0.0	1263.0	27.40	6-25-54	Test hole.
6-1-22ad	SE NE sec. 22	do	A	34.0	4	N	Sand	do	N	N	do	0.0	1266.3	31.20	4-16-54	Did not reach bedrock.
6-1-24ab	NW NE sec. 24	C. Pederson	D	66.0	18	GI	Sand and gravel	do	T, B	I	Hole in pump base	0.3	1252.8	23.87	10-25-55	Estimated yield about 1100 gpm.
6-1-24bc	SW NW sec. 24	C. E. Sundgren	D	95.0	18	GI	do	do	T, B	I	do	1.3	1254.5	22.00	10-25-55	Estimated yield about 2000 gpm.
6-1-25aaa	NE NE sec. 25	U. S. Geol. Survey	A	24.0	4	N	Sand	do	N	N	Land surface	0.0	1248.9	21.60	4-16-54	Did not reach bedrock.
6-1-25baa	NE NW sec. 25	do	A	24.0	4	N	do	do	N	N	do	0.0	1250.8	21.20	4-16-54	do
6-1-26aaa	NE NE sec. 26	do	A	29.0	4	N	do	do	N	N	do	0.0	1254.1	20.50	4-16-54	do
6-1-26baa	NE NW sec. 26	do	A	39.0	4	N	Sand and gravel	do	N	N	do	0.0	1267.7	36.00	4-16-54	do
6-1-26dcc	SW SE sec. 26	do	A	39.0	4	N	Clay	Terrace and colluvium	N	N	do	0.0	1261.9	20.80	4-19-54	Lower 20 feet penetrated was red clay.
6-1-26ddd	SE SE sec. 26	do	A	24.0	4	N	Sand	do	N	N	do	0.0	1252.4	19.50	4-19-54	Did not reach bedrock.
6-1-28dda	SE SE sec. 28		D	66.6	6	GI	Sandstone	Dakota Formation	N	N	Top of casing	0.3	1317.0	19.92	9-3-54	Abandoned stock well.
6-1-29ccd	SW SW sec. 29	School District	D	48.6	6	GI	do	do	Cy, H	D	Base of pump	0.7	1371.3	27.50	9-2-54	
6-1-36baa	NE NW sec. 36	U. S. Geol. Survey	A	29.0	4	N	Sand	Terrace deposits	N	N	Land surface	0.0	1250.1	23.60	4-19-54	Did not reach bedrock.
	T. 6 S., R. 2 E.															
*6-2-3ad	SE NE sec. 3	F. W. Cox	Du	59.0	54	R	Sandstone	Dakota Formation	Cy, W	S	Top of platform	0.9	1404.7	43.10	8-20-54	
6-2-5da	NE SE sec. 5	Joseph Knoetgen	Du	54.6	40	R	do	do	N	N	do	0.6	1312.8	43.62	8-20-54	
6-2-19ab	NW NE sec. 19	U. S. Geol. Survey	A	14.0	4	N	Sand	Alluvium	N	N	Land surface	0.0	1240.1	9.10	4-20-54	Did not reach bedrock.
6-2-20ab	NW NE sec. 20	do	A	19.0	4	N	do	Terrace deposits	N	N	do	0.0	1247.5	16.80	4-20-54	do
6-2-20bb	NW NW sec. 20	do	A	14.0	4	N	do	Alluvium	N	N	do	0.0	1238.6	9.00	4-20-54	do
6-2-26ad	SE NE sec. 26	J. P. Stromwall est.	Du	32.7	48	R	Sandstone	Dakota Formation	Cy, W, H	S	Top of platform	0.4	1316.2	20.92	8-20-54	

TABLE 10.—*Records of wells, springs, and test holes in Clay County*—*Continued*

Well number	Location	Owner or tenant	Type of well (1)	Depth of well, feet (2)	Diameter of well, inches	Type of casing (3)	Principal water-bearing bed: Character of material	Principal water-bearing bed: Geologic source	Method of lift (4)	Use of water (5)	Measuring point: Description	Measuring point: Distance above land surface, feet	Measuring point: Height above mean sea level, feet	Depth to water level below land surface, feet (6)	Date of measurement	REMARKS (Yield given in gallons a minute; drawdown in feet)
6-2-28cd	SE SW sec. 28	U. S. Geol. Survey	A	19.0	4	N	Sand	Terrace deposits	N	N	Land surface	0.0	1246.1	13.80	4-20-54	Did not reach bedrock.
6-2-29ac	SW NE sec. 29	Millies	D	40.5	18	GI	do	Alluvium	Ce, T	I	Top of casing	0.3	1242.8	9.00	10-25-55	Yields about 1000 gpm.
6-2-29dac	NE SE sec. 29	do	D	53.5	18	GI	do	do	Ce, T	I	do	0.3	1242.4	10.00	10-25-55	do
6-2-29dd	SE SE sec. 29	U. S. Geol. Survey	A	9.0	4	N	do	do	N	N	Land surface	0.0	1239.9	7.60	4-20-54	Did not reach bedrock.
6-2-30ccc	SW SW sec. 30	do	A	19.0	4	N	do	Terrace deposits	N	N	do	0.0	1244.8	18.10	4-19-54	do
6-2-30dc	SW SE sec. 30	do	A	24.0	4	N	do	do	N	N	do	0.0	1243.5	18.70	4-19-54	do
6-2-31cd	SE SW sec. 31	do	D	48	4	N	do	do	N	N	do	0.0	1253.8	29.30	6-25-54	Test hole.
6-2-31dc	SW SE sec. 31	do	D	70	4	N	do	do	N	N	do	0.0	1232.9	18.62	6-22-54	do
6-2-32ab	NW NE sec. 32	do	A	14.0	4	N	do	Alluvium	N	N	do	0.0	1239.3	9.60	4-20-54	Did not reach bedrock.
6-2-32bbb	NW NW sec. 32	do	A	24.0	4	N	do	Terrace deposits	N	N	do	0.0	1241.5	18.30	4-19-54	do
*6-2-32ccc	SW SW sec. 32	do	D	80	4	N	do	Alluvium	N	N	do	0.0	1225.6	5.01	6-25-54	Test hole.
6-2-32cd	SE SW sec. 32	do	D	70	4	N	do	do	N	N	do	0.0	1233.7	......	6-23-54	do
6-2-32dd	SE SE sec. 32	do	D	70	4	N	do	do	N	N	do	0.0	1225.2	7.40	6-28-54	do
*6-2-33cd	SE SW sec. 33	do	D	80	4	N	do	Terrace deposits	N	N	do	0.0	1236.9	21.30	6-24-54	do
6-2-33dcb	SW SE sec. 33	Bill Silver	D	69.6	18	GI	Sand and gravel	do	T, NG	I	Hole in pump base	1.5	1241.2	24.20	10-25-55	Yields about 1000 gpm.
6-2-34abb	NW NE sec. 34	U. S. Geol. Survey	A	44.0	4	N	Clay	Colluvium (?)	N	N	Land surface	0.0	1306.9	36.20	4-20-54	May have reached Dakota Formation.
6-2-34bbb	NW NW sec. 34	do	A	34.0	4	N	Sand	Terrace deposits	N	N	do	0.0	1258.1	30.00	4-20-54	Did not reach bedrock.
6-2-34cd	SE SW sec. 34	do	D	46	4	N	do	do	N	N	do	0.0	1239.2	24.50	6-28-54	Test hole.
	T. 6 S., R. 3 E.															
6-3-2dd	SE SE sec. 2	M. Sanneman	D	46.7	6	GI	Limestone	Nolans Limestone	Cy, W	S	Top of casing	1.1	1311.9	23.70	8-19-54	
6-3-8ccd	SW SW sec. 8	G. Jeilum	D	41.4	6	GI	Sandstone	Dakota Formation	Cy, W	S	Base of pump	1.5	1342.0	8.19	10-26-54	
6-3-15cb	NW SW sec. 15	F. J. Doberer	Du	10.4	40	R	do	do	Cy, W	S	Top of platform	0.0	1321.2	6.82	8-19-54	

6-3-23dc	SW SE sec. 23	Alvenia Franson	D	67.7	6	GI	Limestone	Nolans Limestone	Cy, W	N	Base of pump	0.2	1362.6	58.86	8-19-54	Abandoned stock well.
	T. 6 S., R. 4 E.															
6-4-4bb	NW NW sec. 4	T. R. Crimmins	Du	35.5	48	R	Limestone	Nolans Limestone	Cy, W	S	Base of pump	1.3		28.77	8-16-54	
6-4-9bb	NW NW sec. 9	A. Boughen	Du	45.2	40	R	do	do	Cy, W	N	do	0.4		21.81	6-16-54	Abandoned stock well.
*6-4-18ba	NE NW sec. 18	R. Johnson	D	76.8	6	GI	do	Nolans and Winfield Limestones	Cy, W	S	do	0.5	1314.0	54.10	8-17-54	
6-4-19cb	NW SW sec. 19	U. S. Geol. Survey	D	52	4	N										Drilled to measure gypsum bed.
6-4-31da	NE SE sec. 31	E. M. Carrithers	D	63	6	GI	Limestone	Nolans Limestone	Cy, W	S	do	0.2		34.15	8-17-54	
*6-4-33ad	SE NE sec. 33	J. Yeager	D	103.2	6	GI	do	Barneston Limestone	Cy, W, H	S	do	0.6		63.60	8-16-54	
	T. 7 S., R. 1 E.															
7-1-2bb	NW NW sec. 2	School District	D	69.7	8	S	Sand	Terrace deposits	Cy, H	D	Base of pump	0.6	1283.3	21.15	9-3-54	
*7-1-6bb	NW NW sec. 6	U. S. Geol. Survey	D	133	4	N	Sandstone	Dakota Formation	N	N	Land surface	0.0	1340.0			
7-1-8bb	NW NW sec. 8	School District	D	55.2	8	GI	do	do	Cy, H	D	Base of pump	0.9	1351.3	30.00	9-2-54	
7-1-13bb	NW NW sec. 13	A. Hanson	Du,D	43.0	5-36	GI,R	do	do	Cy, W	S	do	0.5	1350.4	35.0	9-30-54	Originally a dug well, has been deepened by drilling.
*7-1-15bcb	SW NW sec. 15	M. M. Conray	Du,D	65.0	6-36	GI,R	do	do	Cy, W,H	D, S	do	0.8	1330.4	18.72	6-9-54	do
7-1-15dda	SE SE sec. 15	School District	D	31.3	6	GI	do	do	Cy, H	D	do	0.1	1315.9	21.90	9-3-54	
*7-1-19bc	SW NW sec. 19	D. B. Moden	Du	50	48	R	do	do	Cy, W	D, S	Land surface	0.0	1298.5	47		
7-1-20cbc	NW SW sec. 20	H. Lippe	D	41.9	6	GI	do	do	Cy, H	S	Base of pump	0.6	1372.9	30.98	9-2-54	
7-1-34bab	NE NW sec. 34	C. W. Crawford	Du	34.8	48	R	do	do	Cy, W	S	do	0.8	1341.0	26.52	9-3-54	
7-1-36bb	NW NW sec. 36	A. Danenhaver	D	51.0	6	GI	do	do	Cy, W	D, S	do	0.4	1313.8	30.88	9-9-54	
	T. 7 S., R. 2 E.															
7-2-3bb	NW NW sec. 3	U. S. Geol. Survey	D	80	4	N	Sand and gravel	Terrace deposits	N	N	Land surface	0.0	1237.9	23.10	6-28-54	Test hole.
7-2-3c	SW SW sec. 3	City of Morganville	D	53	12	S	Gravel	do	T, R	P	do	0.0	1228.3	22		Near water tower.
*7-2-4ddc	SE SE sec. 4	do	D	57	12	S	do	do	T, E	P	do	0.0	1231.4	20		Four blocks west of water tower.
7-2-6bb	NW NW sec. 6	U. S. Geol. Survey	D	140	4	N	Sandstone	Dakota Formation	N	N	do	0.0	1315.0	82.20	10-22-54	Test hole.
7-2-7ab	NW NE sec. 7	do	A	14.0	4	N	Sand	Alluvium	N	N	do	0.0	1224.4	12.10	4-20-54	Did not reach bedrock.
7-2-7ad	SE NE sec. 7	do	A	14.0	4	N	do	do	N	N	do	0.0	1221.5	11.50	5-26-54	do
7-2-7dc	SW SE sec. 7	do	A	45.0	4	N	do	Terrace deposits	N	N	do	0.0	1245.1	32.50	5-26-54	do
7-2-8ac1	SW NE sec. 8	do	A	14.0	4	N	do	Alluvium	N	N	do	0.0	1218.8	12.10	4-20-54	do
7-2-8ac2	SW NE sec. 8	do	A	19.0	4	N	do	do	N	N	do	0.0	1217.5	9.80	4-20-54	do
7-2-8ca	NE SW sec. 8	do	A	14.0	4	N	do	do	N	N	do	0.0	1219.2	10.10	4-20-54	do
7-2-9ab	NW NE sec. 9	do	A	39.0	4	N	do	Terrace deposits	N	N	do	0.0	1232.1	18.80	4-20-54	do
7-2-9bd	SE NW sec. 9	do	A	24.0	4	N	do	do	N	N	do	0.0	1224.5	17.20	4-20-54	do
7-2-10ab	NW NE sec. 10	do	A	34.0	4	N	do	do	N	N	do	0.0	1230.1	22.40	4-20-54	do
7-2-10bb	NW NW sec. 10	do	A	24.0	4	N	do	do	N	N	do	0.0	1225.3	17.00	4-20-54	do

TABLE 10.—*Records of wells, springs, and test holes in Clay County—Continued*

Well number	Location	Owner or tenant	Type of well (1)	Depth of well, feet (2)	Diameter of well, inches	Type of casing (3)	Principal water-bearing bed: Character of material	Principal water-bearing bed: Geologic source	Method of lift (4)	Use of water (5)	Measuring point: Description	Measuring point: Distance above land surface, feet	Measuring point: Height above mean sea level, feet	Depth to water level below land surface, feet (6)	Date of measurement	REMARKS (Yield given in gallons a minute; drawdown in feet)
7-2-11abb	NW NE sec. 11	U. S. Geol. Survey	A	29.0	4	N	Sand	Terrace deposits	N	N	Land surface	0.0	1236.6	12.30	4-20-54	Did not reach bedrock.
7-2-14cd	SE SW sec. 14	do	A	29.0	4	N	do	do	N	N	do	0.0	1219.3	19	5-25-54	do
7-2-15dd	SE SE sec. 15	do	A	19.0	4	N	do	do	N	N	do	0.0	1220.2	18.50	5-25-54	do
7-2-15cd	SE SW sec. 15	do	A	23.0	4	N	do	do	N	N	do	0.0	1221.2	22.70	4-21-54	do
7-2-16cd	SE SW sec. 16	do	A	14.0	4	N	do	do	N	N	do	0.0	1212.9	12.00	4-21-54	do
7-2-16dd	SE SE sec. 16	do	A	39.0	4	N	do	do	N	N	do	0.0	1227.9	23.50	4-21-54	do
7-2-18aa	NE NE sec. 18	do	A	30.0	4	N	do	do	N	N	do	0.0	1230.7	22.00	5-26-54	do
7-2-18dd	SE SE sec. 18	do	A	34.0	4	N	do	do	N	N	do	0.0	1233.3	25.00	5-26-54	do
7-2-19bb	NW NW sec. 19	E. Affolter	D	44.1	5	GI	Sandstone	Dakota Formation	N	N	Top of casing	1.1	1292.4	31.90	9-30-54	Abandoned stock well.
7-2-21ac	SW NE sec. 21	E. H. Eickerman	D	53.0	18	GI	Sand and gravel	Terrace deposits	N	N	do	0.3	1212.0	10.95	10-25-55	Unused irrigation well.
7-2-21bb	NW NW sec. 21	U. S. Geol. Survey	A	24.0	4	N	Sand	do	N	N	Land surface	0.0	1218.3	14.70	4-21-54	Did not reach bedrock.
7-2-23aa	NE NE sec. 23	do	A	34.0	4	N	do	do	N	N	do	0.0	1227.0	30.30	5-26-54	do
7-2-28dac	NE SE sec. 28	Cecil Cole	D	41.0	6	GI	Sand and gravel	do	Ce, T	I	Top of casing	1.2	1206.4	10.50	10-28-55	A four-well battery.
7-2-34aa	NE NE sec. 34	U. S. Geol. Survey	A	34.0	4	N	Sand	do	N	N	Land surface	0.0	1214.9	22.20	5-26-54	Did not reach bedrock.
7-2-34ba1	NE NW sec. 34	do	A	26.0	4	N	do	do	N	N	do	0.0	1212.7	19.20	5-26-54	do
7-2-34ba2	NE NW sec. 34	do	A	29.0	4	N	do	do	N	N	do	0.0	1214.4	22.00	5-25-54	do
7-2-35aa	NE NE sec. 35	do	A	29.0	4	N	do	do	N	N	do	0.0	1212.7	23.50	5-26-54	do
7-2-35ab	NW NE sec. 35	do	A	29.0	4	N	do	do	N	N	do	0.0	1214.2	24.20	5-26-54	do
7-2-36aa	NE NE sec. 36	do	A	34.0	4	N	do	do	N	N	do	0.0	1217.5	31.00	5-26-54	do
7-2-36ba	NE NW sec. 36	do	A	24.0	4	N	do	do	N	N	do	0.0	1209.5	22.00	5-26-54	do
	T. 7 S., R. 3 E.															
7-3-1cc	SW SW sec. 1	School District	Du	9.5	48	R	Sandstone	Dakota Formation	N	N	Top of platform	1.8	1396.5	6 02	8-19-54	Abandoned.

*7-3-4da	NE SE sec. 4	G. W. Rook	Sp	......	...	...	Shale	Wellington Formation					1289.0			Estimated flow of 200 gpm.
7-3-5bb	NW NW sec. 5	U. S. Geol. Survey	D	58	4	N	Sandstone	Dakota Formation	N	N	Land surface	0.0	1333.7	19.20	10-22-54	Test hole
7-3-6dd	SE SE sec. 6	G. Hongsermeier	Du	46.0	48	R	do	do	Cy, H	N	Base of pump	0.6	1324.5	11.95	10-26-54	Formerly domestic
7-3-9aa	NE NE sec. 9	W. H. Rundle	Du	44.6	36	R	Shale	Wellington Formation	N	N	Top of platform	0.2	1291.7	13.50	8-19-54	do
7-3-19aad	NE NE sec. 19	C. Engquist	D	78.0	6	GI	Limestone	Nolans Limestone	Cy, W	S	Base of pump	0.1	1293.3	35.75	10-26-54	
7-3-22cc	SW SW sec. 22	M. Smith	Du	40.1	36	R	do	Wellington Formation	Cy, W	S	Top of platform	0.1	1300.9	35.42	8-19-54	
7-3-26cc	SW SW sec. 26	School District	D	94.1	6	GI	do	Nolans Limestone	Cy, H	N	Base of pump	0.3	1284.3	53.63	8-19-54	School is abandoned.
*7-3-29cd	SE SW sec. 29	Nicholas Schlits	D	76.6	5	GI	do	Wellington Fm. and Nolans Ls.	Cy, W	S	do	0.3	1296.2	39.25	10-26-54	
7-3-31ddc	SE SE sec. 31	T. Gerriets	D	57.0	18	S	Sand and gravel	Terrace deposits	T, T	I	Top of casing	1.3	1205.2	26.26	10-28-55	
	T. 7 S., R. 4 E.															
7-4-10ab	NW NE sec. 10	F. E. Harner	D	89	6	GI	Limestone	Winfield Limestone	Cy, H	D	Base of pump	0.4		77.40	8-16-54	
7-4-18ba	NE NW sec. 18	Geo. Masterson	D	97.1	6	GI	do	Nolans (?) Limestone	Cy, W	S	do	0.3		85.95	8-17-54	
*7-4-20ad	SE NE sec. 20	City of Green	D	170	8	S	do	Barneston Limestone	T, E	P						Estimated yield 15 gpm.
*7-4-21bc	SW NW sec. 21	do	D	190	10	S	do	do	T, E	P				..	..	Estimated yield 25 gpm.
*7-4-32cc	SW SW sec. 32	J. Heilman	D	195.3	6	GI	do	do	Cy, W	S	Base of pump	0.3		112.30	8-17-54	
	T. 8 S., R. 1 E.															
8-1-4ddb	SE SE sec. 4	P. F. Johnson	D	36.4	6	GI	Sandstone	Dakota Formation	N	N	Top of casing	0.5	1293.5	14.51	9-3-54	Abandoned stock well.
8-1-5bb	NW NW sec. 5	Geo. Blackwood	D	50.6	6	GI	do	do	Cy, W	D, S	Base of pump	0.8	1367.8	20.34	9-2-54	
8-1-7dd	SE SE sec. 7	School District	D	112.0	6	GI	do	do	Cy, H	D	Top of casing	0.0	1346.8	30.41	9-2-54	
8-1-9ddc	SE SE sec. 9	M. McNeil	D	97.1	6	GI	do	do	Cy, W	S	do	0.5	1325.8	32.38	9-3-54	
8-1-12aa	NE NE sec. 12	J. W. Hay	D	53.7	6	GI	do	do	Cy, W	S	Base of pump	1.1	1295.0	22.95	9-30-54	
*8-1-13ca	NE SW sec. 13	City of Idana	D	40	6	S	Sand	Terrace deposits	J, E	P		...	1239.3	22	...	Well reached blue shale at 40 feet.
8-1-26cc	SW SW sec. 26	School District	D	22.6	6	GI	Sandstone	Dakota Formation	Cy, H	D	Base of pump	0.2	1286.2	17.85	9-3-54	
8-1-30ad	SE NE sec. 30	do	D	51.0	6	GI	do	do	N	N	Top of casing	0.4	1382.3	15.80	9-2-54	School is abandoned.
	T. 8 S., R. 2 E.															
8-2-1ab	NW NE sec. 1	G. Dittmar	D	64.0	18	S	Sand and gravel	Terrace deposits	T, G	I	do	1.0	1205.2	23.70	10-26-54	Estimated yield 1500 gpm.
8-2-1dc	SW SE sec. 1	U. S. Geol. Survey	A	29.0	4	N	Sand	do	N	N	Land surface	0.0	1204.8	25.60	5-27-54	Did not reach bedrock
8-2-1dd	SE SE sec. 1	do	A	34.0	4	N	do	do	N	N	do	0.0	1201.8	26.40	5-27-54	
8-2-2cc	SW SW sec. 2	G. Dittmar	D	48.2	18	S	Sand and gravel	Alluvium	T, G	I	Base of pump	0.2	1193.3	11.90	9-30-54	

TABLE 10.—*Records of wells, springs, and test holes in Clay County—Continued*

Well number	Location	Owner or tenant	Type of well (1)	Depth of well, feet (2)	Diameter of well, inches	Type of casing (3)	Principal water-bearing bed: Character of material	Principal water-bearing bed: Geologic source	Method of lift (4)	Use of water (5)	Measuring point: Description	Measuring point: Distance above land surface, feet	Measuring point: Height above mean sea level, feet	Depth to water level below land surface, feet (6)	Date of measurement	REMARKS (Yield given in gallons a minute; drawdown in feet)
8-2-4da	NE SE sec. 4	J. B. Kamphaus	D	81.0	6	GI	Limestone	Winfield Limestone	Cy, W	S	Base of pump	1.2	1270.6	67.65	9-30-54	
8-2-5aa	NE NE sec. 5	Eric Swenson	D	76.3	6	GI	do	do	Cy, W	S	do	0.3	1250.1	21.04	9-30-54	
8-2-9cd	SE SW sec. 9	F. N. Schlitz	D	60.9	6	GI	Sand	Terrace deposits	Cy, W	S	do	0.5	1234.1	26.25	9-30-54	
8-2-10aa1	NE NE sec. 10	U. S. Geol. Survey	A	19.0	4	N	do	Alluvium	N	N	Land surface	0.0	1198.2	16.10	5-27-54	Did not reach bedrock.
8-2-10aa2	NE NE sec. 10	do	D	40	4	N	do	do	N	N	do	0.0	1194.6	11.80	6-30-54	Test hole.
8-2-10dd	SE SE sec. 10	do	A	75.0	4	N	do	Terrace deposits	N	N	do	0.0	1216.1	40.00	6-8-54	Hit shale at 74 feet.
8-2-11aa1	NE NE sec. 11	do	A	29.0	4	N	do	do	N	N	do	0.0	1205.5	20.10	5-27-54	Did not reach bedrock.
8-2-11aa2	NE NE sec. 11	H. Walker	D	57.0	16	S	Sand and gravel	do	T, G	I	Top of casing	1.0	1206.4	25		Estimated yield 1600 gpm.
8-2-11ad	SE NE sec. 11	do	D	40.0	16	GI	do	Alluvium	Ce, G	I	do	1.0	1193.2	12		Estimated yield 600 gpm.
8-2-11da	NE SE sec. 11	do	D	42.0	16	GI	do	do	Ce, G	I	do	1.0	1193.8	12		do
8-2-23dc	SW SE sec. 23	J. D. Shepherd	Du	58.0	48	R	Limestone ?	Wellington Formation	Cy, W	S	Base of pump	0.8	1242.6	42.00	10-21-54	
8-2-27ba	NE NW sec. 27	Leona Sylvester	D	86.7	6	GI	do	do	Cy, W	S	do	0.4	1303.5	61.60	10-21-54	
•8-2-30dd	SE SE sec. 30	School District	D		6	GI	Sandstone	Dakota Formation	Cy, H	D						High nitrates.
8-2-33dd	SE SE sec. 33	Mathew Hill	D	95.4	6	GI	Limestone	Winfield Limestone	Cy, W	S	Base of pump	0.6	1291.1	53.60	9-30-54	
	T. 8 S., R. 3 E.															
8-3-4ab	NW NE sec. 4	W. A. Piper	D	118.2	6	GI	Limestone	Winfield Limestone	Cy, W	S	Base of pump	0.5		78.85	8-19-54	
8-3-8bb1	NW NW sec. 8	Swift and Co.	D	65	8	S	Gravel	Terrace deposits	T, E	Ind.	Land surface			25		Goes to bedrock. Pumps 120 gpm 24 hours day.
8-3-8bb2	NW NW sec. 8	City of Clay Center	D	55	18	S	do	do	T, E	P				22		North Utility Park well.
8-3-8bb3	NW NW sec. 8	do	D	55	18	S	do	do	T, E	P	Land surface	0.0	1185.9	22		Center Utility Park well 20 ft. drawdown after 4 hrs at 900 gpm.

