Ground Water in the Oil-Field Areas of Ellis and Russell Counties, Kansas

By

JOHN C. FRYE and JAMES J. BRAZIL

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BULLETIN 50

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By JOHN C. FRYE and JAMES J. BRAZIL
with analyses by
HOWARD STOLTENBERG

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

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† Absent on leave for military service.

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By JOHN C. FRYE AND JAMES J. BRAZIL

ABSTRACT

The oil-field areas described are located in western, central, and southern Russell county, and east-central and northeastern Ellis county. This area is a part of the Plains Border section of the Great Plains physiographic province. The area is well dissected and is drained by Smoky Hill and Saline rivers and their tributaries.

The stratified rocks of this area consist of deposits of Cretaceous, Tertiary, Pleistocene, and Recent age, and include the Dakota formation, Graneros shale, Greenhorn limestone, Carlile shale, and Niobrara formation of Cretaceous age; the Ogallala formation(?) of Tertiary age; Pleistocene terrace deposits of sand, gravel, silt, and volcanic ash; and Recent alluvium. Although not exposed in this area, the Kiowa shale, Cheyenne sandstone, and Permian redbeds were encountered in test holes. The quality of the water contained in these formations ranges within wide limits. Water in the Cheyenne sandstone probably is highly mineralized everywhere in this area. Water in some of the sandstones of the Dakota formation is also mineralized; however, many wells obtain potable water from sandstone beds in the Dakota formation. Waters contained in rocks younger than the Dakota formation are generally of a quality satisfactory for most uses, except in some places where they have been polluted by brines from deeper formations.

The depth to water level in wells ranges from about 5 feet in wells along the valley flats of the major streams to more than 150 feet in some upland wells tapping sandstones in the Dakota formation.

The ground-water reservoir is recharged by downward percolation of rainfall in the area, and by lateral migration of water through the rocks from areas to the west.

The physical properties of sandstones of the Dakota formation and sand and gravel of the Tertiary, Pleistocene, and Recent deposits are summarized. These water-bearing materials range from coarse gravel to very fine sand and sandstone, and have coefficients of permeability ranging from less than 1 to as much as 50,000. Generally the sandstones of the Dakota formation are much finer and have lower coefficients of permeability than the sand and gravel of Tertiary, Quaternary, and Recent age.

INTRODUCTION

In July, 1941, an investigation of the ground-water resources of the oil-field areas of western, central, and southern Russell county and northeastern Ellis county was undertaken by the Division of Ground Water of the United States Geological Survey, the State Geological Survey of Kansas, and the Division of Sanitation of the Kansas State Board of Health, with the coöperation of the Division of Water Resources of the State Board of Agriculture. This work was under the immediate supervision of S. W. Lohman, Federal geologist in charge of ground-water investigations in Kansas, and Ogden S. Jones, geologist in charge of the Oil-field Section, Division of Sanitation, Kansas State Board of Health. The location of the area discussed in this report and of other areas in Kansas on which coöperative ground-water reports have been published or are in preparation is shown in figure 1.

We spent three months in the field, assisted by Gordon Shaffer and Hubert Duckett. Outcrops of Cretaceous, Tertiary, and Quaternary rocks were studied, and thicknesses of the exposed formations were measured. A test-drilling program was carried out with a portable hydraulic rotary drilling machine owned by the State and Federal Geological Surveys and operated by Ellis Gordon, James Cooper, and LeRoy Fugitt. During the course of the field work, 232 water wells were visited by Gordon Shaffer and us, including 163 wells in Russell county and 69 wells in Ellis county. Instrumental levels were run to all of the test holes and to some of the wells by LeRoy Fugitt, assisted by John Conard. The depth to water level was measured in all of these wells, samples of water for chloride analysis were collected from most of them, and 2-liter samples of the water for complete chemical analyses were collected from 34 wells. The analyses of water were made by Howard Stoltenberg, chemist in the Water and Sewage Laboratory of the Kansas State Board of Health.

Microscopic examination was made of the cuttings obtained from the test holes and from a few oil wells in the area. Mechanical analyses and determinations of permeability of samples of sandstone from the Dakota formation and of samples of Quaternary and Tertiary sand and gravel in Russell county were made in the laboratories of the Geological Survey by us, assisted by Gordon Shaffer and L. P. Buck. C. W. Hibbard and A. B. Leonard spent several days with us in the field studying the Pleistocene deposits and collecting

