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BULLETIN 106

GEOLOGY AND GROUND-WATER RESOURCES OF MARSHALL COUNTY, KANSAS

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

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GEOLOGY AND GROUND-WATER RESOURCES OF MARSHALL COUNTY, KANSAS

by Kenneth L. Walters

ABSTRACT

This report describes the geography, geology, and ground-water resources of Marshall County in northeastern Kansas. The county has an area of 911 square miles and had a population of 17,926 in 1950. Large areas of the county have till plains, gently undulating divide areas, and deep dissection along the major streams. The normal annual precipitation at Blue Rapids in Marshall County is 28.30 inches.

The rocks that crop out in this area range in age from Pennsylvanian to Recent. The oldest formation cropping out in the county is the Pony Creek shale, which is exposed in a few places in eastern Marshall County. The bed-rock is blanketed by Kansas glacial till and loess of the Sanborn formation in large areas of the county. The valleys of the major streams of the area are underlain by alluvial deposits of Recent age.

The principal water-bearing formations in the county are alluvium, terrace deposits, and the Barneston limestone. Glacial till and associated deposits generally do not yield large quantities of water to individual wells, but because of the large number of wells obtaining water from them, they probably should be considered the principal aquifers in the county. The Wreford, Beattie, and Grenola limestones yield moderate quantities of water to wells in the county, and the Winfield, Bader, Red Eagle, and Foraker limestones yield small to moderate quantities. Ground water in Marshall County is generally hard, but except for individual wells that are contaminated by surface seepage, the water is suitable for most uses. Ground water is used in Marshall County for municipal supplies, for domestic and stock supplies, and for industrial and air conditioning purposes. No irrigation with ground water is practiced in Marshall County.

This report contains a map showing the areas of outcrop of the geologic formations, a map showing ground-water regions and the location of wells and test holes for which records are given, and cross sections of the area showing the character and thickness of the unconsolidated deposits overlying the Pennsylvanian and Permian bedrock. The field data upon which this report is based are given in tables; they include records of 248 wells, chemical analyses of water from 30 representative wells, logs of 60 test holes, and 9 measured stratigraphic sections.

INTRODUCTION

Purpose and Scope of the Investigation

A program of investigation of the ground-water resources of Kansas was started in 1937 by the State Geological Survey of Kansas and the United States Geological Survey, in cooperation with the Division of Sanitation of the Kansas State Board of Health and the

Division of Water Resources of the Kansas State Board of Agriculture. The purpose of this program is to survey county areas and major stream valleys or irrigation districts to determine the availability of ground-water supplies. The present status of investigations resulting from this program is shown in Figure 1.

As a part of this program, an investigation of the geology and ground-water resources of Marshall County was begun in June 1951. Ground water is one of the most important natural resources of Marshall County; 9 municipal water supplies and nearly all domestic and stock supplies are obtained from wells. Increased availability of electricity in rural areas and the use of domestic

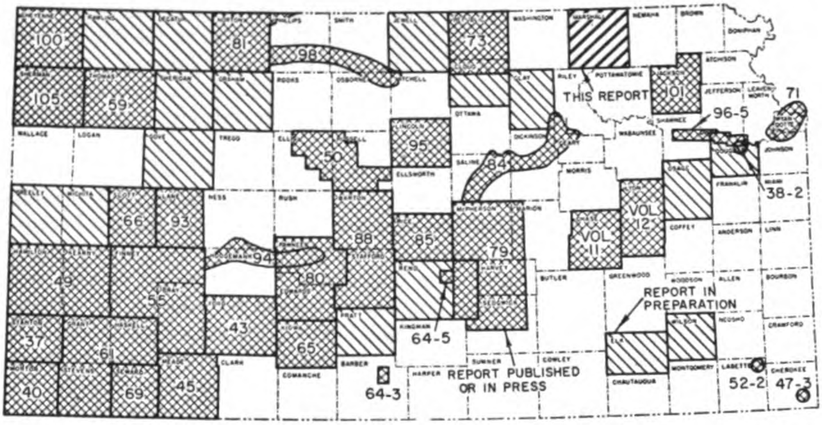

Fig. 1.—Index map of Kansas showing area covered by this report and areas for which cooperative ground-water reports have been published or are in preparation.

and industrial practices which require larger amounts of water have increased materially the rate of withdrawal of ground water in the last decade. The principal purpose of this investigation has been to provide information necessary to the satisfactory and economical development of domestic, stock, industrial, and municipal ground-water supplies.

The investigation was made under the general direction of A. N. Sayre, Chief of the Ground Water Branch of the United States Geological Survey, and under the immediate supervision of V. C. Fishel, District Engineer in charge of ground-water work in Kansas.

Previous Investigations

Although a detailed study of the geology of Marshall County has not been made previously, early reports concerning the areas of Marshall County where gypsum was mined or was known to occur were written. Mudge (1866) and Grimsley and Bailey (1899) made the most important of these early studies. Haworth (1913) discussed in some detail the geology and ground water of Blue River Valley and more generally the water-bearing characteristics of glacial drift and Permian formations.

In 1940 Moore and others prepared a generalized report on the ground-water resources of Kansas including Marshall County. Jewett (1941) made a study of the geology of Riley and Geary Counties; Riley County borders Marshall County on the southwest. A report published in 1942 (Lohman and others) on the availability of ground-water supplies for national defense industries in Kansas includes a description of the availability of ground-water supplies in Big Blue River Valley and discusses general ground-water conditions in northeastern Kansas. The subsurface stratigraphy as related to oil and gas exploration has been discussed by Lee (1943), by Jewett and Abernathy (1945), and by Jewett (1949). Fairchild (1949) made a study of the geology and petrography of the gypsum deposits near Blue Rapids in Marshall County. Geologic cross sections and interpretations of test hole data in Marshall County are included in a report by Frye and Walters (1950). A summary of the stratigraphic sequence of rocks in Kansas was prepared by Moore and others (1951).

Methods of Investigation

Five months in the summer and fall of 1951 were spent in the field collecting the data upon which this report is based. Geologic mapping in the field was done on aerial photographs from field observations and stereoscopic study of the photographs. A base map of the county was made by Bernita K. Mansfield from a county map prepared by the Soil Conservation Service, and the geologic mapping was transferred to it from the aerial photographs by the use of a vertical sketchmaster.

Data on the depth, depth to water, yield, and character of the water-bearing material of 248 wells (Table 11) were collected. Many of these wells were measured with a steel tape; however, some depths and water levels were reported by the owner or driller.

The material below the land surface was determined by drilling 60 test holes (Pl. 3) through the unconsolidated sediments and into the underlying limestone or shale of Paleozoic age. Data on 20 test holes drilled in 1949 as a part of an earlier study are included in this report. All test holes were drilled with the hydraulic rotary drilling machine owned by the State Geological Survey of Kansas and operated by William T. Connor and Max Yazza during the season of 1949 and by Connor and Norman W. Biegler during the season of 1951. Logs of the test holes were prepared in the field; later well cuttings were examined microscopically in the laboratory. Level parties headed by Woodrow W. Wilson and Norman W. Biegler determined the altitude of the land surface at each test hole by using a plane table and alidade.

Samples of water from 30 wells in the county were collected and chemical analyses of them were made by Howard Stoltenberg, chemist in the Water and Sewage laboratory of the Kansas State Board of Health.

The stratigraphic sections included in this report were measured by field parties supervised by Frank E. Byrne of the United States Geological Survey.

Well-Numbering System

In this report, wells 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, the range number, the section number, and the two lower case letters which indicate, respectively, the quarter section and the quarter-quarter section in which the well is located. The lower case letters are assigned in counterclockwise order beginning with the letter a, in the northeast quarter or quarter-quarter section. For example, well 2-7-17cc (Fig. 2) is in the SW¼ SW¼, sec. 17, T. 2 S., R. 7 E. If two or more wells are within the same quarter-quarter section, the wells are numbered serially according to the order in which they were inventoried.

Acknowledgments

Many residents of Marshall County gave permission to measure their wells and supplied helpful information about them. The city officials of the cities of Marshall County contributed data on municipal water supplies and several water well drillers operating in the area furnished logs and other pertinent data concerning water supplies. Albert Carlson, retired well driller, supplied information on many of the old wells in the county.

The manuscript for this report has been reviewed critically by several members of the Federal and State Geological Surveys; by Robert Smrha, Chief Engineer, and George S. Knapp, Engineer, Division of Water Resources, Kansas State Board of Agriculture,

and by Dwight Metzler, Director, and Willard Hilton, Geologist, of the Division of Sanitation of the Kansas State Board of Health. The illustrations were drafted by Woodrow W. Wilson and David E. Gray of the Federal Geological Survey.

GEOGRAPHY

Location and Extent of the Area

Marshall County is in the first tier of counties south of the north border of Kansas and is the fourth county west of the east border. Marshall County is bounded on the west by Washington County, on the south by Riley and Pottawatomie Counties, on the east by Nemaha County, and on the north by Nebraska. The county contains 25 townships totaling 911 square miles.

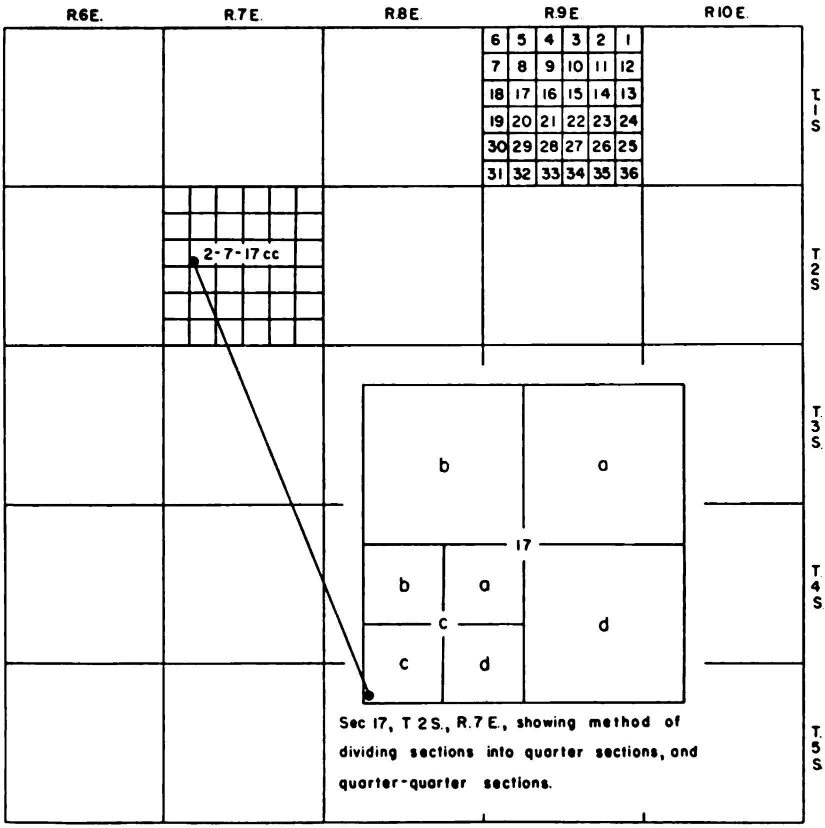

Fig. 2.—Map of Marshall County illustrating the well-numbering system used in this report.

Topography and Drainage

Marshall County lies within the region designated by Fenneman (1931) as the Dissected Till Plains section of the Central Lowlands province. Most of Marshall County east of Big Blue River and north of Black Vermillion River is topographically till plains. Here the divide areas between major drainage lines are gently undulating, and the local relief seldom exceeds 100 feet. Near the larger streams the relief is more pronounced, and the wide valleys are flanked by a subdued bluff line.

The parts of Marshall County lying west of Big Blue River and south of Black Vermillion River have chiefly a rock-controlled type of topography similar to that of the Flint Hills region farther south. In parts more remote from major streams, the rock-controlled topography is mantled by glacial drift and loess.

The major alluvial valleys are those of the Big Blue River, the Little Blue River, Black Vermillion River, and Vermillion Creek.

Big Blue River and its tributaries drain almost all of Marshall County. Little Blue River, the largest tributary of Big Blue River, joins it near the City of Blue Rapids. Black Vermillion River is a large, westward-flowing tributary of Big Blue River and joins it about a mile north of the Pottawatomie County line. Vermillion Creek, a major southward-flowing tributary of Black Vermillion River, joins it near the City of Frankfort. A small area in the northeast corner of Marshall County is drained by Nemaha River, and another in the southeast corner by a tributary of Vermillion River.

Climate

Marshall County is well supplied by precipitation, especially during the growing season, and has abundant sunshine. During the summer, the highest daily temperatures seldom rise above 100 degrees for more than a few successive days, and during the winter the lowest temperature seldom falls below zero for more than three or four consecutive days.

According to data presented by the United States Weather Bureau, the normal annual temperature for Oketo in Marshall County is 53.6° F. The hottest month, in general, is July which has a normal temperature of 79.7° F., and the coldest month is January, which has a normal temperature of 25.8° F. The average growing season, the interval between the last killing frost in the spring and the first killing frost in the fall, is approximately 170 days. The normal annual precipitation at Blue Rapids is 28.30 inches. The annual

TABLE 1.—*The normal monthly precipitation at Blue Rapids, Kansas*

Month	Precipitation, inches	Month	Precipitation, inches
Jan.	0.60	July	3.01
Feb.	0.94	Aug.	3.57
Mar.	1.40	Sept.	3.65
Apr.	2.60	Oct.	2.28
May	3.54	Nov.	1.50
June	4.44	Dec.	0.77

precipitation and the cumulative departure from normal precipitation at Blue Rapids for the period 1911 through 1951 are shown in Figure 3. The normal monthly precipitation for the period 1898 through 1942 is given in Table 1.

POPULATION

According to the 1950 Federal Census, the population of Marshall County was 17,926, the average density of population being 19.7 to the square mile. The population of Marshall County decreased

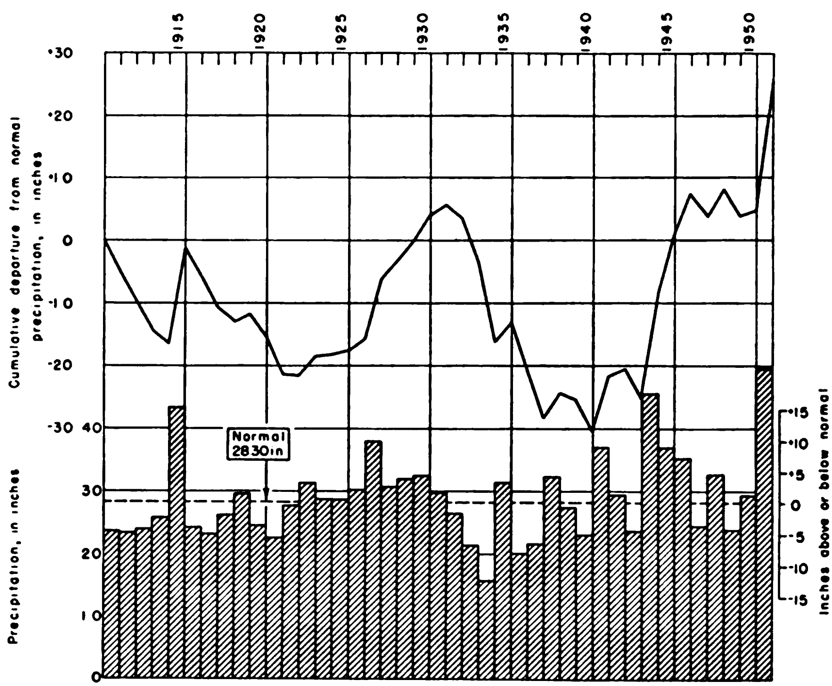

FIG. 3.—Annual precipitation and the cumulative departure from normal precipitation at Blue Rapids.

14.6 percent between 1940 and 1950, and decreased 9.0 percent between 1930 and 1940. In 1950, 21.6 percent of the population of the county was urban. The urban population of the county decreased 4.7 percent between 1940 and 1950, while the rural population decreased 17.0 percent during the same period. The population of the cities in Marshall County, as reported by the 1950 census, were as follows: Marysville, 3,866; Blue Rapids, 1,430; Frankfort, 1,237; Waterville, 676; Axtell, 510; Beattie, 321; Summerfield, 305; Vermillion, 283; Irving, 279; and Oketo, 169.

Transportation

Marshall County is crossed by the Topeka cut-off of the Union Pacific Railroad Company, which connects Topeka with the main west coast line of that company. A branch line of the Union Pacific Railroad Company extends up the Big Blue River Valley from Manhattan in Riley County to Beatrice, Nebraska. A branch line of the Union Pacific Railway Company also connects Marysville with St. Joseph, Missouri. The Central Branch of the Missouri Pacific Railroad Company passes through Waterville, Blue Rapids, and Irving.

Several hard-surfaced Federal and State highways pass through Marshall County. U. S. Highway 36 traverses the county east-west through Home City and Marysville, and U. S. Highway 77 north-south through Marysville, Blue Rapids, and Waterville. State Highway 9, east-west through Frankfort, Blue Rapids, and Waterville, is not hard-surfaced between Frankfort and Blue Rapids. State Highway 99, which is partly hard-surfaced and partly gravel-surfaced, passes north-south through Summerfield, Beattie, and Frankfort. State Highway 13, a gravel-surfaced road traversing the valleys of Big Blue River and Black Vermillion River from the south line of Marshall County, joins State Highway 9 about a mile southwest of Frankfort. State Highway 113, a gravel-surfaced road, extends from Blue Rapids to its junction with State Highway 13 a few miles southeast of Irving. State Highway 87 is a gravel-surfaced road extending straight north from Vliets to U. S. Highway 36. Marshall County maintains many graveled county and township roads in addition to the highways.

Agriculture

Agriculture is the chief occupation in Marshall County. Corn, wheat, alfalfa, and oats are the principal crops. About one-third of the acreage of Marshall County is grazing land; a large part of this is in the southwest quarter of the county where the soil is less suitable for tilling. The comparative value of the agricultural products of Marshall County for 1948 is shown in Table 2.

TABLE 2.—*Comparative values of the agricultural products of Marshall County for 1948*

Crops produced in 1948			Livestock on farms in 1948		
Crop	Acres	Value	Livestock	Number	Value
Corn......	125,400	$6,956,700	Cattle (other than milk cows)	32,480	$3,361,200
Wheat....	102,200	4,169,000	Milk cows......	13,520	2,217,300
Alfalfa....	30,300	1,019,890	Swine..........	28,100	1,171,900
Oats......	33,390	718,080	Chickens.......	379,900	456,300
Sorghum...	7,470	210,070	Horses & mules..	5,920	248,640
Others....	17,397	285,770	Sheep & lambs..	6,710	115,000
Total...	....	$13,359,510	Total.........	....	$7,570,340

About 160 acres of land are irrigated from Big Blue River near Marysville.

MINERAL RESOURCES

Marshall County has a greater diversity of mineral raw materials than most counties of northeast Kansas. The principal mineral resources of the county, aside from ground water, are sand, gravel, gypsum, and limestone. No oil or gas is produced in Marshall County.

Sand and gravel.—Marshall County is one of the largest producers of sand and gravel in northeast Kansas. According to figures released by the United States Bureau of Mines and the State Geological Survey of Kansas, Marshall County produced approximately 38,000 short tons of this material in 1951. Of this total about 77 percent was structural sand for use in concrete and mortar, about 6 percent was structural gravel for use in concrete, and the remaining 17 percent was paving gravel and miscellaneous sand and gravel. The large plants now in operation in the county pump the sand and gravel directly from the stream beds of Big Blue and Little Blue Rivers. Several large nonoperating gravel pits are located on terraces of Little Blue River. The sand and gravel of these river deposits is of good quality and is satisfactory for most uses.

Several pits in the county are producing gravel from glacial deposits. The material in these deposits is, in general, very poorly sorted and the mineral composition of the sand and gravel is variable. The glacial gravel produced in Marshall County is used almost exclusively for road surfacing.

Gypsum.—The first gypsum deposits worked within the State of Kansas were in the area around Blue Rapids (Grimsley and Bailey, 1899). The first mine, which operated on a very small scale, was opened in 1872; the locations of several abandoned mines are as follows; Fowler mine, NW¼ NE¼ sec. 18, T. 4 S., R. 7 E.; Electric mine, in NE¼ SE¼ sec. 17, T. 4 S., R. 7 E.; Blue Rapids Gypsum Company mine, SW¼ NW¼ sec. 17, T. 4 S., R. 7 E.; Winter mine, NE¼ SE¼ sec. 24, T. 4 S., R. 6 E.; U. S. Gypsum mine, near the SE cor. sec. 29, T. 4 S., R. 7 E. The Certainteed Products mine near the NE cor. sec. 21, T. 4 S., R. 7 E., is the only mine now operating in Marshall County. The Certainteed mine is worked by the room and pillar method, and the gypsum is processed into "specialty gypsums" at the Blue Rapids plant.

The age and stratigraphic position of the gypsum deposits are discussed in the section on geologic formations and their water-bearing properties.

Limestone.—Abundant limestone suitable for building stone is available in Marshall County. Although no building stone is now being produced, large quantities have been quarried in the past. The Fort Riley, Cottonwood, and Neva limestone members have been quarried at many sites in the county for use as building dimension stone, foundation blocks, and bridge material. In addition to the above mentioned units, the Florence, Schroyer, Eiss, and Morrill limestone members have been quarried for riprap material, road metal, or agricultural lime.

GROUND WATER

Principles of Occurrence

The following discussion of the occurrence of ground water has been adapted from Meinzer (1923) and the reader is referred to his report for a more detailed discussion. A general discussion of the principles of ground-water occurrence with special reference to Kansas has been made by Moore and others (1940). The rocks that make up the crust of the earth generally are not solid, but have numerous openings, called voids or interstices, which may contain air, natural gas, oil, or water. The many different kinds of rocks differ greatly in the number, size, shape, and arrangement of their interstices; therefore, the occurrence of water in any region is determined by the geology of the region.

The interstices or voids in rocks range in size from microscopic openings to huge caverns found in some limestones. The porosity of a rock is expressed quantitatively as the percentage of the total volume of the rock that is occupied by interstices or that is not occupied by solid rock material. Uncemented gravel deposits having a uniform grain size have a high porosity, whereas deposits made up of a mixture of sand, clay, and gravel may have a very low porosity because the smaller particles occupy the space between adjacent large particles. Relatively soluble rock such as limestone, though originally dense, may become cavernous as a result of the removal of part of its substance through the solvent action of percolating water. Hard, brittle rock may acquire large interstices through fracturing that results from shrinkage or deformation of the rocks or through other agencies.

The hydraulic permeability or perviousness of a rock is its capacity for transmitting water under pressure and is measured by the rate at which it will transmit water through a given cross section under a given difference of head per unit of distance. A rock containing many very small interstices may be very porous but difficult to force water through, whereas a coarser grained rock that may have less porosity may be much more permeable. The specific yield of a rock or soil, with respect to water, is the ratio of (1) the volume of water that, after being saturated, it will yield by gravity to (2) its own volume. This ratio may be stated as a percentage. The specific retention of a rock is the ratio of (1) the volume of water which, after being saturated, it will retain against the pull of gravity to (2) its own volume.

The permeable rocks that lie below a certain level are generally saturated with water under hydrostatic pressure. These saturated rocks are said to be in the zone of saturation (Fig. 4). The zone of saturation ordinarily extends down to a depth much greater than is reached by modern drilling methods. The term internal water may be applied to the water in the interior of the earth where the pressure of overlying rocks is so great that interstices cannot exist. The term ground water is used to designate that part of the subsurface water within the zone of saturation. The upper surface of the zone of saturation is called the ground-water table, or simply the water table. In most places there is only one zone of saturation, but in certain localities the water may be hindered in its downward course by an impermeable or nearly impermeable bed to such an extent that an upper zone of saturation, or perched water body, not associated with the lower zone of saturation, is formed.

All rocks above the water table are in the zone of aeration, which ordinarily consists of three parts: the belt of soil water; the intermediate, or vadose zone; and the capillary fringe.

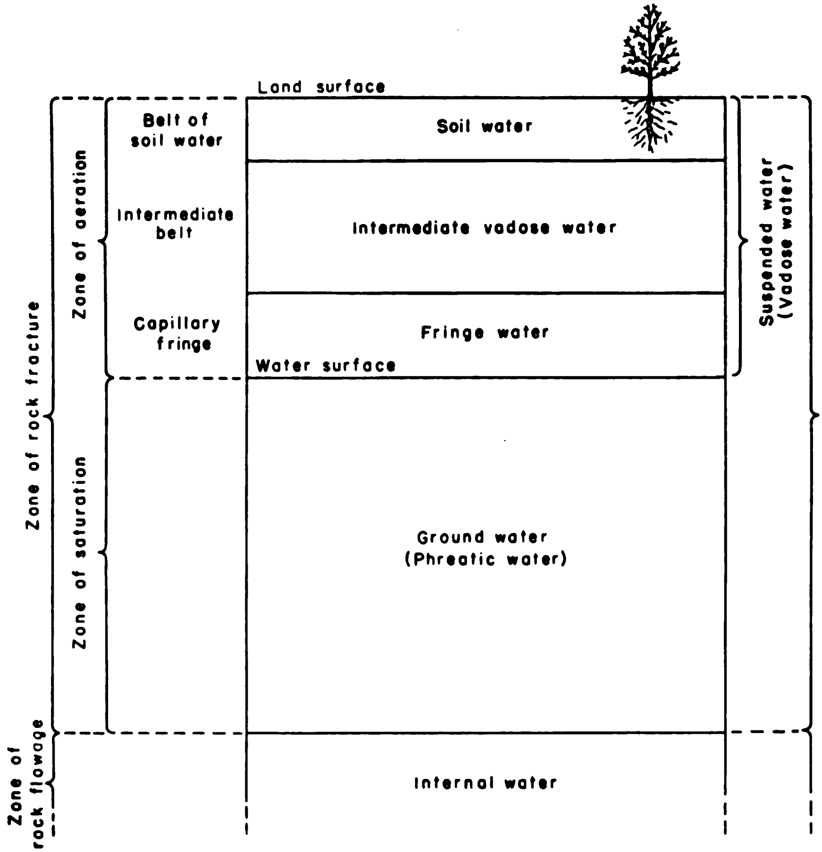

FIG. 4.—Diagram showing divisions of subsurface water. (after Meinzer)

The belt of soil water, which contains water held by molecular attraction, lies just below the land surface and extends down to the maximum depth at which evaporation and plant action occur. The water in the belt of soil water is not available to wells but is of the utmost importance to agriculture. In this belt the amount of water must exceed that which will be held by molecular attraction before any water can percolate downward to the water table. The belt of soil water is limited in thickness by the texture of the rock or soil, and by the character of the vegetation.

The space between the lower limit of the belt in which water can be withdrawn by plant action and the upper limit of the capillary fringe forms an intermediate belt which is thick where the depth to the water table is great and may be absent where the water table is at or near the surface. In this belt the interstices in the rocks contain some water held by molecular attraction but also may contain appreciable quantities of water while it is moving downward from the belt of soil moisture to the water table.

The capillary fringe lies directly above the water table and is formed by water held above the zone of saturation by capillary force. The water in the capillary fringe is not available to wells, which must be deepened to the zone of saturation before water will enter them. The capillary fringe may be very thin in coarse-grained sediments, in which the capillary action is negligible, or it may be several feet thick in fine-grained sediments.

Artesian Conditions

Artesian conditions exist where a water-bearing bed is overlain by an impermeable or relatively impermeable bed that dips from its outcrop to the discharge area. Water percolates downward to the water table at the point of outcrop of the water-bearing bed, and then moves down dip beneath the overlying impermeable bed. The hydrostatic pressure of the ground water is due to the weight of water at higher levels in the water-bearing bed, or aquifer as it is usually called. The pressure head of water at a given point in an aquifer is its hydrostatic pressure expressed as the height of a column of water that can be supported by the pressure. The pressure head is the height that a column of water rises in a tightly cased well that has no discharge. If the pressure in the aquifer is sufficient to lift the water above the top of the aquifer, artesian conditions are said to exist. The difference in height between the point of outcrop of the aquifer and the point of discharge must be sufficient to develop a pressure equal to the weight of the column of water in the well plus the loss of head by friction in the aquifer before a well will flow at the surface.

No flowing wells were encountered in Marshall County; however, many wells obtaining water from limestone have artesian pressure. Many wells in glacial material have artesian pressure because dipping lenses of sand and gravel are overlain by relatively impermeable clay.

The Water Table and Movement of Ground Water

The water table has been defined as the upper margin of the zone of saturation. The zone of saturation is, in a sense, a ground-water reservoir just as a lake or river is a surface-water reservoir. The water table is not a static, level surface; generally it is a sloping surface having many irregularities and is constantly changing. There are many causes of irregularities and fluctuations in the water table.

Ground water moves in the downslope direction of the water table, but this movement is very slow because of the frictional resistance offered by the small interstices through which the water must pass. In an area where conditions are suitable for a high rate of recharge, water may percolate down to the water table faster than it can spread out and a mound or ridge is formed in the water table. By the same process, if water is withdrawn from the zone of saturation faster than it can flow in laterally, the water table is lowered locally forming an inverted cone or a trough. The permeability of the water-bearing material has a significant effect upon the slope of the water table. In a fine-grained deposit having a low permeability the slope of the water table must be much steeper than in a coarse-grained, highly permeable deposit in order to have the same rate of flow.

In the parts of Marshall County where glacial deposits are thick and the surface is dissected, the water table is as near the surface on the hill tops as it is in many of the adjacent alluvial valleys. This is probably because the glacial deposits in the hills are relatively impermeable and the slope of the water table toward the valleys is quite steep, whereas the more highly permeable alluvium in the valleys allows rapid downstream movement of the water at a lower gradient.

In Marshall County the water confined in permeable limestone beds by relatively impermeable shale beds moves in the direction of regional dip, which is to the west.

Ground-Water Recharge

The amount of water in storage in the zone of saturation does not remain constant but fluctuates with the precipitation. Water is continually being discharged from the underground reservoir by seepage, wells, and springs. The water table lowers in times of drought and rises during times of precipitation.

The addition of water to the underground reservoir, termed recharge, may occur in several ways. Water available to wells in Marshall County originally fell as rain or snow within the county or surrounding area. Water reaches the zone of saturation in Marshall County by direct recharge from local precipitation, by recharge from streams and ponds, and by subsurface movement from outside the area.

RECHARGE FROM LOCAL PRECIPITATION

The normal annual precipitation in Marshall County is 28.30 inches. Of the total precipitation, a large part is consumed by evaporation and transpiration, a small part leaves the county as surface runoff, and a small part reaches the zone of saturation and becomes ground water. According to records of the U. S. Geological Survey and the Kansas State Board of Agriculture, the annual net runoff in the drainage area of Big Blue River above Randolph, Kansas, during the 10 years 1936 to 1945, inclusive, ranged from 0.55 inch in 1940 to 5.43 inches in 1945; the average for the 10-year period was 2.40 inches. The annual net runoff in the drainage area of Little Blue River above Waterville during the same period ranged from 0.52 inches in 1940 to 5.56 inches in 1945, and the average for the 10-year period was 2.30 inches. Comparison of these runoff figures with the precipitation records at Blue Rapids for the same period of time indicates a runoff of slightly less than 8 percent of the precipitation.

A large part of the precipitation in Marshall County occurs during the summer months when conditions are favorable for a high rate of evaporation and transpiration, and the bulk of the water is probably lost in this way.

Factors favoring a high rate of runoff are steep slopes of the land surface, heavy downpours of precipitation, sparse coverings of vegetation, impermeable materials at or near the surface, and rainfall when the ground is frozen.

RECHARGE FROM STREAMS AND PONDS

Streams and ponds may receive water from the underground reservoir, or they may add to the water in the ground-water reservoir. To add to the ground water, the surface of the water in the stream or pond must be above the level of the water table, and the material surrounding the body of water must be permeable enough to allow downward percolation of water to the water table. Streams that satisfy these conditions are called influent or losing streams (Fig. 5).

None of the streams of Marshall County are normally of the influent type, because the surface of the water in the streams is generally below the water table. During times of prolonged drought, however, the water table may fall to such a low level that some of the major streams become temporarily influent. Heavy pumping from the alluvium bordering a stream may lower the water table near the stream sufficiently to induce recharge from the stream and thus recover water that would otherwise be lost as runoff.

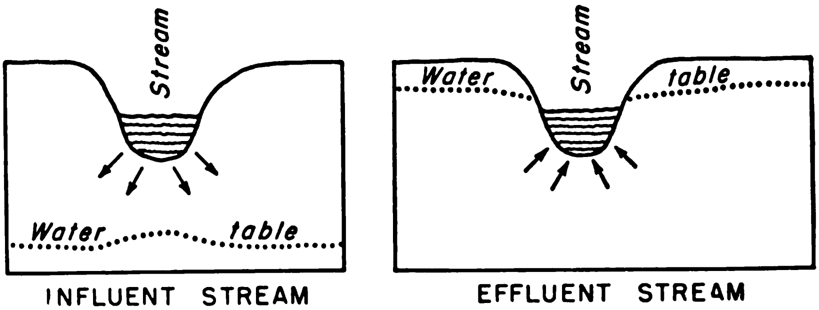

FIG. 5—Diagrammatic sections showing influent and effluent streams.

RECHARGE FROM OUTSIDE AREAS

Most of the ground water entering Marshall County by movement from adjacent areas probably fell as precipitation in the areas immediately surrounding the county. Ground water in some of the deep-lying formations, which are not generally exploited for water in Marshall County, probably entered the formation at the area of outcrop, which may be at a considerable distance. The amount of ground water entering the county by subsurface inflow is small and is probably about equal to the amount leaving the county in the same way.