8-3-8bb4	NW NW sec. 8	do	D	55	18	S	do	do	T, E	P	do	0 0	1187 4	22		South Utility Park well. 14 ft. drawdown after 8 hrs at 850 gpm.
8-3-8bc	SW NW sec. 8	Coca Cola Co.	D	56	7	S	do	do	J, E	Ind.	Top of curb	0 0	1198 0	26		Yields about 50 gpm.
8-3-8bd	SE NW sec. 8	City of Clay Center	D	60	16	S	do	do	T, E	P	Land surface	0 0	1197 0	29		Dexter Park well. Reported drawdown of 4 ft. after 8 hrs at 500 gpm.
8-3-8cc	SW SW sec. 8	U. S. Geol. Survey	A	29	4	N	do	do	N	N	do	0.0	1195 0	26 90	6- 4-54	At corner of 6th and Mabel St.
•8-3-8db	NW SE sec. 8	City of Clay Center	D	58	16	S	Sand and gravel	do	T, E	P	do	0 0		28		At 8th and McBratney St.
8-3-11dd	SE SE sec. 11	Eliz. Schlitz	D	124.1	6	GI	Limestone	Barneston Formation	Cy, W	S	Base of pump	0 3		112 90	8-19-54	
8-3-16cdc	SE SW sec. 16	Steinbach	D	22 2	6	GI	Sand and gravel	Alluvium	Ce, B	I	Top of casing west well	1 0	1161 9	8 50	10-28 55	Battery of 3 wells, yield 350 gpm. Wells go to shale.
8-3-17ba	NE NW sec. 17	U. S. Geol. Survey	D	44	4	N	do	Terrace deposits	N	N	Land surface	0 0	1179 3	9 10	6-30 54	Test hole.
8-3-17bb	NW NW sec. 17	do	A	14.0	4	N	Sand	Alluvium	N	N	do	0 0	1179 3	13 20	5-27 54	Did not reach bedrock.
8-3-17cc	SW SW sec. 17	do	A	19 0	4	N	do	do	N	N	do	0 0	1179 2	13 00	5-27-54	do
8-3-19dd	SE SE sec. 19	do	A	34 0	4	N	Clay	Terrace deposits	N	N	do	0 0	1196 7	26 20	5 27 54	do
8-3-21bbd	NW NW sec. 21	Marshall	D	42.3	12	S	Gravel	do	Ce, T	I	Top of casing	-3.6	1160 7	12 40	10-28-55	Yields about 500 gpm.
8-3-25aa	NE NE sec. 25	H. A. Mosburg	D	112 3	6	GI	Limestone	Barneston Limestone	Cy, W,H	S	Base of pump	0 3		92 72	8-19-54	
8-3-26bdd	SE NW sec. 26	U. S. Geol. Survey	A	35.0	4	N	Sand	Terrace deposits	N	N	Land surface	0 0	1185 3	29 80	5-28-54	Did not reach bedrock.
8-3-27ca	NE SW sec. 27	do	A	14 0	4	N	do	Alluvium	N	N	do	0 0	1168 4	10 50	5-27-54	do
8-3-27da	NE SE sec. 27	do	A	19 0	4	N	do	do	N	N	do	0 0	1173 9	15 00	5-27 54	do
8-3-28ac	SW NE sec. 28	do	A	19 0	4	N	do	Terrace deposits	N	N	do	0 0	1162 4	15 50	5-27-54	do
8-3-28bc	SW NW sec. 28	do	A	19 0	4	N	do	do	N	N	do	0 0	1168 1	15 20	5-27-54	do
8-3-28bd	SE NW sec. 28	Albert Parry	D	45 0	18	GI	Gravel	Alluvium	T, B	I	Top of casing	2 3	1161.9	8 00	10-28-55	Yields about 720 gpm.
8-3-28da	NE SE sec. 28	Norquist	D	37.6	18	GI	do	do	T, B	I	do	1 0	1159 4	10 90	10-28-55	Yields about 500 gpm.
8-3-28dda	SE SE sec. 28	U. S. Geol. Survey	A	14.0	4	N	Sand	do	N	N	Land surface	0.0	1159.2	13.20	5-27-54	Did not reach bedrock.
8-3-34cd	SE SW sec. 34	do	A	19 0	4	N	do	Terrace deposits	N	N	do	0 0	1166 1	18 40	5-27-54	do
8-3-35aac	NE NE sec. 35	Bob Bowers	D	33.9	18	GI	Sand and gravel	do	T, B	I	Hole in pump base	0 5	1168.1	12 60	10-28-55	Yields about 350 gpm.
8-3-35da1	NE SE sec. 35	U. S. Geol. Survey	A	19.0	4	N	Sand	Alluvium	N	N	Land surface	0.0	1164.7	10 10	5-27-54	Did not reach bedrock.
•8-3-35da2	NE SE sec. 35	do	D	37	4	N	do	do	N	N	do	0 0	1161.5	6 40	6-29-54	Test hole.
8-3-35dd	SE SE sec. 35	do	D	30	4	N	do	do	N	N	do	0 0	1159.3			do

TABLE 10.—*Records of wells, springs, and test holes in Clay County*—*Continued*

Well number	Location	Owner or tenant	Type of well (1)	Depth of well, feet (2)	Diameter of well, inches	Type of casing (3)	Principal water-bearing bed		Method of lift (4)	Use of water (5)	Measuring point			Depth to water level below land surface, feet (6)	Date of measurement	REMARKS (Yield given in gallons a minute; drawdown in feet)
							Character of material	Geologic source			Description	Distance above land surface, feet	Height above mean sea level, feet			
8-3-36bb...	NW NW sec. 36...	U. S. Geol. Survey	D	50	4	N	Sand.....	Terrace deposits...	N	N	Land surface..	0.0	1181.9	22.00	7-12-54	Test hole
8-3-36bbc..	NW NW sec. 36...	do..............	A	31.0	4	N	do.......	do...............	N	N	do...........	0.0	1182.5	26.20	5-27-54	Did not reach bedrock.
	T. 8 S., R. 4 E.															
8-4-4dd....	SE SE sec. 4.......	School District....	D	132.5	6	GI	Limestone	Barneston Limestone	Cy, H	D	Base of pump	0.3	....	85.30	8-16-54	
•8-4-15dc...	SW SE sec. 15....	Nellie Senn........	D	118.3	6	GI	do.......	do..............	Cy, W	S	do...........	0.1	......	61.62	8-17-54	
8-4-17cd...	SE SW sec. 17....	Baxter...........	D	130	......	......	do.......	do..............	T, B	I	Land surface..	0.0	1276.8	....	....	Yields 50 gpm.
8-4-20ab...	NW NE sec. 20...	Samuel Goodin....	D	100	12	S	do.......	do..............	T, G	I	Base of pump	0.1	1247.4	55.90	10-28-55	Yields 200 gpm.
8-4-21ac....	SW NE sec. 21..	H. Mall..........	D	62	12	S	do.......	do..............	T, T	I	do...........	......	1223.7	....	....	Flowed when drilled, yields 260 gpm.
8-4-21dc...	SW SE sec. 21....	do	D	72.0	12	S	do.......	do..............	T, T	I	do...........	0.1	1220.4	14.90	10-28-55	Yields 125 gpm.
8-4-34cba...	NW SW sec. 34...	Robt. Lloyd......	D	87.3	6	GI	do.......	do..............	Cy, W	S	do...........	1.0	....	63.42	10-26-54	
	T. 9 S., R. 1 E.															
9-1-1dd....	SE SE sec. 1......	Ernest Landin....	D	89.8	6	GI	Sandstone	Dakota Formation	Cy, W	S	Base of pump	0.8	1372.1	62.40	9-30-54	
9-1-4dd....	SE SE sec. 4......	O. Sterrett.......	Du	41.7	48	R	do.......	do..............	Cy, W	S	do..........	1.6	1418.2	19.77	9- 3-54	
9-1-7dcd...	SW SE sec. 7......	Abigail Bull......	D	64.0	6	GI	do.......	do..............	Cy, W	S	do...........	1.0	1313.7	19.32	9- 2-54	
9-1-26bb...	NW NW sec. 26...	School District....	Du	15.0	46	R	do.......	do..............	Cy, H	D	do.	0.1	1302.1	11.00	9- 3-54	
9-1-27bba..	NW NW sec. 27...	Mathew Hill......	Du	49.0	56	R	do	do..............	Cy, H	S	Top of curb...	0.8	1361.7	30.51	9- 3-54	
9-1-32bb...	NW NW sec. 32...	O. M. Panton.....	Du	50.2	30	R	do.......	do..............	N	N	do...........	0.5	1366.0	42.25	9- 2-54	
	T. 9 S., R. 2 E.															
9-2-11cb...	NW SW sec. 11..	School District..	D	70.1	6	GI	Limestone	Nolans Limestone	Cy, H	D	Base of pump	0.2	......	46.00	9-30-54	
9-2-16ab...	NW NE sec. 16...	U. S. Geol. Survey	A	50.0	4	N	Sandstone	Dakota Formation	N	N	Land surface.	0.0	1323.3	37.00	6- 7-54	Wellington shale at 38 feet.
9-2-17bb...	NW NW sec. 17...	Fed. Land Bank...	Du	61.0	40	R	do	do	Cy, W	S	Base of pump	1.3	1392.8	47.20	9-30-54	
9-2-24cc....	SW SW sec. 24...	Geo. Lenhart	D	75.7	6	GI	(?).....	Wellington Formation	Cy, W	S	do...........	0.3	......	43.18	10-21-54	

*9-2-30bb...	NW NW sec. 30.	J. C. Lloyd	Sp				Sandstone	Dakota Formation		S	Land surface	0.0	1365.9			Flows 2.5 gpm.
9-2-33dd	SE SE sec. 33...	F. H. Hughes	D	74.0	6	GI	Limestone	Nolans Limestone	Cy, W	S	Base of pump	0.7		40.40	9-30-54	
	T. 9 S., R. 3 E.															
9-3-1ba.	NE NW sec. 1	Wynn Bauer	D	38	14	GI	Gravel	Terrace deposits	Ce, B	I	Top of casing	0.4	1161.8			Yields about 150 gpm.
9-3-1cbb	NW SW sec. 1	U. S. Geol. Survey	A	19.0	4	N	Sand	Alluvium	N	N	Land surface	0.0	1156.7	18.20	5-28-54	Did not reach bedrock.
*9-3-1cc....	SW SW sec. 1	Fred Fox	D	93.0	6	GI	Limestone	Barneston	Cy, W	S	Top of casing	0.9	1220.9	53.14	10-21-54	
9-3-2aa....	NE NE sec. 2	U. S. Geol. Survey	A	14.0	4	N	Sand	Alluvium	N	N	Land surface	0.0	1159.3	11.00	5-27-54	Did not reach bedrock.
9-3-2bb...	NW NW sec. 2...	do	A	19.0	4	N	do	do	N	N	do	0.0	1161.7	14.00	5-27-54	do
9-3-13cd	SE SW sec. 13	do	A	39.0	4	N	do	Terrace deposits	N	N	do	0.0	1157.7	33.20	5-28-54	do
9-3-17aab.	NE NE sec. 17	J. V. Yarrow	D	79.0	6	GI	Limestone	Winfield Limestone	Cy, W	S	Base of pump	1.0		49.30	10-21-54	
*9-3-20bc...	SW NW sec. 20	School District	D	78.5	6	GI	(?)	Wellington Formation	Cy, H	D	do	0.6	1298.7	62.50	6-9-54	
*9-3-23cc....	SW SW sec. 23....	H. B. Ruscoe	D	99.5	6	GI	Limestone	Barneston Limestone	Cy, W	S	do	1.2		70.97	10-21-54	
9-3-31cc...	SW SW sec. 31	H. E. McDonald	D	92.2	6	GI	do	Winfield Limestone	Cy, W	S	do	0.3		85.50	10-21-54	
	T. 9 S., R. 4 E.															
9-4-6bb...	NW NW sec. 6...	Wynn Bauer	D	47	14	GI	Gravel	Terrace deposits	T, B	I	Top of casing	0.8	1175.2			Yields about 500 gpm.
9-4-18aa...	NE NE sec. 18...	School District	D	82.7	6	GI	Limestone	Barneston Limestone	Cy, H	D	Base of pump	0.3	1222.3	65.01	8-17-54	
9-4-18abb.	NW NE sec. 18...	U. S. Geol. Survey	A	11.0	4	N	Sand	Terrace deposits	N	N	Land surface	0.0	1151.5	12.10	5-28-54	Did not reach bedrock.
*9-4-21aa...	NE NE sec. 21..	Eug. Elking....	D	144.4	6	GI	Limestone	Barneston Limestone	Cy, W	S	Base of pump	1.3		74.00	8-17-54	
9-4-29ac....	SW NE sec. 29...	U. S. Geol. Survey	D	41	4	N	Sand and gravel	Alluvium	N	N	Land surface	0.0	1140.2			Test hole.
9-4-29bc...	SW NW sec. 29	do	D	58	4	N	do	Terrace deposits	N	N	do	0.0	1164.0	29.90	7-12-54	do
9-4-29bcc..	SW NW sec. 29.	do	A	34.0	4	N	Sand	Alluvium	N	N	do	0.0	1159.1	29.20	5-28-54	Did not reach bedrock.
9-4-29bd...	SE NW sec. 29....	do	D	34	4	N	do	do	N	N	do	0.0	1152.2	18.20	7-12-54	Test hole.
9-4-30dd...	SE SE sec. 30....	Wm. Avery	D	....	18	S	do	Terrace deposits	T, G	I		....		...		Reported to have a low yield.
9-4-31dbb..	NW SE sec. 31...	U. S. Geol. Survey	A	44.0	4	N	do.....	do	N	N	Land surface	0.0	1162.5	31.30	5-28-54	Did not reach bedrock.
9-4-32adb..	SE SE sec. 32	do	A	14.0	4	N	do	Alluvium	N	N	do	0.0	1136.2	11.30	5-28-54	do
*9-4-32adc..	SE NE sec. 32....	do	D	40	4	N	Sand and gravel	Terrace deposits	N	N	do	0.0	1136.0	11.50	7-12-54	Test hole.
9-4-32dba..	NW SE sec. 32....	do	A	14.0	4	N	Sand	Alluvium	N	N	do	0.0	1136.9	13.50	5-28-54	Did not reach bedrock.
9-4-32dcd..	SW SE sec. 32	do	A	14.0	4	N	do	do	N	N	do	0.0	1134.2	12.20	5-28-54	do
9-4-33add..	SE NE sec. 33	do	A	29.0	4	N	do	Terrace deposits	N	N	do	0.0	1148.1	20.30	5-28-54	do
9-4-33dbb..	NW SE sec. 33...	do	A	14.0	4	N	do	do	N	N	do	0.0	1136.7	8.60	5-28-54	do

TABLE 10.—*Records of wells, springs, and test holes in Clay County—Concluded*

Well number	Location	Owner or tenant	Type of well (1)	Depth of well, feet (2)	Diameter of well, inches	Type of casing (3)	Principal water-bearing bed: Character of material	Principal water-bearing bed: Geologic source	Method of lift (4)	Use of water (5)	Measuring point: Description	Measuring point: Distance above land surface, feet	Measuring point: Height above mean sea level, feet	Depth to water level below land surface, feet (6)	Date of measurement	REMARKS (Yield given in gallons a minute; drawdown in feet)
	T. 10 S., R. 1 E.															
10-1-1da	NE SE sec. 1	School District	D	47.4	6	GI	Sandstone	Dakota Formation	Cy, H	N	Base of pump	0.4	1268.3	30.85	9-30-54	School abandoned.
10-1-3cc	SW SW sec. 3	do	D	39.0	6	GI	(?)	Wellington Formation	N	N	Top of casing	0.1	1260.5	21.80	9- 3-54	do
10-1-5cbb	NW SW sec. 5	G. C. Stevens	Du	16.2	48	R	Sand	Terrace deposits	Cy, W	S	Base of pump	1.0	1277.8	9.53	9- 2-54	
•10-1-17dc1	SW SE sec. 17	City of Longford	D	100	8	S	Sandstone	Dakota Formation	Cy, E	P	Land surface	0.0	1378.3	...	...	East well.
10-1-17dc2	SW SE sec. 17	do	D	110	8	S	do	do	T, E	P	do	0.0	1392.5	...	...	West well, yields 100 gpm.
10-1-22bba	NW NW sec. 22	J. M. Schneider	D	99.9	6	S	do	do	Cy, W	S	Base of pump	0.6	1330.5	41.88	9- 3-54	
10-1-29bc	SW NW sec. 29	...	Sp	...	...	...	do	do	...	S	Land surface	0.0	1297.1	...	...	
10-1-30cbc	NW SW sec. 30	Geo. Emrich	Du	42.3	48	R	do	do	N	N	Top of platform	0.3	1403.7	42.00	9- 2-54	Abandoned domestic well.
	T. 10 S., R. 2 E.															
10-2-12cc	SW SW sec. 12	F. Roderick	Du	48.7	36	R	Limestone	Nolans Limestone	Cy, W	S	Base of pump	0.3	...	48.40	9-30-54	
10-2-17aa1	NE NE sec. 17	Henry Youse	Du	37.3	48	R	do	Wellington Formation	Cy, W	N	do	0.8	...	30.90	9-30-54	Abandoned stock well.
10-2-17aa2	NE NE sec. 17	U. S. Geol. Survey	A	15.0	4	N	Clay	Terrace deposits	N	N	Land surface	0.0	1213.7	7.20	6- 8-54	Did not reach bedrock.
10-2-17cc	SW SW sec. 17	do	A	14.0	4	N	do	do	N	N	do	0.0	1207.3	9.20	6- 8-54	Did not reach bedrock.
•10-2-17cd1	SE SW sec. 17	Lawrence Falen	D	55.0	8	S	Sand	do	Cy, W	S	Base of pump	1.0	1209.6	12.50	6- 9-54	
10-2-17cd2	SE SW sec. 17	U. S. Geol. Survey	A	19.0	4	N	do	do	N	N	Land surface	0.0	1206.8	11.20	6- 8-54	Did not reach bedrock.
10-2-18ada	SE NE sec. 18	do	A	19.0	4	N	Clay	do	N	N	do	0.0	1213.3	9.40	6- 8-54	do
10-2-20da	NE SE sec. 20	do	A	19.0	4	N	Sand	do	N	N	do	0.0	1203.7	16.00	6- 8-54	do
•10-2-23bb	NW NW sec. 23	School District	D	65.0	6	GI	Limestone	Nolans Limestone	Cy, H	D	Base of pump	0.6	...	49.90	6- 9-54	
10-2-27ad	SE NE sec. 27	A. H. Green	D	51.0	6	GI	do	Winfield Limestone	Cy, W	S	do	0.2	...	34.15	9-30-54	
10-2-31cc	SW SW sec. 31	J. W. Chestnut	D	65.4	6	GI	(?)	Wellington Formation	Cy, W	S	do	0.2	...	31.83	9-30-54	
10-2-34aa	NE NE sec. 34	U. S. Geol. Survey	A	19.0	4	N	Sand	Terrace deposits	N	N	Land surface	0.0	1192.3	17.30	6- 8-54	Did not reach bedrock.

10-2-34ab	NW NE sec. 34	do	A	29.0	4	N	do	do	N	N	do	0.0	1188.1	20.00	6-8-54	do
10-2-35aab	NE NE sec. 35	do	A	11.0	4	N	do	do	N	N	do	0.0	1193.6	8.80	6-8-54	do
10-2-35dc	SW SE sec. 35	do	A	50.0	4	N	do	do	N	N	do	0.0	1175.2	18.00	6-8-54	do
	T. 10 S., R. 3 E.															
10-3-3aad	NE NE sec. 3	S. D. Avery	D	115.3	6	GI	Limestone	Barneston Limestone	Cy, W	S	Base of pump	1.0		125.62	10-21-54	
*10-3-13ba	NE NW sec. 13	G. E. Hawes	D	106.9	5	GI	do	do	Cy, W	S	do	0.3		87.19	10-21-54	
10-3-16ab	NW NE sec. 16	School District	D	80.2	6	GI	do	do	N	N	Top of casing	0.2		74.45	19-21-54	School is abandoned.
10-3-30cd	SE SW sec. 30	C. M. Miles	Du	28.2	60	R	(?)	Alluvium	Cy, W	S	Top of platform	0.3		21.55	10-21-54	
10-3-34ab	NW NE sec. 34	Mary Heaston	D	127.5	6	GI	Limestone	Barneston Limestone	Cy, W	S	Base of pump	0.0		107.80	10-21-54	
	T. 10 S., R. 4 E.															
10-4-4aa	NE NE sec. 4	U. S. Geol. Survey	A	9.5	4	N	Sand	Terrace deposits	N	N	Land surface	0.0	1134.0	8.20	6-1-54	
*10-4-5db1	NW SE sec. 5	City of Wakefield	D	57	12	S	Gravel	do	T, E	P	Top of platform		1151.9	34		Yields about 100 gpm.
*10-4-5db2	NW SE sec. 5	do	D	57	12	S	do	do	T, E	P	do		1151.8	31		do
10-4-5dd	SE SE sec. 5	G. W. Gaston	D	50.7	18	GI	do	do	T, G	I	Top of casing	1.8	1142.7	26.00	10-26-54	Yields about 750 gpm
10-4-8ab	NW NE sec. 8	U. S. Geol. Survey	A	40.0	4	N	Sand	do	N	N	Land surface	0.0	1152.3	32.10	6-1-54	Did not reach bedrock.
10-4-8dbb	NW SE sec. 8	do	A	35.0	4	N	Clay	do	N	N	do	0.0	1133.8	33.70	6-2-54	do
10-4-9bb	NW NW sec. 9	do	A	20.0	4	N	Sand	do	N	N	do	0.0	1131.7	18.20	6-1-54	do
10-4-9bd	SE NW sec. 9	do	A	20.0	4	N	do	do	N	N	do	0.0	1129.0	14.30	6-1-54	do
10-4-9cc	SW SW sec. 9	H. A. Elkins	D	48.4	18	GI	Gravel	do	N	I	Top of casing	1.2	1140.2	26.64	10-26-54	New well pump not installed.
10-4-15bc	SW NW sec. 15	U. S. Geol. Survey	A	36.0	4	N	Silt	do	N	N	Land surface	0.0	1160.5	18.60	6-2-54	Did not reach bedrock
10-4-16ab	NW NE sec. 16	do	A	25.0	4	N	Sand	do	N	N	do	0.0	1136.0	22.40	6-1-54	do
10-4-16bc	SW NW sec. 16	do	A	35.0	4	N	do	do	N	N	do	0.0	1143.4	24.20	6-2-54	do
10-4-16bd	SE NW sec. 16	do	A	40.0	4	N	do	do	N	N	do	0.0	1143.2	31.20	6-1-54	do
10-4-17ca	NE SW sec. 17	Augusta Meek	D	55.8	6	GI	Limestone	Barneston Limestone	N	N	Top of casing	0.1		42.19	10-21-54	Abandoned stock well.
*10-4-32aa	NE NE sec. 32	W. L. Streeter	D	133.5	6	GI	do	do	Cy, W	S	do	0.3		97.82	10-21-54	

* Indicates a chemical analysis is given.

1. A, Auger hole; D, Drilled; Du, Dug; Sp, Spring.
2. Reported depths given in feet; measured depths given in feet and tenths.
3. GI, Galvanized iron; N, None; R, Rock; S, Steel.
4. Type of pump: Ce, Centrifugal; Cy, Cylinder; J, Jet; N, None; T, Turbine.
   Type of power: B, Butane engine; E, Electric motor; G, Gasoline engine; H, Hand; N, None; NG, Natural gas engine; T, Tractor; W, Wind.
5. D, Domestic; I, Irrigation; Ind., Industrial; N, None; P, Public supply; S, Stock.
6. Measured depths to water level are given in feet, tenths, and hundredths; reported depths to water level are given in feet.

LOGS OF TEST HOLES

On the following pages are given the logs of 28 test holes drilled in Clay County (Pl. 2). The holes were drilled chiefly in areas of thick alluvial deposits, but several were drilled to determine the character, thickness, and water-bearing properties of the Dakota Formation. One test hole was drilled through the gypsum deposits in the northeastern part of the county. The geologic cross sections shown in Plate 3 are based principally on data obtained from test-hole logs. Many holes were drilled with a power auger to determine the depth to water level or as a guide in preparing the geologic map. Logs of these auger holes are not given, as most of them were very shallow. The test holes were drilled by the State Geological Survey. Samples were collected and studied in the field and later examined microscopically in the laboratory.

6-1-2bac.—*Drillers log of test hole in SW¼ NE¼ sec. 2, T. 6 S., R. 1 E. Near the site of Clifton city wells. Static water level 21 feet below land surface. Drilled by Layne-Western Co.*

	Thickness, feet	Depth, feet
Soil	4	4
Clay	24	28
Sand, fine, gray	2	30
Sand, coarse, gray	3	33
Sand and gravel, gray	10	43
Clay	1	44
Sand, fine	2	46
Sand, coarse, gray, and gravel on shale	16	62

6-1-2bb.—*Sample log of test hole in NW¼ NW¼ sec. 2, T. 6 S., R. 1 E. On east side of road south of Vining, 0.2 mile south of section corner. Drilled June 17, 1954. Surface altitude, 1,272.0 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Wisconsinan Stage—Terrace deposits		
Silt, black	3	3
Silt, tan	3	6
Clay, sticky, tan to gray	7	13
Clay, slightly sandy, dark gray	7	20
Clay, sandy, soft, light gray	3	23
Sand, fine to coarse, and fine to medium gravel	14	37
Clay, greenish gray	23	60
PERMIAN—Leonardian		
Wellington Formation	9	69
Dolomite, light gray	1	70

6-1-2cc.—*Sample log of test hole near SW cor. sec. 2, T. 6 S., R. 1 E. On east side of road, 200 feet north of section corner. Drilled June 17, 1954. Surface altitude, 1,256.8 feet; depth to water, 7.10 feet, June 18, 1954.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Recent and Wisconsinan Stages—Alluvium and terrace deposits		
Silt, black	3	3
Sand, fine to coarse, and fine to medium gravel	13	16
Clay, blue gray	4	20
Gravel, medium, and coarse arkosic sand	37	57
Kansan Stage—unnamed formation		
Sand, medium to coarse, and fine to medium limestone and arkosic gravel	6	63
Gravel, fine to medium; mostly sandstone and limestone pebbles	4	67
PERMIAN—Leonardian		
Wellington Formation		
Shale, platy, black and gray	3	70

6-1-11bc.—*Sample log of test hole in SW¼ NW¼ sec. 11, T. 6 S., R. 1 E. On east side of road 0.3 mile south of section corner, at north end of row of large cottonwood trees. Drilled June 18, 1954. Surface altitude, 1,258.3 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Recent and Wisconsinan Stages—Alluvium and terrace deposits		
Silt, black	2	2
Silt, tan	3	5
Sand, fine to coarse, and fine to medium arkosic gravel	12	17
Clay, sandy, blue	3	20
Sand, fine to coarse, and fine to medium arkosic gravel	39	59
Kansan Stage—unnamed formation		
Clay, yellow	1	60
Gravel, fine to medium; many sandstone and limestone pebbles	8	68
Clay, yellow; contains some sandstone and limestone gravel	1	69
PERMIAN—Leonardian		
Wellington Formation		
Shale, platy, blue black	1	70

6-1-14bb.—*Sample log of test hole in NW¼ NW¼ sec. 14, T. 6 S., R. 1 E. On east side of road, 25 feet south of point where road turns west. Drilled June 18, 1954. Surface altitude, 1,267.0 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Recent Stage—Dune sand		
Sand, very fine	10	10
Recent and Wisconsinan Stages—Alluvium and terrace deposits		
Silt, light tan, very soft	2	12
Clay, gray	3	15

	Thickness, feet	Depth, feet
Silt, black	3	18
Silt, light tan	8	26
Sand, very fine	4	30
Gravel, medium to coarse, arkosic, and coarse sand	26	56
Sand and gravel, arkosic, mixed with green clay	4	60
Gravel, fine to medium, arkosic, and fine to coarse sand	10	70
Kansan Stage—unnamed formation		
Gravel, fine to medium, chiefly limestone and sandstone pebbles, and coarse sand	6	76
PERMIAN—Leonardian		
Wellington Formation		
Shale, platy, blue black	1	77

6-1-15da.—*Sample log of test hole in NE¼ SE¼ sec. 15, T. 6 S., R. 1 E. On west side of road, about 250 feet north of quarter-mile hedge row. Drilled June 18, 1954. Surface altitude, 1,261.2 feet; depth to water, 22.00 feet June 18, 1954.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Wisconsinan Stage—Terrace deposits		
Clay and silt, black	2	2
Clay, silty, tan	3	5
Clay, tough, black	2	7
Silt, sandy, tan	13	20
Sand, fine to coarse, arkosic, and fine gravel	10	30
Gravel, fine to medium, arkosic, and fine to coarse sand	30	60
PERMIAN—Leonardian		
Wellington Formation		
Limestone, gray	3	63

6-1-22aad.—*Sample log of test hole in NE¼ NE¼ sec. 22, T. 6 S., R. 1 E. On west side of road, midway between abandoned farm house on east and house on west. Drilled June 22, 1954. Surface altitude, 1,263.0 feet; depth to water, 27.40 feet June 25, 1954.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Wisconsinan Stage—Terrace deposits		
Silt, clayey, black	2	2
Silt, tan	6	8
Clay, gray	10	18
Clay, very sandy, light gray	3	21
Clay, sandy, pinkish tan	4	25
Sand, fine to coarse, and fine to medium gravel	35	60
Sand, fine to coarse, fine to medium gravel, and yellow clay	3	63
PERMIAN—Leonardian		
Wellington Formation		
Limestone, hard, dark gray	0.5	63.5

6-2-31cd.—*Sample log of test hole in SE¼ SW¼ sec. 31, T. 6 S., R. 2 E. On north side of road 15 feet west of drive to house on hill south of road. Drilled June 22, 1954. Surface altitude, 1,253.8 feet; depth to water, 29.30 feet June 25, 1954.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Wisconsinan Stage—Terrace deposits		
Silt, black	2	2
Silt, sandy, gray to tan	9	11
Clay, silty; contains some sand and ironstone	15	26
Sand, fine	7	33
Clay, sandy, tan	3	36
Sand, fine to coarse	8	44
Clay, yellow	3	47
PERMIAN—Leonardian		
Wellington Formation		
Shale, or soft limestone, gray to black	1	48

6-2-31dc.—*Sample log of test hole in SW¼ SE¼ sec. 31, T. 6 S., R. 2 E. On north side of road about 500 feet east of drive to house on north side of road. Drilled June 22, 1954. Surface altitude, 1,232.9 feet; depth to water, 18.62 feet June 22, 1954.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Wisconsinan Stage—Terrace deposits		
Silt, black	7	7
Silt, sandy, tan	5	12
Clay, blue gray	3	15
Sand, fine to coarse, and fine to medium arkosic gravel,	29	44
Clay, greenish gray	2	46
Sand, fine to coarse, and fine to medium gravel	14	60
Sand, fine to medium, arkosic	5	65
PERMIAN—Leonardian		
Wellington Formation		
Shale, dark gray, grades downward into harder shale and limestone	5	70

6-2-32ccc.—*Sample log of test hole in SW cor. sec. 32, T. 6 S., R. 2 E. In center of old roadbed, 35 feet north of section corner. Drilled June 22, 1954. Surface altitude, 1,225.6 feet; depth to water, 5.01 feet June 25, 1954.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Recent and Wisconsinan Stages—Alluvium and terrace deposits		
Silt, tan	2	2
Sand, fine to coarse, and fine to medium arkosic gravel,	48	50
Sand, fine to medium; contains some green clay and sandstone gravel	10	60
Kansan Stage—unnamed formation		
Sand, fine to medium; contains much locally derived gravel and shale	9	69
PERMIAN—Leonardian		
Wellington Formation		
Shale, black	11	80

6-2-32cd.—*Sample log of test hole in SE¼ SW¼ sec. 32, T. 6 S., R. 2 E. At end of trail leading east along section line toward Republican River. Drilled June 23, 1954. Surface altitude, 1,233.7 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Recent and Wisconsinan Stages—Alluvium and terrace deposits		
Silt, black	2	2
Silt, tan	4	6
Sand, fine to medium	4	10
Sand, fine to coarse, and fine to medium arkosic gravel,	29	39
Clay, blocky, green	10	49
Sand and gravel, fine to medium	12	61
Clay, silty and sandy, dark gray	2	63
Kansan Stage—unnamed formation		
Gravel, fine to medium, mostly locally derived; some thin clay streaks	6	69
PERMIAN—Leonardian		
Wellington Formation		
Shale, micaceous, sandy, light gray	1	70

6-2-32dd.—*Sample log of test hole in SE¼ SE¼ sec. 32, T. 6 S., R. 2 E. On north side of road, 175 feet east of creek bridge. Drilled June 23, 1954. Surface altitude, 1,225.2 feet; depth to water, 7.40 feet June 28, 1954.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Recent and Wisconsinan Stages—Alluvium and terrace deposits		
Silt, black	3	3
Silt, tan	6	9
Silt, sandy, black	5	14
Sand, fine to coarse, and fine to medium arkosic gravel,	36	50
Clay, tan to gray	4	54
Kansan Stage—unnamed formation		
Gravel, locally derived, fine to medium; some yellow clay	12	66
PERMIAN—Leonardian		
Wellington Formation		
Shale, blue gray	4	70

6-2-33cd.—*Sample log of test hole in SE¼ SW¼ sec. 33, T. 6 S., R. 2 E. On south side of road, 40 feet east of railroad track. Drilled June 24, 1954. Surface altitude, 1,236.9 feet; depth to water, 21.30 feet June 24, 1954.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Wisconsinan Stage—Terrace deposits		
Silt, black	2	2
Silt, tan	5	7
Silt, sandy, tan; contains snail shells	8	15
Sand, fine to medium, arkosic	19	34
Sand, medium to coarse, and fine to medium arkosic gravel	36	70

	Thickness, feet	Depth, feet
Kansan Stage—unnamed formation		
Sand, fine to coarse, mostly locally derived	5	75
PERMIAN—Leonardian		
Wellington Formation		
Shale, blocky, light gray	5	80

6-2-34cd.—*Sample log of test hole in SE cor. SW¼ sec. 34, T. 6 S., R. 2 E. On north side of road, 100 feet west of bridge across drainage ditch. Drilled June 22, 1954. Surface altitude, 1,239.2 feet; depth to water, 24.50 feet June 28, 1954.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Wisconsinan Stage—Terrace deposits		
Silt, black	2	2
Silt, tan	9	11
Clay, hard, gray	3	14
Clay, sandy, tan	14	28
Sand, fine to coarse, and fine arkosic gravel	16	44
PERMIAN—Leonardian		
Wellington Formation		
Shale, slightly calcareous, blue gray and tan	2	46

6-4-19cb.—*Sample log of test hole in NW¼ SW¼ sec. 19, T. 6 S., R. 4 E. On top of second hill north of corner, west of bend in creek where creek is nearest to road. Drilled October 14, 1954.*

	Thickness, feet	Depth feet
PERMIAN—Leonardian		
Wellington Formation		
Shale, greenish buff; contains some thin dolomitic streaks	4	4
Shale, noncalcareous, yellowish green	3	7
Shale, noncalcareous, bright green	1	8
Shale, silty, noncalcareous, chocolate brown	6.5	14.5
Shale, mottled red brown and green	2.5	17
Shale, silty, noncalcareous, red brown	1	18
Shale, greenish gray	3	21
Shale, noncalcareous, light gray	1	22
Shale, noncalcareous, greenish gray	3.5	25.5
Shale, noncalcareous, red brown	1	26.5
Shale, noncalcareous, greenish gray	1.5	28
Shale, silty, noncalcareous, red brown	1	29
Shale, noncalcareous, green; contains some gypsum stringers	2.5	31.5
Shale, platy, greenish gray	1.5	33
Gypsum	1	34
Shale, green	1.5	35.5
Shale, greenish gray; contains gypsum	1	36.5
Gypsum; contains 6-inch shale layer at 38.5 to 39	3.5	40
Gypsum, very clean	8	48
Gypsum, shaly	0.5	48.5
Gypsum	0.5	49
PERMIAN—Wolfcampian		
Nolans Limestone—Herington Limestone member		
Limestone, hard, dolomitic	3	52

7-1-6bb.—*Sample log of test hole in NW cor. sec. 6, T. 7 S., R. 1 E. About 60 feet east and 8 feet south of section corner. Drilled October 7, 1954. Surface altitude, 1,390.0 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Wisconsinan Stage—Peoria Formation		
Silt, dark gray to brown	2	2
Silt, tan	2	4
Clay, buff; contains a few ironstone pebbles	5	9
Clay, sandy, brown to gray	2	11
CRETACEOUS—Gulfian		
Dakota Formation		
Sandstone, fine grained, brown	13.5	24.5
Clay, light gray to brown	4.5	29
Clay, sandy, buff to brown	16	45
Clay, sandy, green gray	4	49
Clay, sandy, red brown to buff	5	54
Clay, greenish gray	5	59
Clay and sandstone	5	64
Shale, clayey, dark gray	10	74
Sandstone, very hard; contains pyrite	3	77
Shale, clayey, sandy, dark gray	5	82
Shale, clayey, sandy, light gray	9.5	91.5
Clay, white, and sandstone	3.5	95
Shale, clayey, dark gray	3	98
Lignite	3	101
Shale, clayey, sandy, gray	27	128
PERMIAN—Leonardian		
Wellington Formation		
Shale, calcareous, very hard, gray, interbedded with limestone	5	133

7-2-3bb.—*Sample log of test hole in NW cor. sec. 3, T. 7 S., R. 2 E. In edge of field south of road, 40 feet east of section corner. Drilled June 25, 1954. Surface altitude, 1,237.9 feet; depth to water, 23.10 feet June 28, 1954.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Wisconsinan Stage—Terrace deposits		
Silt, black	3	3
Silt, tan	8	11
Clay, compact, tan	5	16
Clay, compact, dark gray	2	18
Clay, sandy, tan	6	24
Sand, fine to coarse, and fine to medium arkosic gravel,	23	47
Clay	2	49
Sand, fine to coarse, and fine to medium arkosic gravel,	8	57
Clay, green	4	61
Gravel, fine to medium, arkosic	8.5	69.5
PERMIAN—Leonardian		
Wellington Formation		
Shale, dark gray	10.5	80

7-2-6bb.—*Sample log of test hole in NW¼ NW¼ sec. 6, T. 7 S., R. 2 E. About 25 feet west of west side of old school house foundation. Drilled October 13, 1954. Surface altitude, 1,315.0 feet; depth to water, 82.20 feet October 22, 1954.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Illinoian Stage—Loveland Formation		
Clay, sandy, reddish tan	4	4
Clay, sandy, buff	11	15
Clay, sandy, yellow	9	24
CRETACEOUS—Gulfian		
Dakota Formation		
Sandstone, very fine grained, loosely cemented, white to yellow	26	50
Sandstone, or sand, fine, brown; contains some mica and ironstone	38	88
PERMIAN—Leonardian		
Wellington Formation		
Clay, light gray	5	93
Shale, hard, platy, somewhat calcareous, dark greenish gray	9	102
Shale, light greenish gray	11	113
Shale, hard, platy, dark greenish gray	5.5	118.5
Shale, hard, platy, very dark gray to black	13.5	132
Shale, platy, alternately hard and soft, very dark gray to black	8	140

7-3-5bb.—*Sample log of test hole near NW cor. sec. 5, T. 7 S., R. 3 E. About 130 feet east of highway and 12 feet south of center of road. Drilled October 14, 1954. Surface altitude, 1,333.7 feet; depth to water, 19.20 feet October 22, 1954.*

	Thickness, feet	Depth, feet
CRETACEOUS—Gulfian		
Dakota Formation		
Clay, sandy, tan to gray	4	4
Clay, sandy, red brown	15	19
Clay, sandy, red and gray	11	30
Clay, sandy, black and gray; contains some lignite	5	35
Clay, very sandy, lignite streaks	10.5	45.5
PERMIAN—Leonardian		
Wellington Formation		
Shale, hard, platy, gray	2.5	48
Shale, black	5	53
Shale, dark gray	4	57
Limestone, hard	1	58

8-2-10aa.—*Sample log of test hole in NE¼ NE¼ sec. 10, T. 8 S., R. 2 E. On west side of road, about 175 feet south of culvert. Drilled June 28, 1954. Surface altitude, 1,194.6 feet; depth to water, 11.80 feet June 30, 1954.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Recent Stage—Alluvium		
Silt and clay, tan	5	5
Silt, black	1	6

	Thickness, feet	Depth, feet
Silt, tan	4	10
Sand, fine to coarse, and fine to medium arkosic gravel,	10	20
Gravel, medium to coarse, arkosic	8	28
PERMIAN—Leonardian		
Wellington Formation		
Shale, blocky, blue gray	12	40

8-3-17ba.—*Sample log of test hole in NE¼ NW¼ sec. 17, T. 8 S., R. 3 E. In east borrow pit, 20 feet south of entrance to C. E. Mullen farm. Drilled June 28, 1954. Surface altitude, 1,179.3 feet; depth to water, 9.10 feet June 30, 1954.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Wisconsinan Stage—Terrace deposits		
Silt, brown	6	6
Sand, fine to coarse, and fine to medium arkosic gravel,	24	30
Sand, fine to coarse, and fine to arkosic gravel	12	42
PERMIAN—Wolfcampian		
Nolans Limestone		
Limestone, trace of chert, yellow to gray	2	44

8-3-35da.—*Sample log of test hole in NE¼ SE¼ sec. 35, T. 8 S., R. 3 E. In west borrow pit. Drilled June 29, 1954. Surface altitude, 1,161.5 feet; depth to water, 6.40 feet June 29, 1954.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Recent Stage—Alluvium		
Sand, fine	14	14
Sand, fine to coarse, and fine gravel	5	19
Sand, medium to coarse, and fine to coarse arkosic gravel	10.5	29.5
PERMIAN—Wolfcampian		
Doyle Shale		
Shale, red and gray	5.5	35
Shale, limy, white	1	36
Limestone, hard	1	37

8-3-35dd.—*Sample log of test hole in SE¼ SE¼ sec. 35, T. 8 S., R. 3 E. On south side of road, 40 feet west of center of old black-top road. Drilled June 29, 1954. Surface altitude, 1,159.3 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Recent Stage—Alluvium		
Silt, black	2	2
Silt, tan	3	5
Sand, fine to coarse	7	12
Sand, fine to coarse, and fine to medium arkosic gravel	15	27
PERMIAN—Wolfcampian		
Doyle Shale		
Shale, chalky, red and green	3	30

8-3-36bb.—*Sample log of test hole near NW cor. sec. 36, T. 8 S., R. 3 E. On east side of road across from Broughton store and service station. Drilled June 29, 1954. Surface altitude, 1,181.9 feet; depth to water, 22.00 feet July 12, 1954.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Wisconsinan Stage—Terrace deposits		
Silt, brown	3	3
Silt, sandy, black	2	5
Clay, brown to tan	6	11
Clay, sandy, tan	11	22
Sand, fine, and light-gray clay	8	30
Sand, fine to coarse, and fine to medium arkosic gravel	18	48
PERMIAN—Wolfcampian		
Doyle Shale		
Limestone, brown	2	50

9-4-29ac.—*Sample log of test hole in SW¼ NE¼ sec. 29, T. 9 S., R. 4 E. South of fence, 40 feet west, 13 feet south of power pole. Drilled June 30, 1954. Surface altitude, 1,149.2 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Recent Stage—Alluvium		
Silt, sandy, tan	15	15
Sand, fine to coarse, and fine to medium arkosic gravel	25	40
PERMIAN—Wolfcampian		
Matfield Shale		
Limestone, or limy shale, greenish gray and black	1	41

9-4-29bc.—*Sample log of test hole in SW¼ NW¼ sec. 29, T. 9 S., R. 4 E. In field, 20 feet north of center of road. Drilled June 30, 1954. Surface altitude, 1,164.0 feet; depth to water, 29.90 feet July 12, 1954.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Wisconsinan Stage—Terrace deposits		
Silt, black	2	2
Silt, brown	3	5
Clay, tan to brown	7	12
Clay, dark gray	6	18
Clay, sandy, light gray	13	31
Sand, fine to coarse, and fine to medium arkosic gravel	22	53
PERMIAN—Wolfcampian		
Barneston Limestone		
Shale, green and red	4	57
Limestone, greenish gray; contains some chert	1	58

9-4-29bd.—*Sample log of test hole in SE¼ NW¼ sec. 29, T. 9 S., R. 4 E. On east side of road, 35 feet north of point where road turns north. Drilled June 30, 1954. Surface altitude, 1,152.2 feet; depth to water, 18.20 feet July 12, 1954.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Recent Stage—Alluvium		
Silt, sandy, tan	10	10
Sand, medium to coarse, and fine to medium arkosic gravel	23	33

	Thickness, feet	Depth, feet
PERMIAN—Wolfcampian		
Barneston Limestone		
Limestone, greenish tan and black	1	34