GROUND-WATER DISCHARGE

Ground-water discharge is the removal, by any method, of water from the zone of saturation. Ground-water discharge in Marshall County is by transpiration and evaporation, by seepage into streams and ponds, by subsurface movement into adjacent areas, and by pumping of wells.

DISCHARGE BY TRANSPIRATION AND EVAPORATION

Transpiration is the process by which water is taken into the root system of plants directly from the zone of saturation or from the capillary fringe just above it and is discharged into the atmosphere.

The depth from which plants will lift the ground water varies with different plant species and different types of soil. Ordinary grasses and field crops will not send their roots more than a few feet in the search for water. If subsurface conditions are suitable alfalfa and certain desert plants are known to send their roots to greater depths. The water table is within easy reach of such deep-rooted plants nearly everywhere in Marshall County, and in the valley areas of the county the water table is probably within reach of the ordinary grasses and field crops.

Loss of ground water by direct evaporation can take place only where the water table is within a few feet of the surface and in Marshall County is probably limited to marshy lands and areas along streams.

DISCHARGE BY SPRINGS AND SEEPS

A stream that stands lower than the water table may receive water from the zone of saturation, and is known as an effluent or gaining stream. This discharge of ground water may exist as a few large springs issuing from highly permeable sand and gravel beds or from fractured limestone beds, or it may occur as seepage along the entire course of the stream. Except for short periods of time during and immediately after rainfall, the perennial streams of Marshall County get their entire volume of water from springs and seeps, either within the county or in the areas upstream.

At present, the bulk of the ground water removed from the subsurface reservoir in the county is discharged by the processes of transpiration and evaporation and by springs and seeps.

DISCHARGE BY MOVEMENT TO AREAS OUTSIDE THE COUNTY

Some ground water leaves Marshall County by movement into adjacent areas. The amount of ground water leaving the county by subsurface flow is small and is probably about equal to the amount entering the county in the same way.

DISCHARGE BY WELLS

Although wells are the most obvious method of ground-water discharge in Marshall County, the quantity of water discharged in this manner is small. It is estimated that about 2,000,000 gallons of ground water is pumped daily in the county. The recovery of ground water from wells is discusssed in the next section.

Recovery

PRINCIPLES OF RECOVERY

When a well is at rest, the pressure of the water outside the well is equal to the pressure of the water inside. When water is removed from the well by pumping, the resulting drawdown or lowering of the water level produces a differential in head or pressure and water flows into the well. When water is being discharged from a well, the water table is lowered in an area around the well to form a depression in the water table that somewhat resembles an inverted cone. This depressed area is known as the cone of depression or the cone of influence. As the pumping rate of the well is increased, the drawdown becomes greater. When a well is first pumped the water level will fall very rapidly, but as pumping is continued at a steady rate the drawdown increases at a diminishing rate. When pumping is stopped, the recovery is rapid at first but gradually tapers off and may continue for many hours or for several days.

The yield or capacity of a well is the continuous rate at which it will yield water after the water stored in the well has been removed. The capacity depends upon the amount by which the water level can be lowered, the thickness and permeability of the water-bearing bed, and the construction and condition of the well. The capacity of a well generally is expressed in gallons a minute.

The specific capacity of a well is the rate of yield per unit of drawdown and is commonly expressed in gallons a minute per foot of drawdown. If a well yields 50 gallons per minute and has a drawdown of 10 feet when pumped at that rate, the specific capacity of the well is 5 gallons a minute per foot of drawdown. In testing the specific capacity of a well, pumping is continued until the water level remains approximately stationary.

DUG WELLS

Dug wells are constructed by excavating with picks and shovels or by power machinery. Those in Marshall County are generally more than 2 feet in diameter and are relatively shallow. Dug wells may be constructed in nearly any type of geologic formation, but in Marshall County they are most common in areas where the aquifers are consolidated bedrock or sand and gravel deposits lying near the surface. This type of well is simply a pit penetrating the water-bearing rocks and walled with rock, brick, or concrete. The advantage of a dug well is the large infiltration area and storage reservoir provided by the large diameter. Dug wells are, in general, more subject to contamination and failure during dry weather than deeper drilled wells.

BORED WELLS

Bored wells are made by augers or post-hole diggers. Such wells are limited to unconsolidated sediments. Bored wells are generally 12 inches or more in diameter and are generally cased with bell-joint tile. Contamination by surface water seeping through the tile joints is likely to occur in bored wells.

DRIVEN WELLS

Some of the wells in the major valleys of Marshall County are driven wells, generally made by driving a 1¼ or 1½-inch pipe, equipped at the bottom with a screened drive point, below the water table. Such wells generally are constructed only where the water-bearing material is sufficiently permeable to permit water to flow freely into the pipe, where the material is unconsolidated enough to permit a pipe to be driven, and where the depth to water level is not more than about 20 feet below the land surface. Where the surface material will not allow a pipe to be driven, the upper part of the well is dug or augered with a post-hole digger, and the pipe is then driven into the bottom of this hole. Driven wells are sometimes equipped with a pitcher pump; if the water level is too deep for a pitcher pump, a cylinder is placed at the bottom of a dug or augered part of the well and the driven pipe placed below this part.

DRILLED WELLS

Most of the wells in the areas of thick unconsolidated sediments, as well as many of the deeper wells in other parts of the county, are of the drilled type. Wells may be drilled either by the percussion method or by the hydraulic-rotary method. The drilled wells for stock and domestic use in Marshall County are generally 3½ to 8 inches in diameter and are cased with galvanized-iron or wrought-iron casing.

Drilled wells obtaining water from consolidated sediments that will not cave are generally cased only in the upper part. Water may enter the well along the entire uncased part of the hole, only the surface seepage water being cased off.

Drilled wells obtaining water from unconsolidated sediments are generally cased to the bottom of the hole. Water enters the well through the bottom of the casing, and, if they are provided, through perforations in the casing. The size of the perforations is a very important factor in the construction of a well. They should be small enough that only the finest material can enter the well, but they should be large enough to allow free flow of water into the well and not become clogged by sand particles. Care should be taken to locate the perforated sections of casing within the water-bearing beds. Some wells in unconsolidated sediments are equipped with special well screens or strainers. By selecting the proper slot size in a well screen, a certain amount of the finer water-bearing material is passed through the screen and the coarser material is retained to form a natural gravel packing around the screen.

Municipal and industrial wells in unconsolidated materials may be artificially gravel-packed. In this type of construction a large-diameter hole is first made and cased. A smaller casing with sections of well screen spaced to correspond to the water-bearing beds is then centered in the hole and the annular space between the large casing and the smaller casing is filled with carefully selected gravel. The larger casing then is withdrawn to permit the water to flow into the well. This type of construction increases the effective diameter of the well and helps to prevent fine sand from entering the well.

METHODS OF LIFT AND TYPES OF PUMPS

Most of the domestic and stock wells in Marshall County are equipped with lift or force pumps. The cylinders in lift pumps and in force pumps are similar and are below the land surface. A lift pump generally discharges water only at the pump head, whereas, a force pump can force water above this point. Stock wells in Marshall County are operated generally by windmills or electric motors, but many of the domestic wells are hand operated. Public-supply wells are equipped almost entirely with turbine pumps powered by electric motors. Electrically powered jet pumps with automatic controls are used on many of the modern domestic installations in the county.

Utilization of Water

Ground water in Marshall County is used chiefly for domestic and stock purposes and for public supplies. A small quantity of ground water is used by small industries and by railroads. No ground water is used in Marshall County for irrigation, except for occasional lawn sprinkling and watering of small vegetable gardens. Ground water is used to air condition several buildings in Marysville.

DOMESTIC AND STOCK SUPPLIES

Nearly all domestic supplies and many of the stock supplies in rural areas are obtained from wells. In parts of Marshall County, streams and ponds are used to some extent to supply stock water. The domestic use of water generally includes drinking, cooking, washing, and in some cases, the disposal of sewage. Water supplies for those schools not served by public-supply systems are considered domestic. In some areas of the county, farmers commonly have a shallow well yielding a small quantity of good quality water for domestic use and a deeper well having a larger yield but more highly mineralized water for stock supplies.

PUBLIC SUPPLIES

Nine municipalities in Marshall County have public water supplies obtained from wells. The City of Marysville, which obtains its water from Big Blue River, is the only city in the county using surface water. Each municipal supply is described briefly in the following paragraphs. The geology and the water-bearing properties of the aquifers are discussed in the section on geologic formations and their water-bearing properties.

Blue Rapids.—The City of Blue Rapids, in Big Blue River Valley, obtains water from two wells (4-7-20cd1 and 4-7-20cd2) in the city park in the western part of the city. Both wells extend into sand and gravel deposits underlying the terrace surface upon which they are located. Well 4-7-20cd1 is 46 feet deep, is cased with 18-inch tile and well screen, and is gravel packed. The well has a reported static water level of 21 feet below the land surface and yields 285 gallons a minute with a drawdown of 3 to 4 feet. This well is equipped with a turbine pump powered by a 40-horsepower electric motor. A chemical analysis of water from this well is given in Table 3. Well 4-7-20cd2, which is 42 feet deep and 20 feet in diameter, is walled with brick. The normal static water level is reported to be 18 to 20 feet below the land surface, and the yield is estimated at 350 gallons a minute with a drawdown of 8 feet. This well is equipped with a centrifugal pump and a 50-horsepower electric motor.

The water from the wells is pumped directly into the mains, and the excess flows into a 150,000-gallon concrete reservoir on a hill just south of the city. The average daily water consumption at Blue Rapids is reported to be about 95,000 gallons of which about 10,000 gallons is used by railroads.

Frankfort.—The City of Frankfort in the valley of Black Vermillion River obtains its water supply from two drilled wells at the east edge of the city. One well (4-9-16aa1) is 117 feet deep and is gravel packed. It is cased with 18-inch steel casing and is equipped with a turbine pump and a 25-horsepower electric motor. This well is reported to have a static water level of 60 feet below the land surface, and a yield of 250 gallons a minute with a drawdown of 50 feet. Well 4-9-16aa2, 104 feet deep, is cased with 18-inch steel casing. It is equipped with a turbine pump and a 40-horsepower electric motor. This well is reported to have a static water level of 60 feet below the land surface, and a yield of 250 gallons a minute with a drawdown of 30 feet. The principal aquifer in both wells is a bed of coarse chert gravel resting upon Permian shale. A chemical analysis of water from well 4-9-16aa2 is given in Table 3.

Water is pumped from the wells directly into the mains, and the excess flows into a 90,000-gallon elevated steel tank. The average daily consumption of water in Frankfort is about 100,000 gallons, of which about 33,000 gallons is used by the Union Pacific Railroad.

Waterville.—Waterville is supplied with water from two drilled wells on the flood plain of Little Blue River north of town. Both wells (4-6-16dd1 and 4-6-16dd2) are reported to be 55 feet deep and are cased with 18-inch steel casing. They are both gravel packed, and well 4-6-16dd1 is equipped with a turbine pump and a 20-horsepower electric motor, well 4-6-16dd2 is equipped with a turbine pump and a 30-horsepower electric motor. An old well in the east part of town is maintained on a stand-by basis for use in emergencies. An analysis of water from well 4-6-16dd1 is given in Table 3.

Water is pumped from the wells directly into the mains; the excess is stored in a 100,000-gallon concrete tank on a hill south of town. The average daily water consumption at Waterville is about 40,000 gallons.

Axtell.—Axtell obtains its water supply from two drilled wells in the south part of town. Both wells have 24-inch concrete casing and are equipped with turbine pumps and electric motors. The wells tap a bed of coarse glacial gravel and yield about 95 gallons a minute each. Well 2-10-24bc1 is 59 feet deep and well 2-10-24bc2 is 57 feet deep; the static water level is reported to be 43 feet below land surface in both wells. An analysis of the water is given in Table 3.

The water is pumped from the wells directly into the mains, and the excess flows into a 50,000 gallon elevated steel tank. The average daily water consumption at Axtell is about 37,000 gallons.

Beattie.—The water supply of Beattie is obtained from two wells tapping glacial sand and gravel. Well 2-9-21ac is dug to a depth of 80 feet, and a drilled portion extends to a depth of 106 feet. The dug part of the well is walled with concrete and the drilled part is cased with 8-inch steel casing. This well has a reported static water level of 76 feet, is equipped with a cylinder pump and 5-horsepower electric motor, and is reported to have a low yield. Well 2-9-21ab is a drilled well 80 feet deep, cased with 6-inch steel casing, and equipped with a cylinder pump and electric motor. It has a reported static water level of 30 feet. An analysis of a composite sample of water from both wells is given in Table 3.

The average daily water consumption at Beattie is 30,000 gallons. Storage is in a 50,000-gallon elevated steel tank near the north edge of town.

Summerfield.—The water supply of Summerfield is obtained from a drilled well (1-9-1db) about a quarter of a mile south of town. The well is 83 feet deep and is cased with 6-inch galvanized iron casing; the static water level is reported to be about 40 feet below the land surface. A turbine pump, powered by a 5-horsepower electric motor, is installed on the well. A complete log of this well was not available, but Permian limestones are the principal water-bearing beds. An analysis of the water is given in Table 3.

The water is pumped from the well directly into the mains, and the excess flows into a 50,000-gallon elevated steel tank. The average daily water consumption at Summerfield is 8,000 gallons.

Vermillion.—Vermillion obtains its water from one drilled well (4-10-11da) in the southeast part of town. The well is 50 feet deep, cased with 12-inch steel casing, and has a reported static water level of 4 feet below the land surface. It has a reported yield of 70 gallons a minute with a drawdown of 19 feet. The well is equipped with a centrifugal pump and 5-horsepower electric motor. Glacial sand and gravel is the principal water-bearing material. An analysis of the water is given in Table 3.

The average daily water consumption at Vermillion is 30,000 gallons. Storage is in a 35,000-gallon elevated steel tank.

Irving.—Two closely spaced wells (5-7-11aa1 and 5-7-11aa2) on the west side of town supply the City of Irving with water. Both wells tap gravel deposits underlying the terrace surface upon which the wells are located. Well 5-7-11aa1 is 80 feet deep, is cased with

12-inch steel casing, and is equipped with a turbine pump and a 7½-horsepower electric motor. Well 5-7-11aa2 is 80 feet deep, is cased with 14-inch steel casing, and is equipped with a cylinder pump and a 7½-horsepower electric motor. The static water level in both wells is reported to be 50 feet below the land surface. An analysis of a composite sample of the water from both wells is given in Table 3.

The average daily water consumption in Irving is 10,000 gallons. Storage is in a 30,000-gallon elevated steel tank.

Oketo.—The water supply of Oketo is obtained from one drilled well (1-7-14ab) on the flood plain of Big Blue River. The well is 32 feet deep and is cased with 10-inch steel casing. When the well was constructed in 1937, the static water level was 17 feet below the land surface, and the well had a yield of 87 gallons a minute with 3½ feet of drawdown. It is equipped with a turbine pump and electric motor. An analysis of the water is given in Table 3.

Water is pumped from the well directly into the mains; the excess flows into a 25,000-gallon elevated steel tank. The average daily water consumption at Oketo is about 3,000 gallons.

INDUSTRIAL SUPPLIES

A record of only one well (4-7-20aa) that supplies water principally for industrial use was obtained in Marshall County. The Certainteed Products Company of Blue Rapids has a drilled well on the flood plain of Big Blue River near its gypsum mine and plant. The well is 29 feet deep and derives water from alluvium. It is cased with 16-inch steel casing and is equipped with a centrifugal pump and electric motor. This well has a reported static water level of 12 feet below the land surface and an estimated yield of 85 gallons a minute. The water from this well is used principally in the manufacturing of gypsum products.

AIR-CONDITIONING SUPPLIES

The three wells in Marysville that are used exclusively for air-conditioning supplies obtain water from the alluvium of Big Blue River. Well 2-7-33ba in the basement of the Pacific Coffee Shop, is 41 feet deep, and is cased with 8-inch steel casing and well screen. This well is equipped with a turbine pump having a capacity of 55 gallons a minute. Well 2-7-33bb, owned by the Howell Lumber Company, is 27 feet deep and is cased with 6-inch galvanized iron casing. It is equipped with an electrically powered turbine pump having a capacity of 250 gallons a minute. The average summer

TABLE 3.—*Analyses of water from typical wells in Marshall County, Kansas*

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

Well No.	Location	Depth, feet	Geologic source	Date of collection	Temperature (°F)	Dissolved solids	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na+K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Hardness as $CaCO_3$		
																	Total	Carbonate	Noncarbonate
	T. 1 S., R. 6 E.																		
1-6-1dd	SE¼ SE¼ sec. 1	80.8	Glacial sand	Dec. 11, 1951	53	364	32	0.86	80	10	31	298	8.2	14	0.1	42	240	240	0
	T. 1 S., R. 7 E.																		
1-7-14db	NW¼ SE¼ sec. 14	32	Alluvium	Oct. 2, 1951	......	648	31	0.10	137	46	12	537	60	17	0.1	37	531	440	91
	T. 1 S., R. 8 E.																		
1-8-21dd	SE¼ SE¼ sec. 21	71.2	Glacial sand, gravel	Dec. 14, 1951	53	544	22	9.8	111	28	37	393	12	43	0.1	97	392	322	70
	T. 1 S., R. 9 E.																		
1-9-1db	NW¼ SE¼ sec. 1	83	Limestone	Sept. 5, 1949	......	2,082	......	0.53	240	172	71	368	1,083	19	1.3	2.2	1,306	302	1,004
	T. 1 S., R. 10 E.																		
1-10-35cd	SE¼ SW¼ sec. 35	64.7	Glacial sand, gravel	Dec. 12, 1951	54	639	22	1.6	75	24	123	450	154	12	0.8	6.2	286	286	0
	T. 2 S., R. 6 E.																		
2-6-3bc	SW¼ NW¼ sec. 3	60	Barneston limestone and Doyle shale	Dec. 11, 1951	54	589	13	1.8	100	56	30	444	158	9.0	0.2	3.7	480	364	116
2-6-35aa	NE¼ NE¼ sec. 35	52	Barneston limestone	Dec. 11, 1951	......	2,495	25	4.0	416	175	103	356	1,538	61	1.1	1.0	1,757	292	1,465
	T. 2 S., R. 7 E.																		
2-7-33db	NW¼ SE¼ sec. 33	24	Alluvium	Dec. 11, 1951	55	3,887	31	1.0	674	250	175	618	599	770	0.1	1,084	2,709	507	2,202
2-7-35aa	NE¼ NE¼ sec. 35	114	Barneston limestone	Dec. 11, 1951	......	409	18	0.29	72	27	40	346	56	23	0.2	2.7	290	284	6
	T. 2 S., R. 8 E.																		
2-8-35dc	SW¼ SE¼ sec. 35	77.6	Wreford limestone	Dec. 12, 1951	55	1,037	19	0.98	212	49	60	425	467	13	0.7	7.5	730	348	382
	T. 2 S., R. 9 E.																		
2-9-21*	Sec. 21	......	Glacial sand, gravel	Jan. 16, 1952	......	983	......	0.08	134	54	99	376	387	32	0.6	17	556	308	248
2-9-32dd	SE¼ SE¼ sec. 32	108.5	Beattie limestone	Dec. 12, 1951	54	3,113	21	32	372	220	315	470	1,689	264	1.0	0.44	1,832	286	1,446
	T. 2 S., R. 10 E.																		
2-10-24bc1	SW¼ NW¼ sec. 24	59	Glacial gravel	Feb. 9, 1948	......	575	......	0.05	107	36	40	425	32	60	0.3	44	415	348	67
2-10-24bc2	SW¼ NW¼ sec. 24	57	do.	Dec. 4, 1948	......	589	......	0.03	104	38	*52*	438	40	60	0.3	53	416	359	57
	T. 3 S., R. 6 E.																		
3-6-6cd	SE¼ SW¼ sec. 6	74.7	Winfield limestone	Dec. 11, 1951	54	1,388	21	10	211	85	94	383	115	173	0.2	500	876	314	562

TABLE 3.—*Analyses of water from typical wells in Marshall County, Kansas—Concluded*

Well No.	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
	T. 3 S., R. 8 E.																		
3-8-36cd....	SE¼ SW¼ sec. 36..	40.6	Beattie limestone..	Dec. 12, 1951	55	672	11	0.39	92	30	107	427	205	12	0.3	4.9	353	350	3
	T. 3 S., R. 9 E.																		
3-9-9bc.....	SE¼ NW¼ sec. 9...	64.8	Grenola limestone...	Dec. 12, 1951	54	1,080	16	19	208	54	63	321	551	27	0.5	2.4	741	263	478
	T. 4 S., R. 6 E.																		
4-6-16dd1...	SE¼ SE¼ sec. 16...	55	Alluvium..........	Nov. 30, 1951	......	469	......	0.07	121	23	8.3	407	51	14	0.2	9.7	396	334	62
4-6-17dc....	SW¼ SE¼ sec. 17..	90	Terrace...........	Dec. 13, 1951	54	193	18	0.29	38	10	12	137	22	7.0	0.2	19	136	112	24
	T. 4 S., R. 7 E.																		
4-7-20cd1...	SE¼ SW¼ sec. 20..	46	do............	Jan. 18, 1952..	......	541	......	0.07	121	26	11	339	98	17	0.2	36	409	278	131
4-7-21cd....	SE¼ SW¼ sec. 21..	32.4	do............	Dec. 13, 1951	55	1,074	12	3.2	187	66	82	403	321	137	0.4	71	738	330	408
	T. 4 S., R. 8 E.																		
4-8-3cd.....	SE¼ SW¼ sec. 3...	75.1	Wreford limestone...	Dec. 12, 1951	54	2,137	16	30	346	166	66	249	1,400	18	0.9	0.66	1,545	204	1,341
	T. 4 S., R. 9 E.																		
4-9-16aa2...	NE¼ NE¼ sec. 16..	104	Glacial gravel.......	Mar. 22, 1950	......	342	......	0.05	78	15	27	321	30	12	0.2	3.6	256	256	0
	T. 4 S., R. 10 E.																		
4-10-8cb....	NW¼ SW¼ sec. 8..	40	Alluvium..........	Dec. 14, 1951	52	587	27	0.11	92	20	103	527	38	44	0.1	2.5	312	312	0
4-10-11da...	NE¼ SE¼ sec. 11..	50	Glacial sand, gravel..	Dec. 13, 1950	......	374	......	3.4	85	15	37	398	10	11	0.2	0.40	274	274	0
	T. 5 S., R. 6 E.																		
5-6-12dd....	SE¼ SE¼ sec. 12...	72	Barneston limestone	Dec. 13, 1951	54	983	19	0.47	163	35	107	512	31	48	0.1	328	550	420	130
	T. 5 S., R. 7 E.																		
5-7-11aa**..	NE¼ NE¼ sec. 11..	......	Terrace...........	Mar. 22, 1951	......	813	......	0.37	141	35	55	282	233	45	0.2	97	496	231	265
	T. 5 S., R. 9 E.																		
5-9-22cc....	SW¼ SW¼ sec. 22..	92	Red Eagle limestone	Dec. 12, 1951	55	1,908	20	0.14	422	72	70	412	1,013	37	0.5	71	1,349	338	1,011
5-9-24ba....	NE¼ NW¼ sec. 24	56	Grenola limestone...	Dec. 12, 1951	54	387	14	2.1	105	16	18	399	23	8.0	0.1	6.2	328	327	1
	T. 5 S., R. 10 E.																		
5-10-26dd...	SE¼ SE¼ sec. 26...	225	Glacial sand, gravel..	Dec. 12, 1951	......	462	18	0.16	78	24	63	434	47	15	0.2	3.0	293	293	0

[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 wells 2-9-21ab and 2-9-21ac.

** Composite sample from well 5-7-11aa₁ and 5-7-11aa₂.

temperature of the water from this well is reported to be about 58° F. A third air-conditioning well in Marysville in the basement of the Brunswick Recreation Parlor, had not been put into service at the time field work was being done for this report. Complete information on this well was not available and it is not included in Table 11.

Chemical Character of Ground Water

The chemical character of ground water in Marshall County is indicated by the analyses in Table 3. The analyses were made by Howard Stoltenberg in the Water and Sewage Laboratory of the Kansas State Board of Health. Samples of water for chemical analysis were collected from 30 wells distributed as uniformly as possible within the county and representing the principal water-bearing formations of the area. Analyses of the water from several municipal wells are also given. The effect of the geologic character of the aquifer upon the quality of water is discussed in the section on quality of water in relation to water-bearing formations. The results of the analyses of the water samples are given in parts per million. Factors for converting parts per million of mineral constituents to equivalents per million are given in Table 4.

Table 4.—*Factors for converting parts per million of mineral constituents to equivalents per million*

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

CHEMICAL CONSTITUENTS IN RELATION TO USE

The following discussion of the chemical constituents of ground water has been adapted in part from publications of the Federal Geological Survey and the State Geological Survey of Kansas.

Dissolved solids.—When water is evaporated, the residue consists mainly of the mineral constituents listed in the tables of analyses and generally includes a small quantity of organic material and a little water of crystallization. Water containing less than 500 parts per million of dissolved solids generally is satisfactory for domestic use except for difficulties resulting from hardness or excessive content of iron. Water containing more than 1,000 parts per million is likely to include enough of certain constituents to cause a noticeable taste or to make the water unsuitable in some other respects.

The dissolved solids in samples of water from Marshall County ranged from 193 to 3,887 parts per million. About 27 percent of the samples contained less than 500 parts per million and about 40 percent of the samples contained between 500 and 1,000 parts per million (Table 5). Ten of the 30 samples contained more than 1,000 parts per million.

TABLE 5.—*Dissolved solids in samples of water from wells in Marshall County*

Range, parts per million	Number of samples
101–200	1
201–300	0
301–400	4
401–500	3
501–600	6
601–700	3
701–800	0
801–900	1
901–1,000	2
More than 1,000	10
Total	30

Hardness.—The hardness of water, which is the property that generally receives the most attention, is recognized most commonly by its effects when soap is used with the water. Calcium and magnesium cause almost all the hardness of ordinary waters. These constituents are also the active agents in the formation of the greater part of the scale formed in steam boilers and other vessels used to heat or evaporate water.

In addition to the total hardness, the table of analyses shows the carbonate hardness and the noncarbonate hardness. The carbonate hardness is due to the presence of calcium and magnesium bicarbonates and can be almost completely removed by boiling. In some reports this type of hardness is called temporary hardness. The permanent or noncarbonate hardness is due to the presence of sulfates or chlorides of calcium and magnesium and cannot be removed by boiling. With reference to use with soap, the carbonate hardness and noncarbonate hardness do not differ. In general, the noncarbonate hardness forms harder scale in steam boilers.

Water having a hardness of less than 50 parts per million is generally rated as soft, and treatment for the removal of hardness is not necessary under ordinary circumstances. Hardness between 50 and 150 parts per million does not seriously interfere with the use of water for most purposes, but the hardness does increase the amount of soap used and removal by a softening process is profitable for laundries or other industries using large quantities of soap. Water having a hardness in the upper part of this range will cause considerable scale on steam boilers. Hardness above 150 parts per million is very noticeable, and if the hardness is 200 or 300 parts per million, water for household use is commonly softened. Where municipal water supplies are softened, an attempt is made generally to reduce the hardness to 80 to 100 parts per million. The additional improvement by further softening of a public supply generally is not deemed worth the increase in cost.

Water samples collected in Marshall County ranged in total hardness from 136 to 2,709 parts per million. Only one sample had a hardness of less than 200 parts per million (Table 6); nearly two-thirds of the samples had hardnesses between 200 and 600 parts per million. Four samples had hardnesses of 700 to 900 parts per million, and 6 had hardnesses of more than 1,000 parts per million.

TABLE 6.—*Hardness of samples of water from wells in Marshall County*

Range, parts per million	Number of samples
101–200	1
201–300	6
301–400	5
401–500	5
501–600	3
601–700	0
701–800	3
801–900	1
901–1,000	0
More than 1,000	6
Total	30

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

The iron content of the water samples from wells in Marshall County ranged from 0.03 to 32 parts per million. One-fifth of the samples contained 0.1 part per million or less, half contained between 0.1 and 2 parts per million, and the remainder contained more than 2 parts per million. It is believed that the excessively high concentrations of iron shown in Table 7 are due to corrosion of the pumping equipment, and are not the natural iron content of the water.

Fluoride.—The fluoride content of water likely to be used by children should be known because fluoride in water is associated with the dental defect known as mottled enamel, which may appear on the teeth of children who drink water containing excessive amounts of fluoride during the period of formation of the permanent teeth. According to the Public Health Service (1946), water containing more than about 1.5 parts per million of fluoride should

TABLE 7.—*Iron content of samples of water from wells in Marshall County*

Range, parts per million	Number of samples
0.0 –0.10	6
0.11–1.0	13
1.1 –2.0	2
2.1 –3.0	1
3.1 –4.0	3
4.1 –5.0	0
5.1 –10.0	2
10.1 –20.0	1
20.1 –30.0	1
30.1 –40.0	1
Total	30

not be used for drinking. If the water contains as much as 4 parts per million of fluoride, 90 percent of the children drinking it are likely to have mottled enamel, and 35 percent or more of the cases will be classified as moderate or worse. Contents of fluoride up to 1 part per million are believed to be beneficial in reducing tooth decay, and fluoride is now being added to some municipal supplies to bring the content up to 1 part per million.

Twenty-one of 30 samples of water from wells in Marshall County had less than 0.5 part per million of fluoride, 6 had between 0.5

and 0.9 part per million, and 3 had between 1.0 and 1.4 parts per million.

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 parts per million of nitrate should not be used in formula preparation for infant feeding. Water containing 90 parts per million of nitrate generally is considered dangerous to infants, and water containing 150 parts per million may cause severe cyanosis. Cyanosis is not produced in adults and older children by the concentrations of nitrate found in drinking water. Boiling water high in nitrate content does not render it safe for use by infants; therefore, only water that is known to be free from high nitrate content should be used for this purpose.

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). In general, water from wells that are most susceptible to surface contamination is likely to be high in nitrate concentration.

The nitrate content of the water from wells sampled in Marshall County ranged from 0.40 to 1,084 parts per million (Table 8). About two-thirds of the samples contained less than 40 parts per million, about a quarter contained between 40 and 100 parts per million, and a tenth contained more than 100 parts per million of nitrate.

TABLE 8.—*Nitrate content of samples of water from wells in Marshall County*

Range, parts per million	Number of samples
0– 10	16
11– 20	2
21– 30	0
31– 40	2
41– 60	3
61– 80	2
81–100	2
101–200	0
More than 200	3
Total	30

Sulfate.—Sulfate (SO_4) in ground water is derived principally from gypsum (calcium sulfate), and from the oxidation of pyrite (iron disulfide). Magnesium sulfate (Epsom Salts) and sodium sulfate (Glauber's Salts), if present in sufficient quantity, will impart a bitter taste to the water and may have laxative effect upon people who are not accustomed to drinking it.

The sulfate content of the water from wells sampled in Marshall County ranged from 8.2 to 1,689 parts per million. Two-fifths of the samples contained less than 50 parts per million, about a fourth of

TABLE 9.—*Sulfate content of samples of water from wells in Marshall County*

Range, parts per million	Number of samples
0–25	5
26–50	7
51–100	4
101–200	3
201–400	4
More than 400	7
Total	30

the samples contained between 50 and 200 parts per million, and about a third contained more than 200 parts per million of sulfate (Table 9).

SANITARY CONSIDERATIONS

The analyses of water given in Table 3 show only the amounts of dissolved mineral matter in the water and, except for fluoride and nitrate, are not considered generally to be indicative of the healthfulness of the water for human consumption.

An excessive amount of certain mineral matter, such as nitrate or chloride, may indicate pollution of the water. A well should not be constructed near sources of pollution, such as barnyards, privies, and cesspools, and every well should be tightly sealed to a level somewhat below the water table. The top of the well should be sealed to prevent the entrance of water, insects, and debris.

GEOLOGIC FORMATIONS AND THEIR WATER-BEARING PROPERTIES *

SUBSURFACE GEOLOGY

The subsurface geology of Marshall County is known largely through the interpretation of data on oil and gas test holes. Records are available on 21 such test holes drilled in Marshall County.

Marshall County is underlain by Pre-Cambrian rocks at known

* Although this report is a cooperative product of the State Geological Survey of Kansas and the United States Geological Survey, the classification and nomenclature of rock units used are those of the State Geological Survey of Kansas.

depths ranging from 1,225 to 2,698 feet. These rocks comprise chiefly granite and metamorphosed sediments such as schist. An oil test hole in sec. 4, T. 4 S., R. 7 E. was drilled 1,770 feet into Pre-Cambrian rocks, all of which probably comprise metamorphosed sediments (Jewett, 1949).

The St. Peter sandstone of Ordovician age is probably the oldest sedimentary formation underlying Marshall County. Any Cambrian rocks deposited in this area were removed by erosion prior to Ordovician deposition. Rocks of Silurian and Devonian age are found in the subsurface of Marshall County. Rocks of Mississippian age were deposited and have been removed by erosion in Marshall County, but are present in the area to the west. Structural movements at the end of Mississippian deposition resulted in the formation of the Nemaha anticline, the crest of which trends slightly southwest from southeastern Nebraska to central Oklahoma. Immediately after its formation the Nemaha anticline consisted of a Pre-Cambrian core with the sedimentary rocks arched over, standing several hundred feet higher than rocks of the same age to the east and west that had not been uplifted. The sedimentary rocks over the anticline were eroded, and by the beginning of Pennsylvanian deposition the Pre-Cambrian rocks were exposed along the crest. This beveling of upturned sedimentary beds resulted in the Pennsylvanian sediments being deposited on successively younger rocks east or west from the anticline. Marshall County is on the west flank of the anticline, the crest of which passes through western Nemaha County. About 1,000 feet of Pennsylvanian rocks underlie all of Marshall County, and the upper 10 to 50 feet of the rocks is exposed at a few places along the eastern edge of the county (Table 10).