9-4-32adc.—*Sample log of test hole in SW¼ SE¼ NE¼ sec. 32, T. 9 S., R. 4 E. On west side of road, 30 feet west and 10 feet north of windmill where highway turns east. Drilled July 1, 1954. Surface altitude, 1,136.0 feet; depth to water, 11.50 feet July 12, 1954.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Wisconsinan Stage—Terrace deposits		
Silt, sandy, tan	4	4
Sand, fine	9	13
Gravel, fine to medium, arkosic	10	23
Clay, blue to black	2	25
Sand, fine to coarse, and fine to medium arkosic gravel	13	38
PERMIAN—Wolfcampian		
Matfield Shale		
Shale, red	2	40

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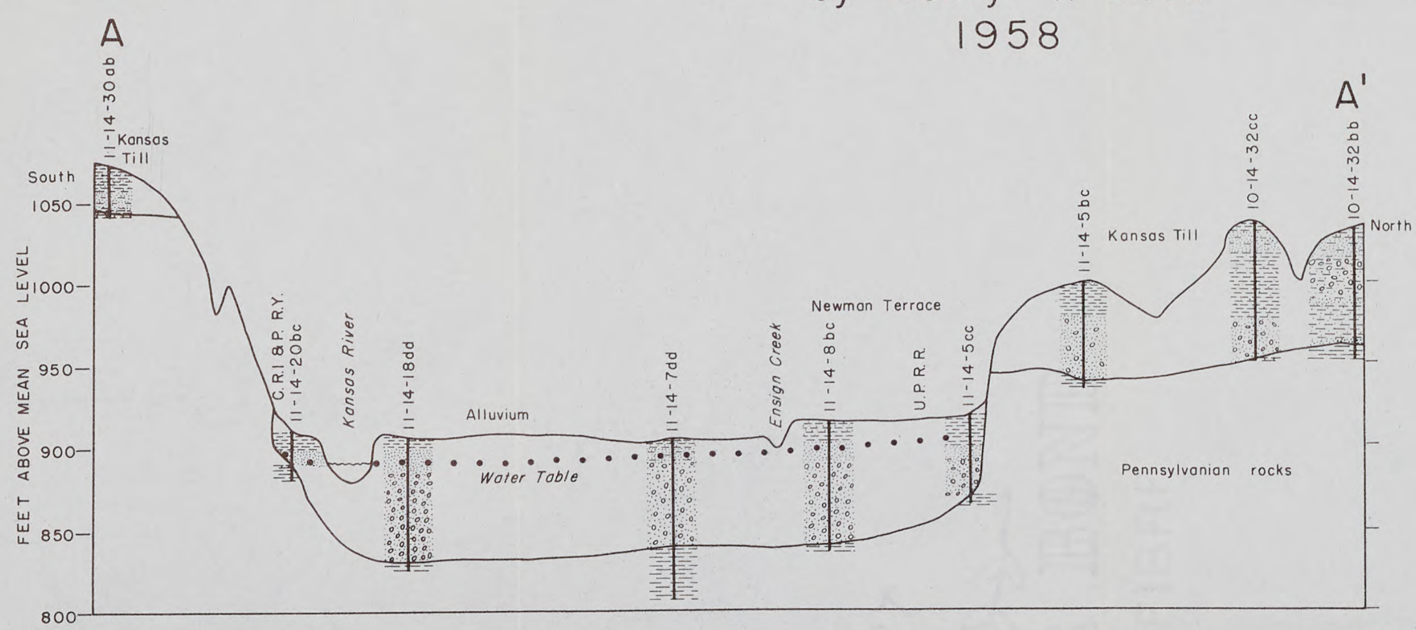
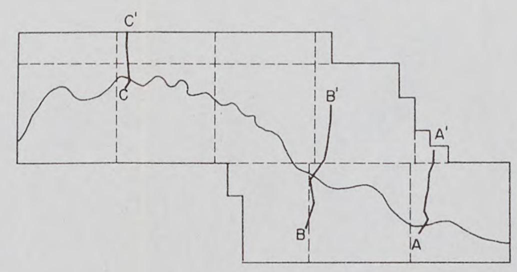
BULLETIN 135, PLATE 3

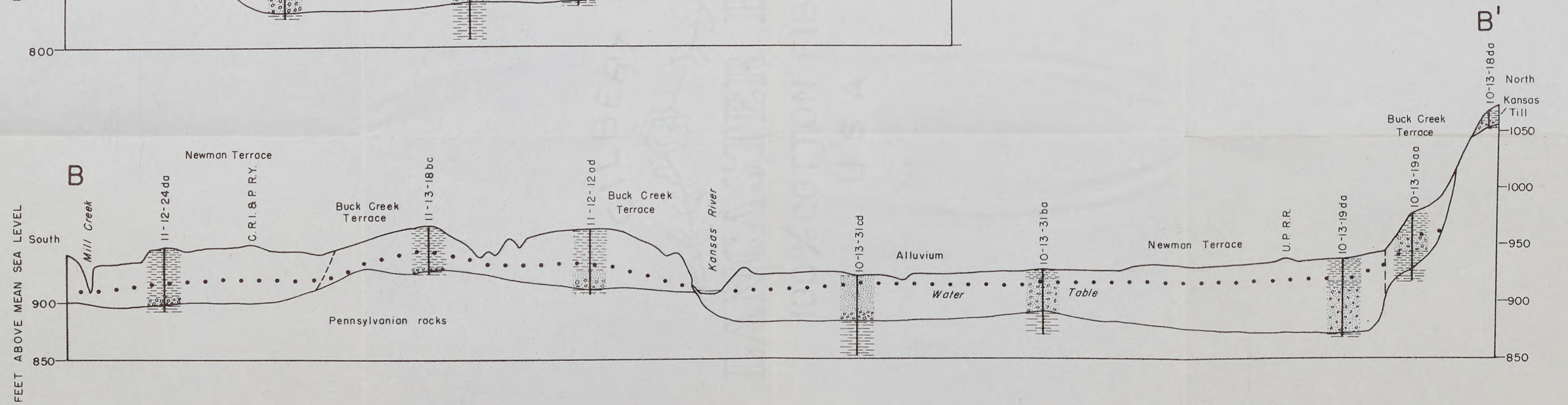
GEOLOGIC SECTIONS OF KANSAS RIVER VALLEY BETWEEN WAMEGO AND TOPEKA VICINITY

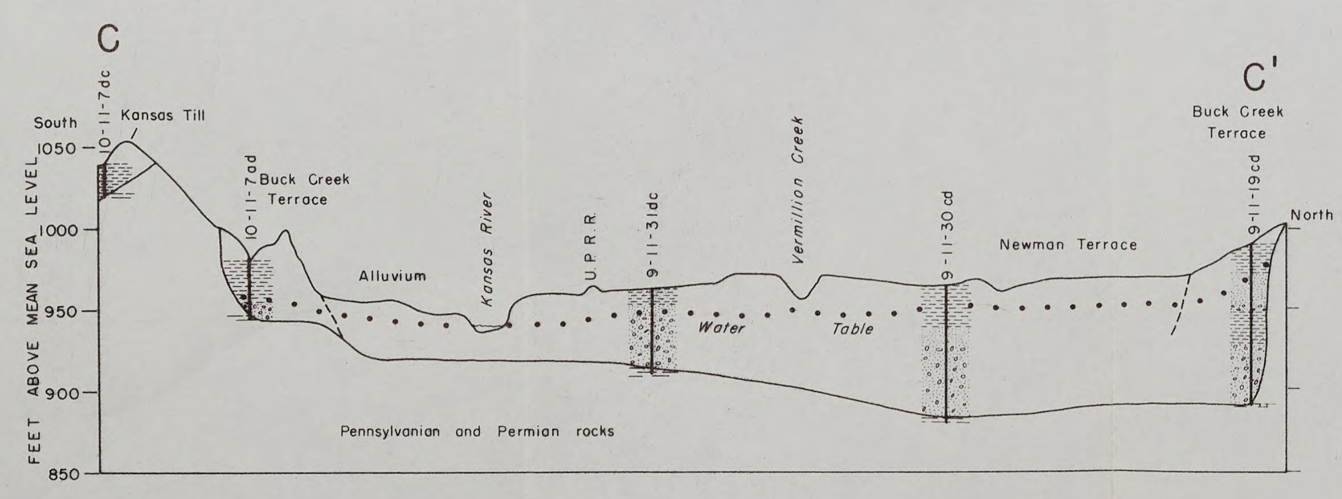
by Henry V. Beck

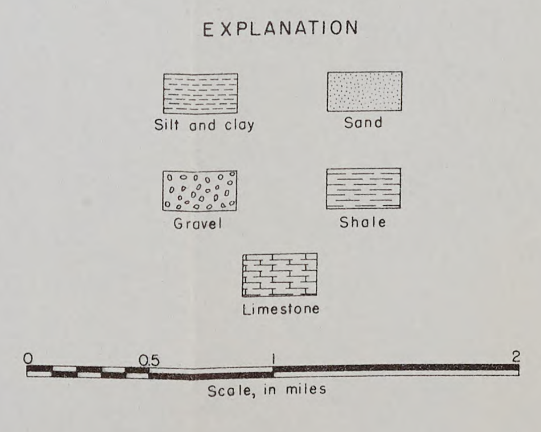
1958











MAP OF KANSAS RIVER VALLEY BETWEEN WAMEGO AND TOPEKA VICINITY

showing water-table contours and locations of wells and test holes

by Henry V. Beck

1956

STATE GEOLOGICAL SURVEY OF KANSAS

BULLETIN 135, PLATE 2

EXPLANATION

- Domestic or stock well
- Drilled test hole
- Augered test hole
- Drilled test hole-observation well
- Irrigation well
- Valley wall
- A–A' Cross section
- 897 Altitude of water table below land surface, in feet
- 180 Depth to water below land surface, in feet
- Brackets indicate chemical analysis
- 930 Water-table contours based on instrumental altitudes. Contour interval five feet
- Federal or state highway
- Graded road
- Railroad
- County line (no road)
- Township line (no road)
- Section line (no road)
- Intermittent stream

0 1 2 3 4

SCALE, IN MILES

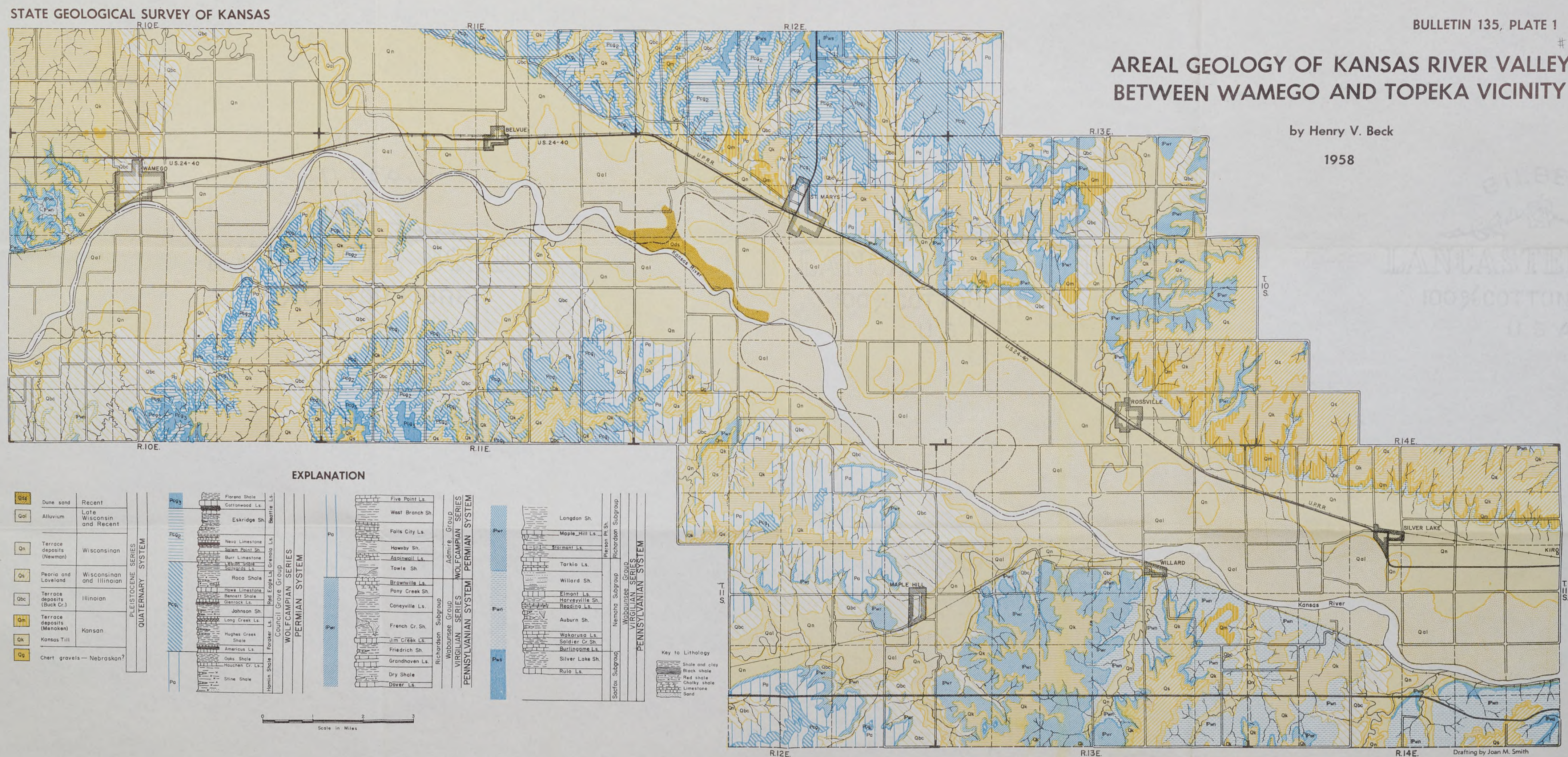
STATE GEOLOGICAL SURVEY OF KANSAS

BULLETIN 135, PLATE 1

AREAL GEOLOGY OF KANSAS RIVER VALLEY BETWEEN WAMEGO AND TOPEKA VICINITY

by Henry V. Beck

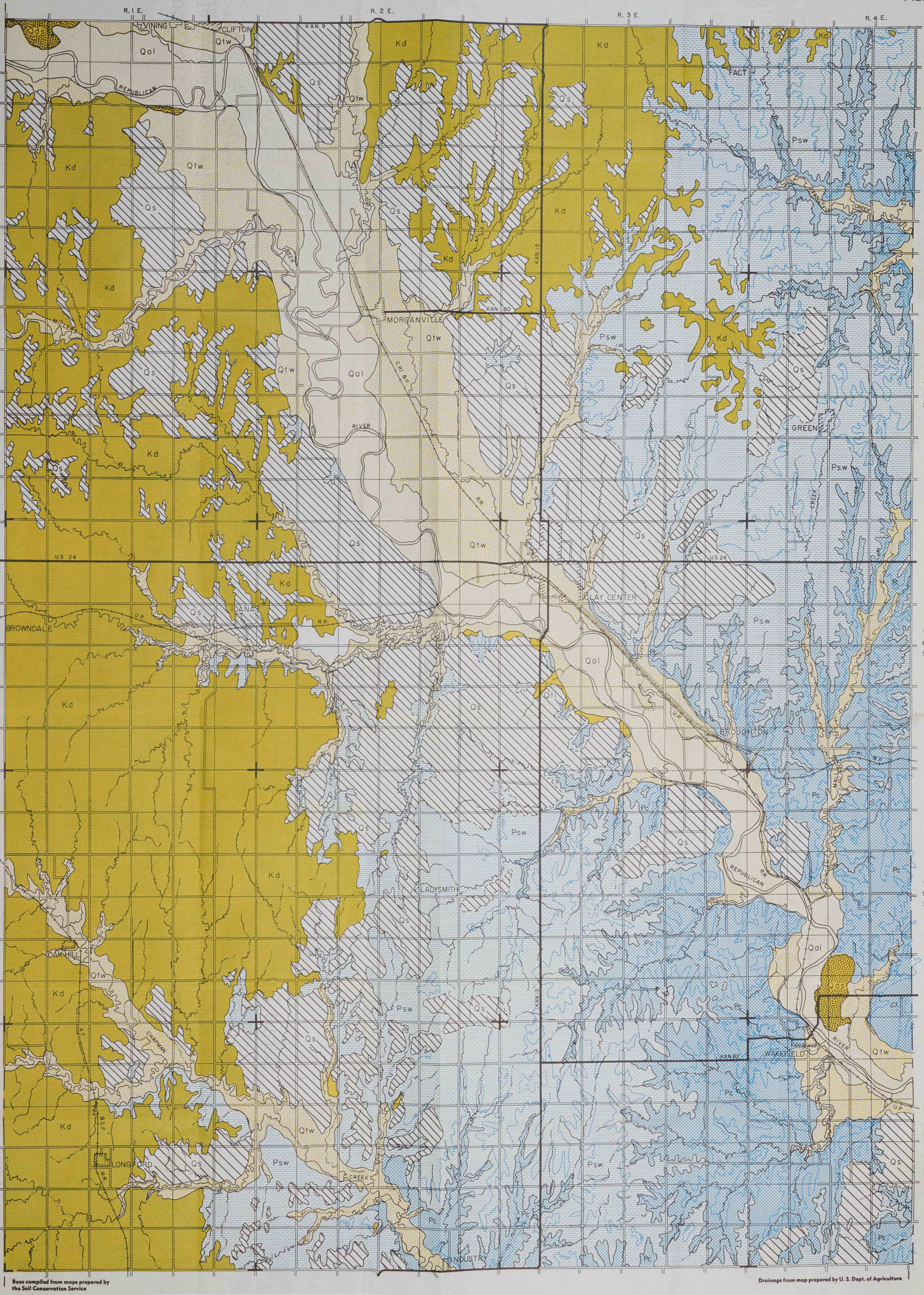
1958



AREAL GEOLOGY OF CLAY COUNTY, KANSAS

By
Kenneth L. Walters and Charles K. Bayne

State Geological Survey of Kansas
1958
Bulletin 136
Plate 1



EXPLANATION

QUATERNARY — PLEISTOCENE

Qds — Dune sand

Fine to medium quartz sand. Above water table and does not yield water to wells.

Qal — Alluvium

Clay, silt, sand, and gravel. Yields large quantities of water of good quality to wells.

Qtw — Wisconsinan terrace deposits

Stream-deposited silt, clay, sand, and gravel. Yield large quantities of water of good quality to wells.

Qs — Eolian silt

Reddish-brown massive silt. Yields no water to wells.

Qti — Illinoian terrace deposits

Chiefly silt and clay; contain much less sand and gravel than Wisconsinan terrace deposits. Yield small to moderate quantities of water to wells.

CRETACEOUS — GULFIAN

Kd — Dakota Formation

Varicolored silt to sandy shale and massive sandstone; as mapped includes Kiowa Shale. Yields moderate amounts of water of good quality to wells.

PERMIAN — LEONARDIAN

Psw (Ch, Ho) — Wellington Formation

Chiefly gray shale containing a chert bed, Ch, and the Hollenberg Limestone member, Ho. Gypsum occurs locally at base of formation. Yields minor quantities of mineralized water to wells.

PERMIAN — WOLFCAMPIAN

Pc (He, Cr, To, Fr) — Chase Group

Upper boundary marked by Herington Limestone member, He, of Nolans Limestone; includes as mapped, Cresswell Limestone member, Cr, of Winfield Limestone; Towanda Limestone member, To, of Doyle Shale; and Fort Riley Limestone member, Fr, of Barneston Limestone. Herington Limestone, Cresswell Limestone, and Towanda Limestone members locally yield small quantities of water to wells. Fort Riley Limestone member yields moderate quantities of water to wells.

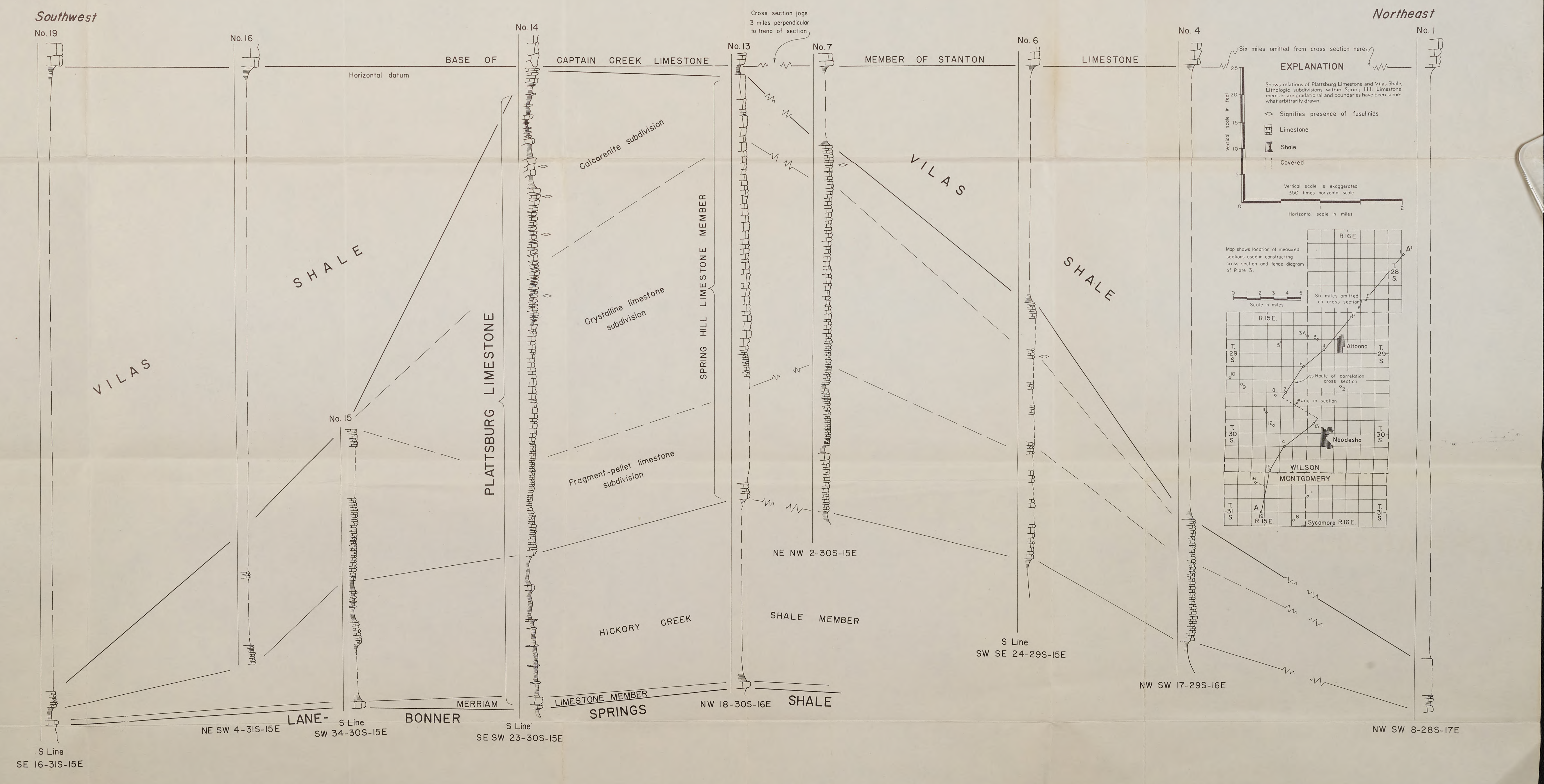
- Federal or State Highway
- Graded road
- Railroad
- County line (no road)
- Township line (no road)
- Section line (no road)
- Intermittent stream

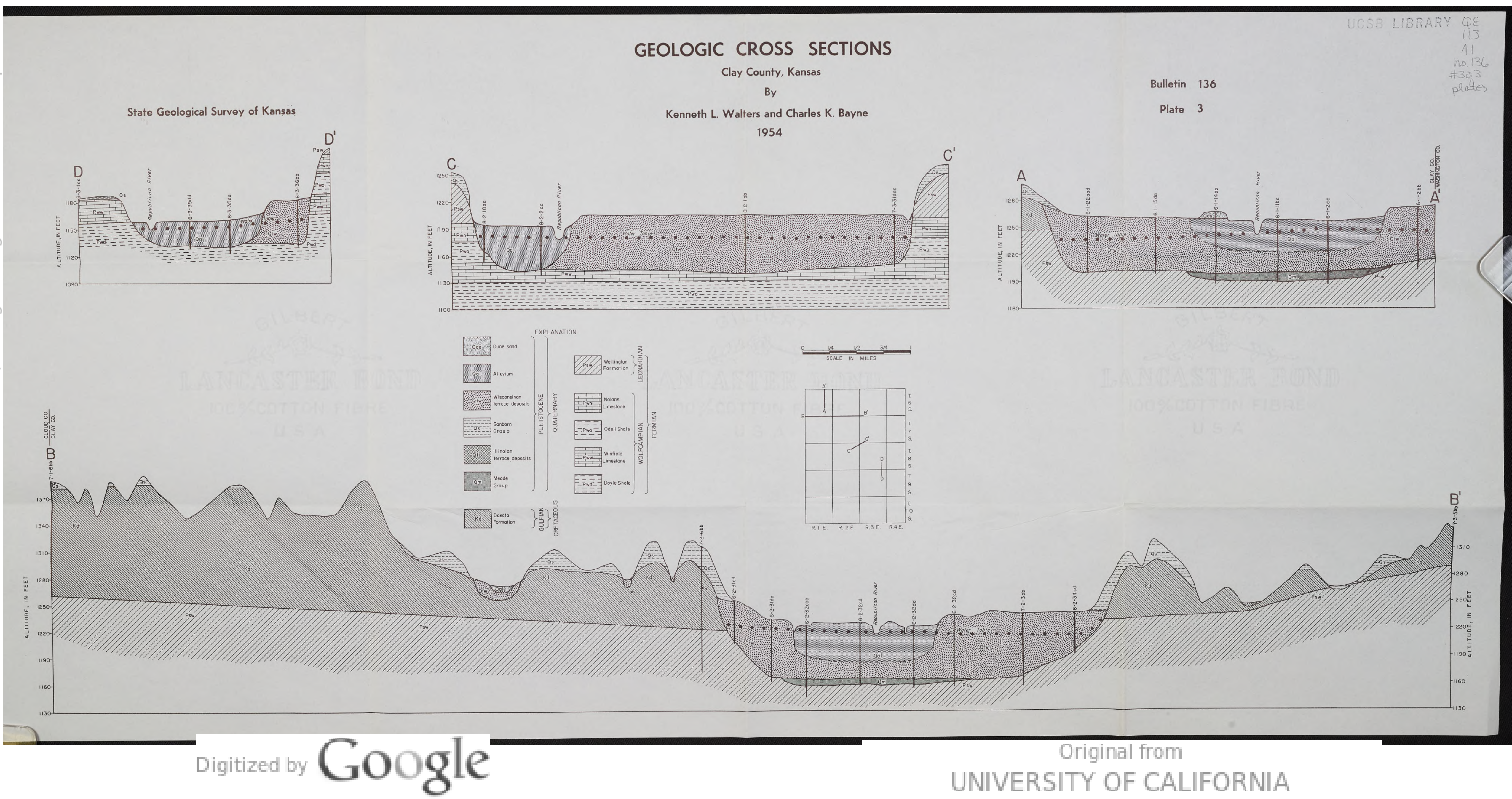
0 1 2 3 4
Scale, in miles

CORRELATION SECTION THROUGH EXPOSED EASTERN PART OF PLATTSBURG BANK, NEODESHA-FREDONIA AREA

STATE GEOLOGICAL SURVEY OF KANSAS
BULLETIN 134, PART 8 PLATE 2

by JOHN W HARBAUGH
1959




GEOLOGIC CROSS SECTIONS
Clay County, Kansas
By
Kenneth L. Walters and Charles K. Bayne
1954
State Geological Survey of Kansas
Bulletin 136
Plate 3
UCSB LIBRARY
EXPLANATION
Qds Dune sand
Qal Alluvium
Qtw Wisconsinan terrace deposits
Qs Sanborn Group
Qti Illinoian terrace deposits
Qm Meade Group
PLEISTOCENE
QUATERNARY
Kd Dakota Formation
GULFIAN
CRETACEOUS
Psw Wellington Formation
LEONARDIAN
Pwn Nolans Limestone
Pwo Odell Shale
Pww Winfield Limestone
Pwd Doyle Shale
WOLFCAMPIAN
PERMIAN
0 1/4 1/2 3/4 1
SCALE IN MILES
R. 1 E. R. 2 E. R. 3 E. R. 4 E.
ALTITUDE, IN FEET
Republican River

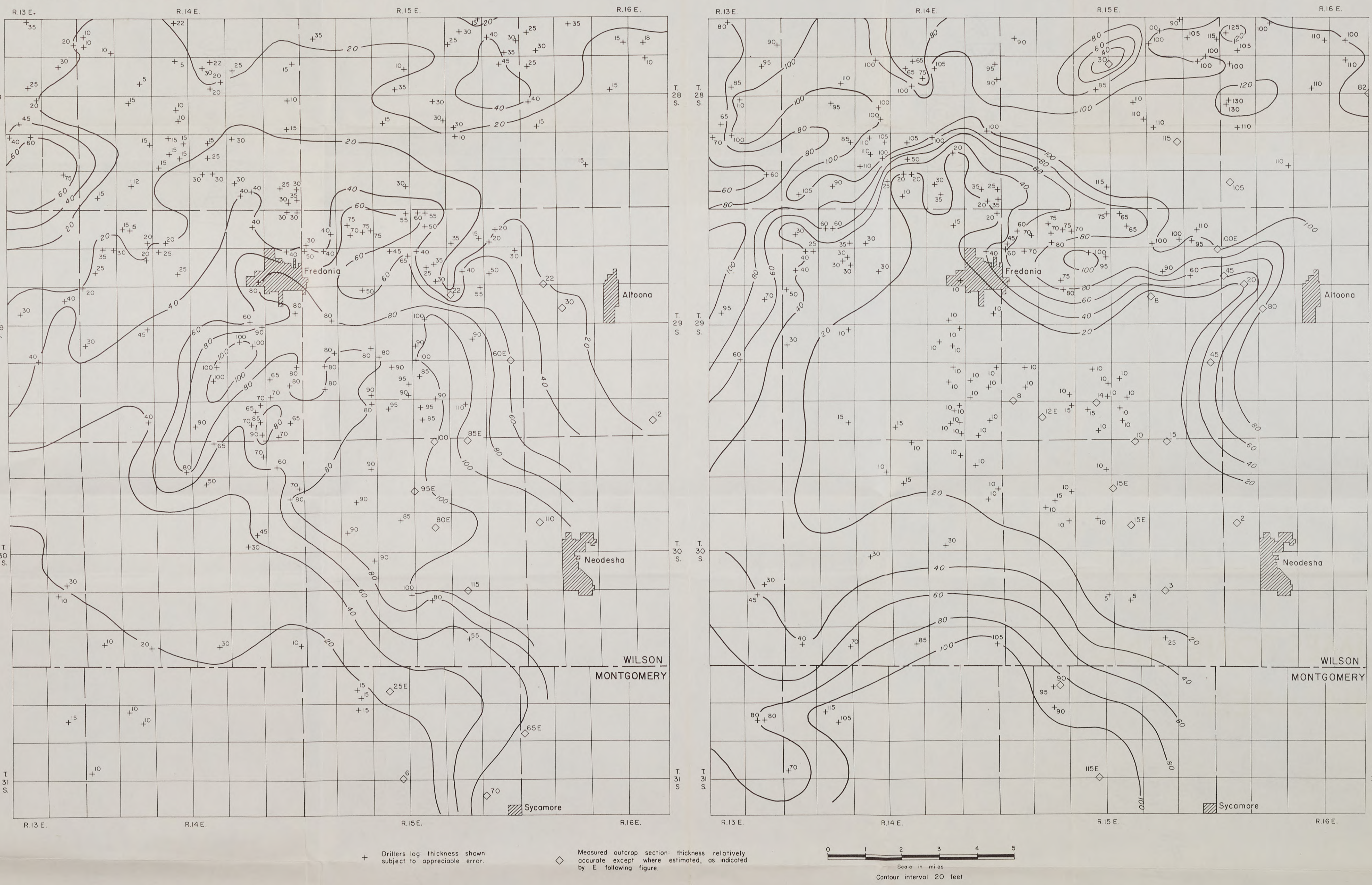
ISOPACHOUS MAPS OF PLATTSBURG LIMESTONE AND VILAS SHALE, NEODESHA-FREDONIA AREA

by JOHN W. HARBAUGH

1959

STATE GEOLOGICAL SURVEY OF KANSAS

BULLETIN 134, PART 8 PLATE 1



A. Isopachous map of Plattsburg Limestone

B. Isopachous map of Vilas Shale

MAP OF CLAY COUNTY, KANSAS

Showing Depth to Water, Location of Wells, Springs, and Test Holes for which Records are Given, and Water-Table Contours

By

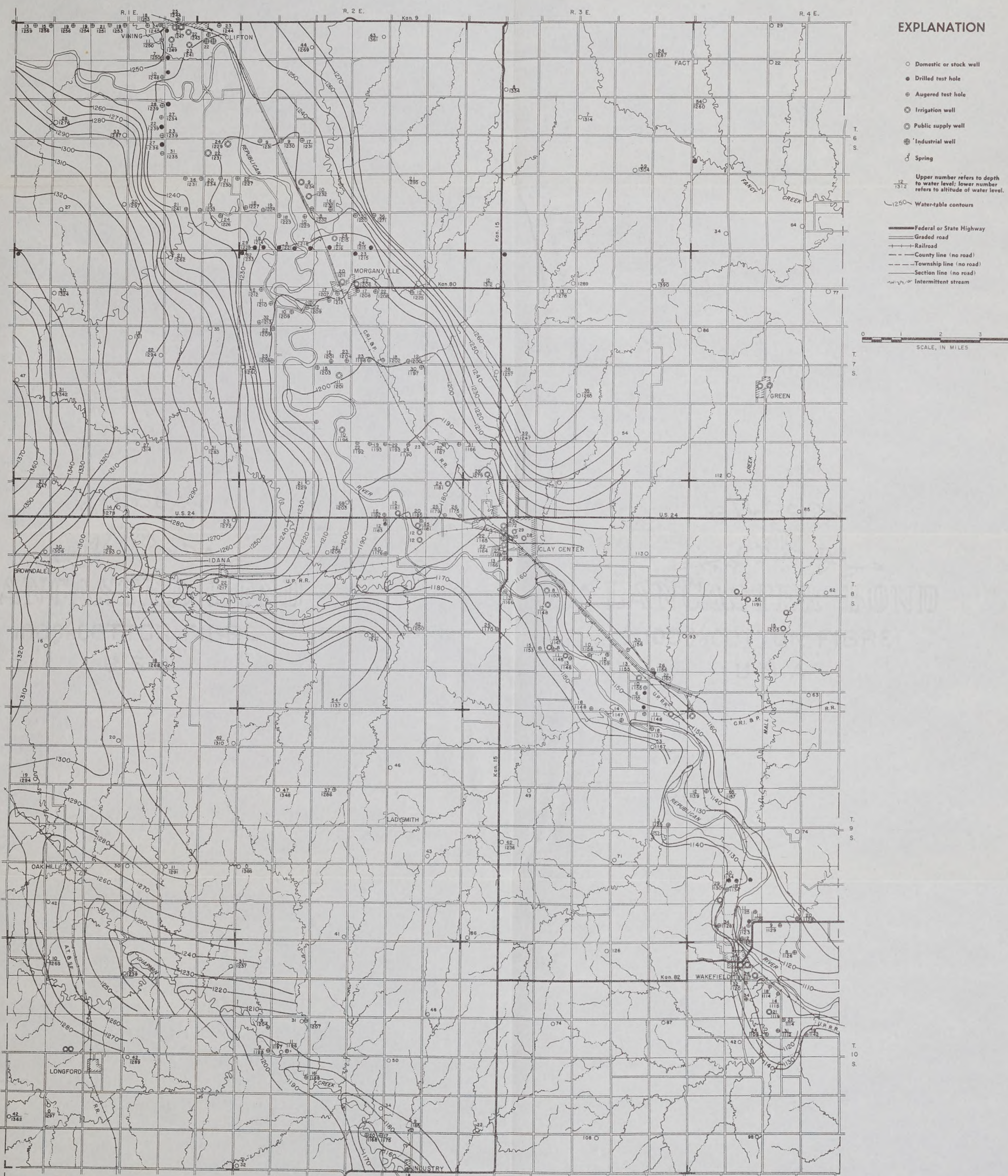
Kenneth L. Walters and Charles K. Bayne

State Geological Survey of Kansas

1954

Bulletin 136

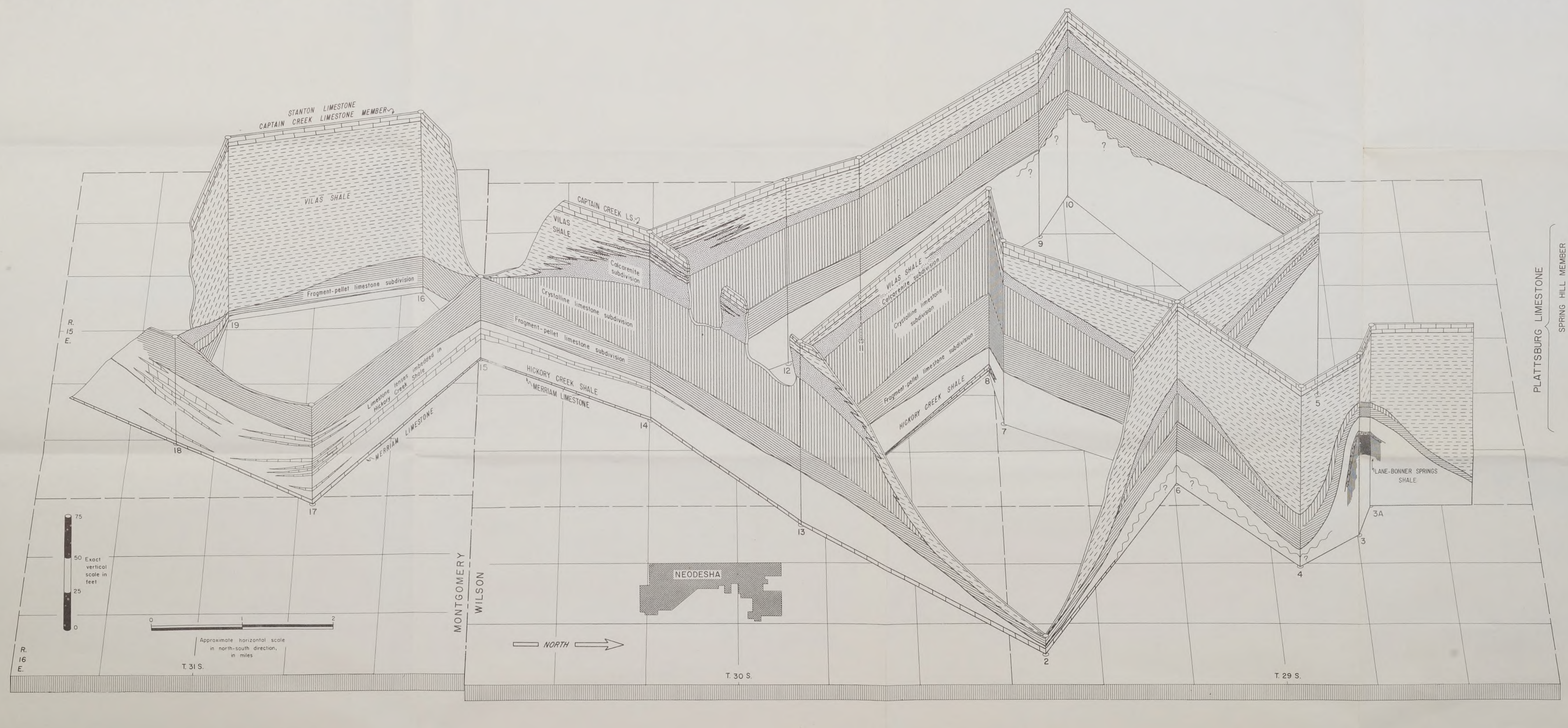
Plate 2



LITHOLOGIC DIVISIONS IN EXPOSED EASTERN PART OF PLATTSBURG BANK, NEODESHA-FREDONIA AREA

by JOHN W. HARBAUGH

STATE GEOLOGICAL SURVEY OF KANSAS
1959
BULLETIN 134, PART 8 PLATE 3



EXPLANATION

STANTON LIMESTONE
CAPTAIN CREEK LIMESTONE MEMBER (lower part only)

VILAS SHALE

PLATTSBURG LIMESTONE

SPRING HILL MEMBER

Calcarenite subdivision

Crystalline limestone subdivision

Fragment-pellet limestone subdivision

HICKORY CREEK MEMBER: (shale with limestone beds)

MERRIAM LIMESTONE MEMBER

LANE-BONNER SPRINGS SHALE

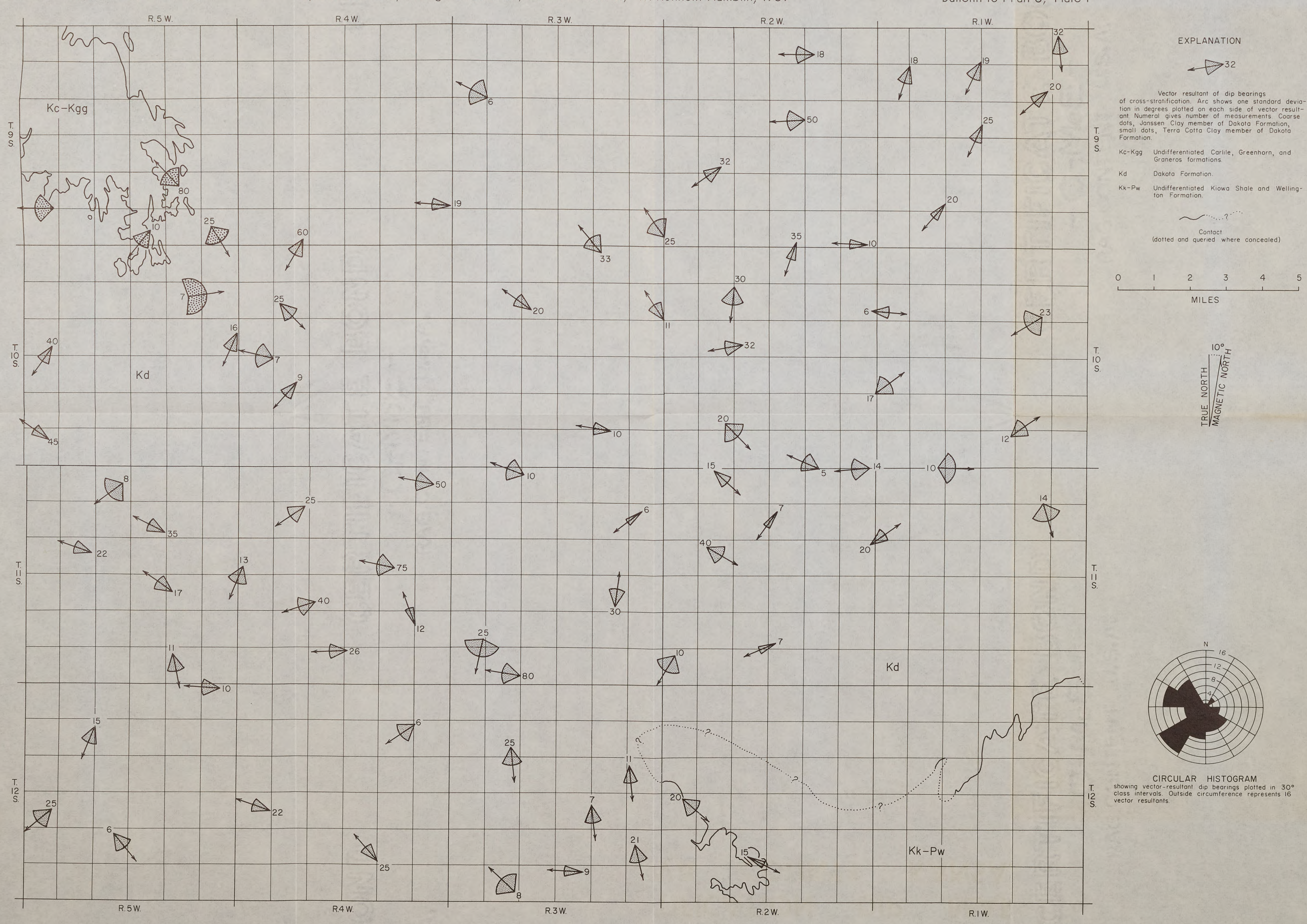
Vertical lines portray measured outcrop sections. Number at each measured section refers to location on map accompanying Plate 2.
Lithologic subdivisions within Spring Hill Limestone member are gradational and boundaries have been somewhat arbitrarily drawn.