Pennsylvanian System (Virgilian Series)

WABAUNSEE GROUP

The Brownville limestone, which is the youngest formation of the Pennsylvanian System, is the only recognizable Pennsylvanian unit cropping out in Marshall County. The Brownville limestone crops out along deep ravines in sec. 36, T. 5 S., R. 10 E. and in sec. 13, T. 3 S., R. 10 E. (Pl. 1). This formation consists of about 2 feet of impure limestone with an abundance of brachiopod, crinoid, and echinoid remains. At the locality in T. 3 S., R. 10 E. the Brownville limestone is underlain by about 12 feet of varicolored, calcareous shale, which is the upper part of the Pony Creek shale.

No wells in Marshall County are known to obtain water from Pennsylvanian rocks.

Permian System (Wolfcampian Series)

ADMIRE GROUP

The Admire group comprises the lower 125 to 150 feet of the Permian System and consists chiefly of shale and some limestone and sandstone. The formations of the Admire group in ascending order are: the Towle shale, Aspinwall limestone, Hawxby shale, Falls City limestone, West Branch shale, Five Point limestone, and Hamlin shale.

The Hamlin shale, which is divided in ascending order into the Stine shale member, the Houchen Creek limestone member, and the Oaks shale member, is the only formation of the Admire group exposed in Marshall County. The Hamlin shale crops out along Black Vermillion River and its tributaries a few miles east of Frankfort. The upper 6 to 8 feet of the Stine shale member consists of dark-green sandy and micaceous shale. The Houchen Creek limestone member in Marshall County is less than 1 foot thick and has a mamillary structure. Nearly the entire bed is made up of concentric layers of pinkish-brown algal deposits. Sandy shale of various shades of green is the predominant material in the Oaks shale member. The average thickness of the member is about 16 feet.

No wells in Marshall County are known to obtain water from rocks of the Admire group.

COUNCIL GROVE GROUP

Foraker Limestone

The Foraker limestone, the oldest formation of the Council Grove group overlies the Hamlin shale of the Admire group. The Foraker limestone is divided into three members: the Americus limestone member at the base, the Hughes Creek shale member in the middle, and the Long Creek limestone member at the top. The average total thickness of the formation in Marshall County is about 43 feet.

The Americus limestone member is composed of two beds of limestone separated by a bed of shale. The lower limestone bed is about 1 foot thick, generally impure, and dark gray in color. The overlying shale is slightly less than 3 feet thick, and is generally black and very fissile. The upper limestone is a very resistant bed, which weathers into large slabs about 1 foot thick. It is a very hard dark bluish-gray limestone containing many crinoid and brachiopod remains.

TABLE 10.—*Generalized section of the geologic formations of Marshall County, Kansas*

System	Series	Group	Formation	Members	Thickness (feet)	Physical character	Water supply
Quaternary	Pleistocene		Alluvium		0–50	Silt and clay with minor quantities of sand in the upper part. Lower part composed chiefly of sand and gravel.	Yields moderate to large quantities of water to wells.
			Sanborn formation	Peoria silt Loveland silt	0–20	Massive, wind-deposited silts.	Lies above the water table, and does not yield water to wells in Marshall County.
			Meade formation	Sappa Grand Island	0–55	Upper member composed of silt and clay, and some fine sand. Locally contains a bed of volcanic ash. Lower member composed of sand and well-rounded granitic gravel.	Lower member yields moderate to large quantities of water to wells where it is below the water table.
			Kansas till (and associated deposits)		0–325	Unconsolidated clay and boulders, with incorporated deposits of sand and gravel.	Yields small to moderate supplies of water to wells in Marshall County.
			Atchison formation		0–115	Silt and very fine sand in upper part. Lower few feet contains coarse sand and gravel.	Yields moderate quantities of water to wells.
			Pre-Kansan gravel		0–22	Medium to coarse chert and quartzite gravel.	Yields moderate to large quantities of water to wells.
	Leonardian	Sumner	Wellington formation		0–45	Varicolored silty and sandy shale.	Does not yield water to wells in Marshall County.
			Nolans limestone	Herington limestone Paddock shale Krider limestone	18–21	Composed of yellowish-gray, sandy to dolomitic limestone and gray shale.	Yields only small quantities of water to wells in Marshall County.
			Odell shale		23–27	Chiefly gray shale; contains some red and green shale in the lower part.	Does not yield water to wells in Marshall County.

Table 10.—*Generalized section of the geologic formations of Marshall County, Kansas—Continued*

System	Series	Group	Formation	Members	Thickness (feet)	Physical character	Water supply
		Chase	Winfield limestone	Cresswell limestone Grant shale Stovall limestone	25–30	Composed of a massive upper limestone member, a gray and red silty shale member, and a thin cherty lower limestone member.	Yields only small quantities of water to wells in Marshall County.
			Doyle shale	Gage shale Towanda limestone Holmesville shale	70–80	Varicolored shale and impure limestone.	Yields only small quantities of water to wells in Marshall County.
			Barneston limestone	Fort Riley limestone Oketo shale Florence shale	45–65	Composed chiefly of massive limestone members separated by a thin shale member. The Florence limestone member is very cherty.	Yields moderate to large quantities of water to wells in Marshall County.
			Matfield shale	Blue Springs shale Kinney limestone Wymore shale	55–65	Consists of two varicolored shale members separated by a thin limestone member.	Does not yield water to wells in Marshall County.
			Wreford limestone	Schroyer limestone Havensville shale Threemile limestone	30–40	Thick cherty limestone beds separated by a bed of gray-green shale.	Yields small to moderate quantities of water to wells in Marshall County.
			Speiser shale		15–20	Varicolored shale and a thin but persistent limestone bed.	Does not yield water to wells in Marshall County.
			Funston limestone		5–7	Massive gray limestone and light-colored shale.	Yields very small quantities of water to a few wells in Marshall County.
			Blue Rapids shale		14–20	Blocky gray shale; contains some green, red, and black.	Does not yield water to wells in Marshall County.
			Crouse limestone		6–8	Massive and platy limestone; contains some gray shale.	Yields very small quantities of water to a few wells in Marshall County.

TABLE 10.—*Generalized section of the geologic formations of Marshall County, Kansas—Continued*

SYSTEM	Series	Group	Formation	Members	Thickness (feet)	Physical character	Water supply
			Easly Creek shale		15–20	Varicolored shale; locally contains a massive bed of gypsum about 8 feet thick.	Does not yield water to wells in Marshall County.
Permian	Wolfcampian		Bader limestone	Middleburg limestone Hooser shale Eiss limestone	17–22	Massive limestone beds, alternating with shale.	Yields small to moderate quantities of water to wells in Marshall County.
		Council Grove	Stearns shale		17–20	Dark-gray, red, and green calcareous shale.	Does not yield water to wells in Marshall County.
			Beattie limestone	Morrill limestone Florena shale Cottonwood limestone	11–19	Soft limestone beds and dark-gray shale in the upper part. Massive limestone in the lower part.	Yields moderate to small quantities of water to wells in Marshall County.
			Eskridge shale		24–28	Varicolored shale and impure limestone.	Does not yield water to wells in Marshall County.
			Grenola limestone	Neva limestone Salem Point shale Burr limestone Legion shale Sallyards limestone	35–40	Alternating beds of massive limestone and gray to black shale.	Yields moderate quantities of water to wells in Marshall County.
			Roca shale		20–28	Varicolored shale and thin impure limestone.	Does not yield water to wells in Marshall County.
			Red Eagle limestone	Howe limestone Bennett shale Glenrock limestone	9–16	Massive and cavernous limestone and gray to black shale.	Yields small quantities of water to wells in Marshall County.

TABLE 10.—*Generalized section of the geologic formations of Marshall County, Kansas—Concluded*

SYSTEM	Series	Group	Formation	Members	Thickness (feet)	Physical character	Water supply
			Johnson shale		15–20	Consists chiefly of gray shale; contains several impure limestone beds.	Does not yield water to wells in Marshall Couuty.
			Foraker limestone	Long Creek limestone Hughes Creek shale Americus limestone	40–50	Impure limestone and limy shale in the upper part; hard, massive limestone in the lower part.	Yields small quantities of water to wells in Marshall County.
		Admire	Hamlin shale	Oaks shale Houchen Creek limestone Stine shale	125–150	Alternating beds of limestone and shale, not well exposed in Marshall County.	Yields littie or no water to wells in Marshall County.
			Five Point limestone				
			West Branch shale				
			Falls City limestone				
			Hawxby shale				
			Aspinwall limestone				
			Towle shale				
Pennsylvanian	Virgilian	Wabaunsee	Brownville limestone		2	Soft, impure limestone.	Does not yield water to wells in Marshall County.
			Pony Creek shale		12	Varicolored shale in exposed part.	Does not yield water to wells in Marshall County.

The Hughes Creek shale member consists of 25 to 30 feet of gray to yellowish gray calcareous shale and impure yellow limestone. It contains an abundance of fusulinids and brachiopods. Local sandy zones occur in the lower part of the member at some exposures.

The Long Creek limestone member is a very crystalline, cavernous or box-work limestone with a very conspicuous yellow coloring. The average thickness of the Long Creek limestone in Marshall County is about 11 feet.

The Foraker limestone yields a small quantity of water to a few wells in a small area just southeast of Frankfort.

Johnson Shale

The Johnson shale is chiefly gray shale but contains several beds of impure limestone or mudstone. Few or no fossils are found in the Johnson shale. The thickness is about 17 feet.

The Johnson shale is not known to yield water to wells in Marshall County.

Red Eagle Limestone

The Red Eagle limestone has an average total thickness of about 11 feet in Marshall County, and like many other limestone formations of the Council Grove group, consists of two limestone members with an intervening shale member. These members are the Glenrock limestone member at the base, the Bennett shale member in the center, and the Howe limestone member at the top.

The Glenrock limestone member has a thickness of about 2.5 feet in Marshall County. This unit consists of a single bed of hard yellowish-brown limestone containing many slender fusulinids.

Dark-gray to black shale is the predominant material in the Bennett shale member. A persistent black very fissile shale bed occurs near the base of the member. This bed is overlain by a dark-gray shale containing many *Orbiculoidea*. The average thickness of the Bennett shale member in Marshall County is about 8 feet.

The Howe limestone member in Marshall County consists of a single bed of impure limestone about 1 foot thick. In many places it has a cavernous and fractured appearance and contains very few fossils.

The Red Eagle limestone yields small quantities of water to wells in Marshall County. The Howe limestone member is the only water-bearing bed of the formation.

Roca Shale

The Roca shale consists of 20 to 28 feet of green, gray, and purple shale. Impure limestones and sandy shale are common in the lower part of the formation.

The Roca shale is not known to yield water to wells in Marshall County.

Grenola Limestone

The Grenola limestone is the oldest bench-forming formation in Marshall County. The Grenola limestone, as now defined by the State Geological Survey of Kansas, consists of the following members in ascending order: Sallyards limestone member, Legion shale member, Burr limestone member, Salem Point shale member, and Neva limestone member. The average total thickness of the Grenola limestone in Marshall County is 35 to 40 feet. The principal outcrop area of the Grenola limestone is along the south side of Black Vermillion River west of Frankfort.

The Sallyards limestone member is not well exposed in Marshall County. In the few exposures found this member consists of about 2 feet of massive limestone that weathers shaly and contains a variety of fossils.

The Legion shale member consists of 3 to 4 feet of fossiliferous shale. The top of this unit is black grading downward into tan and dark gray.

The Burr limestone member is composed of two distinct limestone beds and a bed of shale between. The lower limestone is about 4 feet thick, massive, and is somewhat impure at the top and bottom. Brachiopods, crinoids, and other fossils are common in this bed. This lower limestone bed is overlain by 2 feet of black to dark-gray fissile shale. The upper part of the Burr limestone member consists of about 3 feet of hard light-gray limestone with several very thin shale partings. The top of the member becomes cavernous when weathered. The total thickness of the Burr limestone member is about 9 feet. It forms a conspicuous bench on hillsides.

The Salem Point shale member is about 8 feet thick and consists chiefly of tan to light-brown shale. Thin irregular limestone beds are generally present in the bottom few feet.

The Neva limestone member consists of a massive limestone bed at the base, alternating shale beds and thin limestone beds in the middle part, and a thick massive limestone at the top. The total thickness of the member in Marshall County is about 13 feet. The features of the Neva limestone member are cellular or cavernous weathering of the limestone beds, breccias of limestone in a lighter colored limestone matrix, and the formation of a conspicuous bench along the outcrop. Ostracods and fusulinids are abundant in the lower limestone beds, and a variety of brachiopods are present in all parts of the member. The upper limestone bed, which is about 7 feet thick, has many irregular shale partings.

The Grenola limestone is an important aquifer in central and south-central Marshall County where it yields moderate quantities of water to many domestic and stock wells. The Neva limestone member is the principal water-bearing member of the formation. The Burr limestone member yields small quantities of water to some shallow dug wells.

Eskridge Shale

Green and gray shale is the predominant material in the upper part of the Eskridge shale. The lower half of the formation is composed chiefly of red and maroon shale. Impure limestone beds less than 1 foot thick occur in all parts of the formation but are most numerous in the upper half. Limestone beds in the upper part of the formation are commonly fossiliferous. The thickness of the Eskridge shale ranges from 24 to 28 feet.

No wells in Marshall County are known to obtain water from the Eskridge shale.

Beattie Limestone

The Beattie limestone is exposed in the valley walls of Big Blue River from the south line of Marshall County north to Blue Rapids, in the area south and west of Frankfort, and along Vermillion Creek as far north as Beattie for which the formation was named. The members of the Beattie limestone are, in ascending order: the Cottonwood limestone member, the Florena shale member, and the Morrill limestone member.

The lower 1 to 2 feet of the Cottonwood limestone member consists of soft, fossiliferous, light-gray limestone that weathers rather slabby. The remaining 5 to 6 feet of the member is very massive, hard, gray limestone containing an abundance of fusulinids and scattered chert nodules. The Cottonwood limestone member forms a very conspicuous bench that is usually accentuated by a heavy growth of vegetation. This member has been extensively quarried in Marshall County for use as building stone and road material.

The Florena shale member consists of 2 to 3.5 feet of tan to dark-gray, calcareous shale. Fossils are very numerous in the Florena shale; locally thin shell beds within the member are composed almost entirely of *Chonetes, Dictyclostus,* and *Composita.*

The Morrill limestone member ranges in thickness from 3.5 to 7.5 feet. The member is made up chiefly of massive, soft, light-gray limestone. Fossils of brachiopods, echinoids, and crinoids are common in the lower part. The Morrill limestone member is less resistant to weathering than the Cottonwood limestone member, and is not generally well exposed in Marshall County.

The Beattie limestone is the most important Permian aquifer in central and south-central Marshall County. The Cottonwood limestone member, which yields moderate quantities of water to wells, is the principal water-bearing part of the formation. The water in the Cottonwood limestone member occurs in joint cracks and in solution channels formed by ground water dissolving part of the limestone material. In many wells the Morrill limestone member is probably a supplemental aquifer to the Cottonwood limestone member.

Stearns Shale

Dark-gray, calcareous shale is the predominant material of the Stearns shale, but red and green shale is present in the upper part. Thin, impure limestone beds occurring near the middle of the formation contain brachiopods and pelecypods. The thickness of the formation in Marshall County ranges from 17 to 20 feet.

No wells in Marshall County are known to obtain water from the Stearns shale.

Bader Limestone

The Bader limestone is divided into three members, which in ascending order are: the Eiss limestone member, the Hooser shale member, and the Middleburg limestone member. The thickness of the formation in Marshall County ranges from 17 to 22 feet.

At the base of the Eiss limestone member is a massive, argillaceous, light-gray limestone about 2.5 feet thick. This bed is nonresistant to weathering and is well exposed in few places. The middle part of the member is composed of fossiliferous gray shale generally about 2.5 feet thick. The upper part of the Eiss limestone member is composed of a very massive limestone about 4 feet thick. In weathered outcrops this upper bed is commonly pitted and has solution channels. A very conspicuous bench is formed by the upper part of the Eiss limestone member.

The Hooser shale member consists of 8 to 11 feet of sparsely fossiliferous shale. A large part of the shale is green and gray, but bands of pink and maroon are common near the center of the member.

At the base of the Middleburg limestone member is a limestone bed about 2 feet thick, dark gray at the top and yellowish brown below, and containing many fossils. About 1 foot of dark-gray calcareous shale separates the lower limestone bed and an upper limestone bed just about a foot thick. The upper bed of the Middleburg limestone member is fossiliferous and weathers pitted. The Middleburg limestone member does not form a conspicuous bench.

The Bader limestone furnishes small to moderate quantities of water to wells in Marshall County, but wells are generally extended to the Beattie limestone which lies about 30 feet deeper and is a more dependable aquifer.

Easly Creek Shale

A massive bed of gypsum 8 to 9 feet thick occurs at the base of the Easly Creek shale in the area around Blue Rapids. This gypsum bed is readily leached away when exposed to weathering and is not generally present in natural outcrops, but it is exposed in mine workings and has been penetrated in many wells in the area. The gypsum is overlain by about 10 feet of gray, green, and red shale.

No wells are known to obtain water from the Easly Creek shale in Marshall County.

Crouse Limestone

The Crouse limestone, typically a platy, thin-bedded, argillaceous, gray limestone, has a bed of gray calcareous shale about 2.5 feet thick near the middle of the formation. The upper limestone bed is more massive and crystalline than the lower bed. Fossil fragments are common, but well-preserved specimens are rare. The total thickness of the formation is about 7.5 feet.

The Crouse limestone may furnish small quantities of water to a few wells in Marshall County.

Blue Rapids Shale

The Blue Rapids shale consists principally of blocky gray shale, but contains a few feet of black shale at the top and some green and red shale in the lower part. Thin impure limestone beds are present in some exposures.

The Blue Rapids shale does not yield water to wells in Marshall County.

4—1648

Funston Limestone

The Funston limestone is not generally well exposed in Marshall County, and the thickness and lithology of the formation vary considerably from exposure to exposure. In general, the Funston limestone consists of two limestone beds with a bed of shale between. The lower limestone is generally massive, argillaceous and weathers pitted. This limestone bed is usually slightly less than 3 feet thick. The lower limestone bed is overlain by about 2 feet of gray, gray-green, and red shale. The upper limestone bed is about a foot thick, somewhat argillaceous, and massive to platy.

The Funston limestone supplies only small quantities of water to wells in Marshall County.

Speiser Shale

The lower part of the Speiser shale in Marshall County consists of about 15 feet of varicolored shale. Only the upper 2 or 3 feet of this part of the Speiser shale is calcareous. The second unit of the formation is a very persistent limestone bed about a foot thick. This limestone is hard, gray, and massive and contains fragments of fossils. The upper unit of the Speiser shale consists of about 3 feet of dark-gray to black calcareous fossiliferous shale.

No wells in Marshall County are known to obtain water from the Speiser shale.

CHASE GROUP

Wreford Limestone

The Wreford limestone, which includes two limestone members and a shale member, has an average thickness of about 35 feet in Marshall County. The Wreford limestone, is the oldest exposed formation in Marshall County which contains an abundance of chert.

The Three Mile limestone member, which overlies the Speiser shale, consists of about 7 feet of hard gray limestone in massive beds about a foot thick. The chert occurs in bands or as scattered nodules (Pl. 4). The limestone beds near the middle of the member contain less chert than the upper and lower beds. Brachiopods are the most common fossils in the Three Mile limestone member.

The Havensville shale member ranges from 14 to 20 feet in thickness in Marshall County. The member is typically a gray to gray-green blocky calcareous shale, but locally it is composed almost entirely of soft thin- bedded gray limestone. Small quartz geodes are generally imbedded in the upper few inches of the member.

The thickness of the Schroyer limestone member ranges from about 10 to 13 feet. The lower 4 or 5 feet of the member is hard, gray, fossiliferous limestone containing only a few thin bands of chert. About 2 feet of buff to brown fossiliferous shale generally separates the relatively noncherty lower bed of limestone from the more cherty upper beds (Pl. 4). The upper 4 to 6 feet of the member consists of beds of tan to buff, hard, fossiliferous limestone containing an abundance of chert.

The Wreford limestone furnishes small to moderate quantities of water to wells in Marshall County. The Three Mile and the Schroyer limestone members are probably of about equal importance as aquifers. The Havensville shale member does not furnish water to wells.

Matfield Shale

The Matfield shale is divided into three members, which are in ascending order: the Wymore shale member, Kinney limestone member, and the Blue Springs shale member. The average thickness of the formation in Marshall County is about 57 feet.

The Wymore shale member consists of 20 to 23 feet of gray, gray-green, and red-brown shale. Thin discontinuous limestone beds are locally present in the lower part.

The Kinney limestone member consists of 2 to 5 feet of massive to platy gray and yellow limestone. The lower part of this member contains many brachiopods and mollusks.

The Blue Springs shale member consists of about 34 feet of silty varicolored shale. The lower part of the member is generally noncalcareous and contains many gypsum nodules and seams.

The Matfield shale is not known to yield water to wells in Marshall County.

Barneston Limestone

The Barneston limestone, the thickest limestone formation in Marshall County, contains the most massive beds of any formation in the county. The average total thickness of the formation is about 50 feet. It crops out in the bluffs along Big and Little Blue Rivers throughout their courses in the county. The members of the Barneston limestone, in ascending order are: the Florence limestone member, the Oketo shale member, and the Fort Riley limestone member.

The Florence limestone member is easily recognized because of the abundance of chert or flint imbedded in the limestone. In fact, this member is often referred to as the Florence flint. The member is actually a series of beds of limestone and beds of chert (Pl. 5).

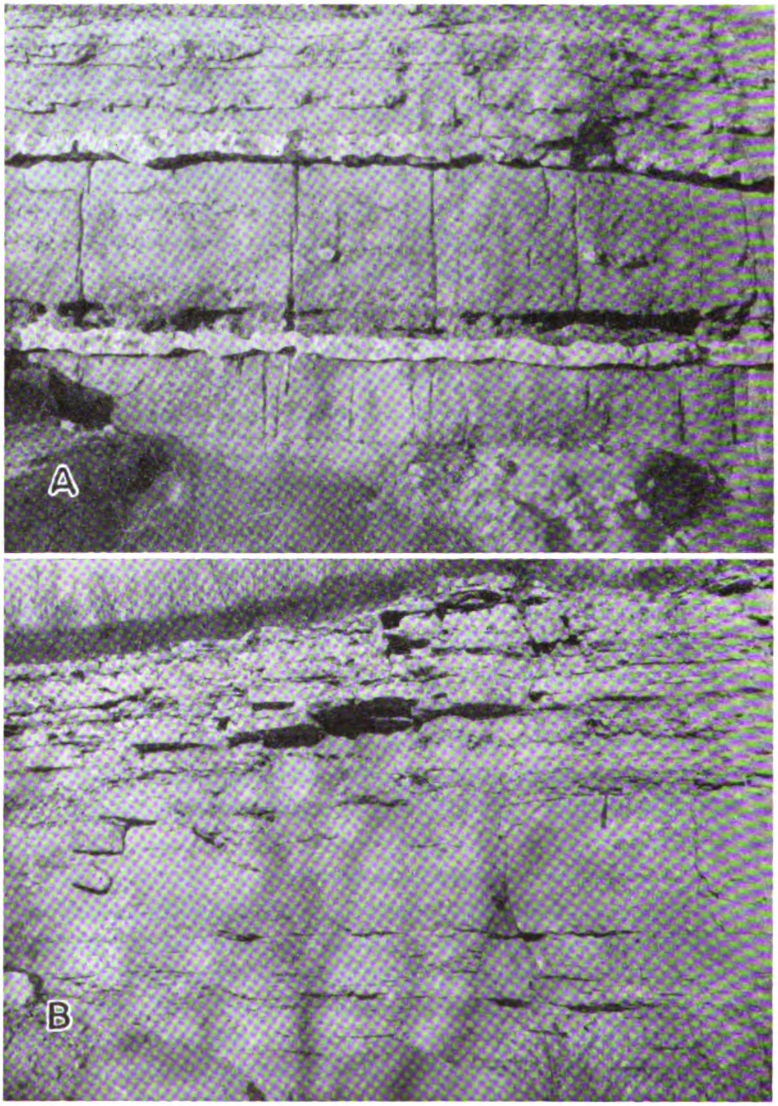

PLATE 4.—Exposures of the Wreford limestone. **A,** Three Mile limestone member exposed in a road cut along the west side of sec. 22, T. 4 S., R. 7 E.; **B,** Schroyer limestone member exposed in quarry face in the NE¼ NE¼ sec. 16, T. 4 S., R. 7 E.

The noncherty beds are generally only slightly thicker than the cherty beds. Many fossils are present in all parts of the Florence limestone member. A rather persistent shale break about 2 feet thick is present in the upper few feet of the member. The Florence is not resistant to weathering and is dissected into steep-sided, rounded hills. The thickness of the member ranges from 22 to 28 feet.

The Oketo shale member, which was named from exposures at Oketo in Marshall County, ranges in thickness from a few inches to more than 6 feet. At most exposures in the county the member consists of hard, gray, calcareous shale containing many brachiopods, crinoids, and echinoid remains.

A hard, gray, very massive bed of limestone about 6 feet thick occurs at or near the base of the Fort Riley limestone member in Marshall County. This is the limestone bed that forms the "rim rock" or natural rock wall type of outcrop seen near the top of many hills bordering the valleys of Big Blue and Little Blue Rivers (Pl. 6A). The massive "rim rock" bed is sometimes underlain by as much as 5 feet of impure, thin-bedded limestone and thin beds of shale. The middle part of the member is composed of alternating thin beds of limestone and shale, the shale beds generally being somewhat thicker than the limestone beds. Beds near the top are generally massive, but are soft and much less resistant than the massive beds in the lower part of the member. Weathered exposures of the upper part of the Fort Riley may have a pitted and cavernous appearance. Massive beds of this limestone have been extensively quarried for use as building stone and road material in Marshall County. The average thickness of the member is about 25 feet.

The Barneston limestone is the most important bedrock aquifer in Marshall County; where it underlies long dip slopes, as it does in Western Marshall County, it furnishes large quantities of water to wells. Both the Fort Riley and Florence limestone members are good aquifers. The Oketo shale does not furnish important quantities of water.

Doyle Shale

The Doyle shale is composed of two shale members and a limestone member. The members of the Doyle shale, in ascending order are, the Holmesville shale member, the Towanda limestone member, and the Gage shale member. The Doyle shale is the thickest bedrock formation exposed in Marshall County. It is as much as 80 feet thick in western Marshall County.

The Holmesville shale member consists of about 20 feet of green,

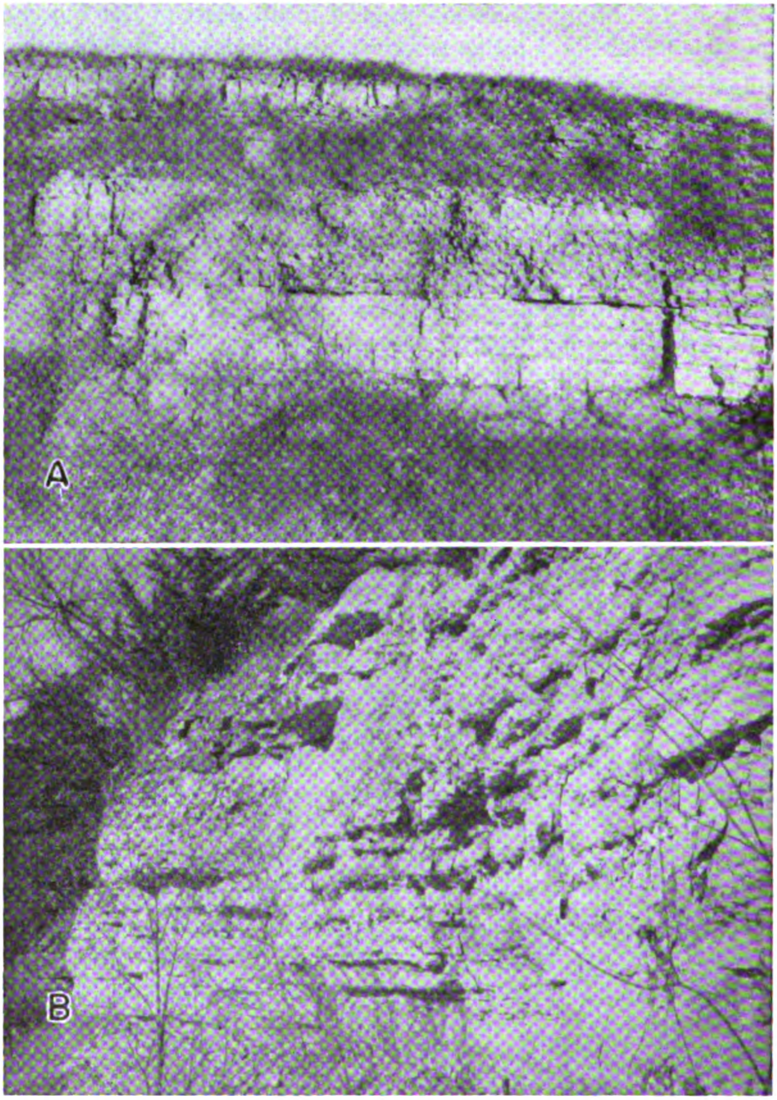

PLATE 5.—Exposures of the Florence limestone member of the Barneston limestone. **A**, Exposure in road cut near the Cen. sec. 21, T. 3 S., R. 7 E. **B**, Lower part of the member showing massive nonflinty bed at base; SE¼ NE¼ sec. 29, T. 4 S., R. 6 E.

gray, and maroon calcareous shale. Lenticular limestone beds about a foot thick are present in the lower few feet of the member.

The thickness of the Towanda limestone member ranges from 8 to 13 feet in Marshall County. Beds of gray to yellow platy-weathering limestone comprise the bulk of the member. The limestone beds in the upper part of the member may be limonite stained and contain many calcite veinlets. Thin and irregular shale breaks are common in the Towanda limestone member.

The Gage shale member is not well exposed in Marshall County, and the thickness of the member can only be estimated. The total thickness is probably 45 to 50 feet. The lower 35 to 40 feet of the member is composed principally of varicolored unfossiliferous shale. A thin but persistent limestone bed about 10 feet from the top of the member separates the lower varicolored shale from the upper unit of the member which consists of tan, gray, and black fossiliferous shale.

The Towanda limestone member of the Doyle shale yields small quantities of water to wells in Marshall County. The Holmesville and Gage shale members do not yield water in Marshall County.

Winfield Limestone

The members of the Winfield limestone are, in ascending order: the Stovall limestone member, the Grant shale member, and the Cresswell limestone member.

The Stovall limestone member consists of a single bed of hard, gray to tan, cherty limestone. Fossils are not abundant in this member, but echinoid spines and many crinoids are present. The Stovall limestone member is generally about a foot thick, and the presence of an abundance of chert in the thin limestone member makes the unit easily identified.

The Grant shale member consists of about 16 feet of calcareous, silty shale containing many quartz geodes in the upper part. The upper and lower parts of the member are tan to gray in color, and the middle part is gray to red-brown.

The basal part of the Cresswell limestone member consists of 2.5 to 4 feet of rather soft, massive limestone containing many quartz geodes and brachiopod fossils. This massive bed weathers pitted, generally becoming brown to tan splotched with pink. The beds of the Cresswell limestone member overlying this massive bed are not well exposed in Marshall County, but they seem to consist largely of shale and a few impure limestone beds. The total thickness of the Cresswell limestone member is about 15 feet.

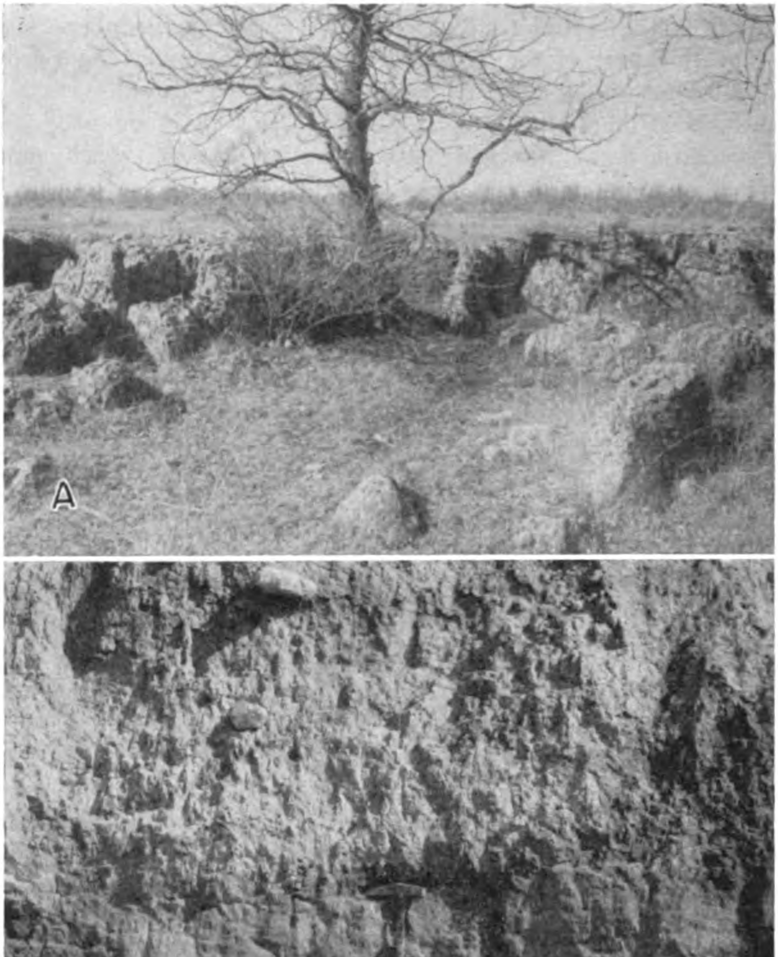

Plate 6.—A, Natural outcrop of Fort Riley limestone member of the Barneston limestone near the Cen. E. line sec. 34, T. 5 S., R. 6 E., showing "rim rock" type of outcrop. **B,** Glacial till overlying the Atchison formation in the NW¼ sec. 4, T. 4 S., R. 9 E.; the head of the hammer is resting on the contact.