VECTOR RESULTANTS OF CROSS-STRATIFICATION DIP BEARINGS IN DAKOTA SANDSTONE, OTTAWA COUNTY, KANSAS

State Geological Survey of Kansas

By Paul C. Franks, George L. Coleman, Norman Plummer, W. Kenneth Hamblin, 1959

Bulletin 134 Part 6, Plate 1



NET THICKNESS OF SANDSTONE BELOW HASKELL LIMESTONE

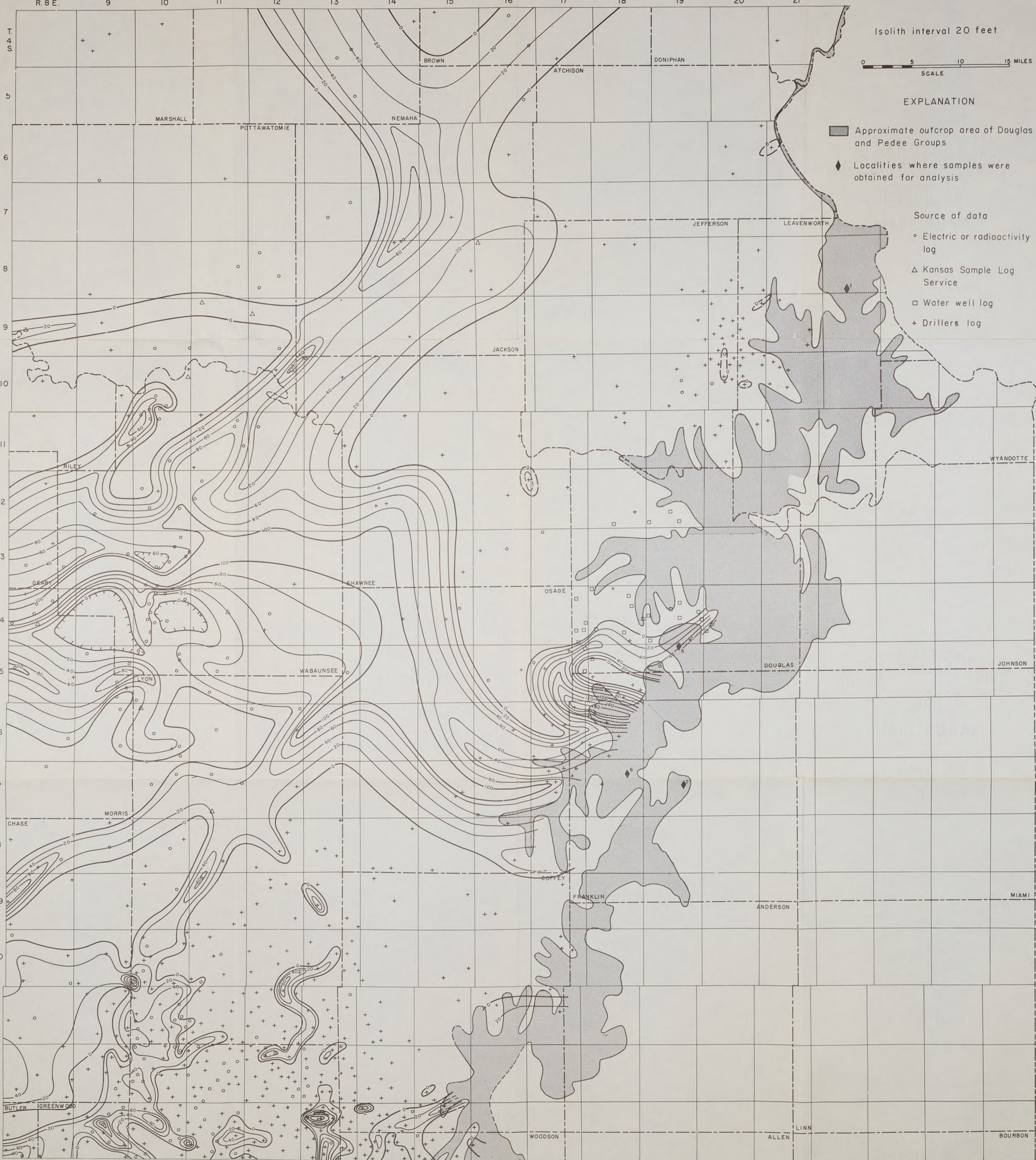
State Geological Survey of Kansas

by Donald T. Sanders, 1957

Bulletin 134 Part 3, Plate 2

NET THICKNESS OF SANDSTONE ABOVE HASKELL LIMESTONE

State Geological Survey of Kansas — by Donald T. Sanders, 1957 — Bulletin 134 Part 3, Plate 1



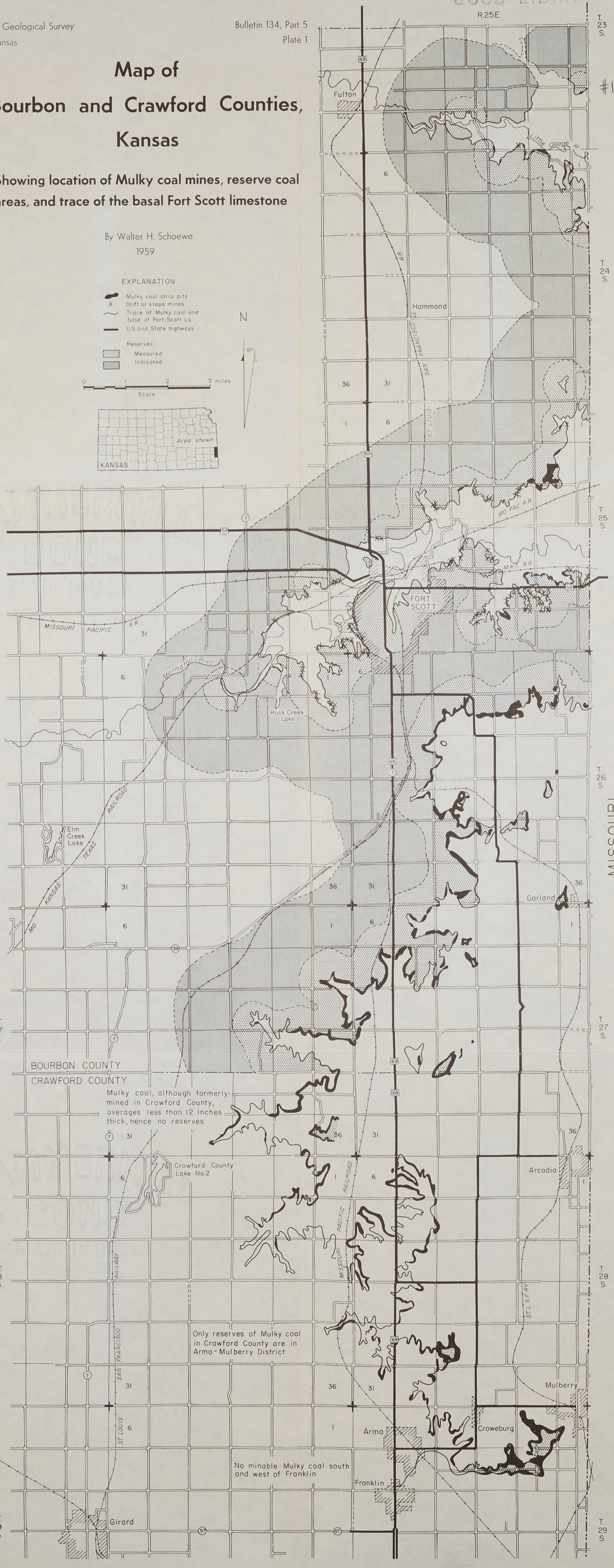
State Geological Survey of Kansas

Bulletin 134, Part 5
Plate 1

Map of Bourbon and Crawford Counties, Kansas

Showing location of Mulky coal mines, reserve coal areas, and trace of the basal Fort Scott limestone

By Walter H. Schoewe
1959



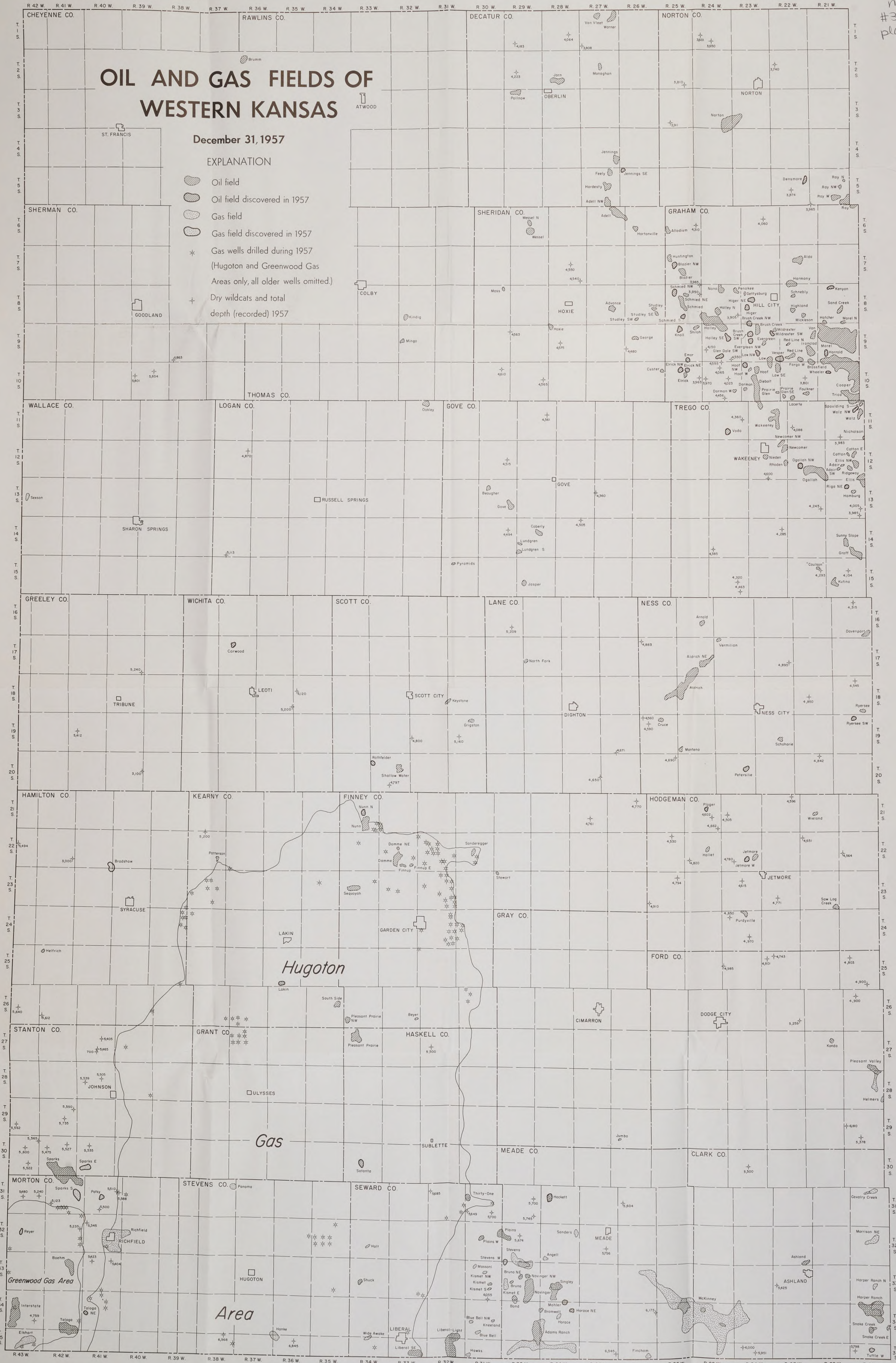
DATA ON SECONDARY RECOVERY PROJECTS IN KANSAS 1957

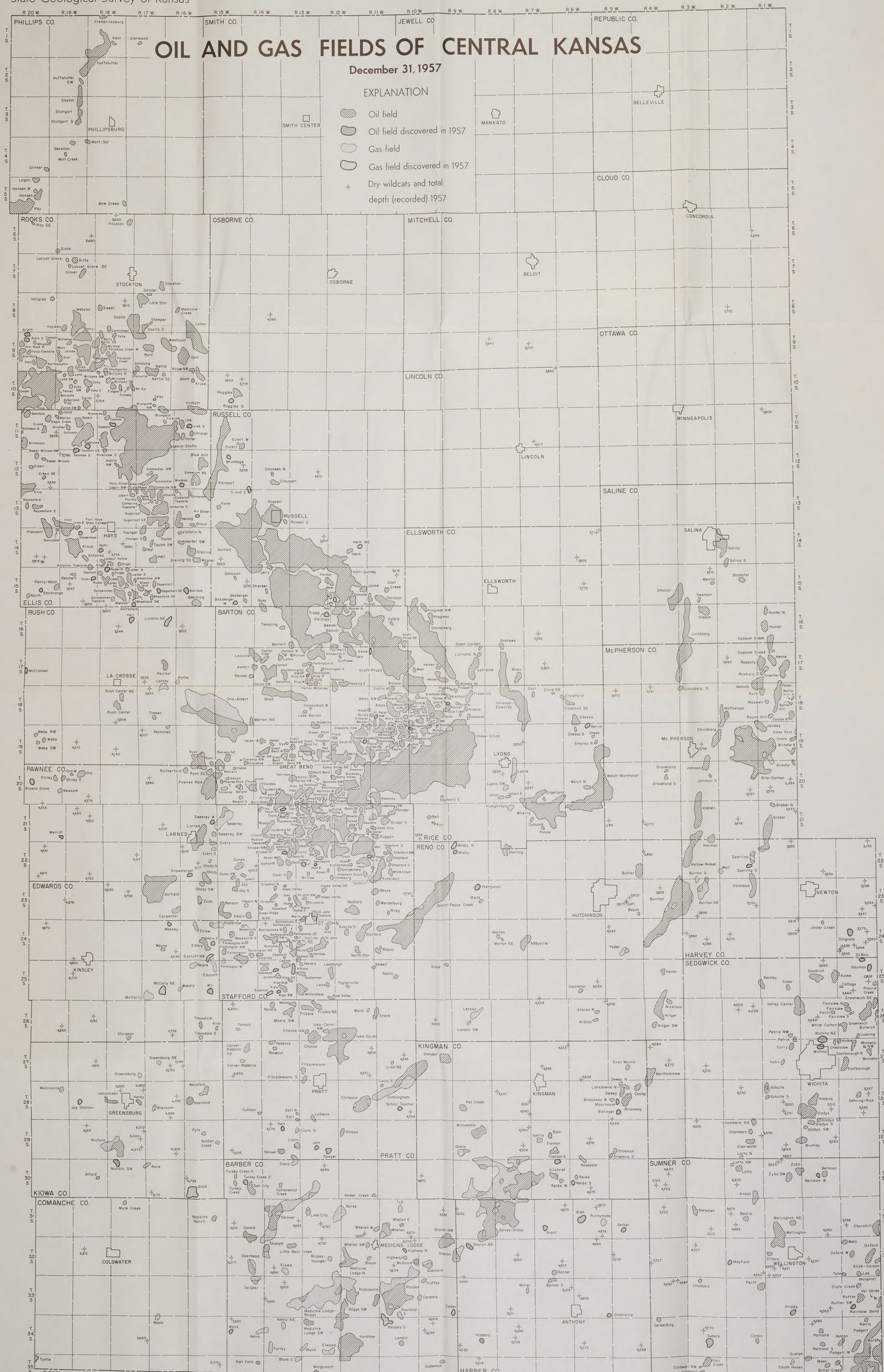
No.	Field	Operator	Project	Location	Cooperative or unitized	Year started	Total developed acres	Producing formation	Thickness of producing zone, feet	Average depth to producing zone, feet	Flowing	Pumping	Total	No. producing wells drilled in 1957	No. active injection wells, 1957	No. injection wells drilled in 1957	Medium of injection	Source of water	Average bbl. water injected per well per day	Cumulative secondary oil recovery per developed acre, bbl.	Production attributable to secondary recovery in 1957, bbl.	No.
				ALLEN COUNTY																		
1	Bronson-Xenia	Ray Beers, Jr.	Southeastern Co.	4-25-21E	Coop.	1956	60	"Bartlesville"	13	765	0	11	11	2	6	2	Salt water	1,200 feet	28	-	*	1
2	do	Mack C. Colt	K-B Project	22,27,28,33-24-21E	No	1951	220	do	18	700	0	132	132	3	117	10	do	Arbuckle	35	4,675	182,183	2
3	do	D and C Oil Co.	Heaton Lease	34-24-21E	-	1955	-	do	12	695	-	-	-	-	-	-	-	Arbuckle and stream	-	-	-	3
4	Elsmore-Shoestring	Fees and Hoyt	Elsmore Shoestring	3,4,10-26-21E	Unit.	1941	180	do	20	660	-	-	-	-	-	-	Fresh and salt water	do	-	-	-	4
5	do	Pavlicek Brothers	Trast and Gray Farms	16-26-21E	-	1944	-	do	28	700	0	9	9	-	-	-	Salt water	-	-	-	*	5
6	Humboldt-Chanute	C and M Oil Co.	Humboldt-Chanute	18,19-26-20E	Coop.	1953	40	do	13	700	-	-	-	-	-	-	Fresh water	Stream and well	-	-	-	6
7	do	Gamble, Wright and Crumley	Wolf-Tebay Lease	24-26-17E	Coop.	1953	160	do	30	840	-	-	-	-	-	-	Salt water	"Oswego lime"	-	-	-	7
8	do	General American Oil Co. of Texas	Matson Group	16,17,18,19, 20-26-18E	No	1938	323	do	30	800	138	14	152	0	147	0	Fresh water	Neosho River	11	3,278	48,275	8
9	do	E. F. Gidley	Diamond	16-26-19E	No	1952	15	do	10	860	-	-	-	-	-	-	Salt water	Mississippian	-	-	-	9
10	do	Weiner Petroleum Co.	Humboldt Water Flood	13,14,23,24-26-18E	No	1942	371	do	25	825	-	-	-	-	-	-	do	do	-	-	-	10
11	do	C. A. Willis	Hoepker	25-26-18E	-	1953	80	do	15	830	-	-	-	-	-	-	-	"Oswego lime"	-	-	-	11
12	Moran	A. P. Brigham	Winslow	34,35-24-20E	-	1958	15	do	16-21	825	0	23	23	0	4	-	-	Mississippian	-	-	-	12
																	Estimated additional secondary recovery production				386,866	
	Totals						1,464				138	189	327	5	274	12					617,324	
				ALLEN and NEOSHO COUNTIES																		
13	Humboldt-Chanute	C. P. M. Corp.	K. T. Unit	32,33-26-18E 4-27-18E	No	1956	45	"Bartlesville"	25	750	-	-	-	-	-	-	Salt water	Mississippian	-	-	-	13
				ANDERSON COUNTY																		
14	Bush City Shoestring	Deep Rock Oil Corp.	Salmon Oil Corp.	7,8,15,16-21-20E	-	1949	371	"Squirrel"	20	800	-	-	-	-	-	-	Salt water	Arbuckle and Mississippian	-	-	-	14
15	do	General American Oil Co. of Texas	Reed Group and Connell and Loriaux Group	13,14-21-20E 4,5,7,8,18-21-21E	No	1939	987	do	30	620	399	18	417	0	389	0	do	Mississippian	22	2,437	140,627	15
16	do	Kewanee Oil Co.	Dengo Waterflood	27,28,32,33-20-21E; 4-21-21E	Neither	1943	351	do	18	600	120	34	154	0	138	0	do	Arbuckle	6	2,668	59,284	16
17	do	Maracaibo Oil Corp.	Starit	8,9,16,17-21-20E	No	1953	80	do	11	700	-	-	-	-	-	-	do	Purchased	-	-	-	17
18	Centerville	Schermerhorn Oil Corp.	Centerville	4,10,15,22-21-21E	Unit.	1947	345	"Bartlesville"	151	725	73	6	79	0	20	0	do	Mississippian	81	1,572	30,768	18
19	Colony-Welda	W. S. Fees	Stauffer-North Hyde	22-22-19E	Neither	1947	20	"Squirrel"	15	800	-	-	-	0	5	0	do	Arbuckle	13	3,484	1,852	19
20	do	W. S. Fees	Unit No. 1	21,22,27,28, 33-22-19E	Unit.	1948	360	do	15	800	-	86	86	0	37	0	do	do	17	795	42,447	20
21	do	W. S. Fees	Unit No. 2	28,29,32,33-22-19E	Unit.	1954	320	do	15	800	-	14	14	0	15	0	do	do	21	165	25,778	21
22	do	W. S. Fees	Unit No. 3	2,3-22-19E	Unit.	1956	219	do	14	825	0	0	0	4	22	22	do	Mississippian	26	.83	181	22
																	Estimated additional secondary recovery production				155,660	
							3,053				592	158	750	4	626	22					456,597	
				BARBER COUNTY																		
23	DeGeer	Lion Oil Co.	DeGeer Unit	2,3-33-15W	Unit.	1954	920	Viola limestone	25	5,200	-	-	-	-	-	-	Salt water	Viola	-	-	-	23
				BARTON COUNTY																		
24	West Great Bend	White Eagle Oil Co.	Flood No. 8	26-19-14W	Coop.	1957	60	Lansing-Kansas City	6	3,320	0	6	6	0	2	0	Fresh water	Sand	140	0	0	24
				BOURBON COUNTY																		
25	Bronson-Xenia	A. B. McClimans and Son	McClimans Oil Lease	8-24-22E	-	1956	2	"Bartlesville"	10	550	0	8	8	3	2	0	-	Mississippian and return	-	-	-	25
26	Davis-Bronson	Albert Markham Oil Co.	Honneus Farm	11-24-21E	Neither	1955	40	do	21	670	-	-	-	-	-	-	Salt water	Mississippian	-	-	-	26
																	Estimated additional secondary recovery production				24,032	
							42				0	8	8	3	2	0					24,032	
				BUTLER COUNTY																		
27	Blankenship	Franco Central Oil Co.	Hughes	9-26-8E	Coop.	1951	80	"Bartlesville"	67	2,500	0	11	11	0	13	0	Salt water	Douglas sand	340	-	29,792	27
28	do	T. O. Lilystrand, Jr.	Dunne	9-26-8E	Coop.	1956	35	do	30	2,500	-	-	-	-	-	-	do	Arbuckle	-	-	-	28
29	do	L. A. Seidenfeld	Sallyards Flood	9,16-26-8E	Coop.	1953	60	do	40	2,520	0	5	5	0	0	0	do	"Bartlesville" and Arbuckle	300	-	5,000	29
30	do	Sohio Petroleum Co.	Sallyards Flood	6,9,17-26-8E	Coop.	1949	157	do	41	2,500	0	18	18	0	16	0	do	Arbuckle	75	4,730	27,800	30
31	El Dorado	Cities Service Oil Co.	El Dorado Shallow Waterflood	25,36-25-4E 19,20,21,22, 27,28,29,30, 31,32,33,34-25-5E; 5,6-26-5E	Coop.	1947	4,945	El Dorado shallow sand	16	650	0	655	655	108	287	32	do	Arbuckle and produced	166	1,092	1,827,032	31
32	do	do	Finney Simpson Waterflood	4,9-26-5E	Coop.	1950	210	Simpson sand	24	2,600	0	15	15	0	7	5	do	do	128	568	60,020	32
33	do	do	Koogler	17,18,19,20, 24-26-4E & 5E	Coop.	1948	1,720	Viola-Simpson	60	2,550	0	168	168	8	91	14	do	do	250	3,083	541,561	33
34	do	do	Marmaton Waterflood	21-25-5E	No	1955	60	Marmaton	30	2,100	0	6	6	0	6	0	do	Produced	151	811	20,341	34
35	do	do	Wilson Kansas City Waterflood	7,8,9-25-5E	Unit.	1956	320	Kansas City	-	2,000	0	21	21	1	8	3	do	do	134	225	69,269	35
36	do	do	Wilson Shallow	8,9-25-5E	Coop.	1954	400	El Dorado shallow sand	10	700	0	59	59	3	21	0	do	do	395	1,900	194,932	36
37	do	do	Wilson Simpson Waterflood	8,9-25-5E	Unit.	1955	120	Simpson sand	20	2,550	0	20	20	0	7	0	do	do	321	4,030	111,464	37
38	do	Gulf Oil Corp.	A. J. Shumway Pilot Waterflood	11-26-4E	Coop.	1956	60	Lansing	23	1,650	0	7	7	0	1	0	do	Lansing and Arbuckle	462	Negligible	Negligible	38
39	do	Magnolia Petroleum Co.	Koogler No. 6	21,29,30-26-5E	Coop.	1951	260	Simpson	-	2,600	0	57	57	0	23	0	do	Arbuckle and produced	470	-	266,000	39
40	do	R. W. Musgrove	Bond	2-25-5E	-	1952	20	"Peru"	20	2,250	0	2	2	0	1	0	do	Viola	300	-	30	40
41	do	Skelly Oil Co.	Hazlett Shallow Waterflood	19-25-5E	Coop.	1954	160	El Dorado shallow sand	12	700	0	9	9	2	8	2	do	Viola lime	140	474	20,163	41
42	do	do	Hill Shallow Waterflood	34-25-5E	Coop.	1957	30	El Dorado shallow sand	9	610	0	2	2	2	2	2	do	Purchased	124	184	5,528	42
43	do	do	Page Waterflood	9-26-5E	Coop.	1950	30	Wilcox sand	30	2,550	0	3	3	0	1	0	do	-	268	1,840	5,873	43
44	do	Stelbar Oil Corp.	Stone Lease	2-25-5E	-	1953	-	"Peru"	40	2,150	-	-	-	-	-	-	do	Water sand	-	-	-	44
45	do	The Texas Co.	El Dorado Project	17-25-5E	Coop.	1954	170	Indian Cave	14	700	0	16	16	0	15	0	do	Viola, Mississippian and produced	150	-	84,258	45
46	Fox-Bush	Eckland Drilling Co.	-	24-28-5E	No	-	60	"Bartlesville"	10-20	2,800	-	-	-	-	-	-	-	-	-	-	-	46
47	do	Magnolia Petroleum Co.	North Fox-Bush Unit	23,24,25,26, 35-28-5E	Unit.	1951	563	do	-	2,760	0	61	61	1	33	0	Salt water	Arbuckle	455	-	286,000	47
48	do	Morrison Producing Co.	Fox Unit No. 1	1,2,11,12, 36-28 and 29-5E	Unit.	1943	880	do	35	2,820	0	34	34	7	25	5	do	Wreford sandy lime	350	2,020	199,690	48
49	Haverhill	Cities Service Oil Co.	Haverhill Unit	15,22,27,34-27-5E	Unit.	1953	180	do	30	2,700	0	26	26	1	6	1	do	Arbuckle and produced	282	1,077	114,143	49
50	Hickory Creek	Nadel and Gussman	Hickory Creek Unit	11,14-28-5E	-	1957	240	"Bartlesville" sand	14	2,700	0	15	15	0	6	0	do	Arbuckle and "Bartlesville"	300	10	2,400	50
51	Smock-Sluss	Burton Oil Producing Co.	Falkenburg	8-26-6E	No	1953	200	"Bartlesville"	20	2,700	-	-	-	-	-	-	do	"Bartlesville"	-	-	-	51
52	do	L. A. Seidenfeld	Smock-Sluss Flood	26-26-5E	No	1953	80	do	30	2,764	0	2	2	0	1	0	do	do	-	-	14,000	52
53	do	Skelly Oil Company	Sluss Waterflood	25,26-26-5E	Coop.	1950	40	"Bartlesville" sand	40	2,710	0	3	3	0	2	0	do	Salt water sand	237	2,119	17,954	53
54	do	The Texas Co.	C. A. Smock Project	2-27-5E	-	1951	70	"Bartlesville"	35	2,700	0	5	5	0	2	0	do	Kansas City and produced	427	-	3,167	54
55	Snowden-McSweeney	Rex and Morris Drlg. Co.	Wunsch	8-29-6E	No	1953	120	do	25	2,800	-	-	-	-	-	-	do	Produced	-	-	-	55
																	Estimated additional secondary recopvery production				210,793	
							11,270				0	1,220	1,220	133	582	64					4,117,210	
				BUTLER AND COWLEY COUNTIES																		
56	Combs	Kewanee Oil Co.	Dillard Waterflood	32,33-29-5E 4,5-30-5E	Neither	1954	210	"Bartlesville" sand	9	2,830	0	16	16	0	7	0	Salt water	Shallow sand	220	756	72,426	56
				BUTLER AND GREENWOOD COUNTIES																		
57	Blankenship and Sallyards	Tidewater Oil Co.	Blankenship and Sallyards Waterflood	1,2,3,9,10, 16,17,21-26-8E 35,36-25-8E	Coop.	1949	1,150	"Bartlesville" sand	36	2,450	0	85	85	5	82	6	Salt water	Arbuckle and "Bartlesville return	134	2,320	582,630	57
				CHASE COUNTY																		
58	Teeter	Glenwood Oil Co.	Leedy	25,36-22-9E	-	1953	80	"Bartlesville"	10	2,500	-	-	-	-	-	-	Salt water	Douglas	-	-	-	58
																	Estimated additional secondary recovery production				(2,958)	
				CHAUTAUQUA COUNTY																		
59	Peru-Sedan	Alpine Oil and Gas Corp.	Alpine Fee	22-34-12E	No	1953	10	"Peru"	20	1,050	0	9	9	0	3	0	Salt water	Return salt	38	-	-	59
60	do	Ralph Bynum	White	22-34-11E	No	1952	10	do	20	1,275	-	-	-	-	-	-	do	Layton or Big salt	-	-	-	60
61	do	G. B. Suppes	McMillan	27-34-12E	-	1952	160	do	20	1,150	-	-	-	-	-	-	do	-	-	-	-	61
62	do	Winona Oil Co. of Del.	Wall	28,29,32,33-33-11E	Coop.	1956	160	do	20	1,200	0	19	19	0	5	2	do	Produced	90	1,300	26,500	62
																	Estimated additional secondary recovery production				576,408	
							340				0	28	28	0	8	2					602,908	
				COWLEY COUNTY																		
63	Couch	Stelbar Oil Corp., Inc.	Couch Unit	12,13-30-5E	Unit.	1955	520	"Bartlesville"	30	2,820	0	27	27	0	7	1	Salt water	Stalnaker sand	130	121	34,621	63
64	Deichman	Anderson-Prichard	Deichman Field	23,24-31-4E	Coop.	1957	300	do	30	2,900	0	12	12	0	15	0	do	do	330	80	23,608	64
65	Eastman	The Texas Co.	Eastman Project	31,36-30-5E 6-31-5E	-	1929	290	do	14	2,850	0	18	18	0	11	0	do	Produced	92	-	*	65
66	Frog Hollow	The Carter Oil Co.	Frog Hollow Pilot Field	16,21-32-5E	-	1952	46	do	17	3,050	0	6	6	0	1	0	do	"Bartlesville" water	478	824	12,927	66
67	Gibson	Aladdin Petroleum Corp.	Baird-Drennan	29,32-34-3E	Neither	1955	250	do	25	3,375	-	-	-	-	-	-	do	"Bartlesville" and Arbuckle	-	-	-	67
68	Geuda Springs	Drillers Production Co.	Aumann	28,33-33-3E	No	1956	170	do	30	3,275	-	-	-	-	-	-	Salt and fresh water	"Bartlesville" and ground water	-	-	-	68
69	Harvey	Gross Producing Co.	Waltz	11-34-3E	-	1955	20	do	20	3,335	-	-	-	-	-	-	Salt water	"Layton"	-	-	-	69
70	Rahn	B. B. Blair	Jesse Rahn	13-34-5E	Unit.	1953	100	do	20-35	2,900	0	3	3	0	2	0	do	Pennsylvanian sand	349	416	13,805	70
71	do	do	Rahn Unit	12,13-34-5E; 6,7-34-6E	Unit.	1951	200	do	20-30	2,900	0	6	6	0	4	0	do	do	358	1,443	76,053	71
72	do	Continental Oil Co.	Rahn Unit No. 1	32,33-33-6E; 5,6-34-6E	Unit.	1952	861	"Burbank sand"	30	3,000	-	-	-	-	-	-	Water	"Elgin"	-	-	-	72
73	do	do	Rahn Unit No. 2	14,22,23-34-5E	Unit.	1953	150	do	22	3,000	-	-	-	-	-	-	do	do	-	-	-	73
74	Rainbow Bend	Sunray-Mid-Continent	Rainbow Bend Waterflood	16,17,20,21, 28,29-33-3E	Partly Unit.	1952	1,080	"Bartlesville"	25	2,900	0	25	25	2	31	0	Fresh water	Alluvial sand	9,500	1,228	313,046	74
75	Rock	Cooperative Refinery Assn.	Rock Unit I	11,12-30-4E	Unit.	1952	80	do	18	2,700	-	-	-	-	-	-	Salt water	Stalnaker	-	-	-	75
76	do	do	Rock Unit II	21-30-4E	Unit.	1953	110	do	18	2,750	-	-	-	-	-	-	do	do	-	-	-	76
77	do	Stelbar Oil Corp., Inc.	Rock Unit	11,14,15,16-30-4E	Unit.	1951	440	do	20	2,800	0	22	22	0	17	0	do	Stalnaker sand	330	1,800	90,255	77
78	Weathered	Bert Frost	Weathered Lease	28-31-3E	No	1946	40	Stalnaker	5	2,100	-	-	-	-	-	-	do	Stalnaker	-	-	-	78
79	Winfield	Gulf Oil Corp.	Winfield Pool Pilot Waterflood	24-32-4E	Coop.	1948	70	"Bartlesville"	40	2,950	0	5	5	0	0	0	do	"Bartlesville" and "Layton"	0	236	*	79
80	do	Sinclair Oil and Gas	Winfield Line Flood	24-32-4E	Coop.	1948	311	do	43	3,000	0	24	24	24	2	1	do	Produced water	762	55	*	80
																	Estimated additional secondary recovery production				484,836	
							5,038				0	148	148	26	90	2					1,060,559	
				CRAWFORD COUNTY																		
81	Brazilton	Walters Drilling Co.	Brazilton	36-28-22E	No	1954	5	"Bartlesville"	50	325	-	-	-	-	-	-	Fresh water	Mississippian and well	-	-	-	81
82	"Houston"	Fallon Gas Corp.	Tri State Oil Producers	3-31-22E	No	1953	22	do	20	200	-	-	-	-	-	-	do	Well	-	-	-	82
83	St. Paul-Walnut	Walters Drilling Co.	Stevens Goff Lease	26,35-28-21E	No	1953	12	do	20	400	-	-	-	-	-	-	Salt water	Arbuckle	-	-	-	83
84	Walnut-Southeast	General American Oil Co. of Texas	Walnut Group	28-28-22E	No	1951	16	do	12	385	0	7	7	0	11	2	do	do	11	1,864	4,286	84
																	Estimated additional secondary recovery production				30,144	
							55				0	7	7	0	11	2					34,430	
				EDWARDS COUNTY																		
85	Enlow	Natural Oil and Gas Co.	Enlow Lease	9-24-16W	Coop.	1956	80	Lansing-Kansas City	6	3,740	0	2	2	0	1	0	Salt water	Lansing-Kansas City	85	18	1,465	85
				ELLIS AND ROOKS COUNTIES																		
86	Brungardt	Champlin Oil and Refining Co.	Brungardt Unit	35,36-10-17W; 2-11-17W	Unit.	1956	150	Pennsylvanian conglomerate	7	3,400	0	9	9	0	7	0	Salt water	Arbuckle	88	451	50,516	86
				FRANKLIN COUNTY																		
87	Paola-Rantoul	General American Oil Co. of Texas	Heminger-Finch Group	20,28,29-16-21E	No	1951	191	"Squirrel"	20	600	20	49	69	0	78	0	Salt water	Mississippian lime	22	1,632	36,232	87
88	do	do	Johnson Group	27,34-16-21E	No	1948	136	do	12	580	30	18	48	0	51	0	do	do	27	1,685	15,018	88
89	do	Kirk Johnson	Ottawa	31,32-16-21E	Coop.	1955	40	do	14	630	-	-	-	-	-	-	do	Roubidoux	-	-	-	89
90	do	Maracaibo Oil Corp.	Group 3	4,8,9,16,17, 20,21-16-21E	Unit.	1911	200	do	20	600	-	-	-	-	-	-	do	-	-	-	-	90
91	do	do	Group 7	3,10,15,22-17-21E	Unit.	1942	-	do	11	600	-	-	-	-	-	-	do	-	-	-	-	91
																	Estimated additional secondary recovery production				223,544	
							567				50	67	117	0	129	0					274,794	
				GREENWOOD COUNTY																		
92	Atyeo	Cities Service Oil Co.	Atyeo	6-22-10E	Unit. and Coop.	1952	230	"Bartlesville"	27	2,300	0	31	31	0	25	0	Salt water	Arbuckle and produced	146	4,277	172,015	92
93	Browning	Sinclair Oil and Gas	Browning Unit	19,20,29,30-22-10E	Unit.	1949	750	do	51	2,300	0	76	76	8	65	14	do	do	390	1,834	*	93
94	Burkett	Phillips Petroleum Co.	Burkett Unit	13,23,24,26, 27-23-10E; 18-23-11E	Unit.	1942	685	do	31	2,100	0	65	65	0	47	0	do	Douglas and produced	200	7,956	137,524	94
95	DeMalorie-Souder	Cities Service Oil Co.	Greenwood Unit	19,30-22-11E	Unit.	1952	66	"Bartlesville" sand	30	2,200	0	5	5	0	5	0	do	do	69	1,324	6,843	95
96	do	Phillips Petroleum Co.	DeMalorie Souder Unit	1,2,11,12-22-10E	Unit.	1949	640	"Bartlesville"	55	2,100	0	36	36	0	38	0	do	Arbuckle and produced	170	2,978	362,529	96
97	do	do	Pix Unit	3,10-22-10E	Unit.	1948	25	do	55	2,100	0	3	3	0	2	0	do	do	150	4,183	6,961	97
98	do	do	Souder "B"	7-22-11E	Unit.	1953	27	do	30	2,100	0	2	2	0	1	0	do	do	300	1,881	7,867	98
99	do	Sunray-Mid-Continent	Clopton-Harris Waterflood	18,19-22-11E	Coop.	1946	220	do	15	2,050	0	12	12	1	7	2	do	Douglas sand	170	2,654	26,788	99
100	Fankhauser	do	Fankhauser Unit	4-22-12E	No	1949	560	"Bartlesville" sand	25	2,500	0	20	20	0	14	0	Water	do	450	2,740	32,529	100
101	Hamilton	Associated Resources Corp.	Associated Resources Corp.	8,9-24-12E	Coop.	1951	160	"Bartlesville"	12-20	1,700	-	-	-	-	-	-	Salt water	do	-	-	-	101
102	do	R. E. Evans	Hillman Unit	35,36-23-11E	Neither	1956	280	do	20	1,865	-	-	-	-	-	-	do	do	-	-	-	102
103	do	Hester and Wright Oil Co.	Hamilton Flood	5,6,7,8-24-12E	No	1953	117	do	20	1,710	0	10	10	2	6	0	do	do	125	848	44,747	103
104	do	Phillips Petroleum Co.	Brothers Unit	35-23-11E	Unit.	1955	28	do	20	1,850	0	4	4	0	2	0	do	Arbuckle and produced	450	974	17,115	104
105	Jackson	T. O. Lilystrand, Jr.	Ladd	35-25-8E	Coop.	1956	30	do	15	2,450	-	-	-	-	-	-	do	Arbuckle	-	-	-	105
106	Madison	Cities Service Oil Co.	Madison Unit	11,12,14,15, 22,23-22-11E	Unit. and Coop.	1948	1,045	"Bartlesville" sand	38	1,850	0	66	66	1	49	0	do	Arbuckle and produced	230	2,508	449,445	106
107	do	Magnolia Petroleum Co.	Kipfer-McGilvray	11,12-22-11E	Unit.	1949	75	do	-	1,800	0	6	6	0	5	0	do	Douglas sand	508	-	22,000	107
108	Polhamus	Glenwood Oil Co.	Polhamus Water Flood	34-24-9E; 3-25-9E	Coop.	1949	248	"Bartlesville"	29	2,250	12	18	30	0	24	0	do	Douglas	225	4,803	94,254	108
109	do	Wood Oil Co.	do	27,34-24-9E; 4-25-9E	Coop.	1949	209	do	27	2,200	12	18	30	0	29	0	do	Produced water	133	5,206	43,578	109
110	Quincy	Delhi-Taylor Oil Co.	North Quincey	6,31-24,25-13E	Coop.	1955	100	"Bartlesville" and "Cattleman"	10 5	1,550	0	8	8	1	5	0	do	Arbuckle	78	315	*	110
111	Sallyards	The Ohio Oil Co.	Bryden-Ladd	25,36-25-8E; 31-25-9E	Coop.	1953	172	"Bartlesville"	40	2,400	0	19	19	0	13	0	do	Douglas sand	170	2,287	113,475	111
112	do	do	Hoffman	30-25-9E	Coop.	1951	71	do	40	2,400	0	7	7	0	4	0	do	do	95	3,251	22,860	112
113	do	do	Ladd Unit	19,30-25-9E	Coop.	1946	205	do	50	2,400	0	8	8	0	1	0	do	do	237	4,963	6,299	113
114	do	do	Ladd "A"	19,20-25-9E	Coop.	1951	79	do	40	2,400	0	9	9	0	5	0	do	do	189	2,787	19,851	114
115	Scott	Phillips Petroleum Co.	Scott Unit	24,25-23-8E 19-23-9E	Unit.	1945	378	do	40	2,600	0	36	36	0	20	0	do	Douglas and produced	190	1,988	75,876	115
116	Seeley-Wick	Cities Service Oil Co.	Clopton Unit	8-23-11E	Unit.	1946	227	do	33	1,900	0	20	20	0	13	0	do	do	215	4,097	42,671	116
117	do	Phillips Petroleum Co.	Beal Unit	21,22,27,28-23-11E	Unit.	1950	513	do	55	1,900	0	61	61	0	50	0	do	Arbuckle and produced	260	8,595	332,060	117

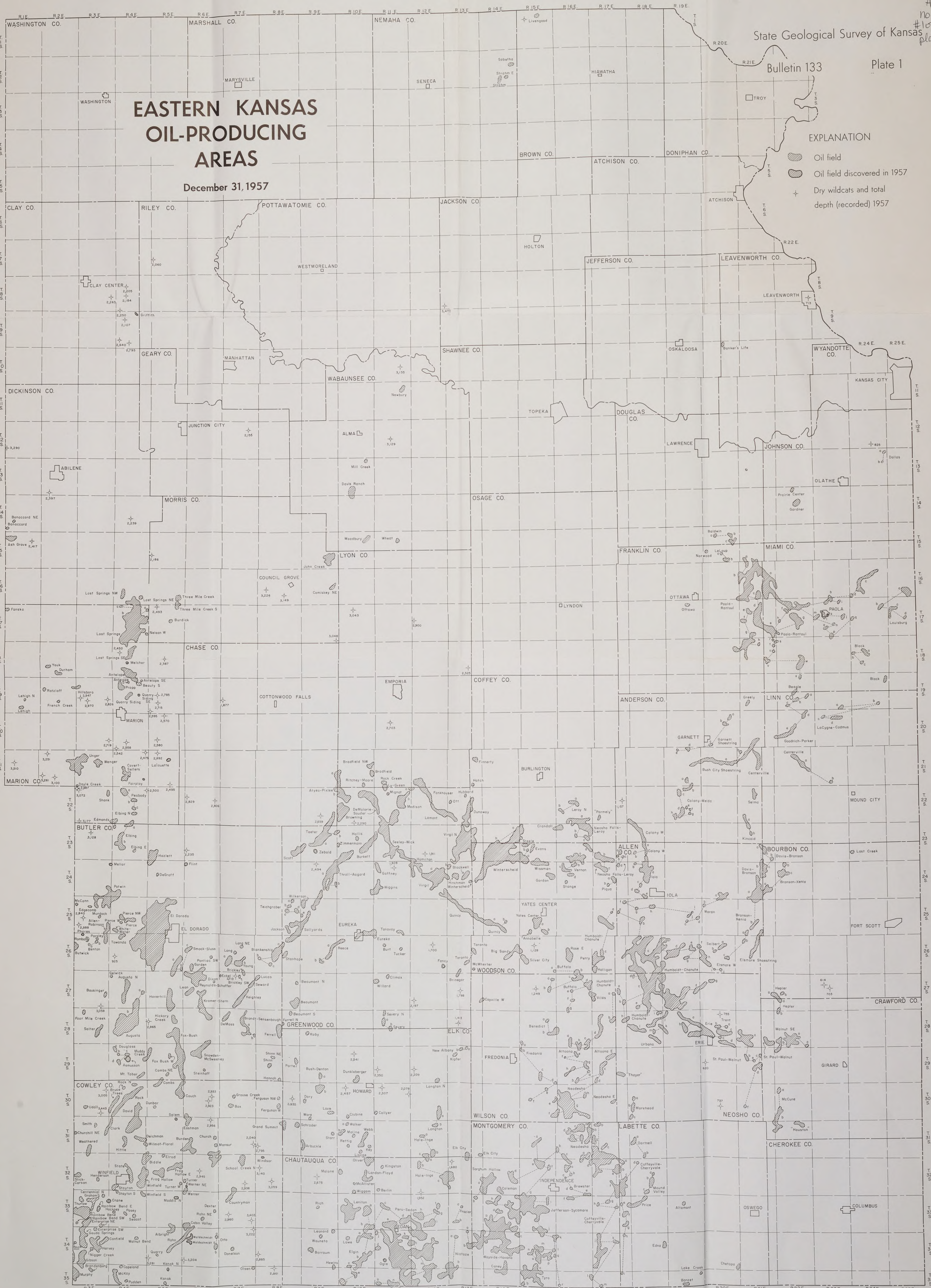
DATA ON SECONDARY RECOVERY PROJECTS IN KANSAS 1957 concluded