The Winfield limestone yields small quantities of water to a few wells in western Marshall County. The Cresswell limestone member is the only part of the formation that yields appreciable quantities of water.

Odell Shale

The Odell shale has a thickness of about 25 feet in Marshall County. The lower 10 feet of the formation consists of alternating bands of red and green shale. The remaining upper 15 feet of the formation is mostly gray shale. Thin, nonpersistent limestone lenses are found in the lower part of the formation at most exposures. Fossils are rare or absent.

The Odell shale is not known to yield water to wells in Marshall County.

Nolans Limestone

The Nolans limestone includes, in ascending order: the Krider limestone member, the Paddock shale member, and the Herington limestone member.

The Krider limestone member, in most exposures, is a sandy-appearing yellowish limestone and is generally rather nodular. In a few exposures the member consists of two thin beds of hard gray limestone separated by a thin bed of shale. The average thickness of the Krider limestone member is about 2 feet.

The Paddock shale member consists of 10 to 13 feet of gray shale and contains several thin limy beds in the upper part. Fossil pelecypods are numerous in the upper part of the member.

The Herington limestone member consists chiefly of yellow, sandy-appearing, resistant limestone containing casts of pelecypods. The massive limestone beds are somewhat dolomitic and contain many quartz geodes. Shaly zones are found throughout the member but are most numerous in the middle part. The average thickness of the Herington limestone member is probably about 6 feet.

The Nolans limestone yields only small quantities of water to wells in Marshall County.

SUMNER GROUP

Wellington Formation

A few inches to as much as 45 feet of varicolored silty and sandy shale overlies the Herington limestone member in extreme west-central Marshall County. This shale section represents the basal part of the Wellington formation and is probably the youngest consolidated bedrock in the county.

The Wellington formation does not yield water to wells in Marshall County.

Quaternary System

PLEISTOCENE SERIES

Deposits of Quaternary age differ greatly from the underlying Permian rocks. The Quaternary deposits are unconsolidated and are of nonmarine origin, whereas the Permian deposits are consolidated and are mostly of marine origin. The time interval between the end of Permian deposition and the beginning of Quaternary deposition includes all the Triassic, Jurassic, Cretaceous, and Tertiary Periods. Erosion was the predominant geologic process active in Marshall County during the Triassic and Jurassic Periods. Sediments were deposited in Marshall County during Early Cretaceous time but were removed by erosion during the Tertiary Period.

All Quaternary deposits in Marshall County except alluvium were deposited as a direct result of continental glaciation. The first continental ice sheet of the Pleistocene Epoch (Nebraskan) did not reach Marshall County, but the drainage pattern of the area may have been changed considerably by sediment-laden melt-water streams flowing across the area. The second continental ice sheet (Kansan) probably covered all of Marshall County, depositing as much as several hundred feet of glacial till and associated deposits in some parts of the area. The third and fourth ice sheets (Illinoian and Wisconsinan) did not reach Kansas, but eolian deposits of loess were laid down in Marshall County during that time.

Pre-Kansan Gravel

Deposits of gravel composed largely of chert with a small amount of quartzite and quartz rest directly on bedrock of Paleozoic age and are overlain by the Atchison formation or by glacial till at many places in southeastern Marshall County. These gravel deposits, considered to be Pleistocene in age because of the quartzite they contain, can be distinguished from younger Pleistocene deposits by the larger percentage of chert they contain. These gravel deposits, which are classified as pre-Kansan in this report, occupy the bottoms of deep channels that have been eroded into the bedrock and are now completely filled with Kansan deposits. A prominent channel or bedrock "sag" (Pl. 2) containing scattered remnants of pre-Kansan gravel crosses the present valley of Black Vermillion River a few miles east of Frankfort and probably represents a post-Nebraskan pre-Kansan valley. The greatest known thickness of pre-Kansan gravel in Marshall County is 22 feet penetrated in test hole 4-9-11bb.

The pre-Kansan gravel deposits are highly permeable, and where they are present in sufficient thickness they yield moderate to large quantities of water to wells. The municipal wells of Frankfort obtain water from pre-Kansan gravel deposits about 8 feet thick.

Atchison Formation

The Atchison formation, which was deposited as pro-Kansan outwash, overlies the bedrock or pre-Kansan gravels and underlies Kansas till in much of southeastern Marshall County (Pl. 6B). Locally in Marshall County the basal part of the Atchison formation is composed of 1 to about 15 feet of coarse sand and gravel containing about 50 percent locally derived limestone and chert. The upper part of the Atchison formation consists of as much as 100 feet of silt and very fine sand. In many exposures the upper part of the Atchison formation is finely laminated and shows cross-bedding. The formation is well exposed in many places north and east of Frankfort and along the county line east of Lillis.

The lower part of the Atchison formation furnishes moderate quantities of water to wells in east-central Marshall County. The upper part of the formation is often referred to as quicksand by water well drillers because of its tendency to cave while being drilled.

Kansas Till

Till is the predominant material of the glacial deposits in Marshall County. Glacially derived till consists of a silty clay matrix containing boulders of quartzite, granite, limestone, and metamorphic rocks as well as gravel and blocks of uncemented sand (Pl. 7). The till is in three intergradational zones caused by different degrees of weathering. The upper zone, when it has not been subjected to severe erosion and is not mantled by younger deposits, averages about 12 feet in thickness. In this zone the till has been oxidized and the calcareous material has been removed by leaching. The till in the upper zone is tan or gray in color and the incorporated granite boulders are often so badly decomposed that they can be crumbled by hand. The second zone is slightly darker than the upper zone and the material is calcareous. Here the till is oxidized, but is not leached of its calcium carbonate. Many exposures of this zone of the till show a joint system in which there is a strongly oxidized border along the joints and an accumulation of calcium carbonate along the joint planes. The base of the oxidized unleached zone generally lies at a depth of 40 to 60 feet. The lower till zone contains fresh or unaltered till. The unaltered till is generally dark blue to almost black and is very calcareous.

Irregular bodies or lenses of intratill sand and gravel are found interstratified with the till. These glacial meltwater or glacioaqueous deposits probably represent minor recessions of the Kansan ice sheet and may be found at any position within the till.

Glacial till, because of its low permeability, is a very poor aquifer. Some of the intratill deposits are good aquifers, especially deposits composed of coarse sand and gravel containing a minimum of incorporated silt and clay. A small intratill deposit that is surrounded by relatively impermeable till and is not connected to other extensive glacioaqueous deposits may fail as an aquifer because of insufficient recharge. Although the permeability and thickness of intratill deposits differ greatly, most farm and domestic wells penetrating such deposits lying below the water table have adequate yields.

Meade Formation

The Meade formation, which includes outwash deposits made by the retreating Kansan glacier, is divided into two members, the Grand Island member below and the Sappa member above.

The Grand Island member, which occurs in relatively high terrace positions along the major streams in the county, is composed predominantly of sand and well-rounded granitic gravel. Two very large gravel pits in secs. 19 and 30, T. 4 S., R. 7 E. show a thickness of approximately 30 feet of gravel of the Grand Island member overlain gradationally by silt and sand of the Sappa member.

The Sappa member of the Meade formation is composed of clay and stratified silt and fine sand. The Pearlette volcanic ash bed, which occurs within the Sappa member, is a very useful stratigraphic marker. Exposures of Pearlette ash were found along State Highway 9 in sec. 11, T. 4 S., R. 9 E. and near the cen. S. line sec. 35, T. 2 S., R. 7 E.

Because the boundaries of the Meade formation cannot always be recognized, and owing to the patchy occurrence of the formation in most parts of the county, it is mapped with other terrace deposits as undifferentiated terrace deposits, and the boundaries shown are approximate. The Grand Island member is highly permeable and is capable of yielding large quantities of water; however, due to its relatively high topographic position in Marshall County, only the

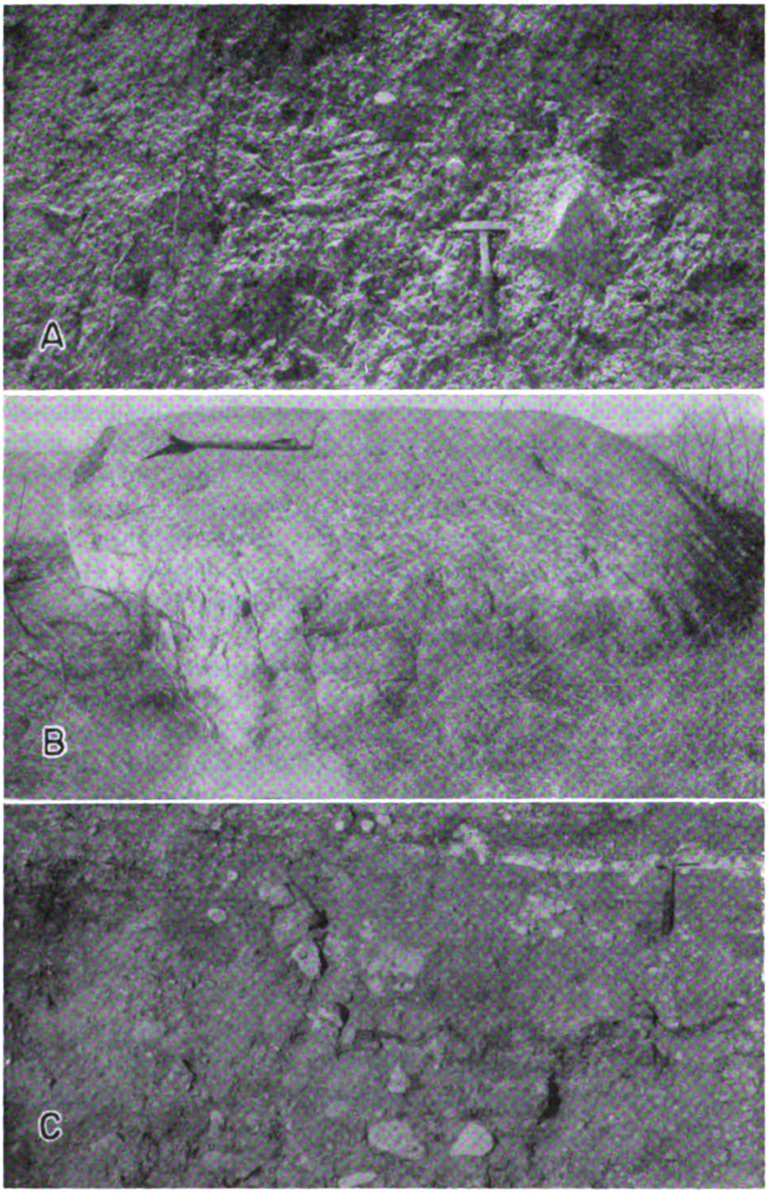

PLATE 7.—Exposures of glacial deposits. **A,** Till in road cut near the Cen. E. line sec. 15, T. 1 S., R. 10 E. **B,** Large quartzite erratic in the SE¼ SE¼ sec. 2, T. 4 S., R. 10 E. **C,** Glacial sand and gravel in a commercial pit near the SE cor. sec. 16, T. 3 S., R. 7 E.

lower part of the member is saturated in most places. Terrace deposits of the Grand Island member along the south side of Little Blue River and along Big Blue River south of Blue Rapids furnish moderate to large quantities of water to wells. The municipal wells of Blue Rapids and Irving obtain water from gravel of the Grand Island member. The Sappa member does not yield water to wells in Marshall County.

Sanborn Formation

The Sanborn formation in Marshall County consists of eolian silt or loess derived largely from the flood plains of streams carrying outwash from late Pleistocene glaciers north of this area.

The basal member of the Sanborn formation, the Crete sand and gravel member, was not recognized in Marshall County.

The Loveland silt member of the Sanborn formation occurs as a loess mantle on many of the upland divide areas and high terrace surfaces of Marshall County. The thickness of Loveland loess penetrated in some test holes could not be determined accurately because of the difficulty in recognizing the contact between the base of the Loveland loess and the top of the Sappa member. The Loveland member is typically a massive reddish-tan silt with a well-developed soil zone (Sangamon) at the top.

The Peoria silt member of the Sanborn formation also occurs as a mantle on the upland divide areas and high terrace surfaces and is much more widespread than the Loveland silt member. The Peoria silt member is a massive tan silt and contains the Brady soil at the top. The thickness of the Peorian in Marshall County probably does not exceed 10 feet anywhere.

The upper member of the Sanborn formation, the Bignell silt member, was not recognized in Marshall County.

The Sanborn formation lies above the water table in Marshall County and does not yield water to wells.

Alluvium

Alluvial deposits of sand, gravel, silt, and clay attaining thicknesses as great as 50 feet underlie the flat valley bottoms of the area. The alluvium of the streams in Marshall County is late Pleistocene (Recent) in age.

Sand and gravel beds in the alluvium are highly permeable, and due to their low topographic position are generally below the water table and yield large quantities of water to wells.

Quality of Water in Relation to Water-Bearing Formations

The quality of water from typical wells deriving water from the principal aquifers in Marshall County is indicated by the analyses in Table 3 and is shown graphically in Figures 6 and 7. The quality of water in the principal aquifers of the county is discussed below.

Red Eagle limestone.—Only one sample of water from the Red Eagle limestone was analyzed (well 5-9-22cc); it contained 1,908 parts per million of dissolved solids and had a hardness of 1,349 parts per million of which 1,011 parts was noncarbonate hardness. The chloride and fluoride contents of the water were low, and the iron content was 0.14 part per million. The sulfate and nitrate contents were high, indicating the possibility of contamination.

Grenola limestone.—Samples of water from wells 3-9-9bd and 5-9-24ba, which obtain water from the Grenola limestone, differed considerably in quality. Water from well 3-9-9bd contained 1,080 parts per million dissolved solids and had a sulfate content of 551 parts per million. The total hardness of this sample was 741 parts per million. Water from well 5-9-24ba contained 387 parts per million dissolved solids and had a sulfate content of 23 parts per million. The total hardness of this sample was 328 parts per million. The chloride, fluoride, and nitrate contents of water from both wells were low.

Beattie limestone.—Samples of water from two wells obtaining water from the Beattie limestone (wells 3-8-36cd and 2-9-32dd) differed considerably in chemical quality. The water sample from well 2-9-32dd contained 3,113 parts per million dissolved solids, 1,689 parts per million of sulfate, 264 parts per million of chloride, and had a total hardness of 1,832 parts per million. The water sample from well 3-8-36cd contained 672 parts per million dissolved solids, 205 parts per million sulfate, and 12 parts per million chloride and had a total hardness of 353 parts per million. The fluoride and nitrate contents of water from both wells were low. Well 2-9-32dd may have been contaminated by water from gypsum-bearing beds.

Wreford limestone.—Samples of water from wells 2-8-35dc and 4-8-3cd, which obtain water from the Wreford limestone, contained respectively 1,037 and 2,137 parts per million dissolved solids and 467 and 1,400 parts per million sulfate; they have total hardnesses of 730 and 1,545 parts per million. The chloride, fluoride, and nitrate contents of water from both wells were low.

Barneston limestone.—Samples of water from four wells obtaining water from the Barneston limestone differed considerably in chemical quality. The dissolved solids content of the four samples ranged from 409 to 2,495 parts per million, the sulfate content ranged from 31 to 1,538 parts per million, and the total hardness ranged from

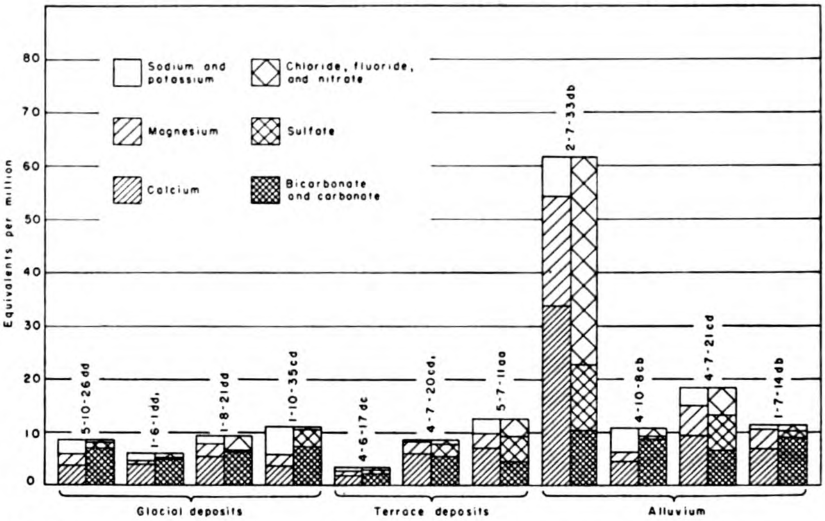

Fig. 6.—Typical analyses of water from Quaternary aquifers in Marshall County.

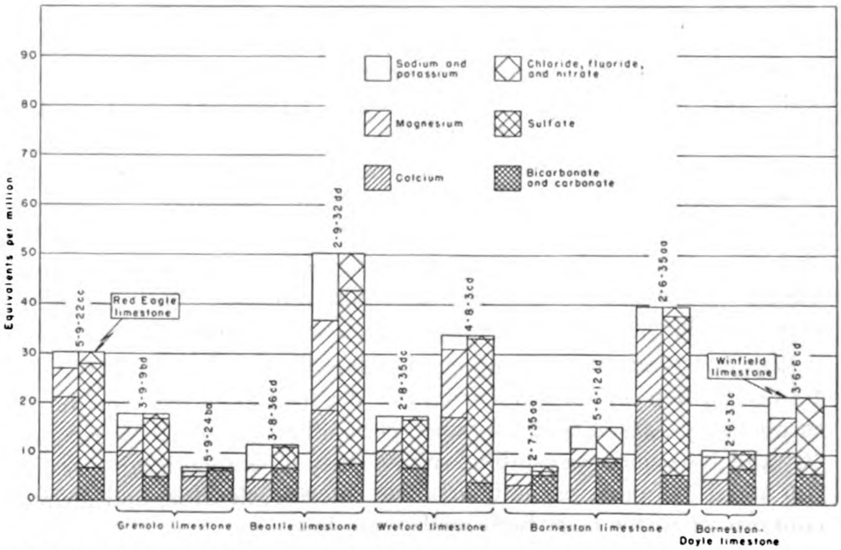

Fig. 7.—Typical analyses of water from Permian aquifers in Marshall County.

290 to 1,757 parts per million. One sample (5-6-12dd) contained excessive nitrate (328 parts per million).

Winfield limestone.—Only one sample of water from the Winfield limestone was analyzed (well 3-6-6cd); it contained 1,388 parts per million of dissolved solids and had a hardness of 876 parts per million. This sample contained 500 parts per million nitrate, and the sulfate and chloride contents were relatively high.

Glacial deposits.—Nine samples of water from glacial deposits were analyzed. The samples ranged in total dissolved solids from 342 to 983 parts per million, and the hardness ranged from 240 to 556 parts per million. The sulfate content ranged from 8.2 to 387 parts per million, chloride from 11 to 60 parts per million, and nitrate from 0.40 to 97 parts per million. The fluoride content of all samples was low.

Terrace deposits.—Samples of water from four wells deriving water from terrace deposits ranged from 193 to 1,074 parts per million dissolved solids, and from 136 to 738 parts per million, total hardness. The sulfate content of the four samples ranged from 22 to 321 parts per million, chloride from 7 to 137 parts per million, and nitrate from 19 to 97 parts per million. The fluoride content of all samples was low.

Alluvium.—Three samples of water from wells deriving water from alluvium were quite similar in chemical quality. The concentration of dissolved solids in these three samples ranged from 469 to 648 parts per million, and the total hardness ranged from 312 to 531 parts per million. The sulfate content of the samples ranged from 38 to 60 parts per million. The chloride, nitrate, and fluoride contents of these samples were low.

A sample of water from a fourth well (2-7-33db) deriving water from alluvium contained 3,887 parts per million dissolved solids and had a total hardness of 2,709 parts per million. The sulfate content of this sample was 599 parts per million, the chloride content 770 parts per million, and the nitrate content 1,084 parts per million. This well is located downgrade from a barnyard and seemingly is being contaminated by surface seepage.

GROUND-WATER REGIONS OF MARSHALL COUNTY

The ground-water conditions in Marshall County are discussed below by regions that are established on the basis of the chief aquifer or group of aquifers within the area. The boundaries of the regions as shown on Plate 3 are generalized, and the following discussion does not apply to each individual well within a given region. Some wells which were constructed to supply a rather limited need do not penetrate deeply enough to obtain water from the most productive aquifer.

Within the regions designated 1, glacial till and associated deposits are the chief aquifers. The depth to water and the quantity and quality of water available are extremely variable in these regions. An adequate supply of water suitable for domestic and stock needs can be developed nearly everywhere within these areas. Many wells extend a few feet into the underlying bedrock but derive their water from glacial gravel deposits overlying the bedrock.

Moderate to large supplies of water are available from sand and gravel in the alluvium and terrace deposits of Marshall County. Such deposits locally attain thicknesses as great as 75 feet and contain considerable thicknesses of saturated coarse gravel. The regions in which alluvium and terrace deposits are the chief aquifers are designated 2 on Plate 3.

Permian rocks younger than the Barneston limestone are the chief aquifers in the regions designated 3 on Plate 3. Most wells within these regions supply only small quantities of water. In some parts of these regions larger supplies of water could be obtained by constructing wells deep enough to penetrate the Barneston limestone, but the water would be more highly mineralized than in areas in which the Barneston limestone is not so deeply buried.

The Barneston limestone is the chief aquifer in the regions designated 4 on Plate 3. The Barneston limestone yields moderate quantities of water of generally good quality to wells in these regions. Both the Fort Riley limestone member and the Florence limestone member are good aquifers, but in general, the Florence limestone member yields the most water. In areas where the Barneston limestone is deeply dissected, as near the west valley wall of Big Blue River, the formation may not yield water. If the formation is deeply buried, the water may be too highly mineralized for domestic use.

Within the regions designated 5 on Plate 3, wells obtain water from Permian rocks older than the Barneston limestone. The Wreford, Bader, Beattie, and Grenola limestones are the chief aquifers in these regions, and all furnish small to moderate quantities of water. In some parts of these regions where dissection is most pronounced, a few wells obtain water from the Red Eagle and Foraker limestones. Rocks older than the Foraker limestone yield only meager water supplies and are not generally tapped by wells in Marshall County because they are generally overlain by more productive Permian or Pleistocene aquifers.

WELL RECORDS

Descriptions of 248 wells visited in Marshall County and near-by areas are described in Table 11. All information classed as reported was obtained from the owner, tenant, or driller. 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.

TABLE 11.—*Records of wells in Marshall County, Kansas*

Well No.	Location	Owner or tenant	Type of well (1)	Depth of well (feet)	Diameter of well (in.)	Type of casing (2)	Principal water-bearing bed		Method of lift (3)	Use of water (4)	Measuring point		Depth to water level below measuring point (feet)	Date of measurement	REMARKS (Yield given in gallons a minute; drawdown in feet)
							Character of material	Geologic source			Description	Distance above land surface (feet)			
	T. 1 S., R. 6 E.														
1-6-1dd1	SE¼ SE¼ sec. 1	William R. Gerdes	Dr	80.8	6	GI	Sand	Glacial	Cy, W	S	Top of casing	—6.0	21.11	10-23-51	Analysis of water is given in table 3.
2dd	SE¼ SE¼ sec. 1	do.	Dr	100	6	S	Sand and gravel	do.	J, E	D			20		
1-6-6cc	SW¼ SW¼ sec. 2	E. Bluhm	Du	66.2	36	R	Sand	do.	Cy, H	N	Top of platform	0.3	27.84	10-19-51	
13bc	SW¼ NW¼ sec. 13	H. F. Leudders	Dr	97.9	6	GI	Limestone	Barneston limestone	Cy, W	S	Top of casing	0.8	53.70	8-21-51	
14cb	NW¼ SW¼ sec. 14	W. Harries	Du	32	48	R	Sand	Glacial	Cy, W	D, S			12		Well goes down to shale.
17cb	NW¼ SW¼ sec. 17	Emma Holle	DD	64.5	36-6	R,GI	do.	do.	Cy, W	S	Top of platform	1.0	34.05	10-19-51	
28cb	NW¼ SW¼ sec. 28	Immanuel Lutheran Church	Dr	150	6	GI	Limestone	Doyle shale	N	N			100		To be used as domestic supply when pump is installed.
33da	NE¼ SE¼ sec. 33	Henry Wollenberg	Dr	101	6	GI	do.	do.	Cy, H	D, S			70		
36cc	SW¼ SW¼ sec. 36	Lewis Meinecke	Dr	55	6	GI	do.	Barneston limestone	J, E	D, S			40		
	T. 1 S., R. 7 E.														
1-7-6da	NE¼ SE¼ sec. 6	Carl Gerdes	Dr	150	6	S	Sand and gravel	Glacial	Cy,W	D, S			75		
9cc	SW¼ SW¼ sec. 9	C. L. Goernandt	Du	35.1	36	R	do.	do.	Cy,W,H	S	Top of platform	0.2	13.00	10-24-51	
10dd	SE¼ SE¼ sec 10	J. C. Pisar	Dr	45	6	GI	Limestone	Barneston limestone	Cy, W	D, S			40		
14db	NW¼ SE¼ sec. 14	City of Oketo	Dr	32	10	S	Sand	Alluvium	T, E	P			19		Analysis of water is given in table 3. Estimated yield 20 G.P.M.
16dd	SE¼ SE¼ sec. 16	D. G. Ausmus	Dr	63	6	S	Limestone	Barneston limestone	Cy, W	D, S			49		
17dd	SE¼ SE¼ sec. 17	do.	Dr	47	6	S	Sand and gravel	Alluvium	Cy,W,H	D, S			31		
18dd	SE¼ SE¼ sec. 18	School District	Dr	115.5	6	GI	Limestone	Barneston limestone	Cy, H	D	Top of casing	0.3	30.64	10-23-51	
20bc	SW¼ NW¼ sec. 20	B. Behrends	Dr	103.2	6	GI	do.	do.	Cy, H	N	do.	0.9	60.09	10-23-51	
23ab	NW¼ NE¼ sec. 26	Marietta Store	Dr	40	6	GI	do.	do.	Cy, H	D			30		
25cb	NW¼ SW¼ sec. 25	Arliene Finch	Dr	36.4	6	GI	Sand and gravel	Glacial	Cy,W,H	D, S	Top of platform	0.8	24.73	11-8-51	
30aa	NE¼ NE¼ sec. 30	F. Scully	Dr	85.4	6	GI	Limestone	Barneston limestone	Cy, W	S	Top of casing	1.1	64.81	10-23-51	
31cb	NW¼ SW¼ sec. 31	Sylves Dursee	Dr	47.0	6	GI	do.	do.	Cy, W	S	do.	1.0	31.04	10-23-51	
	T. 1 S., R. 8 E.														
1-8-1cd	SE¼ SW¼ sec. 1	School District	Dr	94.8	6	GI	do.	do.	Cy,H	D	do.	0.4	26.21	11-6-51	
5da	NE¼ SE¼ sec. 5	Mary Moore	DD	80	36-6	R,GI	do.	do.	Cy, W	S			30		

1-8-6cc	SW¼ SW¼ sec. 6	School District	Dr	41.2	6	GI	Limestone	Barneston limestone	N	N	Top of platform	0.5	19.72	8-9-51	
7ba	NE¼ NW¼ sec. 7	Fed. Land Bank	Dr	81.5	6	GI	do.	do.	Cy, W	S	Top of casing	2.1	30.85	11-8-51	
14aa	NE¼ NE¼ sec. 14	Christine Sible	DD	80	36-6	R,GI	do.	do.	Cy, W	D, S	....	.....	25	....	
20bb	NW¼ NW¼ sec. 20	School District	Dr	73.3	6	GI	do.	do.	Cy, H	D	Top of casing	0.1	53.29	11-7-51	
21dd	SE¼ SE¼ sec. 21	H. H. Voet	Dr	71.2	6	GI	Sand and gravel	Glacial	Cy, W	S	Base of pump	0.3	36.35	11-7-51	Analysis of water is given in table 3.
28dc	SW¼ SE¼ sec. 28	Laura Krotsch	Dr	65.1	4	S	do.	do.	Cy, W	N	Top of casing	0.3	34.11	11-7-51	
30ba	NE¼ NW¼ sec. 30	C. T. Finch	Du	59.4	30	R	Limestone	Barneston limestone	N	N	do.	0.0	46.54	11-8-51	
	T. 1 S., R. 9 E.														
1-9-1db	NW¼ SE¼ sec. 1	City of Summerfield	Dr	83	6	GI	do.	?	T, E	P	....	.....	40	....	Analysis of water is given in table 3.
11dd	SE¼ SE¼ sec. 11	School District	B	41.0	12	CT	Sand and gravel	Glacial	Cy, H	D	Top of tile	0.2	6.60	10-11-51	
15bb	NW¼ NW¼ sec. 15	Chas. Koepp	Dr	90.7	6	GI	do.	do.	Cy,W,H	D, S	Top of casing	−4.5	25.20	10-16-51	
23cd	SE¼ SW¼ sec. 23	Albert Volle	Dr	112	8	GI	do.	do.	Cy,W,H	D, S	....	.....	100	....	
30bb	NW¼ NW¼ sec. 30	School District	Dr	49.7	6	GI	do.	do.	Cy, H	N	Top of casing	0.1	8.98	11-6-51	
30dd	SE¼ SE¼ sec. 30	W. W. Edmond	Du,B	71.7	28-12	R,CT	do.	do.	Cy, W	S	Top of platform	0.6	51.87	10-16-51	
32aa	NE¼ NE¼ sec. 32	School District	Dr	62.1	8	GI	do.	do.	Cy, H	N	do.	0.2	30.65	10-16-51	
33dd	SE¼ SE¼ sec. 33	L. C. Koepp	Dr	80	6	GI	do.	do.	Cy, W	D, S	....	.....	25	....	
	T. 1 S., R. 10 E.														
1-10-8cc	SW¼ SW¼ sec. 8	Claeys Bros.	Dr	115	6	GI	do.	do.	Cy, W	S	....	.....	20	....	
14ac	SW¼ NE¼ sec. 14	Ed Young	B	50	12	CT	do.	do.	Cy, E	D, S	....	.....	15	....	
17aa	NE¼ NE¼ sec. 17	School District	B	53.4	12	CT	do.	do.	Cy, H	N	Top of platform	0.3	14.68	9-28-51	
28ad	SE¼ NE¼ sec. 28	A. Moser	B	26.4	12	CT	do.	do.	Cy, H	S	Top of tile	0.4	3.55	9-28-51	
29bb	NW¼ NW¼ sec. 29	Florence Totten	Dr	107.0	6	GI	do.	do.	Cy, W	S	Hole in side of casing	0.3	43.60	10-11-51	
35cd	SE¼ SW¼ sec. 35	School District	B	64.7	12	CT	do.	do.	Cy, H	D	Top of platform	0.8	8.53	9-28-51	Analysis of water is given in table 3.
	T. 2 S., R. 6 E.														
2-6-3bc	SW¼ NW¼ sec. 3	Lewis Meineicke	Dr	60.0	6	GI	Limestone	Doyle shale and Barneston limestone	Cy, W	S	Top of casing	1.0	25.20	8-20-51	Analysis of water is given in table 3.
5bb	NW¼ NW¼ sec. 5	Marie Drinkgern	Dr	57.7	6	GI	do.	Winfield limestone	Cy, W	S	Top of platform	0.1	31.85	10-19-51	
	T. 2 S., R. 6 E.														
2-6-6aa	NE¼ NE¼ sec. 6	Henry Drinkgern	Dr	60	6	GI	Limestone	Winfield limestone	Cy, W	S	....	.....	40	....	
8cd	SE¼ SW¼ sec. 8	Edwin Duensing	DD	50	36-6	R,GI	do.	do.	Cy, W	S	Top of platform	0.8	11.65	10-19-51	
18aa	NE¼ NE¼ sec. 18	M. Pralle	Dr	68.6	6	GI	do.	do.	Cy, W	S	Top of casing	0.2	38.11	10-19-51	
20bc	SW¼ NW¼ sec. 20	Rudolf Stohs	Dr	100	6	GI	do.	do.	CY, E	S	....	.....	80	....	
21aa	NE¼ NE¼ sec. 21	R. H. Baker	DD	50.2	36-6	R,GI	do.	do.	Cy, W	S	Top of platform	0.4	14.71	10-23-51	
22cd	SE¼ SW¼ sec. 22	J. Zimmerman	Dr	103.4	6	GI	do.	do.	Cy,W,H	N	Top of casing	0.8	35.76	10-23-51	
35aa	NE¼ NE¼ sec. 35	Joseph Bitterly	Dr	52	6	GI	do.	Barneston limestone	J, E	D	....	.....	44	....	Analysis of water is given in table 3.
36bd	SE¼ NW¼ sec. 36	E. Kohors	Dr	60	6	GI	do.	do.	Cy, W	D, S	....	.....	45	....	Reported yield 20 G.P.M.