No.	Field	Operator	Project	Location	Cooperative or unitized	Year started	Total developed acres	Producing formation	Thickness of producing zone, feet	Average depth to producing zone, feet	Active wells: Flowing	Active wells: Pumping	Active wells: Total	No. producing wells drilled in 1957	No. active injection wells, 1957	No. injection wells drilled in 1957	Medium of injection	Source of water	Average bbl. water injected per well per day	Cumulative secondary oil recovery per developed acre, bbl.	Production attributable to secondary recovery in 1957, bbl.	No.
118	do	do	McGilvray Unit	8,9,16,17-23-11E	Unit.	1948	379	do	37	1,950	0	35	35	0	18	4	do	do	320	4,176	376,888	118
119	do	do	York, DeMalorie and O'Neal Unit	32-22-11E	Unit.	1937	178	do	47	1,950	0	18	18	0	16	0	do	Douglas and produced	240	8,833	37,301	119
120	do	Skelly Oil Co.	Wick Waterflood Project	22,27,34-22-11E	Coop.	1943	570	"Bartlesville" sand	20	1,959	1	23	24	0	17	0	do	Douglas water sand	288	2,480	85,310	120
121	Teeter	Cities Service Oil Co.	Teeter Unit	10,11,14,15,16-23-9E	Unit. and Coop.	1947	760	do	37	2,470	0	76	76	4	34	5	do	Arbuckle and produced	226	1,121	254,313	121
122	do	Kirkpatrick & McGuire	Refiners Oil-Morris-McGinnis	20,21-23-9E	-	1951	92	"Bartlesville"	36	2,550	0	5	5	0	4	0	do	Douglas sand	260	635	14,644	122
123	do	Skelly Oil Co.	Hartley Waterflood	2-23-9E	-	1944	30	"Bartlesville" sand	45	2,350	0	2	2	0	1	0	do	Salt water sand	289	6,440	5,441	123
124	Thrall-Aagard	Arkansas Fuel Oil Corp.	E. Marshall	1-24-9E	No	1944	84	"Bartlesville"	37	2,300	0	9	9	0	6	0	do	Douglas	169	5,222	16,664	124
125	do	The Ohio Oil Co.	Martindell-Teeter	31-23-10E	No	1948	377	do	50	2,300	0	43	43	1	37	0	do	Arbuckle and Douglas	124	5,425	119,951	125
126	do	do	Olson-Anderson	11-24-9E	Unit.	1944	98	do	42	2,200	0	7	7	0	0	0	do	Douglas sand	194	7,202	6,669	126
127	do	Phillips Petroleum Co.	Cartwright Unit	36-23-9E; 1-24-9E; 6-24-10E	Unit.	1952	196	do	35	2,200	0	24	24	3	14	0	do	Arbuckle and produced	360	4,316	150,796	127
128	do	do	Lewis and Cannon Unit	11,12-24-9E	Unit.	1945	95	do	50	2,300	0	12	12	2	8	0	do	Douglas and produced	200	7,445	48,703	128
129	do	Sinclair Oil and Gas	Thrall-McKee Consolidated Water Flood	28,29,30,32,33-23-10E	Unit.	1949	644	do	31	2,300	26	46	72	0	48	0	do	do	239	4,777	*	129
130	Virgil	Alf M. Landon	Hamilton Leases Water Flood	15,16,21,22-24-12E	No	1951	60	do	20	1,615	0	37	37	0	4	0	do	Arbuckle and Douglas sand	697	-	1,000	130
131	Wiggins	Glenwood Oil Co.	Wiggins Water Flood	25,36-24-10E 19,30,31-24-11E	No	1956	547	"Cattleman" sand	17	1,800	0	46	46	14	22	9	do	Douglas sand	375	505	252,800	131
																	Estimated additional secondary recovery production				1,512,407	
							11,250				51	923	974	37	659	34					5,874,961	
	GREENWOOD AND WOODSON COUNTIES																					
132	Quincy	Delhi-Taylor Oil Co.	South Quincey	14,15-25-13E	Coop.	1948	160	"Bartlesville" shoestring	15	1,500	0	12	12	0	19	1	Salt water	Arbuckle	104	960	40,126	132
	KINGMAN AND PRATT COUNTIES																					
133	Cunningham	Skelly Oil Co.	Cunningham Pressure Maintenance Project	19,20,29,30,31-27-10,11W	-	1936	1,400	Lansing limestone	16	3,400	0	64	64	0	5	0	Gas		453 MCF	1,539	79,725	133
	LABETTE COUNTY																					
134	Edna	Veeder Supply and Dev. Co.	Brown-Wilmoth	12,13-34-18E	No	1954	22	"Bartlesville"	10	560	0	5	5	0	4	0	Salt water	Arbuckle	20	958	6,120	134
																	Estimated additional secondary recovery production				35,361	
																					41,481	
	LINN COUNTY																					
135	Goodrich-Parker	General American Oil Co. of Texas	Goodrich Group	19,20,29,30-20-22E	No	1944	211	"Squirrel"	30	570	83	16	99	0	99	0	Salt water	Mississippian lime	16	1,890	26,977	135
136	LaCygne-Cadmus	do	LaCygne Group	34,35,36-19-23E; 2,3-20-23E	No	1942	81	"Prue"	20	250	23	27	50	0	48	0	do	Wilcox sand	22	1,762	12,441	136
																	Estimated additional secondary recovery production				32,105	
							292				106	43	149	0	147	0					71,523	
	LYON COUNTY																					
137	Atyeo-Pixlee	Barbara Oil Company	Jones Water Flood	30-21-10E	Coop.	1948	50	"Bartlesville"	30	2,200	0	5	5	0	3	0	Salt water	Arbuckle and "Bartlesville"	238	2,953	10,655	137
138	do	The Ohio Oil Co.	Atyeo Communization	30,31-21-10E	No	1945	280	do	35	2,200	0	33	33	0	26	0	do	Arbuckle	172	5,809	67,464	138
139	Fankhauser	W. M. Michaelis	Jeck-Childers	32-21-12E	Coop.	1956	-	do	40	1,900	-	-	-	-	-	-	do	"Bartlesville"	-	-	-	139
																	Estimated additional secondary recovery production				41,037	
							330				0	38	38	0	29	0					119,156	
	McPHERSON COUNTY																					
140	Graber	Cities Service Oil Co.	Graber	31,32-21-1W	Coop.	1952	30	"Hunton"	25	3,285	0	3	3	0	1	0	Fresh water	Shallow water sand	67	3,221	12,924	140
141	do	Continental Oil Co.	Graber Pool Water Flood	20,29,32-21-1W	Coop.	1947	1,400	do	16	3,200	-	-	-	-	-	-	Salt and fresh water	"Hunton", Kansas City and fresh water	-	-	-	141
							1,430				0	3	3	0	1	0					12,924	
	MEADE COUNTY																					
142	Novinger	Columbian Fuel Corp.	Novinger Unit	2,3,22,23,26,27,34,35-33,34-30W	Unit.	1956	1,470	Marmaton	15	5,300	10	19	29	0	5	0	Fresh water	Meade water sand	2,696	-	-	142
	MIAMI COUNTY																					
143	Paola-Rantoul	A. L. Anderson and H. M. Bristol	Big Lake Development	20,29-16-24E	Coop.	1953	370	"Peru"	35	400	0	100	100	34	100	16	Salt water	Arbuckle	7,000	900	72,000	143
144	do	W. M. Dary	Alvord and Minden Farms	11-17-22E	No	1953	20	"Squirrel"	20	630	-	-	-	-	-	-	do	Mississippian lime	-	-	-	144
145	do	do	Robert I. Nicholson	11-17-22E	No	1956	8	"Bartlesville"	10	600	-	-	-	-	-	-	do	do	-	-	-	145
146	do	General American Oil Co. of Texas	NYK No. 2-Seaborn Group	22,23,26,27-18-22E	No	1944	287	"Peru"	20	350	105	0	105	0	99	0	do	Arbuckle	32	1,246	18,559	146
147	do	do	Producers Group	15,16,21,22,26,27-17-22E	No	1945	627	do	14	350	186	1	187	0	196	0	do	Mississippian	36	985	45,313	147
148	do	J. C. Hart	Hart and Buster	10-17-22E	No	1955	80	"Squirrel" sand	23	750	0	40	40	3	19	5	do	Heartha lime	15	300	29,616	148
149	do	Kirk Johnson	Klein	26-16-21E	Coop.	1948	40	"Squirrel"	10	625	-	-	-	-	-	-	do	Pennsylvanian lime	-	-	-	149
150	do	Maracaibo Oil Corp.	Units 1, 2, and 3	11,13,14,23,24,25,26,35-16-21E; 31-16-22E; 5,6,8,9-17-22E	Unit.	1948	500	do	30	600	-	-	-	-	-	-	do	Arbuckle	-	-	-	150
151	do	C. P. Weisner	Phillips Unit	24-16-21E	No	1956	140	do	12	670	-	-	-	-	-	-	do	do	-	-	-	151
																	Estimated additional secondary recovery production				230,525	
							2,072				291	141	432	37	414	21					396,013	
	MONTGOMERY COUNTY																					
152	Caney	Alpine Oil and Gas Corp.	Roper	34-34-14E; 3-35-14E	No	1953	20	"Bartlesville"	18	1,240	0	10	10	0	2	0	Salt water	Return salt	34	-	-	152
153	Coffeyville-Cherryvale	Atlantic Refining Co.	Coffeyville	17,19,20,30-34-17E	No	1954	9	do	20	600	-	-	-	-	-	-	Fresh water and produced	River	-	-	-	153
154	do	E. W. Hayes		7-34-17E	-	1946	60	"Peru"	20	330	-	-	-	-	-	-	Salt and Fresh water	Formation and City of Coffeyville	-	-	-	154
155	do	do	Rector Field	9,10-34-17E	No	1948	60	do	20	320	-	-	-	-	-	-	Salt water	Arbuckle and formation	-	-	-	155
156	do	Layton Oil Co.	Mardoc Flood	10-32-17E	-	1953	150	"Bartlesville"	18	700	0	29	29	6	34	6	do	Arbuckle	54	1,101	37,800	156
157	Jefferson-Sycamore	W. E. Butler	Schaub, Frost, Benson, Provorse and Jackson	11,14-33-15E	-	1955	50	do	25	1,109	-	-	-	-	-	-	Fresh water	City of Independence	-	-	-	157
158	do	Kirkpatrick and McGuire	Speed Recovery, Inc.	22-33-15E	-	1952	12	do	20	1,153	0	4	4	0	1	0	Fresh and salt water	do	94	-	-	158
159	Neodesha	Layton Oil Co.	Flood 11	12-31-16E	No	1952	55	do	12	915	-	-	-	-	-	-	Salt water	Arbuckle	-	-	-	159
160	do	Omega Oil Co., Inc.	Gray	16-31-16E	Unit.	1956	20	"Weiser" sand	18	500	-	-	-	-	-	-	Salt and fresh water	Formation and well	-	-	-	160
161	Wayside-Havana	Alpine Oil and Gas Corp.	Alpine Fee No. 2	34-33-14E	No	1949	20	"Wayside"	18	860	0	18	18	1	2	0	Salt water	Return salt	26	-	-	161
162	do	Consolidated Gas, Oil and Mfg. Co.	Bell No. 1 and 2	10,11-34-14E	No	1944	47	do	22	637	6	13	19	0	9	0	Salt and fresh water	Wells and Return	16	1,359	*	162
163	do	do	Flanagan No. 1 and 2	10,11-34-14E	No	1942	105	do	22	637	10	28	38	0	25	0	do	do	17	2,756	*	163
164	do	do	Havener	33-33-14E	No	1953	95	do	22	680	0	26	26	6	17	1	do	do	23	537	14,943	164
165	do	do	Shinn	11-34-14E	No	1945	40	do	22	636	0	16	16	0	10	0	do	do	10	2,464	2,923	165
166	do	Forest Oil Corp.	Flood No. 32	14,23-34-14E	No	1955	117	"Wayside" sand	20	635	0	45	45	4	29	6	Salt water	Big sand (salt) and return water	20	618	*	166
																	Estimated additional secondary recovery production				207,006	
							860				16	189	205	17	129	13					297,993	
	MONTGOMERY AND LABETTE COUNTIES																					
167	Coffeyville-Cherryvale	Buffalo Oil Co.	Ord Project	26,27-32-17E	Coop.	1955	5	"Bartlesville"	15	700	-	-	-	-	-	-	Salt water	Mississippian and produced	-	-	-	167
168	do	do	Price Project	26,27-32-17E	Coop.	1955	3	"Dennis" sand	25	200	-	-	-	-	-	-	do	do	-	-	-	168
																	Estimated additional secondary recovery production				(69,264)	
	NEOSHO COUNTY																					
169	Erie	Earl Beeler	Barnhart, Ermey and Faust	34,35-28-20E	Unit.	1953	40	"Bartlesville"	25	500	-	-	-	-	-	-	-	City water and lime	-	-	-	169
170	do	J. O. Purviance	Edwards and Purviance	14,15,19-28-19E	Unit.	1949	60	do	15	600	0	16	16	0	7	0	Fresh water	Cherokee shale	12	-	5,580	170
171	Humboldt-Chanute	Belleair Oil Corp.	Odense Block	7,18-27-20E	No	1953	40	do	14	750	-	-	-	-	-	-	Salt water	Mississippian lime	-	-	-	171
172	do	do	Weiner Block	4,9-27-18E	No	1951	150	do	18	750	-	-	-	-	-	-	do	do	-	-	-	172
173	do	C. P. M. Corp.	Chanute Flood	1,2,10,11,12,14,15,22,23,27,28-27-18E; 6,7-27-19E	No	1938	1,000	do	30	760	-	-	-	-	-	-	Salt and fresh water	Return and Neosho River	-	-	-	173
174	do	Caddo Oil Co.	W. M. Wells Flood Project	14,15-27-19E	Coop.	1952	35	"Bartlesville" sand	30	825	0	7	7	0	3	0	Salt water	Mississippian lime	45	405	1,561	174
175	do	do	do	6,7-28-19E; 12-28-18E	Coop.	1952	108	do	35	750	0	30	30	6	14	6	do	do	77	663	24,818	175
176	do	Keas Drlg. Co., Inc.	Chanute Project	3,4,9,10,15,16-27-18E	-	1939	285	"Bartlesville"	25	750	56	92	148	2	91	-	Salt and fresh water	Gravel and return water	50	-	48,129	176
177	do	R. J. Sanders	Banks	13-27-18E	Unit.	1955	-	do	20	735	0	0	0	1	0	0	Salt water	"Bartlesville"	5	-	-	177
178	St. Paul-Walnut	W. P. Callahan, Jr.	Henry Van Leeuwen	33-28-21E	No	1955	80	do	15	400	-	-	-	-	-	-	Fresh water	Surface water	-	-	-	178
179	do	Walters Drlg. Co.	Dent	21,28-28-21E	No	1953	10	do	20	380	-	-	-	-	-	-	do	Shallow sand	-	-	-	179
																	Estimated additional secondary recovery production				347,761	
							1,808				56	145	201	9	115	6					427,849	
	PHILLIPS COUNTY																					
180	Stuttgart	Phillips	Stuttgart Unit	13,14,23-3-19W	Unit.	1952	165	Lansing-Kansas City	35	3,200	0	10	10	0	3	0	Salt water	Dakota	300	341	28,406	180
	PRATT COUNTY																					
181	Chitwood	Lion Oil Co.	Chitwood Unit	14,22,23,26,27-28-12W	Unit.	1955	1,492	Simpson sand	25	4,415	0	48	48	0	14	0	Salt water	Simpson, Viola and Topeka	676	497	423,904	181
182	Moore Southwest	Champlin Oil and Refining Co.	S. W. Moore Unit	10,11,14,15-26-14W	Unit.	1957	73	"Kinderhook" sand	7	4,255	0	3	3	0	3	0	do	Simpson	72	0	0	182
							1,565				0	51	51	0	17	0					423,904	
	RENO COUNTY																					
183	Abbyville	Skelly Oil Co.	Abbyville Waterflood	24-24-8W	-	1948	200	Lansing limestone	15	3,525	0	4	4	0	2	0	Salt water	Douglas sand	169	532	37,896	183
184	Zenith-Peace Creek	Cities Service Oil Co.	Peace Creek Unit	1,2,6,11,12,30,31,35,36-22,23-9,10W	Unit.	1951	480	Viola	10	3,750	0	21	21	0	7	0	do	Produced and shallow supply	835	98	43,232	184
							680				0	25	25	0	9	0					81,128	
	RICE COUNTY																					
185	Orth	Skelly Oil Co.	Volkland "A" Salt Water Repressure Project	27-18-10W	-	1954	50	Topeka lime	16	2,670	0	3	3	0	1	-	Salt water	Produced, Topeka and quartzite water	136	297	8,778	185
	ROOKS COUNTY																					
186	Dorr	Cities Service Oil Co.	Dorr Waterflood	16,17,20,21-9-16W	No	1952	120	Lansing-Kansas City	-	3,290	0	24	24	0	1	0	Salt water	Produced	116	0	0	186
187	Layton	do	Holy Cross	4,33-8,9-16W	No	1953	80	do	-	3,340	0	9	9	0	1	0	do	do	137	0	0	187
							200				0	33	33	0	2	0						
	RUSSELL COUNTY																					
188	Fairport	Pan American Petroleum Co.	F. Booth "A" Lease	32-11-15W	-	1956	40	Dodge	10	2,875	0	1	1	0	1	0	Salt water	Produced, Dodge and Reagan	185	625	17,580	188
189	do	The Texas Co.	L. J. Ginther Project	19-12-15W	-	1954	30	Lansing	-	3,100	0	1	1	0	1	0	do	Produced	447	-	3,579	189
190	Gorham	do	D. Brandenburg Project	20-14-14W	Coop.	1954	130	Lansing lime	-	3,100	0	6	6	0	1	0	do	do	890	-	7,639	190
191	Hall-Gurney	Cities Service Oil Co.	Carter-Graham Waterflood	28,29-14-13W	No	1950	180	Lansing-Kansas City	-	2,945	0	7	7	0	1	0	do	do	115	151	4,075	191
192	do	do	Hall-Gurney Waterflood	24,25,36-14-14W	Coop.	1949	270	do	-	2,950	0	16	16	0	3	0	do	do	281	113	23,005	192
193	do	Colorado Oil and Gas Corp.	Weimaster Waterflood	36-14-13W	No	1957	30	Tarkio	3	2,200	0	3	3	0	1	0	do	Arbuckle and Tarkio	300	166	4,978	193
194	do	Pan American Petroleum Co.	Krug Waterflood	27,28-14-14W	Coop.	1953	480	Lansing	136	3,000	0	16	16	0	9	0	do	Dakota sand	182	506	120,000	194
195	do	Skelly Oil Co.	Hall-Gurney Area	29,32-14-13W; 25,27-14-14W	Coop.	1950	680	Lansing lime	18	2,890	0	18	18	0	6	0	do	Arbuckle, Dakota and Lansing	142	153	30,840	195
196	do	Sunray-Mid-Continent	Boxberger Lansing Flood	22-14-14W	Coop.	1956	80	Kansas City lime	8	300	0	3	3	0	1	0	do	Kansas City lime	125	857	46,342	196
197	do	do	Strecker "A" and "B" Lansing Project	25-14-14W	Coop.	1956	160	do	8	2,800	0	6	6	1	1	0	do	do	850	917	89,585	197
198	do	The Texas Co.	G. Boxberger "A" and "B" Project	22-14-14W	Coop.	1951	200	Lansing lime	-	3,100	0	7	7	0	2	0	do	Produced and Dakota	410	-	20,191	198
199	do	do	L. H. and S. Boxberger Project	10,11,14,15-14-14W	-	1954	230	do	-	3,050	0	11	11	0	6	0	do	do	126	-	29,290	199
200	do	do	E. P. Gurney Project	23-14-14W	Coop.	1955	100	do	-	3,150	0	2	2	0	2	0	do	do	277	-	3,673	200
201	do	do	Mohl and Shaffer Project	18-14-13W	Coop.	1953	200	Tarkio sand	11	2,325	0	14	14	0	5	0	do	do	77	-	10,383	201
202	Trapp	Cities Service Oil Co.	Eichman "A" Waterflood	12,24-15-14W	No	1957	36	Lansing-Kansas City	-	3,050	0	10	10	0	1	0	do	Produced	41	59	2,139	202
							2,846				0	121	121	1	41	0					413,299	
	RUSSELL AND ELLIS COUNTIES																					
203	Fairport	Pan American Petroleum Co.	Kate Austin Waterflood	25,36-12-16W; 30,31-12-15W	Coop.	1952	450	Dodge and Lansing-Kansas City	90	3,000	0	14	14	0	2	0	Salt water	Dakota sand	649	-	34,474	203
	SALINE COUNTY																					
204	Smolan Pool	Republic Natural Gas Co.	Smolan Pool Pilot Flood Oborg No. 3	26-15-4W; 35-15-4W	-	1957	160	Viola (Marquoketa)	5	3,420	0	4	4	0	1	1	Salt water	Viola	700	3	345	204
	SEDGWICK COUNTY																					
205	Robbins	Magnolia Petroleum Co.	Robbins	20-28-1E	Coop.	1945	80	Mississippian lime	-	3,100	0	4	4	0	4	0	Salt water	Produced	169	-	9,000	205
206	do	Pan American Petroleum Co.	Robbins Field	20-28-1E	Coop.	1947	190	Mississippian chat	40	3,080	0	9	9	0	5	0	Salt and fresh water	Produced and wells	1,054	1,665	33,638	206
							270				0	13	13	0	9	0					42,638	
	SEDGWICK AND KINGMAN COUNTIES																					
207	Bartholomew	Cities Service Oil Co.	Bartholomew Unit	30,31-27-4W; 36-27-5W; 1-28-5W; 6-28-4W	Unit.	1957	40	Mississippian	11	3,700	0	56	56	0	4	0	Salt water	Topeka lime and produced	86	0	0	207
	STAFFORD COUNTY																					
208	Jordan	Cities Service Oil Co.	Jordan Pool Waterflood	15,16-25-14W	No	1956	170	Lansing-Kansas City	37	3,800	0	10	10	1	1	0	Salt water	Produced	383	0	0	208
	SUMNER COUNTY																					
209	Fall Creek	The Texas Co.	Fall Creek Unit	3,4,9,10-35-3W	Unit.	1956	510	Simpson sand	26	4,750	1	13	14	0	0	0	-	-	-	-	-	209
	WILSON COUNTY																					
210	Neodesha	Keas Drlg. Co., Inc.	Thayer	16,17-29-17E	-	1954	40	"Bartlesville"	30	840	0	57	57	10	19	0	Salt water	Deep well and return	1,200	-	44,271	210
211	Neodesha East	RuJo Drlg. Co.	Dickens-Sapp	15-30-17E	No	1956	15	do	14	910	Abandoned during 1957											211
																	Estimated additional secondary recovery production				33,532	
							55				0	57	57	10	19	0					77,803	
	WOODSON COUNTY																					
212	Neosho Falls-Leroy	Susmio Oil Co.	Neosho Falls Water Flood	24-23-16E	No	1952	88	"Squirrel"	8	950	0	22	22	0	13	0	Salt water	Kansas City lime	25	1,139	19,534	212
																	Estimated additional secondary recovery production				528,397	
																					547,931	

* Production not to be revealed; included in county total.


OIL AND GAS FIELDS OF
WESTERN KANSAS
December 31, 1957
EXPLANATION
Oil field
Oil field discovered in 1957
Gas field
Gas field discovered in 1957
Gas wells drilled during 1957
(Hugoton and Greenwood Gas Areas only, all older wells omitted.)
Dry wildcats and total depth (recorded) 1957
CHEYENNE CO.
RAWLINS CO.
DECATUR CO.
NORTON CO.
SHERMAN CO.
THOMAS CO.
SHERIDAN CO.
GRAHAM CO.
WALLACE CO.
LOGAN CO.
GOVE CO.
TREGO CO.
GREELEY CO.
WICHITA CO.
SCOTT CO.
LANE CO.
NESS CO.
HAMILTON CO.
KEARNY CO.
FINNEY CO.
HODGEMAN CO.
GRAY CO.
FORD CO.
STANTON CO.
GRANT CO.
HASKELL CO.
MEADE CO.
CLARK CO.
MORTON CO.
STEVENS CO.
SEWARD CO.
ST. FRANCIS
ATWOOD
OBERLIN
NORTON
GOODLAND
COLBY
HOXIE
HILL CITY
WAKEENEY
GOVE
RUSSELL SPRINGS
SHARON SPRINGS
TRIBUNE
LEOTI
SCOTT CITY
DIGHTON
NESS CITY
JETMORE
SYRACUSE
LAKIN
GARDEN CITY
CIMARRON
DODGE CITY
JOHNSON
ULYSSES
SUBLETTE
MEADE
ASHLAND
RICHFIELD
HUGOTON
LIBERAL
Hugoton
Gas
Area
Greenwood Gas Area


OIL AND GAS FIELDS OF CENTRAL KANSAS
December 31, 1957
EXPLANATION
Oil field
Oil field discovered in 1957
Gas field
Gas field discovered in 1957
Dry wildcats and total depth (recorded) 1957
PHILLIPS CO.
SMITH CO.
JEWELL CO.
REPUBLIC CO.
ROOKS CO.
OSBORNE CO.
MITCHELL CO.
CLOUD CO.
OTTAWA CO.
LINCOLN CO.
RUSSELL CO.
ELLIS CO.
ELLSWORTH CO.
SALINE CO.
RUSH CO.
BARTON CO.
McPHERSON CO.
PAWNEE CO.
RICE CO.
RENO CO.
EDWARDS CO.
STAFFORD CO.
HARVEY CO.
SEDGWICK CO.
KIOWA CO.
PRATT CO.
KINGMAN CO.
BARBER CO.
SUMNER CO.
COMANCHE CO.
HARPER CO.
PHILLIPSBURG
SMITH CENTER
MANKATO
BELLEVILLE
CONCORDIA
STOCKTON
OSBORNE
BELOIT
MINNEAPOLIS
LINCOLN
RUSSELL
HAYS
ELLSWORTH
SALINA
LA CROSSE
GREAT BEND
LYONS
Mc PHERSON
LARNED
KINSLEY
HUTCHINSON
NEWTON
GREENSBURG
PRATT
KINGMAN
WICHITA
COLDWATER
MEDICINE LODGE
ANTHONY
WELLINGTON


State Geological Survey of Kansas
Bulletin 133
Plate 1
EASTERN KANSAS
OIL-PRODUCING
AREAS
December 31, 1957
EXPLANATION
Oil field
Oil field discovered in 1957
Dry wildcats and total depth (recorded) 1957
WASHINGTON CO.
MARSHALL CO.
NEMAHA CO.
BROWN CO.
DONIPHAN CO.
ATCHISON CO.
CLAY CO.
RILEY CO.
POTTAWATOMIE CO.
JACKSON CO.
JEFFERSON CO.
LEAVENWORTH CO.
GEARY CO.
SHAWNEE CO.
WYANDOTTE CO.
WABAUNSEE CO.
DICKINSON CO.
DOUGLAS CO.
JOHNSON CO.
MORRIS CO.
OSAGE CO.
LYON CO.
FRANKLIN CO.
MIAMI CO.
CHASE CO.
COFFEY CO.
ANDERSON CO.
LINN CO.
MARION CO.
BUTLER CO.
ALLEN CO.
BOURBON CO.
WOODSON CO.
GREENWOOD CO.
ELK CO.
CRAWFORD CO.
COWLEY CO.
WILSON CO.
NEOSHO CO.
MONTGOMERY CO.
LABETTE CO.
CHEROKEE CO.
CHAUTAUQUA CO.
WASHINGTON
MARYSVILLE
SENECA
HIAWATHA
TROY
ATCHISON
HOLTON
WESTMORELAND
CLAY CENTER
LEAVENWORTH
MANHATTAN
OSKALOOSA
KANSAS CITY
TOPEKA
JUNCTION CITY
ALMA
LAWRENCE
ABILENE
OLATHE
COUNCIL GROVE
OTTAWA
LYNDON
PAOLA
EMPORIA
COTTONWOOD FALLS
MARION
GARNETT
BURLINGTON
MOUND CITY
EL DORADO
EUREKA
YATES CENTER
IOLA
FORT SCOTT
FREDONIA
GIRARD
HOWARD
ERIE
WINFIELD
SEDAN
INDEPENDENCE
OSWEGO
COLUMBUS