TABLE 11.—*Records of wells in Marshall County, Kansas—Continued*

Well No.	Location	Owner or tenant	Type of well (1)	Depth of well (feet)	Diameter of well (in.)	Type of casing (2)	Principal water-bearing bed: Character of material	Principal water-bearing bed: Geologic source	Method of lift (3)	Use of water (4)	Measuring point: Description	Measuring point: Distance above land surface (feet)	Depth to water level below measuring point (feet)	Date of measurement	REMARKS (Yield given in gallons a minute; drawdown in feet)
	T. 2 S., R. 6 E.														
2-6-36ca	NE¼ SW¼ sec. 36	Paul Holle	Dr	62	6	GI	Limestone	Barneston limestone	J, E	D			47		Reported yield 20 G.P.M.
	T. 2 S., R. 7 E.														
2-7-2cc	SW¼ SW¼ sec. 2	Margaret Lillig	Du	37.4	36	R	do.	do.	Cy, W	S	Top of platform	1.8	33.42	11-9-51	
2da	NE¼ SE¼ sec. 2	School District	Dr	66.2	6	GI	Sand and gravel	Glacial	N	N	Top of casing	0.1	52.04	11-8-51	
3ab	NW¼ NE¼ sec. 3	Nina Kirkwood	Dr	79.1	5	GI	do.	Terrace	Cy, H	N	do.	0.4	18.06	12-6-51	
3bc	SW¼ NW¼ sec. 3	O. W. Dam	Du	24.2	36	R	do.	do.	Cy, W	S	Top of platform	0.4	14.93	10-24-51	
5ba	NE¼ NW¼ sec. 5	School District	Du	42.3	24	OB	Limestone	Barneston limestone	Cy, H	D	Base of pump	0.1	36.02	10-24-51	
13cc	SW¼ SW¼ sec. 13	E. Claeys	Dr	178	6	GI	do.	do.	Cy, E	D, S			68		Driller reported clay and sand to depth of 92 feet.
14bb	NW¼ NW¼ sec. 14	S. Schmidt	Du	51.8	38	R	Sand and gravel	Glacial	Cy, H	S	Top of platform	0.9	47.45	11-9-51	
17cc	SW¼ SW¼ sec. 17	C. H. Thiele	Dr	65.4	6	GI	Limestone	Barneston limestone	N	N	Top of casing	0.8	45.61	10-24-51	To be used as domestic supply when pump is installed.
18dd	SE¼ SE¼ sec. 18	Claton Otto	Dr	62	6	GI	do.	do.	Cy, E	D, S			47		
23dd	SE¼ SE¼ sec. 23	Jennie Scott	DD	130	36-6	R, S	Gravel	Glacial	Cy, W	D, S	Top of platform	0.3	81.98	11-8-51	
28bc	SW¼ NW¼ sec. 28	Union Pacific Railroad Co.	Du	37	144	C	Sand and gravel	Alluvium	T, E	S			20		Reported to yield 165 GPM with less than 1 ft. drawdown.
29db	NW¼ SE¼ sec. 29	Vernon Dammon	Dr	65	6	GI	Limestone	Barneston limestone	J, E	D, S			50		
32bb	NW¼ NW¼ sec. 32	Archie Breeding	Dr	73.4	6	GI	do.	do.	N	N	Top of casing	2.2	44.12	10-24-51	
33ac	SW¼ NE¼ sec. 33	Charles Butler	Dr	24.5	8	GI	Sand and gravel	Alluvium	Cy, H	D	do.	2.1	13.95	12-6-51	
33ba	NE¼ NW¼ sec. 33	Pacific Coffee Shop	Dr	41	8	S	Sand and gravel	Terrace	T, E	AC			21		Yields more than 55 G.P.M.
33bb	NW¼ NW¼ sec. 33	Howell Lumber Co.	Dr	27	6	GI	do.	do.	T, E	AC			18		
33db	NW¼ SE¼ sec. 33	Ted Grover	Dr	24	6	GI	do.	Alluvium	Cy, H	S			12		Analysis of water is given in table 3.
35aa	NE¼ NE¼ sec. 35	Fred Unger	Dr	114	6	S	Limestone	Barneston limestone	J, E	D, S			100		Analysis of water is given in table 3*
35ab	NW¼ NE¼ sec. 35	Marysville Drive-In Theatre	Dr	155	6	S	do.	do.	J, E	D			88		

	T. 2 S., R. 8 E.														
2-8-2aa	NE¼ NE¼ sec. 2	V. Grisp	Dr	84.3	6	GI		?	Cy, H	D	Top of casing	0.6	33.19	11-6-51	
2dc	SW¼ SE¼ sec. 2	G. W. Lewis	Du	32.9	36	R	Sand	Glacial	Cy, H	N	Top of platform	0.4	9.18	11-6-51	
4ad	SE¼ NE¼ sec. 4	C. Pape	Du	38.4	30	R	do.	do.	Cy, H	N	do.	0.2	17.97	11-7-51	
6cc	SW¼ SW¼ sec. 6	Lois Williams	Dr	28.3	6	GI	do.	Alluvium	Cy, H	S	Top of casing	0.3	18.92	11-8-51	
15cc	SW¼ SW¼ sec. 15	E. C. Koepp	Dr	26.2	6	GI	do.	do.	Cy, H	N	do.	0.3	7.88	11-7-51	
21dd	SE¼ SE¼ sec. 21	School District	Dr	57.4	6	GI	Limestone	Barneston limestone	Cy, H	D	do.	0.1	17.24	11-7-51	
26aa	NE¼ NE¼ sec. 26	Charlette Harry	Dr	55.0	6	GI	do.	Schroyer limestone	Cy, W	N	do.	0.4	20.91	10-16-51	
27cc	SW¼ SW¼ sec. 27	Kromme	Dr	40	6	GI	do.	Barneston limestone	J, E	D			38		
31cd	SE¼ SW¼ sec. 31	School District	Dr	43.4	6	GI	Gravel	Glacial	Cy, H	D	Top of casing	0.3	16.20	11-8-51	
33aa1	NE¼ NE¼ sec. 33	Henry Prigle Garage	Dr	96	6	GI	Limestone	Barneston limestone	J, E	D			81		
33aa2	NE¼ NE¼ sec. 33	Henry Prigle	Dr	80	6	GI	do.	do.	J, E	D			65		
33ad	SE¼ NE¼ sec. 33	School District	Dr	46	6	GI	do.	do.	Cy, H	D			40		
35dc	SW¼ SE¼ sec. 35	do.	Dr	77.6	6	GI	do.	Wreford limestone	Cy, H	D	Top of casing	0.2	39.64	11-6-51	Analysis of water is given in table 3.
36da	NE¼ SE¼ sec. 36	Elmer Brown	Du	80	36	R	do.	Bader limestone	Cy,W,H	D, S			70		
	T. 2 S., R. 9 E.														
2-9-1bb	NW¼ NW¼ sec. 1	J. N. Hillyer	Dr	106.5	6	GI	Sand and gravel	Glacial	Cy, H	N	Top of casing	0.2	13.57	10-11-51	
6da	NE¼ SE¼ sec. 6	J. I. Lewellin	Dr	71.1	8	GI	do.	do.	Cy, H	N	do.	0.2	22.83	10-16-51	
12dd	SE¼ SE¼ sec. 12	R. S. Weaver	Dr	187	3.5	S	do.	do.	Cy, W	S			75	10-11-51	Well is reported to go 85 feet into rock.
14bb	NW¼ NW¼ sec. 14	School District	Dr	68.4	6	GI	do.	do.	N	N	Top of casing	0.3	3.80	10-11-51	
21ab	NW¼ NE¼ sec. 21	City of Beattie	Dr	80	6	S	do.	do.	Cy, E	P			30		
21ac	SW¼ NE¼ sec. 21	do.	DD	106	48-8	C,S	do.	do.	Cy, E	P			76		
24cb	NW¼ SW¼ sec. 24	J. W. Blair	Dr	140	6	S	do.	do.	Cy, W	S			54		
25aa	NE¼ NE¼ sec. 25	Howard Anderson	Dr	146	6	S	do.	do.	Cy, E	S			25		
25bc	SW¼ NW¼ sec. 25	F. C. Totten	Du	68.3	48	R	do.	do.	Cy, H	D, S	Top of platform	0.2	51.13	10-11-51	
25dd	SE¼ SE¼ sec. 25	Ralph Anderson	Dr	158	3.5	S	do.	do.	Cy, W	S			30		
32dd	SE¼ SE¼ sec. 32	P. J. Gurtler	Dr	108.5	6	GI	Limestone	Beattie limestone	Cy, W	S	Top of casing	0.95	35.29	10-13-51	Analysis of water is given in table 3.
	T. 2 S., R. 10 E.														
2-10-5bb	NW¼ NW¼ sec. 5	Emma Rohmeyer	B	94.9	12	CT	Sand and gravel	Glacial	Cy, W	S	do.	0.9	4.55	10-11-51	
6aa	NE¼ NE¼ sec. 6	B. H. Finlayson	Dr	62.9	6	GI	do.	do.	Cy, W	S	do.	1.0	5.80	10-11-51	
7ad	SE¼ NE¼ sec. 7	F. Bernasek	Du	36.4	36	R	do.	do.	Cy, H	N	Top of platform	1.0	8.75	10-11-51	
16dc	SW¼ SE¼ sec. 16	Claud Kincaid	Dr	120	6	GI	do.	do.	Cy, E	S			50		
19aa	NE¼ NE¼ sec. 19	Ed Bergman	Dr	147	3.5	S	do.	do.	Cy, W	S			75		Well is reported to go 6 feet into rock.
24bc1	SW¼ NW¼ sec. 24	City of Axtell	Dr	59	24	C	Gravel	do.	T, E	P			43		Analysis of water is given in table 3.
24bc2	SW¼ NW¼ sec. 24	do.	Dr	57	24	C	do.	do.	T, E	P			43		Analysis of water is given in table 3.
30da	NE¼ SE¼ sec. 30	Harold Bergman	Dr	187	3.5	S	Sand and gravel	do.	Cy, E	S			106		
35ad	SE¼ NE¼ sec. 35	School District	B	54.3	12	CT	do.	do.	N	N	Top of platform	0.5	51.00	9-27-51	

TABLE 11.—*Records of wells in Marshall County, Kansas*—*Continued*

Well No.	Location	Owner or tenant	Type of well (1)	Depth of well (feet)	Diameter of well (in.)	Type of casing (2)	Principal water-bearing bed: Character of material	Principal water-bearing bed: Geologic source	Method of lift (3)	Use of water (4)	Measuring point: Description	Measuring point: Distance above land surface (feet)	Depth to water level below measuring point (feet)	Date of measurement	REMARKS (Yield given in gallons a minute; drawdown in feet)
	T. 3 S., R. 6 E.														
3-6-6cd	SE¼ SW¼ sec. 6	P. A. Farrell	Dr	74.7	6	GI	Limestone	Winfield limestone	Cy,W,H	N	Top of platform	3.1	27.70	10-25-51	Analysis of water is given in table 3.
10dc	SW¼ SE¼ sec. 10	H. J. Sandmann	Dr	115.2	6	GI	do	Barneston limestone	Cy,W,H	S	Top of casing	0.3	95.47	10-25-51	
11ba	NE¼ NW¼ sec. 11	H. W. Iles	Dr	66.4	6	GI	do	Doyle shale	Cy, H	S	do	0.1	29.92	11-23-51	
19cd	SE¼ SW¼ sec. 19	Karl Frohberg	Dr	127	6	GI	do	Winfield limestone	Cy, W	S			67		
22aa	NE¼ NE¼ sec. 22	George Blanchard	DD	130	36-6	R,GI	do	Barneston limestone	Cy, E	D, S			95		
22da	NE¼ SE¼ sec. 22	do	Dr	87.2	6	GI	do	Doyle shale	N	N	Top of casing	0.4	68.14	10-25-51	
22dc	SW¼ SE¼ sec. 22	Orval Scheller	Du	106	36	R	do	Barnston limesto ne	J, E	D, S			94		
28dc	SW¼ SE¼ sec. 28	W. W. Monteith	Dr	74.7	6	GI	do	do	Cy, W	S	Top of casing	1.0	32.54	10-25-51	
31da	NE¼ SE¼ sec. 31	G. H. Taplin	Dr	93.3	6	GI	do	do	Cy, H	N	Top of platform	1.8	73.85	10-25-51	
35cc	SW¼ SW¼ sec. 35	F. B. Wheeler	Dr	69.5	3.5	S	do	do	Cy, W	S	Top of casing	0.5	53.15	10-25-51	
	T. 3 S., R. 7 E.														
3-7-2dc	SW¼ SE¼ sec. 2	Schmidt Comm. Co.	Dr	20.1	6	GI	Sand	Alluvium	Cy, H	D, S	do	2.6	10.94	11-15-51	
11dc	SW¼ SE¼ sec. 11	J. Ring	Dr	76.7	6	GI	Limestone	Barneston limestone	Cy, H	S	do	0.2	29.32	11-15-51	
16ca	NE¼ SW¼ sec. 16	Mida McMahn	Dr	44.0	6	GI	do	Wreford limestone	Cy, W	S	do	0.4	20.14	11-20-51	
29bc	SW¼ NW¼ sec. 29	F. W. Hammett	Dr	140.0	6	GI	do	Bader limestone	Cy, H	D, S	do	2.0	17.85	6-30-51	
30cc	SW¼ SW¼ sec. 30	Gertrude Kirkendall	Dr	50.9	8	GI	Gravel	Terrace	Cy, W	D, S	Top of platform	0.8	24.86	11-23-51	Not used.
31cd1	SE¼ SW¼ sec. 31	D. Hammett	Dr	47.3	6	GI	Sand and gravel	Alluvium	Cy, H	D	Top of casing	2.1	19.41	11-23-51	Not used.
31cd2	SE¼ SW¼ sec. 31	D. Hammett	Dr	43.7	6	GI	Gravel	Terrace	Cy, H	D	do	0.4	32.69	11-23-51	
34bc	SW¼ NW¼ sec. 34	Chas. Butler	Dr	87	6	GI	Limestone	Barneston limestone	Cy,W,H	D, S			78		
36cb	NW¼ SW¼ sec. 36	F. J. Sandmann	Dr	87.8	6	GI	do	do	Cy, W	S	Top of casing	0.9	42.55	11-15-51	
	T. 3 S., R. 8 E.														
3-8-1bb	NW¼ NW¼ sec. 1	E. C. Koepp	Dr	29.1	6	GI	do	Funston limestone	Cy, H	S	do	0.9	11.11	11-6-51	
7cd	SE¼ SW¼ sec. 7	School District	Dr	23.6	6	GI	Sand	Alluvium	Cy, H	D	do	0.8	8.28	11-10-51	
10bc	SW¼ NW¼ sec. 10	Wilfred Zech	Dr	117	6	S	Sand and gravel	Glacial	J, E	D			40		
13ab	NW¼ NE¼ sec. 13	School District	Dr	37.8	6	GI	Sand	Terrace	Cy, H	D	Top of casing	0.2	4.31	11-6-51	
17cd	SE¼ SW¼ sec. 17	L. C. Koepp	Dr	85.0	3.5	S	Sand and gravel	Glacial	Cy,W,H	S	do	1.0	71.97	11-10-51	
19ad	SE¼ NE¼ sec. 19	Joe Cooper	Dr	183	3.5	S	do	do	Cy, W	D, S			82		
21cc	SW¼ SW¼ sec. 21	School District	Dr	87.2	6	GI	Limestone	Bader limestone	Cy, H	D	Top of casing	0.2	72.25	11-7-51	

24cc	SW¼ SW¼ sec. 24	Community of Winifred	Du	37.7	36	R	Sand	Terrace	Cy, H	D	Top of platform	1.0	24.95	11-6-51	
26dd	SE¼ SE¼ sec. 26	George Feldhausen	Dr	76	6	S	Sand and gravel	Glacial	Cy, W	S			38		
29cc	SW¼ SW¼ sec. 29	J. Voglesburg	Dr	84.5	6	GI	do	do	N	N	Top of casing	0.7	62.12	11-10-51	
36cd	SE¼ SW¼ sec. 36	School District	Dr	40.6	6	GI	Limestone	Beattie limestone	Cy, H	D	do	0.5	16.21	10-17-51	Analysis of water is given in table 3.
	T. 3 S., R. 9 E.														
3-9-2ab	NW¼ NE¼ sec. 2	Anna Samuelson	Dr	58.5	3.5	S	Sand and gravel	Glacial	Cy, H	N	do	0.3	9.83	10-11-51	
4ab	NW¼ NE¼ sec. 4	Mable Larkin	Dr	65	6	GI	Limestone	Grenola limestone	Cy, W	S			25		
4cc	SW¼ SW¼ sec. 4	W. R. Cassidy	Dr	109.5	4	GI	do	Beattie limestone	Cy, W	S	Top of casing	0.5	66.89	12-13-51	
7da	NE¼ SE¼ sec. 7	Mrs. Peter Wanklyn	Dr	72	6	GI	do	Bader limestone	J, E	S			56		
9bd	SE¼ NW¼ sec. 9	A. Samuelson	Dr	64.8	6	GI	do	Grenola limestone	Cy,W,H	S	Top of casing	0.7	40.81	10-15-51	Analysis of water is given in table 3.
15bb	NW¼ NW¼ sec. 15	Tillie Cole	DD	112.4	36-3.5	R,S	do	do	Cy, W	S	Top of platform	0.3	47.68	10-13-51	
19da	NE¼ SE¼ sec. 19	J. V. Miller	DD	55	36-6	R,GI	do	do	J, E	D, S			40		
25aa	NE¼ NE¼ sec. 25	Moses Saville	Dr	172	3.5	S	Sand and gravel	Glacial	Cy,W,H	D, S	Top of casing	1.1	34.00	10-10-51	Driller reported that well penetrated 5 ft. into consolidated rock.
26aa	NE¼ NE¼ sec. 26	J. Morton	Dr	170.0	3.5	S	do	do	Cy, W	D, S	do	0.4	90.20	10-10-51	
35bc	SW¼ NW¼ sec. 35	F. Millenbruch	Dr	161.4	3.5	S	do	do	Cy, W	S	do	0.6	113.81	10-12-51	
	T. 3 S., R. 10 E.														
3-10-2aa	NE¼ NE¼ sec. 2	H. E. Olson	B	29.4	14	CT	do	do	Cy,W,H	S	Top of tile	1.2	17.82	9-27-51	
7dc	SW¼ SE¼ sec. 7	Carl A. B. Swanson	Dr	193	3.5	S	do	do	Cy, E	D, S			137		
8dc	SW¼ SE¼ sec. 8	Conrad Anderson	Dr	105.0	3.5	S	do	do	Cy, T	D, S	Top of casing	0.4	29.86	10-10-51	
10cc	SW¼ SW¼ sec. 10	School District	B	50.6	18	C	do	do	Cy, H	N	Top of platform	0.2	10.19	9-28-51	
11ad	SE¼ NE¼ sec. 11	do	Du	45.1	36	R	do	do	N	N	do	0.2	11.35	9-27-51	
11cd	SE¼ SW¼ sec. 11	Leland Chapman	B	46.8	12	CT	do	do	Cy,W,H	S	Top of tile	1.0	28.35	10-10-51	
19cb	NW¼ SW¼ sec. 19	H. T. VanDorn	Dr	166	3.5	S	do	do	Cy, W	D, S			30		
25cb	NW¼ SW¼ sec. 25	School District	B	33.8	12	CT	do	do	N	N	Top of tile	0.3	24.80	9-27-51	
29cb	NW¼ SW¼ sec. 29	Joseph Lilley	Dr	185	3.5	S	do	do	Cy,W,H	D, S			35		
	T. 4 S., R. 6 E.														
4-6-2cc	SW¼ SW¼ sec. 2	T. H. Hauley	Dr	51.1	6	GI	Limestone	Barneston limestone	Cy, W	S	Base of pump	0.6	15.81	10-25-51	
3dd	SE¼ SE¼ sec. 3	H. P. Nelson	Dr	150	6	GI	do	do	Cy, W	D, S			125		
11dd	SE¼ SE¼ sec. 11	Schmidt and Koester	Dr	103.8	6	GI	do	do	Cy,W,H	D	Top of casing	0.6	15.69	11-23-51	
16dd1	SE¼ SE¼ sec. 16	City of Waterville	Dr	55	18	S	Sand	Alluvium	T, E	P			21		Analysis of water is given in table 3.
16dd2	SE¼ SE¼ sec. 16	do	Dr	55	18	S	do	do	T, E	P			21		
17dc	SW¼ SE¼ sec. 17	Arch Argenbrite	Dr	90	6	GI	Gravel	Terrace	Cy, E	D			60		Analysis of water is given in table 3.
23cb	NW¼ SW¼ sec. 23	J. Seaton	Dr	46.5	6	GI	do	do	Cy,W,H	S	Top of casing	0.4	23.81	11-28-51	
28dd	SE¼ SE¼ sec. 28	Allen Travelute	Dr	86	6	GI	Limestone	Barneston limestone	Cy, E	D, S			60		

TABLE 11.—*Records of wells in Marshall County, Kansas*—*Continued*

Well No.	Location	Owner or tenant	Type of well (1)	Depth of well (feet)	Diameter of well (in.)	Type of casing (2)	Principal water-bearing bed: Character of material	Principal water-bearing bed: Geologic source	Method of lift (3)	Use of water (4)	Measuring point: Description	Measuring point: Distance above land surface (feet)	Depth to water level below measuring point (feet)	Date of measurement	REMARKS (Yield given in gallons a minute; drawdown in feet)
	T. 4 S., R. 7 E.														
4-7-12dc	SW¼ SE¼ sec. 12	Fed. Farm Mtg. Company	Dr	72.9	6	GI	Limestone	Barneston limestone	Cy, H	D	Top of casing	0.3	23.83	11-15-51	
19cc	SW¼ SW¼ sec. 19	School District	Dr	58.2	6	GI	Gravel	Terrace	Cy, H	N	do.	0.1	39.29	11-28-51	
20aa	NE¼ NE¼ sec. 20	Certainteed Products	Dr	29	16	S	do.	do.	C, E	Ind			12		Yields about 85 G.P.M.
20cd1	SE¼ SW¼ sec. 20	City of Blue Rapids	Du	46	18	C T	Sand	do.	T, E	P			21		Analysis of water is given in table 3.
20cd2	SE¼ SW¼ sec. 20	do.	Du	42	240	B	do.	do.	C, E	P			12		
21cd	SE¼ SW¼ sec. 21	F. M. Brown	Dr	32.4	5	GI	do.	do.	Cy, H	N	Top of casing	1.3	17.95	12-7-51	Analysis of water is given in table 3.
25bc	SW¼ NW¼ sec. 25	A. R. Atkinson	Dr	50	6	GI	Limestone	Wreford limestone	Cy, H	D, S			35		
25cc	SW¼ SW¼ sec. 25	Kirby	Dr	80	6	GI	do.	do.	J, E	D			67		
28dc	SW¼ SE¼ sec. 28	T. F. Musil	Dr	84.7	6	GI	Gravel	Terrace	Cy, H	N	Top of platform	0.3	56.22	11-27-51	
30cb	NW¼ SW¼ sec. 30	Fred Stocks	Dr	40	6	GI	do.	do.	C, E	D, S			13		
32dd	SE¼ SE¼ sec. 32	J. O. Honeycutt	Dr	58	6	GI	Limestone	Funston limestone	Cy, W, H	D, S			48		
35ad	SE¼ NE¼ sec. 35	L. E. Magnuson	Dr	65	6	GI	Sand	Terrace	Cy, W	D, S			35		
	T. 4 S., R. 8 E.														
4-8-2dd	SE¼ SE¼ sec. 2	Mrs. Joe Lierz	DD	80	36-6	R,GI	Limestone	Wreford limestone	Cy, H	D			58		
3cc	SW¼ SW¼ sec. 3	Earl Shaw	Dr	51	6	GI	do.	do.	Cy, E	D, S			45		
3cd	SE¼ SW¼ sec. 3	School District	Dr	75.1	6	GI	do.	do.	Cy, H	N	Top of casing	0.2	36.59	12-12-51	Analysis of water is given in table 3.
7ba	NE¼ NW¼ sec. 7	do.	Dr	88.4	6	GI	do.	Barneston limestone	Cy, H	N	do.	0.9	29.43	11-10-51	
13cd	SE¼ SW¼ sec. 13	Alf Morton	Dr	97	6	GI	do.	Beattie limestone	Cy,W,H	D, S			43		
14cd	SE¼ SW¼ sec. 14	School District	Dr	98.0	6	GI	do.	Bader limestone	Cy, H	D	Top of casing	0.4	83.30	11-6-51	
15cd	SE¼ SW¼ sec. 15	Bethany Methodist Hospital	Dr	78.4	6	GI	do.	do.	Cy,W,H	S	do.	0.9	66.54	11-7-51	
	T. 4 S., R. 9 E.														
4-9-3dc	SW¼ SE¼ sec. 3	John Horigan	Dr	182	3.5	S	Sand and gravel	Glacial	Cy,W,H	D, S			60		
4dc	SW¼ SE¼ sec. 4	F. G. Powell	Dr	144.1	3.5	S	do.	do.	Cy, W	N	Top of casing	1.0	67.67	10-15-51	
6dc	SW¼ SE¼ sec. 6	H. Feldhausen	Dr	82.1	6	GI	Limestone	Foraker limestone	Cy, H	N	do.	0.3	54.06	10-17-51	

7ab	NW¼ NE¼ sec. 7	Carrie Powell	Dr	82.6	6	GI	do	do	Cy,W,H	S	do	0.5	52.45	12-12-51	
16aa1	NE¼ NE¼ sec. 16	City of Frankfort	Dr	117	18	S	Gravel	Glacial	T, E	P			60		Analysis of water is given in table 3.
16aa2	NE¼ NE¼ sec. 16	do	Dr	104	18	S	do	do	T, E	P			60		Analysis of water is given in table 3.
19cb	NW¼ SW¼ sec. 19	F. E. Denlinger	Dr	90.2	6	GI	do	Terrace	N	N	Top of casing	1.0	48.59	10-17-51	
19cd	SE¼ SW¼ sec. 19	T. J. Rhodes	Dr	45.1	6	GI	Sand and gravel	do	Cy,H,T	S	do	0.6	11.78	10-18-51	
29cc	SW¼ SW¼ sec. 29	Community of Barrett	Du	31.4	70	R	Sand	Alluvium	N	N	Top of platform	2.7	13.02	10-17-51	
	T. 4 S., R. 10 E.														
4-10-7dd	SE¼ SE¼ sec. 7	Albert Carlson	Dr	123	3.5	S	Gravel	Glacial	Cy,H	D			15		
8cb	NW¼ SW¼ sec. 8	Owen's Store	Du	40	36	R	do	Alluvium	Cy, H	D			12		Analysis of water is given in table 3.
11da	NE¼ SE¼ sec. 11	City of Vermillion	Dr	50	12	S	Sand and gravel	Glacial	T, E	P			4		Analysis of water is given in table 3.
17ab	NW¼ NE¼ sec. 17	Anna Brophy	Dr	160.0	3.5	S	do	do	Cy, W	S	Top of casing	0.2	44.97	10-10-51	
18aa	NE¼ NE¼ sec. 18	School District	Dr	123.0	6	GI	do	do	Cy, H	N	do	0.8	42.39	10-9-51	
20da1	NE¼ SE¼ sec. 20	Paul Mitchell	Dr	330	6	S			Cy, E	N			100		Water is salty.
20da2	NE¼ SE¼ sec. 20	do	Dr	253	3.5	S	Sand and gravel	Glacial	Cy, W,H	D, S			97		
22dc	SW¼ SE¼ sec. 22	V. Carlson	B	92.1	18	CT	do	do	Cy, W	D, S	Top of platform	0.2	54.80	9-28-51	
23bc	SW¼ SE¼ sec. 23	School District	B	38.7	14	CT	do	do	Cy, H	D	do	0.4	8.15	9-27-51	
27cd	SE¼ SW¼ sec. 27	W. Sheehy	B	58.7	24	CT	do	do	Cy, H	N	do	1.4	7.60	9-28-51	
29cc	SW¼ SW¼ sec. 29	Ralph Clark	Dr	80	6	GI	do	do	Cy, W	D, S			60		
30dd	SE¼ SE¼ sec. 30	William Clark	Du	21.4	36	R	do	do	Cy, W	D, S	Top of platform	0.6	3.38	10-12-51	
34ba	NE¼ NW¼ sec. 34	E. J. Shafer	B	96.4	24	CT	do	do	N	N	do	0.8	94.90	9-28-51	
	T. 5 S., R. 6 E.														
5-6-6dd	SE¼ SE¼ sec. 6	H. J. Anderson	Dr	75.9	6	GI	Limestone	Barneston limestone	Cy, W	S	Top of casing	0.2	69.50	11-28-51	
9ad1	SE¼ NE¼ sec. 9	Frank Dobrovolny, Sr.	Dr	130	6	GI	do	Wreford limestone	Cy, W	N			100		Water is salty.
9ad2	SE¼ NE¼ sec. 9	do	Dr	80	6	GI	do	Barneston limestone	Cy, W	D, S			49		Quality of water is reported to be good.
12dd	SE¼ SE¼ sec. 12	Earl Lamb	Dr	72	6	GI	do	do	Cy, E	D			42		Analysis of water is given in table 3.
15ad	SE¼ NE¼ sec. 15	C. E. Nichols	Dr	47.1	6	GI	do	do	Cy, H	S	Top of casing	0.5	38.48	11-28-51	
15cc	SW¼ SW¼ sec. 15	Sander Larson	Dr	36	6	GI	Gravel	Glacial	Cy,E,W	D, S			26		
19cd	SE¼ SW¼ sec. 19	do	Dr	149.1	6	GI	Limestone	Winfield limestone	Cy, W	S	Top of casing	0.4	78.04	11-28-51	
21dd	SE¼ SE¼ sec. 21	Clarence Smith	Dr	120	6	GI	do	Barneston limestone	Cy,W,H	D, S			40		
26cb	NW¼ SW¼ sec. 26	George Roepke	Dr	34	6	GI	do	do	Cy, W	D, S			28		
28cd	SE¼ SW¼ sec. 28	G. Hersey	Dr	55.1	6	GI	do	do	Cy,W,H	S	Top of casing	0.5	17.68	11-28-51	

TABLE 11.—*Records of wells in Marshall County, Kansas—Concluded*

Well No.	Location	Owner or tenant	Type of well (1)	Depth of well (feet)	Diameter of well (in.)	Type of casing (2)	Principal water-bearing bed: Character of material	Principal water-bearing bed: Geologic source	Method of lift (3)	Use of water (4)	Measuring point: Description	Measuring point: Distance above land surface (feet)	Depth to water level below measuring point (feet)	Date of measurement	REMARKS (Yield given in gallons a minute; drawdown in feet)
	T. 5 S., R. 7 E.														
5-7-1cc	SW¼ SW¼ sec. 1	C. Jones	Dr	55.7	6	GI	Gravel	Terrace	Cy, H	N	Top of casing	0.6	38.57	12-7-51	
5cc	SW¼ SW¼ sec. 5	School District	Dr	66.2	6	GI	Limestone	Barneston limestone	Cy, H	D	do.	0.3	47.72	11-24-51	
6cd	SE¼ SW¼ sec. 6	Harry Lamb	Dr	65	6	GI	do.	do.	Cy,W,H	D, S			50		
11aa1	NE¼ NE¼ sec. 11	City of Irving	Dr	80	12	S	Gravel	Terrace	T, E	P			50		
11aa2	NE¼ NE¼ sec. 11	do.	Dr	80	14	S	do.	do.	Cy, E	P			50		
13dd	SE¼ SE¼ sec. 13	F. C. Fellows	Dr	96	6	GI	Limestone	Beattie limestone	N	N			72		To be used as a stock well when pump is installed.
15ab	NW¼ NE¼ sec. 15	School District	Dr	88.7	6	GI	do.	Wreford limestone	Cy, H	N	Top of casing	0.9	21.35	11-27-51	
20cc	SW¼ SW¼ sec. 20	J. Novak	Dr	56.8	6	GI	do.	Barneston limestone	Cy, H	D	do.	0.1	38.64	11-24-51	
24cc	SW¼ SW¼ sec. 24	J. F. Smutny	Dr	173.2	6	GI	do.	Wreford limestone	Cy, W	N	do.	0.9	94.20	11-27-51	
28aa	NE¼ NE¼ sec. 28	Mrs. E. Kotapish	Dr	60	6	GI	do.	Barneston limestone	Cy,W,H	D, S			30		
	T. 5 S., R. 8 E.														
5-8-9ca	NE¼ SW¼ sec. 9	N. Everson	Dr	48.3	6	GI	Sand	Alluvium	Cy, H	S	Top of casing	0.4	22.80	11-7-51	
13ca	NE¼ SW¼ sec. 13	R. Cobb	Dr	64	6	GI	Limestone	Beattie limestone	Cy, E	D, S			44		
25da	NE¼ SE¼ sec. 25	School District	Dr	91.8	6	GI	do.	Wreford limestone	Cy, H	D	Top of casing	0.3	46.30	10-20-51	
27da	NE¼ SE¼ sec. 27	do	Dr	61.1	6	GI	do.	do.	Cy, H	N	do.	0.2	46.39	10-20-51	
35bb	NW¼ NW¼ sec. 35	Mable Templin	Dr	83.2	6	GI	do.	do.	Cy, W	N	do.	0.2	36.28	10-20-51	
	T. 5 S., R. 9 E.														
5-9-3cb	NW¼ SW¼ sec. 3	W. T. Herigan	Dr	90.3	6	GI	do.	Grenola limestone	Cy, W	S	Top of platform	0.5	79.05	10-12-51	
6da	NE¼ SE¼ sec. 6	C. M. Owen	Dr	44.1	6	GI	do.	do.	Cy, H	N	Top of casing	0.2	7.15	10-17-51	
10bb	NW¼ NW¼ sec. 10	C. E. Leinweber	Dr	104.1	6	GI	do.	do.	Cy, H	N	do.	0.1	51.70	10-12-51	
12dd	SE¼ SE¼ sec. 12	P. J. McGeeney	Dr	90	6	GI	do.	do.	Cy, H	D, S	do.	2.1	42.40	9-25-51	
17aa	NE¼ NE¼ sec. 17	School District	Dr	56.0	6	GI	do.	do.	Cy, H	N	do.	0.1	31.54	10-17-51	
22cc	SW¼ SW¼ sec. 22	G. V. Shineman	Dr	92	6	GI	do.	Red Eagle limestone	Cy, E	D			42	10-12-51	Analysis of water is given in table 3.
22cd	SE¼ SW¼ sec. 22	do.	Du	53.2	36	R	do.	Grenola limestone	Cy, H	N	Top of platform	0.5	43.75	10-12-51	
24ba	NE¼ NW¼ sec. 24	C. D. Weinert	Dr	86.0	6	GI	do.	do.	Cy, W	S	Top of casing	0.8	25.04	12-12-51	Analysis of water is given in table 3.

24bb	NW¼ NW¼ sec. 24	do	Dr	85.7	6	GI	do	do	Cy, H	N	do	1.1	59.78	10-12-51	
26dd	SE¼ SE¼ sec. 26	J. Kennedy	Dr	110.5	6	GI	do	do	Cy,W,H	S	do	0.6	35.53	10-12-51	
28cd	SE¼ SW¼ sec. 28	F. H. Bienks	Dr	117.7	6	GI	do	do	Cy,W,H	S	do	0.7	28.63	10-12-51	
30dc	SW¼ SE¼ sec. 30	L. H. Johnson	Dr	66.1	6	GI	do	Wreford limestone	Cy, W	N	do	0.2	42.36	10-17-51	
	T. 5 S., R. 10 E.														
5-10-1cb	NW¼ SW¼ sec. 1	F. O. Weeks	Dr	183.3	3.5	S	Sand and gravel	Glacial	Cy, W	N	do	1.1	122.60	9-27-51	
16dd	SE¼ SE¼ sec. 16	Union Pacific Railroad	B	25.0	12	CT	do	Alluvium	Cy, H	S	Top of platform	1.3	9.25	10-9-51	
18ad	SE¼ NE¼ sec. 18	J. M. McGerry	Dr	60.0	6	GI	Limestone	Red Eagle limestone	Cy, W	S	Top of casing	1.4	27.42	10-12-51	
26dd	SE¼ SE¼ sec. 26	August Kramer	Dr	225	6	S	Sand and gravel	Glacial	Cy, W	D, S	....	.....	85	....	Analysis of water is given in table 3.
29cb	NW¼ SW¼ sec. 29	C. D. Weinert	Dr	113.0	6	GI	Limestone	Red Eagle limestone	Cy,W,H	S	Top of casing	1.4	53.88	10-9-51	

1. B, bored; Dr, drilled; Du, dug; DD, dug and drilled.
2. B, brick; C, cement; CT, clay tile; GI, galvanized iron; OB, oil barrel; R, rock; S, steel.
3. Type of pump: C, centrifugal; Cy, cylinder; J, jet; N, none; T, turbine.
   Type of power: E, electric motor; H, hand; T, tractor; W, wind.
4. AC, air conditioning; D, domestic; Ind, industrial; N, none; P, public supply; S, stock.

LOGS OF TEST HOLES

Listed on the following pages are logs of 60 test holes in Marshall County and in the adjoining counties along the county lines. The test holes were drilled by the State Geological Survey in 1949 and 1951. All but one test hole (4-8-25ab) were drilled through the entire thickness of unconsolidated sediments and into the underlying bedrock. In some cases drilling was not continued far enough into the bedrock to permit identification of the bedrock formation, and some of the bedrock identifications thus are doubtful.

1-6-11cb. *Sample log of test hole in the SW cor. NW¼ SW¼ sec. 11, T. 1 S., R. 6 E., 23 feet east of the center of north-south road, center of east-west road; drilled December 1951. Surface altitude, 1,329.0 feet.*

	Thickness, feet	Depth, feet
Road fill	1	1
QUATERNARY—Pleistocene		
Sanborn formation		
Silt and clay, compact, dark-gray	2	3
Silt and clay, compact, tan-gray	4	7
Kansan glacial deposits		
Till, clay, compact, red-brown	6	13
Till, clay, sandy, yellow-brown	3	16
Sand, fine, silty	10	26
Till, clay, light-gray	4.5	30.5
Gravel, very coarse	1	31.5
PERMIAN—Wolfcampian		
Shale, hard, light-gray	2.5	34

1-7-4ab. *Sample log of test hole in the NW¼ NE¼ sec. 4, T. 1 S., R. 7 E., 200 feet east of the half-mile line; drilled December 1951. Surface altitude, 1,347.7 feet.*

	Thickness, feet	Depth, feet
Road fill	3	3
QUATERNARY—Pleistocene		
Sanborn formation		
Silt and clay, calcareous, mottled, tan and brown	4	7
Kansan glacial deposits		
Till, clay, gray; contains some sand and gravel	2.5	9.5
Till, clay, compact, brown	3.5	13
Till, clay, mottled yellow and tan	3	16
Till, compact, tan	11	27
Sand, fine	2	29
Till, clay, gray to gray-green	4	33
Till, clay, sandy, tan	6	39
Gravel; contains some yellow-brown silt	2.5	41.5
Sand, fine; contains some gravel	7.5	49

	Thickness, feet	Depth, feet
Till, clay; contains some sand and gravel	12	61
Sand, very fine, silty	8	69
Till, clay, calcareous, blue-gray	14	83
Till, clay, silty to very silty; contains some sand and gravel	13	96
Sand, fine	20	116
Sand and gravel	2.5	118.5
PERMIAN—Wolfcampian		
Barneston limestone		
Limestone, hard, cherty, yellow-tan	1.5	120

1-7-5cb. *Sample log of test hole in the NW¼ SW¼ sec. 5, T. 1 S., R. 7 E., 10 feet east of road center, 0.35 mile north of SW cor. sec. 5; drilled December 1951. Surface altitude, 1,371.6 feet.*

	Thickness, feet	Depth, feet
Soil, black to dark-gray	2	2
QUATERNARY—Pleistocene		
Kansan glacial deposits		
Till, clay, tan to gray	6	8
Till, clay, compact, gray to brown	6	14
Till, clay, silty; contains some sand and gravel	23	37
Sand, fine; contains some coarse gravel and tan clay	50	87
Till, clay, yellow-brown; contains coarse gravel in thin bands	37	124
Sand, fine to coarse; contains some gravel	22	146
PERMIAN—Wolfcampian		
Barneston limestone		
Limestone, hard, light-tan	4	150

1-7-20cc. *Sample log of test hole in the SW¼ SW¼ sec. 20, T. 1 S., R. 7 E., on north shoulder of road 100 feet east of SW cor. sec. 20; drilled December 1951. Surface altitude, 1,284.4 feet.*

	Thickness, feet	Depth, feet
Road fill	1	1
QUATERNARY—Pleistocene		
Sanborn formation		
Silt and clay, black	1	2
Clay, silty, light-tan	4	6
Clay, silty, red-brown	4	10
Kansan glacial deposits		
Till, clay, light-tan	2	12
Till, clay, tan; contains some gravel	6	18
Sand, fine, silty, gray	12.5	30.5
Till, clay, tan to gray; contains some fine sand	21.5	52
Till, clay, gray; contains some sand and gravel	6	58
Sand and gravel; contains some silt	6	64
PERMIAN—Wolfcampian		
Doyle shale?		
Shale, silty, varicolored	2	66

1-7-21dc. *Sample log of test hole in the SW¼ SE¼ sec. 21, T. 1 S., R. 7 E., on the north shoulder of road 0.3 mile west of the SE cor. sec. 21; drilled December 1951. Surface altitude, 1,230.8 feet.*

	Thickness, feet	Depth, feet
Road fill	1	1
Soil	1	2
QUATERNARY—Pleistocene		
Sanborn formation		
Clay, dark-gray	1.5	3.5
Clay, tan	4.5	8
Clay, silty, red-brown	7	15
Meade formation		
Clay, tan to brown	19	34
Sand, fine to medium, silty	4	38
Sand, fine to coarse; contains some fine gravel	12	50
PERMIAN—Wolfcampian		
Barneston limestone?		
Shale, very limy, tan to buff	2	52

1-7-22dc. *Sample log of test hole in the SW¼ SE¼ sec. 22, T. 1 S., R. 7 E., on north shoulder of road 0.3 mile west of the SE cor. sec. 22; drilled December 1951. Surface altitude, 1,208.1 feet.*

	Thickness, feet	Depth, feet
Road fill	1.5	1.5
QUATERNARY—Pleistocene		
Sanborn formation		
Clay, tan	4.5	6
Clay, silty, red-brown	10.5	16.5
Kansan glacial deposits		
Clay, silty, tan	3.5	20
Clay, gray and tan	5	25
Sand, fine to coarse, and fine to medium gravel	10	35
PERMIAN—Wolfcampian		
Barneston limestone		
Limestone, hard, fossiliferous, gray	0.5	35.5

1-7-23cc. *Sample log of test hole in the SW¼ SW¼ sec. 23, T. 1 S., R. 7 E., on the north shoulder of road, 0.1 mile east of the Blue River bridge; drilled December 1951. Surface altitude, 1,164.5 feet.*

	Thickness, feet	Depth, feet
Road fill	1	1
QUATERNARY—Pleistocene		
Alluvium (Recent)		
Silt and clay, black	2	3
Clay, compact, dark-brown	2	5
Sand, fine silty, gray	7	12
Sand and gravel, fine to coarse; contains some dark-gray silt	20	32
PERMIAN—Wolfcampian		
Matfield shale		
Shale, silty, tan and gray	4	36

1-7-23dd. *Sample log of test hole in the SE¼ SE¼ sec. 23, T. 1 S., R. 7 E., on north shoulder of road, 0.1 mile west of the SE cor. sec. 23; drilled December 1951. Surface altitude, 1,243.1 feet.*

	Thickness, feet	Depth, feet
Road fill	2	2
QUATERNARY—Pleistocene		
Kansan glacial deposits		
Till, clay, gray-brown	6	8
Sand, fine to medium, silty	27	35
Till, clay, red-brown	5	40
Sand, fine to medium	4	44
Sand, fine to coarse	9	53
PERMIAN—Wolfcampian		
Barneston limestone		
Limestone, hard, light-gray	1.5	54.5

1-7-28bb. *Sample log of test hole in the NW¼ NW¼ sec. 28, T. 1 S., R. 7 E., on south shoulder of road, 0.15 mile east of the NW cor. sec. 28; drilled December 1951. Surface altitude, 1,272.0 feet.*

	Thickness, feet	Depth, feet
Road fill	1.5	1.5
QUATERNARY—Pleistocene		
Sanborn formation		
Clay, silty, tan	3.5	5
Clay, silty, red-brown	4.5	9.5
Kansan glacial deposits		
Till, clay, tan	3.5	13
Till, clay, silty, light-gray	2	15
Till, clay; contains much weathered limestone gravel	3	18
Gravel, weathered limestone, and shale; contains some silt and clay	5	23
PERMIAN—Wolfcampian		
Doyle shale		
Shale, silty, red and green	3	26

1-8-28aa. *Sample log of test hole in the NE¼ NE¼ sec. 28, T. 1 S., R. 8 E., on the south shoulder of road, 0.25 mile west of the NE cor. sec. 28; drilled June 1949. Surface altitude, 1,345.5 feet.*

	Thickness, feet	Depth, feet
Road fill	1	1
QUATERNARY—Pleistocene		
Sanborn formation		
Silt and clay, slightly calcareous, gray to tan	3	4
Silt and clay, noncalcareous, brown	7	11
Silt, slightly calcareous, gray	2	13
Kansan glacial deposits		
Till, clay, light-tan	32	45
Till, clay, sandy, tan	3	48

	Thickness, feet	Depth, feet
Till, clay, tan; contains much weathered red and green shale	2	50
PERMIAN—Wolfcampian		
Shale, calcareous, red	4	54
Shale, slightly calcareous, greenish-gray	2	56
Shale, limy, greenish-tan	4	60

1-9-19cd. *Sample log of test hole in the SE¼ SW¼ sec. 19, T. 1 S., R. 9 E., on the north shoulder of road, 15 feet west of half-mile line of sec. 19; drilled June 1949. Surface altitude, 1,423.9 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Sanborn formation		
Silt, black	1.5	1.5
Silt, noncalcareous, gray	4.5	6
Silt and clay, noncalcareous, brown and tan	14	20
Kansan glacial deposits		
Till, clay, sandy, light-tan	12	32
Till, clay, sandy, tan; contains some chert gravel	7	39
Till, clay, tan to brown	4	43
Till, clay, tan; contains some medium gravel	2	45
PERMIAN—Wolfcampian		
Shale, calcareous, tan	5	50

1-9-23dd. *Sample log of test hole in the SE¼ SE¼ sec. 23, T. 1 S., R. 9 E., on west shoulder of road, 100 feet north of the SE cor. sec. 23; drilled July 1949. Surface altitude, 1,416.7 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Kansan glacial deposits		
Till, clay, tan	8	8
PERMIAN—Wolfcampian		
Shale, calcareous, green	3	11
Limestone, gray	1	12

1-9-26bb. *Sample log of test hole in the NW¼ NW¼ sec. 26, T. 1 S., R. 9 E., on the south shoulder of road, 0.2 mile east of the NW cor. sec. 26; drilled June 1949. Surface altitude, 1,487.9 feet.*

	Thickness, feet	Depth, feet
Soil, black	2	2
QUATERNARY—Pleistocene		
Kansan glacial deposits		
Till, clay, gray; contains some fine gravel	5	7
Till, clay, tan to brown	3	10
Till, clay, sandy, tan	3.5	13.5
Till, clay, sandy, tan; contains some fine to coarse gravel	16.5	30
Till, clay, tan; contains considerable medium gravel	40	70
Till, clay, sandy, blue	19	89

	Thickness, feet	Depth, feet
PERMIAN—Wolfcampian		
Limestone, light-gray	0.5	89.5
Shale, calcareous, green	3.5	93
Limestone, light-gray	0.5	93.5

1-9-27bb. *Sample log of test hole in the NW¼ NW¼ sec. 27, T. 1 S., R. 9 E., on the south shoulder of road, 0.2 mile east of the NW cor. sec. 27; drilled July 1949. Surface altitude, 1,452.7 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Sanborn formation		
Silt and clay, noncalcareous, dark-gray	2	2
Silt and clay, noncalcareous, light-gray	4	6
Silt and clay, noncalcareous, tan	4	10
Kansan glacial deposits		
Till, clay, brownish-tan	7	17
Till, clay, sandy, yellow to tan	19	36
Till, clay, tan and gray; contains a little fine gravel	34	70
Gravel, fine to medium; contains some blue clay	7	77
PERMIAN—Wolfcampian		
Limestone, gray	3	80

1-9-28bb. *Sample log of test hole in the NW¼ NW¼ sec. 28, T. 1 S., R. 9 E., on the south shoulder of road, 0.15 mile east of the NW cor. sec. 28; drilled July 1949. Surface altitude, 1,400.3 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Sanborn formation		
Silt, dark-gray	3	3
Silt and clay, noncalcareous, gray	2	5
Kansan glacial deposits		
Till, clay, tan; contains some gravel	8	13
Sand, medium to coarse, and fine gravel	2	15
Till, clay, tan; contains some fine gravel	4	19
Till, clay, tan	12	31
Gravel, fine to medium	4	35
Gravel, medium to coarse	3.5	38.5
PERMIAN—Wolfcampian		
Limestone, gray to tan	1	39.5

1-10-1da. *Sample log of test hole in the NE¼ SE¼ sec. 1, T. 1 S., R. 10 E., on west shoulder of road, 210 feet south of the half-mile line of sec. 1; drilled June 1949. Surface altitude, 1,305.3 feet.*

	Thickness, feet	Depth, feet
Soil, black	2	2
QUATERNARY—Pleistocene		
Kansan glacial deposits		
Till, clay, sandy, tan	1	3
Till, clay, sandy, tan; contains some gravel	25	28
Till, clay, gray	16	44
Till, clay, sandy, blue	27	71

	Thickness, feet	Depth, feet
PERMIAN—Wolfcampian		
Shale, calcareous, dark blue-gray	1	72
Limestone, gray to white	1	73
Shale, calcareous, gray	3	76

1-10-29aa. *Sample log of test hole in the NE¼ NE¼ sec. 29, T. 1 S., R. 10 E., on west shoulder of road, 280 feet south of the NE cor. sec. 29; drilled June 1949. Surface altitude, 1,446.7 feet.*

	Thickness, feet	Depth, feet
Soil, black	2	2
QUATERNARY—Pleistocene		
Kansan glacial deposits		
Till, clay, gray and tan	8	10
Till, clay, tan; contains much gravel	6	16
Till, clay, tan and gray	8	24
Till, clay, sandy, light-tan; contains some medium gravel	9	33
Till, clay, tan	8	41
Till, clay, sandy, gray	29	70
Till, clay, blue	10	80
Till, clay, blue; contains some gravel	9	89
PERMIAN—Wolfcampian		
Limestone, soft, greenish-gray	3	92

1-10-30bb. *Sample log of test hole in the NW¼ NW¼ sec. 30, T. 1 S., R. 10 E., on south shoulder of road, 600 feet east of the NW cor. sec. 30; drilled July 1949. Surface altitude, 1,502.2 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Sanborn formation		
Soil, black	2.5	2.5
Silt and clay, noncalcareous, gray	4.5	7
Silt and clay, noncalcareous, tan	3	10
Kansan glacial deposits		
Till, clay, reddish-tan	12	22
Till, clay, light-tan; contains some gravel	8	30
Till, clay, tan; contains some gravel	49	79
Till, clay, blue; contains some fine gravel	21	100
Till, clay, blue; contains some fine to medium sand	28	128
Gravel, fine to medium	5	133
PERMIAN—Wolfcampian		
Shale, calcareous, gray	2	135

1-11-30cb (Nemaha County). *Sample log of test hole in the NW¼ SW¼ sec. 30, T. 1 S., R. 11 E., on the south shoulder of road, 0.2 mile east of the Cen. W. line sec. 30; drilled June 1949. Surface altitude, 1,355.7 feet.*

	Thickness, feet	Depth, feet
Soil, black	1	1
QUATERNARY—Pleistocene		
Kansan glacial deposits		
Till, clay, dark-tan; contains some gravel	2.5	3.5

	Thickness, feet	Depth, feet
Till, clay, tan; contains some gravel	9.5	13
Till, clay, light-gray	3	16
Till, clay, gray and tan; contains some medium gravel,	11	27
Till, clay, light-gray; contains some gravel	11	38
Till, clay, sandy, tan and gray; contains some medium gravel	3	41
Gravel, fine to medium	9	50
Till, clay, sandy, tan	13	63
Till, clay, blue	7	70
Till, clay, sandy, blue; contains much medium gravel	27	97
PERMIAN—Wolfcampian		
Limestone, very hard, dark-gray	2	99

2-7-15ba. *Sample log of test hole in the NE¼ NW¼ sec. 15, T. 2 S., R. 7 E., 20 feet south of road center, 0.25 mile east of the NW cor. sec. 15; drilled December 1951. Surface altitude, 1,255.9 feet.*

	Thickness, feet	Depth, feet
Soil, black	1.5	1.5
QUATERNARY—Pleistocene		
Kansan glacial deposits		
Clay, silty, gray to brown	2.5	4
Till, clay, tan	2.5	6.5
Sand, fine to medium; contains some yellow-brown silt,	10.5	17
Till, clay, compact, dark-brown	5	22
Till, clay, sandy, tan and yellow	7.5	29.5
Till, clay, silty, green, yellow, and red	4	33.5
Till, clay, red and green	3.5	37
Sand and gravel	12.5	49.5
PERMIAN—Wolfcampian		
Barneston limestone		
Limestone, very hard	0.5	50

2-7-35da. *Sample log of test hole in the NE¼ SE¼ sec. 35, T. 2 S., R. 7 E., 12 feet west of road center, 0.1 mile south of half-mile line; drilled December 1951. Surface altitude, 1,246.6 feet.*

	Thickness, feet	Depth, feet
Road fill	1	1
QUATERNARY—Pleistocene		
Kansan glacial deposits		
Till, clay, compact, dark-gray	1	2
Till, clay, silty, tan and gray	5	7
Till, clay, red-brown	5	12
Till, clay, sandy to very sandy, red-brown; contains some coarse sand and fine gravel	5	17
Till, clay, sandy, gray	2	19
Sand, fine, silty, gray	16	35
Sand, fine to medium, silty, yellow-tan	15.5	50.5
PERMIAN—Wolfcampian		
Barneston limestone		
Limestone, finely crystalline, hard, light-gray	0.5	51

2-9-25dd. *Sample log of test hole in the SE¼ SE¼ sec. 25, T. 2 S., R. 9 E., on west shoulder of road, 0.1 mile north of SE cor. sec. 25; drilled June 1949. Surface altitude, 1,373.8 feet.*

	Thickness, feet	Depth, feet
Soil, brown	3	3
QUATERNARY—Pleistocene		
Kansan glacial deposits		
Till, clay, tan	3	6
Till, clay, tan; contains some fine gravel	30	36
PERMIAN—Wolfcampian		
Limestone	0.5	36.5

2-10-25dd. *Sample log of test hole in the SE¼ SE¼ sec. 25, T. 2 S., R. 10 E., on west road shoulder 30 feet north of U. S. Highway 36; drilled June 1949. Surface altitude, 1,334.0 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Sanborn formation		
Soil, black	1	1
Silt and clay, gray to tan	3	4
Kansan glacial deposits		
Till, clay, slightly sandy, reddish-tan	3	7
Till, clay, sandy, tan	3	10
Till, clay, tan; contains some gravel	8	18
Gravel, medium to coarse	8	26
Sand, coarse; contains some light-tan clay	3	29
Till, clay, brown and tan; contains much chert gravel	3	32
Till, clay, gray and tan	3	35
Till, clay, tan; contains some gravel	11	46
Gravel, medium, and angular chert	2	48
Till, clay, tan; contains some gravel	2	50
Till, clay, tan	15	65
Till, clay, sandy, tan and gray	3	68
PERMIAN—Wolfcampian		
Limestone, very hard, blue-gray	2	70

2-10-29dd. *Sample log of test hole in the SE¼ SE¼ sec. 29, T. 2 S., R. 10 E., in southwest corner of school yard, 350 feet west of the SE cor. sec. 29; drilled June 1949. Surface altitude, 1,385.1 feet.*

	Thickness, feet	Depth, feet
Road fill	3	3
QUATERNARY—Pleistocene		
Kansan glacial deposits		
Till, clay, tan-brown; contains some gravel	2	5
Till, clay, tan; contains some gravel	8.5	13.5
Till, clay, tan	6.5	20
Till, clay, greenish-tan	7	27
Till, clay, tan; contains some gravel	3	30
Till, clay, sandy, tan	28	58

	Thickness, feet	Depth, feet
Sand, coarse, and medium to coarse gravel	6.5	64.5
Till, clay, tan	5.5	70
Till, clay, blue	3	73
Gravel, medium to coarse	3	76
Sand, coarse	4	80
Till, clay, blue	22	102
PERMIAN—Wolfcampian		
Shale, calcareous, gray-green	10	112

2-11-6cc (Nemaha County). *Sample log of test hole in the SW¼ SW¼ sec. 6, T. 2 S., R. 11 E., on east shoulder of road, 150 feet north of the SW cor. sec. 6; drilled June 1949. Surface altitude, 1,338.0 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Sanborn formation		
Silt, noncalcareous, light-tan	4	4
Kansan glacial deposits		
Till, clay, reddish-brown; contains some coarse to fine gravel	8	12
Till, clay, light-gray; contains some fine gravel	5	17
Till, clay, sandy, tan	6	23
Till, clay, tan; contains some fine gravel	5	28
Sand, medium to coarse, and fine to medium gravel	10	38
Sand, fine to medium	29	67
Till, clay, blue	17	84
PERMIAN—Wolfcampian		
Shale, noncalcareous, tan	3	87

3-7-14cb. *Sample log of test hole in the NW¼ SW¼ sec. 14, T. 3 S., R. 7 E., 0.35 mile north of the SW cor. sec. 14; drilled November 1951. Surface altitude, 1,346.4 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Kansan glacial deposits		
Silt and clay, black to dark-gray	3	3
Clay, silty, gray to tan	3	6
Till, clay, silty, mottled brown and red-brown	3.5	9.5
Till, clay, yellow and brown	7.5	17
Sand, fine to coarse, and fine gravel; contains some clay	2.5	19.5
Till, clay, silty, tan to yellow	14.5	34
Sand, very fine; contains a few coarse sand grains and much yellow clay	17	51
Sand, medium to coarse, and fine gravel; contains much clay	6	57
PERMIAN—Wolfcampian		
Doyle shale		
Shale, varicolored, red and green	3	60

3-7-19dc. *Sample log of test hole in the SW¼ SE¼ sec. 19, T. 3 S., R. 7 E., on south shoulder of road, 100 feet west of Union Pacific Railroad track; drilled November 1951. Surface altitude, 1,131.8 feet.*

	Thickness, feet	Depth, feet
Road fill	4	4
QUATERNARY—Pleistocene		
Alluvium (Recent)		
Clay, compact, gray	4.5	8.5
Silt and clay, gray	10.5	19
Sand, very fine, silty	5	24
Sand, fine to coarse; contains some fine to medium gravel	20.5	44.5
PERMIAN—Wolfcampian		
Crouse limestone?		
Limestone, crystalline, gray	1	45.5

3-7-25bb. *Sample log of test hole in the NW¼ NW¼ sec. 25, T. 3 S., R. 7 E., on south shoulder of road, 40 feet east of the NW cor. sec. 25; drilled November 1951. Surface altitude, 1,296.6 feet.*

	Thickness, feet	Depth, feet
Soil and road fill	3	3
QUATERNARY—Pleistocene		
Sanborn formation		
Clay, mottled gray and yellow	3	6
Clay, silty, red-brown	5	11
Kansan glacial deposits		
Till, clay, tan	27	38
Till, clay, sandy, dark-brown	3	41
Till, clay, brown; contains much coarse sand	2	43
PERMIAN—Wolfcampian		
Matfield shale?		
Limestone, hard, light-tan	3	46

3-7-30ba. *Sample log of test hole in the NE¼ NW¼ sec. 30, T. 3 S., R. 7 E., on south shoulder of road, 500 feet west of west end of Blue River bridge; drilled November 1951. Surface altitude, 1,128.1 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Alluvium (Recent)		
Silt and clay, black	5.5	5.5
Sand, fine to coarse, and fine to coarse gravel	30	35.5
PERMIAN—Wolfcampian		
Crouse limestone?		
Limestone, crystalline, hard, gray to tan	1	36.5

3-8-15bc. *Sample log of test hole in the SW¼ NW¼ sec. 15, T. 3 S., R. 8 E., on east shoulder of road, 160 feet north of the Cen. W. line sec. 15; drilled November 1951. Surface altitude, 1,320.9 feet.*

	Thickness, feet	Depth, feet
Road fill	1	1
QUATERNARY—Pleistocene		
Kansan glacial deposits		
Till, clay, gray	2	3
Till, clay, silty, red-brown	4	7
Till, clay, brown; contains some sand and gravel	12	19
Till, clay, sandy brown; contains some gravel	43	62
Till, clay, tan	17	79
Atchison formation		
Sand, fine, silty	84	163
PERMIAN—Wolfcampian		
Shale, calcareous, silty, light-gray	3	166

3-8-25ba. *Sample log of test hole in the NE¼ NW¼ sec. 25, T. 3 S., R. 8 E., on south shoulder of road, 200 feet west of the half-mile line; drilled December 1951. Surface altitude, 1,204.1 feet.*

	Thickness, feet	Depth, feet
Road fill	2	2
QUATERNARY—Pleistocene		
Undifferentiated terrace deposits		
Clay, sandy, tan-brown	5	7
Sand, clayey, tan; contains some fine to coarse sand	2	9
Clay, sandy to silty, tan-green; contains some coarse sand and fine to medium gravel	1.5	10.5
Sand and gravel, fine to coarse; contains some silt and clay	15.5	26
Atchison formation		
Sand, fine, silty	44	70
Sand, fine, silty, gray; contains some clay	41.5	111.5
PERMIAN—Wolfcampian		
Shale, silty, calcareous, tan and gray	2.5	114

3-8-28ba. *Sample log of test hole in the NE¼ NW¼ sec. 28, T. 3 S., R. 8 E., on south shoulder of road, 300 feet west of the half-mile line; drilled November 1951. Surface altitude, 1,327.3 feet.*

	Thickness, feet	Depth, feet
Road fill	2	2
QUATERNARY—Pleistocene		
Kansan glacial deposits		
Till, clay, yellow and brown	17	19
Till, clay, sandy; contains some chert gravel	12	31
Till, clay, gray; contains some coarse sand	5	36
PERMIAN—Wolfcampian		
Matfield shale		
Shale, silty, red and green	4	40

3-8-30ab. *Sample log of test hole in the NW¼ NE¼ sec. 30, T. 3 S., R. 8 E., on south shoulder of road, 0.4 mile west of the NE cor. sec. 30; drilled November 1951. Surface altitude, 1,324.3 feet.*

	Thickness, feet	Depth, feet
Silt and clay (road fill and colluvium)	8	8
QUATERNARY—Pleistocene		
Kansan glacial deposits		
Till, clay, compact, brown	3	11
Till, clay, tan; contains some sand and gravel	28.5	39.5
Sand, fine to coarse	1	40.5
Sand and gravel, fine to coarse; contains some tan clay,	3	43.5
PERMIAN—Wolfcampian		
Limestone, tan	3.5	47

3-9-19cd. *Sample log of test hole in the SE¼ SW¼ sec. 19, T. 3 S., R. 9 E., on north shoulder of road, 500 feet west of the half-mile line; drilled December 1951. Surface altitude, 1,176.3 feet.*

	Thickness, feet	Depth, feet
Road fill	4.5	4.5
QUATERNARY—Pleistocene		
Alluvium (Recent)		
Clay, compact, tan	13.5	18
Silt and clay, sandy, gray	5	23
Clay, compact, gray-green	10	33
Gravel and sand; composed largely of limestone and chert	4	37
Atchison formation		
Sand, fine, silty	41.5	78.5
PERMIAN—Wolfcampian		
Shale, silty, gray	5.5	84

3-9-20cc. *Sample log of test hole in the SW¼ SW¼ sec. 20, T. 3 S., R. 9 E., on east shoulder of road, 100 feet north of the SW cor. sec. 20; drilled December 1951. Surface altitude, 1,221.8 feet.*

	Thickness, feet	Depth, feet
Road fill	2.5	2.5
QUATERNARY—Pleistocene		
Undifferentiated terrace deposits		
Clay, silty, red-brown	9.5	12
Clay, silty, gray-green	2.5	14.5
Sand and gravel; contains some red silt	6.5	21
Clay, compact, tan to gray	14	35
Clay, gray to tan; contains some gravel	3	38
Sand and gravel; contains some clay	5	43
Atchison formation		
Sand, fine, silty	115	158
PERMIAN—Wolfcampian		
Limestone, hard, tan to yellow	2	160

3-9-26aa. *Sample log of test hole in the NE¼ NE¼ sec. 26, T. 3 S., R. 9 E., on the south shoulder of road, 270 feet west of the NE cor. sec. 26; drilled November 1951. Surface altitude, 1,341.1 feet.*

	Thickness, feet	Depth, feet
Road fill	1.5	1.5
QUARTERNARY—Pleistocene		
Kansan glacial deposits		
Till, clay, brown	2.5	4
Till, clay, tan to yellow; contains some gravel	13.5	17.5
Till, clay, gray to tan	9.5	27
Till, clay, yellow-brown; contains some gravel	13	40
Till, clay, gray to yellow	28.5	68.5
Sand, fine to coarse; contains some fine to medium gravel	10.5	79
Atchison formation		
Sand, fine; contains some silt	57	136
Sand and clay, silty	23	159
Clay, silty, gray	3	162
Sand, fine, silty	6	168
Clay, silty and sandy, gray	14	182
Pre-Kansan deposits		
Sand and gravel; composed mostly of chert	7.5	189.5
PERMIAN—Wolfcampian		
Shale, weathered, silty and sandy, green and tan	14.5	204
Shale, silty, gray	4	208

3-9-28ab. *Sample log of test hole in the NW¼ NE¼ sec. 28, T. 3 S., R. 9 E., on south shoulder of road, 500 feet east of the half-mile line; drilled November 1951. Surface altitude, 1,290.3 feet.*

	Thickness, feet	Depth, feet
Road fill	1.5	1.5
QUATERNARY—Pleistocene		
Kansan glacial deposits		
Till, clay, tan	3.5	5
Till, clay, tan and brown; contains some gravel	32	37
Till, clay, sandy; contains some gravel	11	48
Sand, fine	5	53
Till, clay, gray	5	58
Till, clay, blue-gray	18	76
Atchison formation		
Sand, fine, silty	55.5	131.5
Clay, silty and sandy; contains some gravel	10.5	142
PERMIAN—Wolfcampian		
Limestone, hard, light-gray	1	143
Shale, black	2	145
Shale, silty, gray to green	4	149

3-10-20dd. *Sample log of test hole in the SE¼ SE¼ sec. 20, T. 3 S., R. 10 E., on north shoulder of road, 0.1 mile west of SE cor. sec. 20; drilled November 1951. Surface altitude, 1,305.9 feet.*

	Thickness, feet	Depth, feet
Road fill	1.5	1.5
QUATERNARY—Pleistocene		
Kansan glacial deposits		
Till, clay, silty, tan to gray	2	3.5
Till, clay, silty, brown	4.5	8
Till, clay, yellow-brown	22	30
Till, clay, silty, brown	87	117
Atchison formation		
Sand, very fine; contains some silt	24	141
PERMIAN—Wolfcampian		
Limestone, very hard, light-gray	4.5	145.5

3-10-22dd. *Sample log of test hole in the SE¼ SE¼ sec. 22, T. 3 S., R. 10 E., on north shoulder of road, 0.1 mile west of SE cor. sec. 22; drilled November 1951. Surface altitude, 1,247.9 feet.*

	Thickness, feet	Depth, feet
Road fill	1.5	1.5
QUATERNARY—Pleistocene		
Kansan glacial deposits		
Till, clay, silty, tan to brown	7.5	9
Till, clay, sandy, tan	8	17
Sand, medium to fine; contains some silt	5	22
Till, clay, sandy, tan to gray	10	32
Sand, fine to medium; contains some silt and some fine gravel	12	44
Till, clay, tan; contains some gravel	9	53
Till, clay, silty, gray	3	56
Till, clay, gray; contains some sand and silt	57	113
Pre-Kansan deposits		
Sand, gravel, chert, and weathered limestone	11.5	124.5
PERMIAN—Wolfcampian		
Limestone, light-gray	0.5	125

3-11-18cc. *Sample log of test hole in the SW¼ SW¼ sec. 18, T. 3 S., R. 11 E., on east shoulder of road, 550 feet north of SW cor. sec. 18; drilled June 1949. Surface altitude, 1,234.6 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Kansan glacial deposits		
Till, clay and silt, red-tan; contains some coarse sand	4.5	4.5
Till, clay, tan	9.5	14
Till, clay, sandy, tan	23	37
Gravel, fine, angular quartz	3	40
Gravel, medium to fine	7	47
Till, clay, blue	2	49

	Thickness, feet	Depth, feet
PENNSYLVANIAN—Virgilian		
Limestone, gray	1.5	50.5
Shale, noncalcareous, blue	3.5	54
Shale, calcareous, gray-green and red	3	57
Shale, calcareous, red	3	60
Shale, noncalcareous, red and gray-green	8	68
Shale, noncalcareous, red	2	70

4-6-20ba. *Sample log of test hole in the NE¼ NW¼ sec. 20, T. 4 S., R. 6 E., on the west shoulder of road, 132 feet south of the Cen. N. line sec. 20; drilled November 1951. Surface altitude, 1,208.6 feet.*

	Thickness, feet	Depth, feet
Soil	1	1
QUARTERNARY—Pleistocene		
Undifferentiated terrace deposits		
Clay, silty, tan to gray	3.5	4.5
Sand, fine to coarse; contains much red clay	3	7.5
Sand, fine to coarse; contains some fine gravel	4.5	12
Sand, fine to coarse; contains some fine gravel and stringers of clay	14	26
Sand, fine to coarse	37	63
PERMIAN—Wolfcampian		
Matfield shale?		
Shale, silty, varicolored	4	67
Limestone, very hard	0.5	67.5

4-6-24da. *Sample log of test hole in the NE¼ SE¼ sec. 24, T. 4 S., R. 6 E., in pasture 60 feet west of the center line of the road, 0.2 mile south of the half-mile line; drilled November 1951. Surface altitude, 1,155.9 feet.*

	Thickness, feet	Depth, feet
Soil	3.5	3.5
QUATERNARY—Pleistocene		
Undifferentiated terrace deposits		
Clay, silty, tan; contains some coarse sand	2.5	6
Sand, fine to coarse, and fine to medium gravel	1.5	7.5
Clay, sandy, greenish-tan; contains some gravel	3	10.5
PERMIAN—Wolfcampian		
Easly Creek shale?		
Shale, silty, tan to gray	3	13.5
Limestone, hard, tan	0.5	14

4-6-24dd. *Sample log of test hole in the SE¼ SE¼ sec. 24, T. 4 S., R. 6 E., in pasture 25 feet west of center line of road, 85 feet north of the SE cor. sec. 24; drilled November 1951. Surface altitude, 1,168.2 feet.*

	Thickness, feet	Depth, feet
Soil, black	2	2
QUATERNARY—Pleistocene		
Meade formation		
Clay, compact, tan to gray	3.5	5.5

	Thickness, feet	Depth, feet
Silty, sandy, red-brown	3	8.5
Clay, sandy, red-brown	6	14.5
Sand and gravel, fine to coarse; contains some silt	20.5	35
Sand, fine to coarse	18	53
PERMIAN—Wolfcampian		
Bader limestone?		
Limestone, medium hard, light-gray	0.5	53.5

4-7-19bb. *Sample log of test hole in the NW¼ NW¼ sec. 19, T. 4 S., R. 7 E., about 450 feet west of the SE cor. NW¼ NW¼ sec. 19; drilled November 1951. Surface altitude, 1,116.2 feet.*

	Thickness, feet	Depth, feet
Soil, very sandy	3	3
QUATERNARY—Pleistocene		
Alluvium (Recent)		
Sand, fine	4	7
Sand, fine to coarse, and fine to medium gravel	20	27
Sand, fine to coarse; contains some silt and clay	5	32
PERMIAN—Wolfcampian		
Stearns shale?		
Shale, silty, red and green	3.5	35.5
Limestone, impure, tan; some interbedded shale	5	40.5
Limestone, shaly, gray	2	42.5

4-7-30bc. *Sample log of test hole in the SW¼ NW¼ sec. 30, T. 4 S., R. 7 E., on east shoulder of road, 500 feet north of Missouri Pacific railroad track; drilled November 1951. Surface altitude, 1,168.0 feet.*

	Thickness, feet	Depth, feet
Road fill	2	2
QUATERNARY—Pleistocene		
Meade formation		
Clay, compact, gray-brown	5	7
Clay, silty, tan	2.5	9.5
Silt, sandy, tan; contains some gravel	14.5	24
Sand and gravel, fine to coarse; contains some yellow silt	25.5	49.5
PERMIAN—Wolfcampian		
Bader limestone?		
Shale, varicolored	6.5	56
Limestone, hard	1	57

4-8-25ab. *Sample log of test hole in the NW¼ NE¼ sec. 25, T. 4 S., R. 8 E., on east shoulder of road, 30 feet south of the Cen. N. line sec. 25; drilled November 1951. Surface altitude, 1,203.0 feet.*

	Thickness, feet	Depth, feet
Soil, silty, black	1.5	1.5
QUATERNARY—Pleistocene		
Kansan glacial deposits		
Till, clay, gray	3.5	5

	Thickness, feet	Depth, feet
Till, clay, brown	4.5	9.5
Till, clay, sandy, gray	20.5	30
Till, clay, tan to gray; contains some fine to coarse sand	18	48
Till, clay, gray	22	70

4-8-36bb. *Sample log of test hole in the NW¼ NW¼ sec. 36, T. 4 S., R. 8 E., on road 20 feet south of the NW cor. sec. 36; drilled November 1951. Surface altitude, 1,170.9 feet.*

	Thickness, feet	Depth, feet
Soil, black	2	2
QUATERNARY—Pleistocene		
Undifferentiated terrace deposits		
Clay, silty, brown	2	4
Clay, silty, red-brown	4	8
Sand, silty, very fine	16.5	24.5
Sand, fine to medium	25.5	50
Sand, medium; contains some tan clay	8	58
PERMIAN—Wolfcampian		
Grenola limestone		
Shale, platy, black	6	64
Limestone, hard, gray	0.5	64.5

4-8-36cc. *Sample log of test hole in the SW cor. Sec. 63, T. 4 S., R. 8 E.; drilled November 1951. Surface altitude, 1,112.8 feet.*

	Thickness, feet	Depth, feet
Soil, black	3	3
QUATERNARY—Pleistocene		
Alluvium (Recent)		
Clay, tan to brown	9	12
Silt and clay, tan	14	26
Sand, fine to medium	9	35
Sand, coarse to fine, and fine gravel	6	41
PERMIAN—Wolfcampian		
Johnson shale?		
Shale, silty to sandy, gray	5.5	46.5

4-9-11bb. *Sample log of test hole in the NW¼ NW¼ sec. 11, T. 4 S., R. 9 E., on east shoulder of road 0.25 mile south of the NW cor. sec. 11; drilled November 1951. Surface altitude, 1,252.2 feet.*

	Thickness, feet	Depth, feet
Soil, black	1.5	1.5
QUATERNARY—Pleistocene		
Kansan glacial deposits		
Till, clay, brown	5	6.5
Till, clay, yellow	5.5	12
Till, clay, gray; contains some gravel	36.5	48.5
Till, clay, gray	2.5	51
Atchison formation		
Sand, fine to very fine; contains some gray silt	122	173

	Thickness, feet	Depth, feet
Pre-Kansan deposits		
Sand and gravel, medium to coarse; composed chiefly of chert and limestone	22	195
PERMIAN—Wolfcampian		
Shale, silty, gray	5	200

4-10-1ad. *Sample log of test hole in the SE¼ NE¼ sec. 1, T. 4 S., R. 10 E., on west shoulder of road, 0.3 mile south of the NE cor. sec. 1; drilled June 1949. Surface altitude, 1,337.5 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Sanborn formation		
Silt and clay, noncalcareous, dark-gray to tan	5	5
Kansan glacial deposits		
Till, clay, tan; contains some coarse sand	3	8
Till, clay, tan; contains some medium gravel	40	48
Gravel, medium to fine	5	53
Till, clay, tan; contains some fine gravel	7	60
Till, clay, sandy, tan	9	69
Till, clay, bluish-gray	21	90
Till, clay, blue; contains much gravel	5	95
PERMIAN—Wolfcampian		
Shale, calcareous, red	5	100
Shale, calcareous, sandy, tan	3.5	103.5
Limestone, gray	1	104.5
Shale, calcareous, greenish-gray	23.5	128
Limestone, gray	0.5	128.5
Shale, calcareous, greenish-gray	1.5	130

4-10-16aa. *Sample log of test hole in the NE¼ NE¼ sec. 16, T. 4 S., R. 10 E., 100 feet south of the NE cor. sec. 16; drilled November 1951. Surface altitude, 1,239.2 feet.*

	Thickness, feet	Depth, feet
Road fill	1	1
QUARTERNARY—Pleistocene		
Kansan glacial deposits		
Silt, clayey, brown	6	7
Silt and clay, yellow-brown; contains some fine sand	3	10
Atchison formation		
Sand, very fine, silty	40	50
Sand, very fine	20	70
Sand, very fine; contains some yellow-brown and gray-green silt	19	89
Clay, silty, very soft, gray	12.5	101.5
Sand, very fine, silty, gray	82.5	184
Pre-Kansan desposits		
Sand and gravel; composed of chert, weathered limestone, and shale; contains very little clay	14	198
PENNSYLVANIAN—Virgilian		
Shale, silty, gray to dark-gray	2	200

4-10-25dd. *Sample log of test hole in the SE¼ SE¼ sec. 25, T. 4 S., R. 10 E., on west shoulder of road, 330 feet north of SE cor. sec. 25; drilled May 1949. Surface altitude, 1,358.7 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Kansan glacial deposits		
Till, clay, brown; contains some gravel	1.5	1.5
Till, clay, tan and brown	3.5	5
Till, clay, sandy, tan; contains some gravel	19	24
Till, clay, light-tan; contains some fine to medium gravel	24.5	48.5
Gravel, fine to medium	2.5	51
Till, clay, reddish-tan; contains some gravel	7	58
Till, clay, sandy, light-tan	3	61
Till, clay, blue	19	80
Till, clay, sandy, blue-gray; contains a few fine gravel,	10	90
Till, clay, blue-gray; contains much very fine sand	10	100
Till, sandy, blue-gray; contains much fine gravel	225	325
Pre-Kansan deposits		
Gravel, medium to coarse, chert and limestone; contains some blue clay	5	330
Clay, blue-gray; contains much angular chert gravel	5	335
PENNSYLVANIAN—Virgilian		
Coal	2	337
Shale, calcareous, sandy, dark-gray	3	340

4-10-27cd. *Sample log of test hole in the SE¼ SW¼ sec. 27, T. 4 S., R. 10 E., on north shoulder of road, 175 feet west of the Cen. S. line sec. 27; drilled June 1949. Surface altitude, 1,371.0 feet.*

	Thickness, feet	Depth, feet
Road fill	1	1
QUATERNARY—Pleistocene		
Kansan glacial deposits		
Till, clay, sandy, reddish-tan	4	5
Till, clay, sandy, tan	42	47
Till, clay, sandy, gray	6	53
Till, clay, tan; contains some gravel	12	65
Till, clay, tan to bluish-tan	7	72
Sand, coarse, and fine to medium gravel	4	76
Till, clay, sandy, tan	14	90
Gravel, fine, mixed with blue clay	10	100
Till, clay, sandy, tan	40	140
Till, clay, sandy, blue; contains some medium gravel	46	186
Till, clay, sandy, blue	24	210
Till, clay, sandy, blue; contains much medium gravel	10	220
Sand, fine	16	236
Till, clay, blue	4	240
Gravel, medium to fine, and some coarse sand	4	244
Till, clay, blue	56	300

	Thickness, feet	Depth, feet
PENNSYLVANIAN—Virgilian		
Limestone, gray	0.5	300.5
Shale, calcareous, blue	24.5	325
Limestone, blue-gray	0.5	325.5

4-10-29dc. *Sample log of test hole in the SW¼ SE¼ sec. 29, T. 4 S., R. 10 E., on north shoulder of road, 300 feet east of the Cen. S. line sec. 29; drilled June 1949. Surface altitude, 1332.5 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Sanborn formation		
Silt and clay, noncalcareous, brownish-tan	4	4
Kansan glacial deposits		
Till, clay, reddish-tan	3	7
Till, clay, tan; contains some coarse gravel	15	22
Till, clay, tan; contains thin sandy streaks	15	37
Till, clay, tan; contains some fine to medium gravel	11	48
Till, clay, blue; contains some medium gravel	45	93
Till, clay, bluish-gray; contains much fine gravel	22	115
Till, clay, sandy, bluish-gray; contains some medium gravel	25	140
Till, clay, gray-green	10	150
PERMIAN—Wolfcampian		
Shale, noncalcareous, blue	15	165
Shale, calcareous, sandy, gray	15	180

5-8-3dc. *Sample log of test hole in the SW¼ SE¼ sec. 3, T. 5 S., R. 8 E., center of road right-of-way, 90 feet east of the Cen. S. line sec. 3; drilled November 1951. Surface altitude, 1,114.8 feet.*

	Thickness, feet	Depth, feet
Soil, black	3	3
QUARTERNARY—Pleistocene		
Alluvium (Recent)		
Silt, very clayey, tan to brown	4	7
Clay, compact, tan-brown	2	9
Silt, clayey, tan	3	12
Silt and very fine sand, tan to gray	16	28
Clay, silty, dark-gray	5	33
Sand, coarse to fine	6	39
Gravel, fine to coarse; composed of weathered limestone and shale with a little chert	2	41
PERMIAN—Wolfcampian		
Roca shale		
Shale, weathered, calcareous, light-gray	2.5	43.5
Shale, silty, medium hard, red-brown, green, and tan	2.5	46

5-8-17bc. *Sample log of test hole in the SW¼ NW¼ sec. 17, T. 5 S., R. 8 E., about 50 feet east of the center line of State Highway 13, 70 feet south of the Missouri Pacific railroad track; drilled November 1951. Surface altitude, 1,135.0 feet.*

	Thickness, feet	Depth, feet
Soil	3	3
QUATERNARY—Pleistocene		
Undifferentiated terrace deposits		
Clay, silty, tan	2.5	5.5
Sand, fine to medium; contains some brown silt	3	8.5
Clay, silty, dark-brown	17	25.5
Sand and gravel, fine to coarse; contains some silt	41.5	67
PERMIAN—Wolfcampian		
Grenola limestone?		
Limestone, hard, light-gray	1	68

5-8-17cc. *Sample log of test hole in SW¼ SW¼ sec. 17, T. 5 S., R. 8 E., on north shoulder of road, 100 feet east of the SW cor. sec. 17; drilled November 1951. Surface altitude, 1,113.3 feet.*

	Thickness, feet	Depth, feet
Road fill and soil	4	4
QUATERNARY—Pleistocene		
Undifferentiated terrace deposits		
Clay, silty, gray	6	10
Clay, sandy and silty, gray	5	15
Sand, fine to coarse; contains some yellow clay	20	35
Sand and gravel, fine to coarse; contains some silt and clay	41	76
PERMIAN—Wolfcampian		
Red Eagle limestone?		
Limestone, hard, light-tan	2	78

5-8-20cc. *Sample log of test hole in the SW¼ SW¼ sec. 20, T. 5 S., R. 8 E., on east shoulder of road, 70 feet north of the SW cor. sec. 20; drilled November 1951. Surface altitude, 1,088.8 feet.*

	Thickness, feet	Depth, feet
Soil, silt and clay, black	2.5	2.5
QUATERNARY—Pleistocene		
Alluvium (Recent)		
Clay, silty, tan-brown	21.5	24
Clay, compact, gray to black	8.5	32.5
Sand, fine to coarse; contains some yellow silt	13.5	46
Sand, fine to coarse	7.5	53.5
PERMIAN—Wolfcampian		
Red Eagle limestone?		
Limestone, hard, gray	1	54.5

5-8-29cc. *Sample log of test hole in the SW¼ SW¼ sec. 29, T. 5 S., R. 8 E., on east shoulder of road, 150 feet north of the Black Vermillion bridge; drilled November 1951. Surface altitude, 1,090.2 feet.*

	Thickness, feet	Depth, feet
QUATERNARY—Pleistocene		
Alluvium (Recent)		
Silt, black	4	4
Silt, clayey, black; contains some gravel	21	25
Sand, fine to coarse, and fine gravel	6	31
Sand and gravel, fine to coarse; contains some silt	15	46
PERMIAN—Wolfcampian		
Red Eagle limestone?		
Limestone, hard, light-gray	1	47

5-11-30bb (Nemaha County). *Sample log of test hole in the NW¼ NW¼ sec. 30, T. 5 S., R. 11 E., on south shoulder of road, 50 feet east of the NW cor. sec. 30; drilled June 1949. Surface altitude, 1,292.2 feet.*

	Thickness, feet	Depth feet
QUATERNARY—Pleistocene		
Sanborn formation		
Silt, noncalcareous, dark-gray	3	3
Kansan glacial deposits		
Till, clay, sandy, dark-tan	3	6
Till, clay, light-tan; contains some coarse gravel	9	15
Till, clay, sandy, tan	3	18
Till, clay, tan	17	35
Gravel, coarse to medium	1	36
Sand, fine to medium	19	55
Till, clay, sandy, blue-gray	16	71
Till, clay, greenish-blue	4	75
Till, clay, silty, light-brown	16	91
Till, clay, dark-gray	9	100
PENNSYLVANIAN—Virgilian		
Shale, black	2	102
Limestone, gray	1	103
Shale, calcareous, micaceous, black	7	110
Shale, calcareous, sandy, gray	7.5	117.5
Limestone, dark-gray, and greenish-gray shale	1.5	119

MEASURED STRATIGRAPHIC SECTIONS

Nine stratigraphic sections were measured in December 1951 by field parties under the supervision of Frank E. Byrne of the United States Geological Survey. The field parties were composed of the individuals mentioned in the headings of the sections.

Section measured in stream bank in the SE¼ NE¼ SE¼ sec. 1, T. 2 S., R. 6 E., west side of the road, 1.35 miles north and 1.3 miles east of Herkimer, Kansas. Measured by M. E. Davis and G. E. Randolph.

	Thickness, feet
PERMIAN—Wolfcampian	
Doyle shale (22.0 feet exposed)	
Towanda limestone member (3.1 feet exposed)	
10. Limestone, soft, thick-bedded, tan-gray; weathers slabby to platy, tan, pitted; contains calcareous geodes	1.8
9. Limestone, thick-bedded, tan-gray; weathers platy, tan, pitted; contains calcareous geodes	1.3
Holmesville shale member (18.9 feet)	
8. Shale, silty, calcareous, thin-bedded, light gray-brown; weathers blocky, light gray-green; contains limonitic seams	2.2
7. Shale, silty, calcareous, limonitic, hard, thick-bedded, light-gray; weathers blocky, tan-gray	0.4
6. Shale, silty to clayey, calcareous, limonitic, thick-bedded, gray-green; weathers blocky, light-green	0.9
5. Shale, silty, slightly calcareous, thin-bedded, red-brown; weathers tan-gray	1.1
4. Shale, silty, calcareous, thick-bedded, light gray-green; weathers blocky	1.2
3. Shale, silty, calcareous, thick-bedded, maroon; weathers blocky, gray-maroon	4.5
2. Limestone, limonitic, thick-bedded, tan-gray; weathers blocky, light-gray; forms minor bench	1.3
1. Shale, silty, calcareous, thick-bedded, mottled maroon, green, and tan; weathers blocky, light-gray; contains thin lentils of limestone	7.3
Barneston limestone—Fort Riley limestone member	

Section measured in stream cut in the SW¼ sec. 10, T. 2 S., R. 6 E., 2 miles east and 0.75 mile south of Bremen on east side of bridge. Measured by M. E. Davis and G. E. Randolph.

	Thickness, feet
PERMIAN—Wolfcampian	
Winfield limestone (19.8 feet exposed)	
Cresswell limestone member (2.6 feet exposed)	
14. Limestone, soft, massive, tan-gray; weathers tan to red-brown, pitted; contains small quartz geodes; forms hillside bench	2.6
Grant shale member (16.0 feet)	
13. Shale, silty, calcareous, thin-bedded, tan; weathers blocky, tan-gray; contains carbon stains and quartz geodes	4.9

	Thickness, feet
12. Shale, siltstone, calcareous, massive, hard, gray to red-brown; weathers blocky, tan; contains quartz geodes	5.1
11. Shale, silty, calcareous, thick-bedded, gray-brown; weathers blocky, tan-gray	6.0
Stovall limestone member (1.2 feet)	
10. Limestone, cherty, hard, massive, tan-gray to gray; weathers red-brown; echinoid spines, *Myalina* sp., *Aviculopina peracuta, Dictyoclostus americanus;* forms hillside bench	1.2
Doyle shale—Gage shale member (11.9 feet exposed)	
9. Shale, silty, calcareous, thick-bedded, tan-gray to gray; weathers blocky, light-gray to gray; contains quartz geodes	2.2
8. Shale, silty, calcareous, hard, thick-bedded, gray to tan; *Pseudomonotis* sp., *Chonetes* sp., *Aviculopecten* sp., *Derbyia crassa, Dictyoclostus* sp.	1.0
7. Shale, silty, calcareous, thick-bedded, dark-gray; weathers slabby, gray, pitted; contains quartz geodes	1.9
6. Shale, calcareous, carbonaceous, soft, thin-bedded, dark-gray to black; weathers dark-gray; microfossils	0.6
5. Shale, silty, calcareous, soft to moderately hard, thick-bedded, gray; weathers blocky; contains quartz geodes	2.0
4. Shale, silty, calcareous, thick-bedded, gray-orange; weathers blocky, red-brown	1.1
3. Shale, clayey and silty, calcareous, blocky, olive-drab; weathers gray-green	1.2
2. Limestone, hard, thin-bedded, gray; weathers blocky, gray to red-brown; forms minor bench	0.2
1. Shale, silty, calcareous, hard, thick-bedded, maroon; weathers blocky	1.7
Base covered	

Section measured in road cut and stream bank in the SW¼ NW¼ NW¼ sec. 22, T. 2 S., R. 7 E., in creek valley 0.1 mile south and 0.1 mile east of bridge north of Marysville. Measured by M. E. Davis and G. E. Randolph.

	Thickness, feet
PERMIAN—Wolfcampian	
Doyle shale—Holmesville shale member	
Barneston limestone (40.4 feet exposed)	
Fort Riley limestone member (23.0 feet)	
16. Limestone, massive, red-brown; weathers blocky, gray-orange	1.8
15. Limestone, soft, thick-bedded, tan; weathers slabby, tan-gray, pitted to cavernous	1.8
14. Limestone, massive, tan; weathers blocky, tan-gray; forms minor bench	0.6
13. Shale, silty, calcareous, thin-bedded, light-gray; weathers tan; occasional plant fossils	5.4
12. Limestone, massive, tan; weathers thin-bedded, gray-orange; abundant microfossils; forms minor bench	0.7
11. Shale, badly slumped	2.9

	Thickness, feet
10. Limestone, hard, massive, light-gray; weathers gray-brown; contains quartz geodes; forms minor bench	0.4
9. Shale, silty, noncalcareous, platy, light-gray; weathers tan, develops fretted appearance; contains quartz geodes	3.2
8. Limestone, silty, hard, massive, tan-gray; weathers thick-bedded, gray-brown; contains quartz geodes; *Derbyia* sp.; forms hillside bench	6.2
Oketo shale member (7.0 feet)	
7. Covered interval	3.6
6. Shale, silty, limonitic, soft, thin-bedded, gray to blue-gray; echinoid spines, crinoid columnals, *Dictyoclostus americanus*, *Ambocoelia planoconvexa*	1.8
5. Shale, silty, calcareous, thin-bedded, dark-gray; crinoid columnals	1.6
Florence limestone member (10.4 feet exposed)	
4. Limestone, noncherty, massive, light-gray; weathers slabby, gray-brown; echinoid spines, crinoid columnals	2.9
3. Limestone, cherty; massive, dark-gray; weathers blocky, light-gray; *Dictyoclostus americanus*, a few crinoid columnals	6.0
2. Shale, silty, calcareous, carbonaceous, thin-bedded, dark-gray; weathers slabby, light-gray; crinoid columnals	0.6
1. Limestone, cherty, slabby, gray; weathers light-gray	0.9
Base covered	

Section measured in road cut and quarry face in the NW¼ NW¼ SE¼ sec. 28, T. 2 S., R. 7 E., 8th and Jenkins Streets, Marysville, Kansas. Measured by M. E. Davis and G. E. Randolph.

	Thickness, feet
PERMIAN—Wolfcampian	
Barneston limestone (46.7 feet exposed)	
Fort Riley limestone member (15.3 feet exposed)	
19. Limestone, soft, thick-bedded, tan-gray; weathers platy, light-gray	3.0
18. Limestone, soft to moderately hard; thick-bedded, gray-orange; weathers red-brown and gray-brown; contains cherty zones; *Edmondia* sp., *Pleurophorus* sp., *Nucula* sp., *Bellerophon* sp.,.*Myalina* sp., and microfossils	2.8
17. Limestone, thin-bedded, tan-gray; weathers platy, gray, pitted to cavernous; contains quartz geodes	1.9
16. Limestone, soft, thick-bedded, tan; weathers tan-gray; *Aviculopecten, Edmondia* sp., *Allorisma terminale;* forms minor bench	1.0
15. Limestone, hard, massive, tan; weathers tan-gray, fretted appearance; contains siliceous bands and quartz geodes	4.7
14. Limestone, hard, massive, tan; weathers tan-gray	1.9
Oketo shale member (3.9 feet)	
13. Shale, silty, calcareous, moderately hard to hard, platy; tan; weathers thin-bedded, tan-gray; *Polypora* sp., *Rhombopora* sp., few *Stenopora* sp., few *Meekella striatocostata, Chonetes*	

	Thickness, feet
granulifer, Dictyoclostus americanus, Derbyia multistriata, D. crassa, D. cymbula, Composita ovata, C. subtilita, crinoid columnals, echinoid spines and plates	3.9
Florence limestone member (27.5 feet)	
12. Limestone, massive, tan-gray; contains quartz geodes and bands of chert in middle part; weathers tan; *Derbyia crassa* and fragments of other brachiopods, echinoid spines, crinoid columnals	2.2
11. Shale, silty, calcareous, blocky, olive-drab to gray-brown; weathers slabby, tan to gray; *Derbyia* sp., *Ambocoelia* sp., *Pleurophorus* sp., *Myalina* sp., *Allorisma terminale,* crinoid columnals, echinoid spines	2.4
10. Limestone, very cherty, hard, massive, tan; weathers blocky, tan-gray; *Meekella striatocostata, Chonetes* sp., *Rhombopora* sp., *Fenestalla* sp., *Polypora* sp., *Derbyia* sp., *Dictyoclostus* sp., echinoid spines, crinoid columnals	1.3
9. Limestone, noncherty, soft, slabby, tan-gray; weathers platy, tan; *Meekella striatocostata, Chonetes* sp., *Rhombopora* sp., *Fenestella* sp., *Polypora* sp., *Derbyia* sp., *Dictyoclostus* sp., echinoid spines, crinoid columnals, *Edmondia* sp.	1.3
8. Limestone, cherty, soft, massive, tan with gray streaks; weathers tan-gray; *Dictyoclostus* sp., *Derbyia* sp., *Ambocoelia* sp., crinoid columnals, echinoid spines and plates	3.6
7. Limestone, noncherty, soft, massive, light-gray; weathers thin-bedded, tan-gray; *Rhombopora* sp., *Polypora* sp., *Derbyia* sp., *Dictyoclostus* sp., crinoid columnals	1.7
6. Limestone, thick-bedded, tan-gray; weathers tan; contains persistent chert band at top; *Rhombopora* sp., *Polypora* sp., *Derbyia* sp., *Dictyoclostus* sp., crinoid columnals	2.7
5. Limestone, massive, cream; weathers tan-gray; contains irregular chert bands; fossils same as for lower zones but not as numerous	5.8
4. Shale, silty, calcareous, hard, thin-bedded, tan; weathers dark-gray	0.1
3. Limestone, hard, massive, tan; weathers gray-brown; contains several bands of chert; fossils same as those given for underlying zone but not as numerous	3.7
2. Shale, silty, calcareous, hard, thick-bedded, tan; weathers thin-bedded, gray; *Ambocoelia* sp., *Rhombopora* sp., *Polypora* sp., *Dictyoclostus americanus, Chonetes granulifer, Meekella striatocostata,* crinoid columnals	0.8
1. Limestone, massive, cream; weathers tan-gray; contains chert band near middle; *Meekella striatocostata, Derbyia* sp., *Rhomborpoa* sp., few *Dictyoclostus americanus,* echinoid spines, crinoid columnals	1.9
Matfield shale—Blue Springs member	

Section measured in operating quarry in the SW¼ NE¼ SW¼ sec. 20, T. 2 S., R. 9 E., 0.5 mile west of Beattie city limits and 0.25 mile south of railroad crossing. Measured by M. E. Davis and G. E. Randolph.

	Thickness, feet
PERMIAN—Wolfcampian	
Bader limestone—Eiss limestone member	
Stearns shale (17.2 feet)	
17. Shale, silty, calcareous, soft, thick-bedded, gray-green; weathers blocky, light-green	2.4
16. Shale, silty, calcareous, thick-bedded, maroon; weathers blocky	2.9
15. Shale, silty, calcareous, soft, thick-bedded, gray-green; weathers blocky, green	0.3
14. Shale, silty, clayey, noncalcareous, thick-bedded, maroon; weathers blocky, red	0.6
13. Shale, clayey, calcareous, thick-bedded, dark-green; weathers slabby, gray-green	1.8
12. Shale, silty, clayey, very calcareous, thick-bedded, gray-green; weathers blocky, light-gray to gray-green; contains concretions of calcite and nodules of limestone	1.6
11. Limestone, soft, thick-bedded, tan-gray; weathers slabby, tan; contains calcite veins and geodes; *Myalina* sp., *Pleurophorus* sp., *Allorisma terminale, Aviculopecten sumnerensis, Pseudomonotis* sp.; forms minor bench	4.1
10. Shale, silty, noncalcareous, thick-bedded, light-gray; weathers blocky, tan-gray; *Allorisma terminale, Myalina* sp., *Pleurophorus* sp., *Nucula* sp., *Aviculopecten* sp.	2.8
9. Shale, silty, calcareous; thin-bedded, dark-brown to black weathers very thin-bedded; *Orbiculoidea missouriensis*	0.7
Beattie limestone (13.3 feet)	
Morrill limestone member (4.6 feet)	
8. Limestone, hard, thick-bedded, tan-gray; weathers slabby, light- to dark-gray; forms minor bench	1.8
7. Limestone, hard, thick-bedded, tan-gray to gray; weathers thick-bedded, tan to gray; brachiopod fragments, echinoid spines, crinoid columnals, *Dictyoclostus americanus, Meekella striatocostata, Derbyia* sp.; forms vertical bank	2.8
Florena shale member (2.3 feet)	
6. Shale, silty, clayey, calcareous, thin-bedded, gray-brown; weathers tan-gray; *Dictyoclostus americanus, Derbyia crassa, Chonetes* sp., *Composita* sp., crinoid columnals	0.6
5. Limestone, thin-bedded, dark-gray; weathers slabby, gray-brown; crinoid columnals, *Meekella striatocostata, Chonetes* sp., *Dictyoclostus americanus;* forms minor ledge	0.3
4. Shale, calcareous, carbonaceous, hard, thin-bedded, tan to dark-gray; weathers thin-bedded, tan-gray to gray; contains silty geodes; *Chonetes granulifer, Derbyia crassa, Dictyoclostus americanus,* crinoid columnals	1.4

	Thickness, feet
Cottonwood limestone member (6.4 feet)	
3. Limestone, cherty, hard, massive, tan-gray; weathers tan; abundant fusulinids; forms hillside bench	2.5
2. Limestone, cherty, hard, massive, tan-gray; weathers tan; abundant fusulinids	2.6
1. Limestone, soft, thin-bedded, gray; weathers slabby, light-gray; *Derbyia* sp., *Dictyoclostus* sp., *Meekella striatocostata*, crinoid columnals	1.3
Eskridge shale	

Section measured in stream bank in the NW¼ NE¼ SW¼ sec. 18, T. 3 S., R. 7 E., in bluffs 300 feet west of winding township road, 0.5 mile west and 1.25 miles north of Schroyer, Kansas. Measured by F. W. Wilson and R. M. Meddles.

	Thickness, feet
PERMIAN—Wolfcampian	
Barneston limestone—Florence limestone member (18.5 feet exposed)	
22. Top covered	
21. Limestone, very cherty, massive, tan-gray; bryozoans; forms rounded hillside bench	14.2
20. Limestone, clayey, massive, tan-gray; weathers flaggy, gray	4.3
Matfield shale (35.2 feet exposed)	
Blue Springs shale member (32.2 feet)	
19. Covered interval	2.0
18. Shale, silty, calcareous, soft, pebbly, gray-green; weathers mealy	6.6
17. Shale, silty, calcareous, hard, massive, red-brown; weathers blocky, rose	3.8
16. Shale, silty, calcareous, thick-bedded, gray-green; weathers pebbly	0.7
15. Siltstone, calcareous, hard, massive, red-brown; forms minor ledge	2.0
14. Shale, silty, calcareous, blocky, gray-green; weathers pebbly	0.7
13. Shale, silty, calcareous, massive, red-brown; weathers blocky,	1.0
12. Shale, silty, calcareous, thick-bedded, brown; weathers blocky, rose	0.8
11. Shale, silty, noncalcareous, blocky, gray-green; weathers pebbly	0.5
10. Shale, silty, calcareous, blocky, gray-red; weathers pebbly, purple	1.2
9. Shale, silty, noncalcareous, pebbly, gray-green; weathers mealy	0.3
8. Shale, silty, noncalcareous, hard, blocky, dark red-brown; weathers pebbly, purple	0.6
7. Shale, silty, noncalcareous, hard, blocky; gray-green; weathers pebbly, green	1.8
6. Mudstone, noncalcareous, hard, massive, gray; weathers light-gray	0.8

	Thickness, feet
5. Mudstone, noncalcareous, hard, massive, gray; weathers platy, light-gray; forms minor ledge	1.9
4. Shale, silty, noncalcareous, hard, thick-bedded, gray-green; weathers blocky, gray	3.5
3. Shale, silty, noncalcareous, blocky, dark-gray; weathers pebbly, medium-gray; contains numerous gypsum seams	4.0
Kinney limestone member (1.5 feet)	
2. Mudstone, calcareous, hard, massive, dark-gray; weathers platy, gray; contains nodules of selenite	1.5
Wymore shale member (1.5 feet exposed)	
1. Shale, clayey, noncalcareous, thick-bedded, dark-gray	1.5
Base covered	

Section measured in stream cut in the SE¼ SE¼ SE¼ sec. 31, T. 3 S., R. 7 E., 0.5 mile east, 2 miles south of Schroyer, Kansas; section begins about 0.25 mile east in stream valley and continues from cut to cut downstream to about 100 yards east of bridge on road. Measured by F. W. Wilson and R. M. Meddles.

	Thickness, feet
PERMIAN—Wolfcampian	
Matfield shale (29.2 feet exposed)	
Blue Springs shale member	
Kinney limestone member (5.0 feet)	
59. Mudstone, noncalcareous, massive, green; weathers flaggy, cream; forms minor ledge	2.0
58. Mudstone, calcareous, hard, massive, gray-green; weathers thick-bedded, cream; brachiopod fragments, *Derbyia* sp., ostracods, bryozoans	3.0
Wymore shale member (24.2 feet)	
57. Shale, silty, noncalcareous, conchoidal fracture, blocky, gray-brown; weathers mealy	2.4
56. Shale, silty, calcareous, blocky, red-brown; weathers pebbly, dark-rose	10.9
55. Shale, noncalcareous, blocky, gray-green; weathers mealy, turquoise, forms columns	4.4
54. Mudstone, calcareous, massive, gray; weathers blocky	1.5
53. Shale, silty, noncalcareous, blocky, gray-green; weathers thick-bedded, gray	5.0
Wreford limestone (35.4 feet)	
Schroyer limestone member (13.2 feet)	
52. Mudstone, soft, massive, thick-bedded, cream; weathers tan; contains geodes	1.2
51. Limestone; contains chert band in middle part	0.3
50. Mudstone, silty, soft, massive, cream; weathers thick-bedded, tan; contains geodes; fossil fragments	1.4
49. Chert, light-gray; contains geodes	0.4
48. Limestone, hard, massive, gray; weathers tan; contains geodes; brachiopod fragments	1.2
47. Chert; contains geodes	0.3

		Thickness, feet
46.	Limestone, hard, massive, gray; weathers tan; contains geodes; brachiopod fragments	0.9
45.	Limestone, hard, massive, cream; weathers gray-brown; contains chert nodules in middle part; forms minor ledge	0.5
44.	Shale, silty, calcareous, hard, thick-bedded, gray-brown; weathers thin-bedded, cream; trilobites, *Dictyoclostus americanus*, numerous other brachiopod fragments	0.2
43.	Limestone, silty, massive, cream; weathers slabby, gray-brown; contains geodes	3.8
42.	Limestone, hard, massive, gray; weathers gray-brown, pitted; brachiopod fragments; forms hillside bench	3.0
Havensville shale member (15.1 feet)		
41.	Limestone, hard, massive, gray; weathers platy, gray-brown, pitted; contains geodes	0.5
40.	Limestone, clayey, massive, medium-gray; weathers shaly, light-gray	0.9
39.	Limestone, clayey, soft, massive, gray; weathers platy, cream,	2.1
38.	Limestone, shaly, soft, massive, tan; weathers thick-bedded to platy, cream	3.8
37.	Limestone, clayey, hard, massive, gray-brown; weathers pitted; forms minor bench	1.9
36.	Limestone, clayey, soft, wavy banded, gray; weathers cream and shaly	4.0
35.	Covered interval	1.9
Three Mile limestone member (7.1 feet)		
34.	Limestone, massive, gray; weathers pitted, light-gray; forms ledge	1.0
33.	Limestone, massive, gray; weathers light-gray	0.6
32.	Chert, hard, banded, straw-colored to light-gray	0.3
31.	Limestone, massive, gray; weathers light-gray, pitted; brachiopod fragments	0.9
30.	Chert, hard, banded, straw-colored to light-gray	0.1
29.	Limestone, massive, gray; weathers light-gray; brachiopod fragments, crinoid columnals	0.7
28.	Chert, straw-colored to light-gray; weathers medium-gray	0.3
27.	Limestone, massive, gray; weathers light-gray, pitted; brachiopod fragments, crinoid columnals	0.7
26.	Limestone, massive, gray; weathers shaly and fretted, light-gray; brachiopod fragments, crinoid columnals, *Septopora*	0.2
25.	Limestone, massive, gray; weathers light-gray; brachiopod fragments, crinoid columnals; forms conspicuous outcrop	0.9
24.	Limestone, massive, gray; weathers shaly, light-gray, fretted; brachiopod fragments, crinoid columnals	0.2
23.	Limestone, hard, massive, gray; weathers light-gray; contains chert in middle part	0.8
22.	Shale, calcareous, hard, thin-bedded, gray	0.1
21.	Limestone, calcareous, hard, massive, tan-gray; weathers pitted, gray; brachiopod fragments	0.3

Speiser shale (14.5 feet)	Thickness, feet
20. Shale, calcareous, hard, thick-bedded, dark-gray; weathers thin-bedded, medium-gray	0.1
19. Limestone, shaly, thick-bedded, dark-gray; weathers thin-bedded, medium-gray	0.1
18. Shale, calcareous, hard, thick-bedded, dark-gray; weathers thin-bedded, medium-gray	0.2
17. Limestone, shaly, thick-bedded, dark-gray; weathers thin-bedded, medium-gray	0.1
16. Shale, silty, calcareous, hard, thin-bedded, dark-gray; weathers medium-gray; crinoid columnals, *Derbyia* sp.	0.9
15. Siltstone, calcareous, massive, medium-gray; weathers thick-bedded; brachiopod fragments, crinoid columnals	0.3
14. Shale, silty, calcareous, thick-bedded, medium-gray; weathers thin-bedded	1.0
13. Shale, silty, calcareous, hard, thick-bedded, gray-brown; weathers thin-bedded, gray	0.4
12. Limestone, hard, massive, tan-gray; weathers medium-gray	1.0
11. Shale, clayey, silty, calcareous, thick-bedded, tan-gray; weathers tan	2.2
10. Shale, silty, noncalcareous, hard, blocky, dark-gray; weathers mealy, gray-green	1.8
9. Shale, silty, hard, massive, purple; weathers columnar, blue,	0.7
8. Shale, silty, noncalcareous, hard, massive, gray-green mottled with purple; weathers pebbly, gray-green to blue, crudely columnar	2.5
7. Shale, silty, noncalcareous, hard, massive, red-brown; weathers blocky, rose	1.4
6. Shale, silty, noncalcareous, massive, gray; weathers mealy, light-gray	0.6
5. Shale, silty, noncalcareous, massive, red; weathers mealy, rose	1.2
Funston limestone (4.3 feet)	
4. Limestone, clayey, massive, gray; weathers light-gray; forms minor ledge	1.2
3. Shale, silty, blocky, gray-green; weathers mealy, turquoise	1.7
2. Limestone, clayey, massive, light-gray; weathers gray; forms minor ledge	1.4
Blue Rapids shale (0.7 foot exposed)	
1. Shale, silty, noncalcareous, blocky, gray-green; weathers mealy, green	0.7
Base covered	

Section measured in stream cut in the SW¼ NW¼ SE¼ sec. 9, T. 5 S., R. 9 E., 200 yards west of K-99 behind farm buildings, 4.7 miles south of Frankfort, 4.3 miles north of Pottawatomie-Marshall County line. Measured by Harry Smedes and R. M. Sullivan.

	Thickness, feet
PERMIAN—Wolfcampian	
Beattie limestone—Cottonwood limestone member (1.0 foot exposed)	
22. Limestone, cherty, massive, tan; weathers slabby, tan-gray, etched; fusulinids; forms prominent ledge	1.0
Eskridge shale (28.9 feet)	
21. Covered interval	28.6
20. Shale, silty, thick-bedded, light-gray; weathers thin-bedded, tan-gray	0.3
Grenola limestone (21.9 feet exposed)	
Neva limestone member (13.4 feet)	
19. Limestone, limonitic, massive, gray; weathers slabby, light-gray; microfossils, echinoid spines, crinoid columnals, *Chonetes* sp., *Marginifera* sp.	7.2
18. Shale, silty, calcareous, fissile, tan; weathers mealy, tan-gray; *Ambocoelia* sp.	0.6
17. Shale, silty, slightly calcareous, hard, thick-bedded, tan; weathers thin-bedded, tan-gray; *Dictyoclostus* sp., *Composita* sp., *Ambocoelia* sp.	1.5
16. Shale, calcareous, silty; thin-bedded, brown; weathers tan; *Lingula* sp., *Ambocoelia* sp., *Chonetes* sp., *Orbiculoidea* sp.	0.6
15. Limestone, limonitic, massive, gray; weathers blocky, tan-gray; *Ambocoelia* sp., brachiopod fragments, echinoid spines, small columnals, ostracods; forms minor ledge	0.4
14. Shale, silty, slightly calcareous, thin-bedded, black; weathers fissile, gray	1.1
13. Limestone, silty, soft, massive, light-gray; weathers blocky, tan-gray; crinoid columnals, abundant fusulinids, *Ambocoelia* sp.	0.2
12. Shale, silty, calcareous, thin-bedded, light-gray; weathers mealy, gray-brown; *Chonetes granulifer, Ambocoelia* sp., *Marginifera* sp., crinoid columnals	0.2
11. Limestone, clayey, limonitic, massive, tan-gray; weathers blocky, tan, pitted; small gastropods, crinoid columnals, ostracods; forms conspicuous ledge	1.6
Salem Point shale member (6.8 feet)	
10. Mudstone, calcareous, massive, light-gray; weathers blocky, tan-gray	0.2
9. Shale, silty, calcareous, thin-bedded, gray-brown; weathers tan	1.0
8. Shale, silty, calcareous, thick-bedded, light-gray; weathers thin-bedded, tan-gray	1.3
7. Shale, silty, slightly calcareous, nodular, thick-bedded, light-gray; weathers blocky	0.6

	Thickness, feet
6. Shale, silty, calcareous, hard, thick-bedded, weathers thin-bedded	0.5
5. Shale, silty, calcareous, thin-bedded, tan; weathers flaky, tan-gray	0.8
4. Shale, silty, calcareous, thin-bedded, brown; weathers mealy, tan	0.7
3. Shale, calcareous, silty, thin-bedded, gray-brown; weathers mealy, light-gray	0.5
2. Shale, silty, calcareous, thin-bedded, tan; weathers mealy, tan-gray	1.2
Burr limestone member (1.7 feet exposed)	
1. Limestone, clayey, limonitic, moderately hard, blocky, light-gray; weathers slabby, tan; forms conspicuous ledge	1.7
Base below water	

Section measured in road cut in the SW¼ SW¼ SW¼ sec. 34, T. 5 S., R. 9 E., 50 yards north of county line, east side of K-99 in ditch. Measured by Harry Smedes and R. M. Sullivan.

PERMIAN—Wolfcampian

Bader limestone (12.6 feet exposed)

	Thickness, feet
Middleburg limestone member (1.5 feet exposed)	
19. Limestone, clayey, hard, massive, light-gray; weathers slabby, tan-gray; small crinoid columnals, brachiopod fragments, *Aviculopecten sumnerensis;* forms minor ledge	1.2
18. Limestone, very clayey, hard, platy, light-gray; weathers slabby, tan-gray	0.3
Hooser shale member (11.0 feet)	
17. Shale, very calcareous, silty, blocky, tan; weathers mealy, tan-gray	2.0
16. Mudstone, slightly calcareous, massive, cream; weathers blocky, tan	0.1
15. Shale, silty, slightly calcareous, thin-bedded, tan-gray; weathers platy, light-gray	0.2
14. Shale, silty, calcareous, massive, gray-brown; weathers mealy, brown	0.5
13. Mudstone, slightly calcareous, massive, cream; weathers blocky, tan	0.1
12. Shale, very silty, calcareous, limonitic, hard, thick-bedded, olive-drab; weathers thin-bedded, tan	2.1
11. Mudstone, slightly calcareous, massive; gray; weathers blocky, light-gray	0.2
10. Shale, silty, slightly calcareous, thin-bedded, maroon; weathers mealy, rose	2.9
9. Mudstone, calcareous, massive, violet; weathers blocky, tan-gray	1.0
8. Shale, silty, calcareous, thick-bedded, light-gray; weathers blocky, tan-gray	0.1

	Thickness, feet
7. Shale, silty, calcareous, thin-bedded, light-maroon; weathers mealy, rose	0.3
6. Shale, silty, calcareous, thin-bedded, light-gray; weathers fissile	0.4
5. Shale, silty, noncalcareous, thin-bedded, light-maroon; weathers mealy, rose	0.3
4. Shale, silty, very calcareous, thin-bedded, gray-orange; weathers mealy, tan	0.2
3. Shale, silty, noncalcareous, soft, thick-bedded, olive-drab; weathers thin-bedded, light-gray	0.2
2. Shale, silty, calcareous, thick-bedded, tan; weathers thin-bedded, tan-gray	0.4
Eiss limestone member (0.1 foot exposed)	
1. Limestone, massive, tan-gray; weathers cellular, tan	0.1
Base covered	

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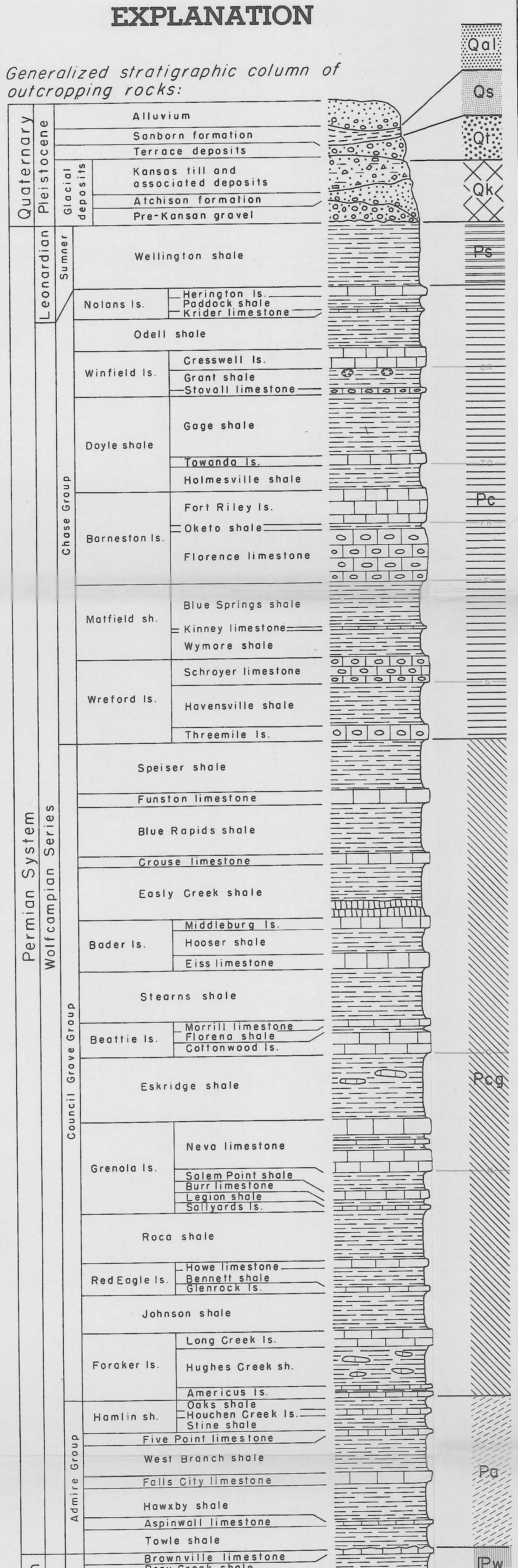
AREAL GEOLOGY OF MARSHALL COUNTY, KANSAS

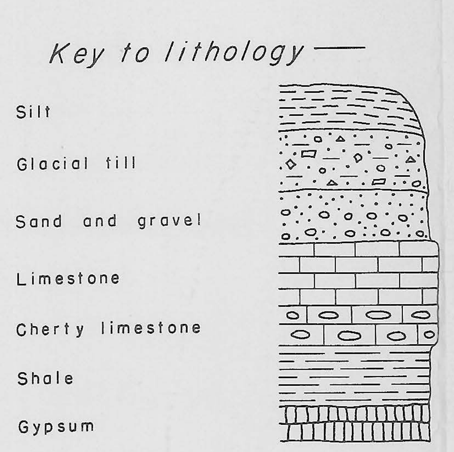
State Geological Survey
of Kansas

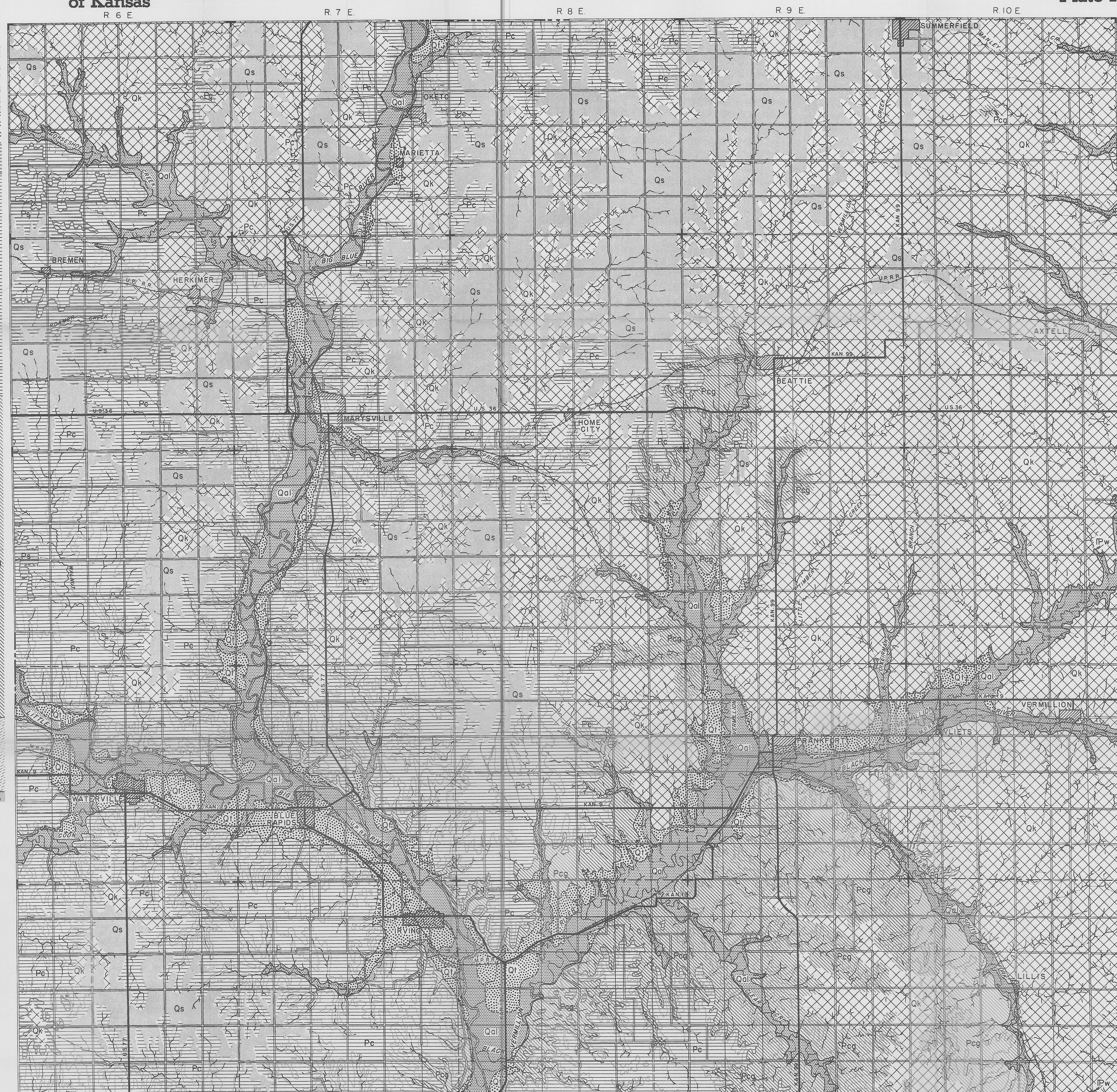
by Kenneth L. Walters
1951

Bulletin 106
Plate 1

EXPLANATION







Base compiled from maps prepared by Soil Conservation Service

Drainage from map prepared by U.S. Dept. of Agriculture

GEOLOGIC CROSS SECTIONS IN MARSHALL COUNTY, KANSAS

by Kenneth L. Walters, 1951

State Geological Survey of Kansas

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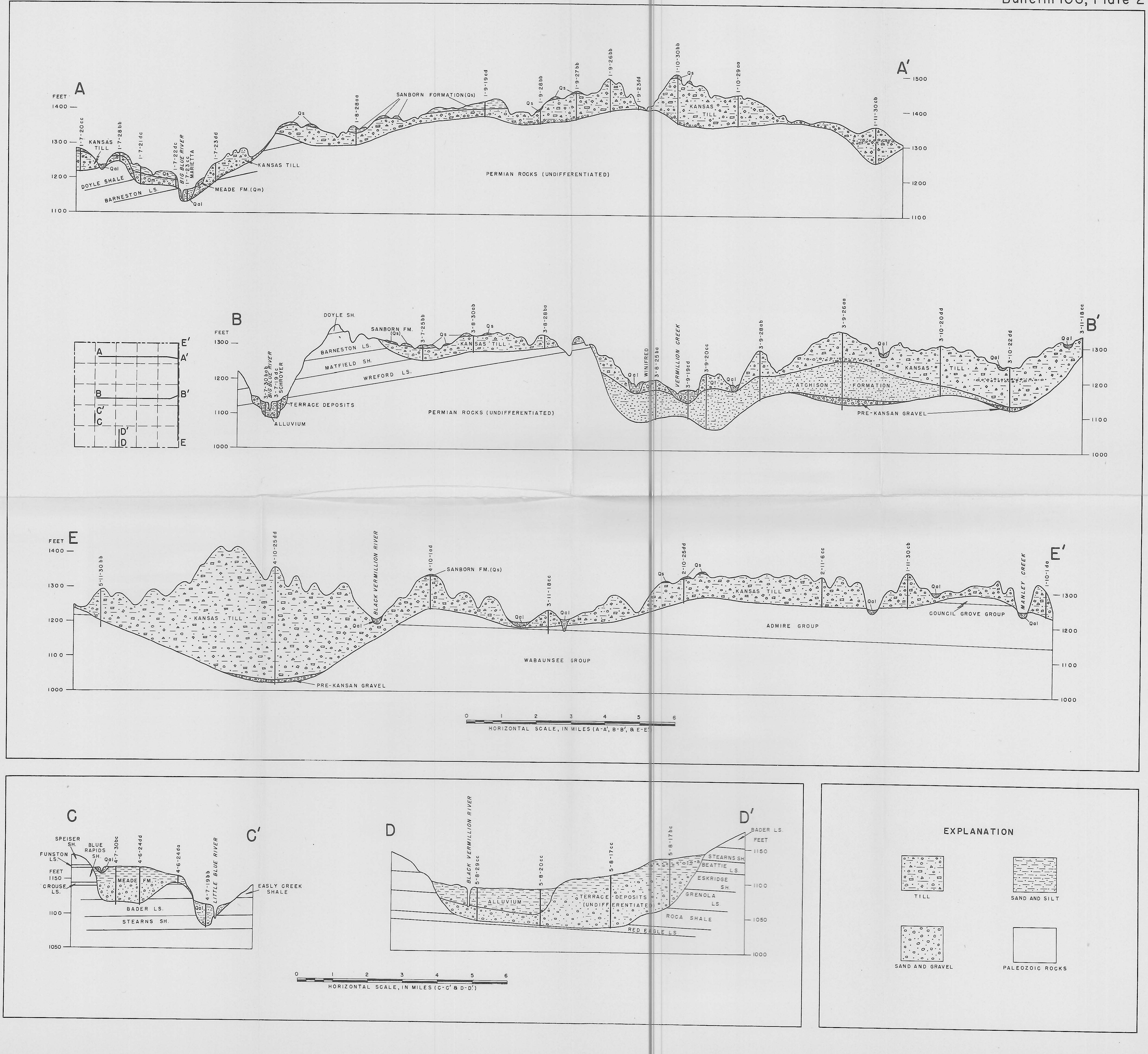

MAP OF MARSHALL COUNTY, KANSAS
Showing the Location of Wells and Test Holes for which Records are given, and Ground-Water Regions

by Kenneth L. Walters

1951

State Geological Survey of Kansas

Bulletin 106
Plate 3

EXPLANATION

- Domestic and stock wells
- Public supply well
- Industrial well
- Air-conditioning well
- Test hole

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Upper number is the depth to water level below land surface, in feet. Lower number is the depth of well below land surface, in feet.

Brackets indicate that water analysis is given.

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

Ground-Water Regions

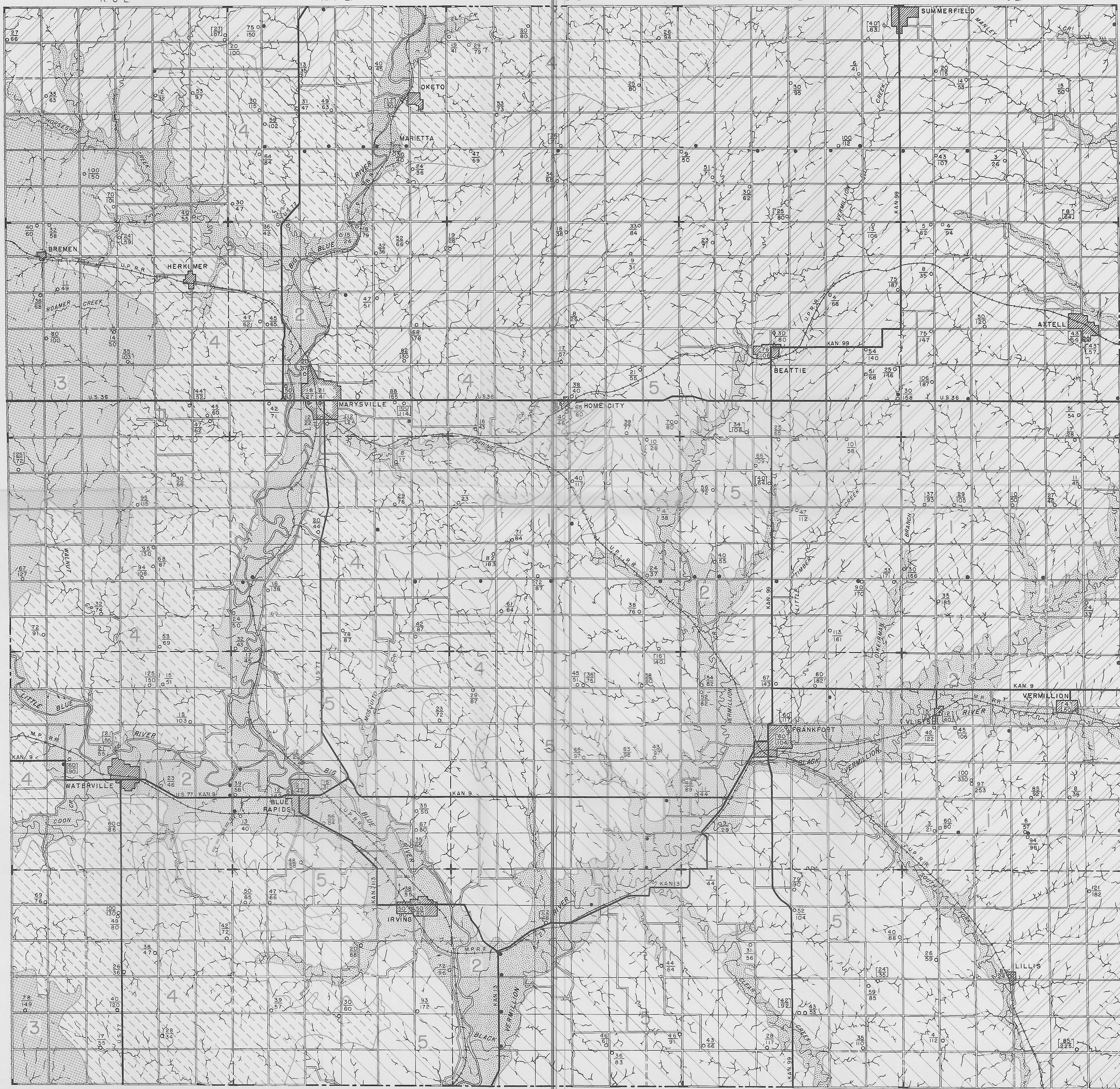
1 — Glacial till and associated deposits are the principal aquifers in these regions. Depths of wells range from a few feet to as much as 200 feet. The quality and quantity of water are generally satisfactory for domestic and stock supplies.

2 — Alluvium and terrace deposits yield moderate to large supplies of water to wells in these regions. The quality of water is satisfactory for most uses. Wells in these regions range in depth from a few feet to more than 70 feet.

3 — Permian rocks overlying the Barneston limestone are the principal aquifers in these regions. Most wells within these regions yield only small quantities of water.

4 — The Barneston limestone is the principal aquifer in these regions. Wells yield moderate quantities of generally good quality water.

5 — Permian rocks underlying the Barneston limestone are the principal aquifers in these regions. Both the quality and quantity of water available are extremely variable from place to place.



Base compiled from maps prepared by Soil Conservation Service

Drainage from map prepared by U.S. Dept. of Agriculture