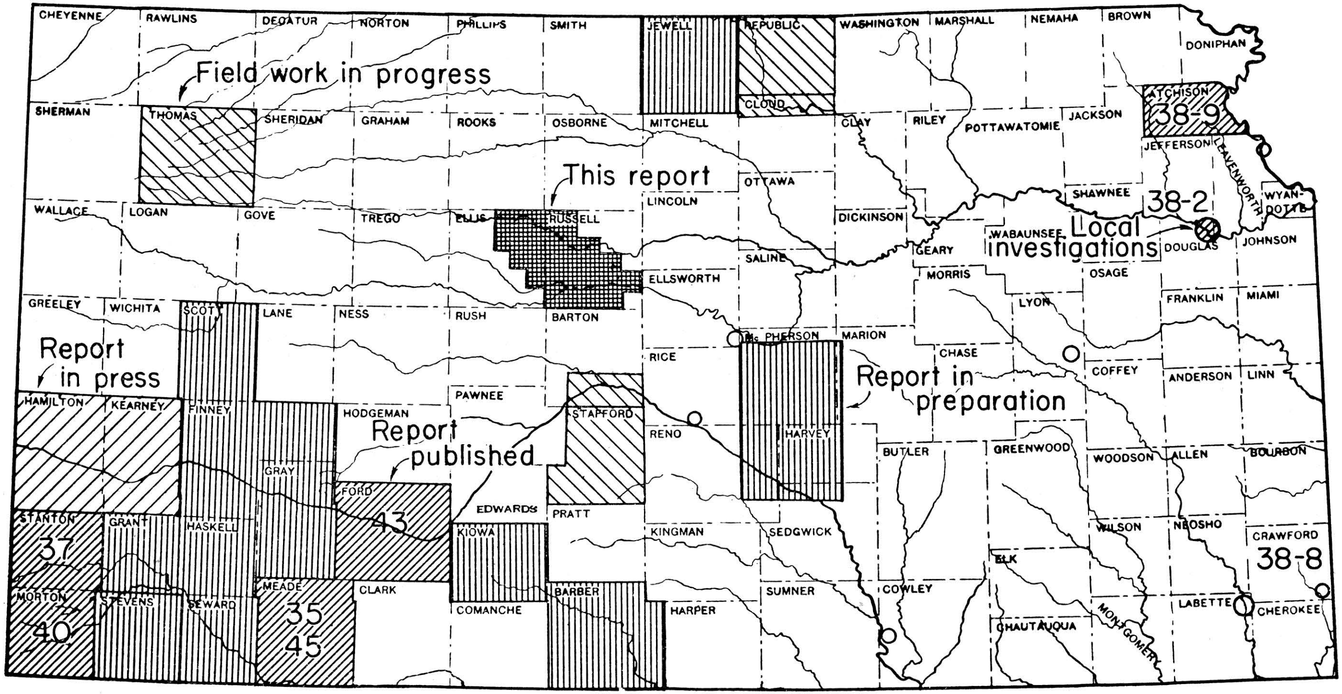

FIG. 1. Map of Kansas showing the location of the area discussed in this report and other areas for which coöperative ground-water reports have been published or are in preparation.

fossils. R. P. Keroher supplied information concerning the Permian rocks of this area. The stratigraphy was studied jointly by us and the ground-water conditions were studied by Frye. Brazil prepared the section on the history of oil-field development, and the remainder of the report was prepared by Frye. Chapters partly prepared on disposal of oil-field brines by Brazil have not been included because of his entrance into military service.

Thanks are expressed to the many residents of the area who assisted in the collection of field data. Thanks are also expressed to the Gulf Oil Corporation for the opportunity to study well samples from this area. The manscript for this report has been critically reviewed by O. E. Meinzer, W. D. Collins, and S. W. Lohman of the Federal Geological Survey; George S. Knapp, chief engineer, Division of Water Resources, Kansas State Board of Agriculture; and Paul Haney, acting director, Division of Sanitation, and Ogden S. Jones, geologist in charge of the Oil-field Waste Disposal Section, Kansas State Board of Health. Dorothea Weingartner drafted the illustrations and Edith H. Lewis edited the manuscript.

HISTORY OF OIL-FIELD DEVELOPMENT

Russell County

The discovery well of Russell county was also the discovery well for western Kansas. This well was completed in November, 1923, in what later became known as the Fairport pool. At that time the closest field of importance was 135 miles to the southeast in Butler county. The Russell county discovery well was drilled on the farm of Carrie Oswald in sec. 8, T. 12 S., R. 15 W. The pioneer oil men who drilled this well were rewarded with a flow of high-gravity oil at a rate of 224 barrels a day from a depth of 2,998 feet. The success of this first well stimulated the drilling of many holes on the trend of the Fairport-Natoma anticline. In 1942 there were 160 wells in the Fairport pool. As a result of drilling southward along the trend of the Fairport-Natoma anticline, the Gorham pool was discovered in October, 1926. In 1929 the Sellens and Ochs pools were discovered. In 1930 the Dillner and Gideon pools were added to the growing list of pools in Russell county, and the Hall pool was found in 1931. No pools were discovered in 1932 and 1933. The Neidenthal and Russell pools were discovered in 1934, and most of the pools now in Russell county were discovered between 1935 and 1942. In 1942 Russell county, with 60 pools, had a greater number of pools than any other county in western Kansas. As drilling has progressed there has been a merging of pools, and discoveries of new pools have become less frequent.

The cumulative production from the principal oil pools in Russell county to January 1, 1942, is given in table 1.

TABLE 1.—*Cumulative production from oil pools in Russell county to January 1, 1942, in barrels*

(Data based on records of pipe-line runs)

Atherton	1,098,045
Big Creek	1,899,309
Big Creek, East	203,063
Boxberger	138,477
Bunker Hill	70,241
Davidson, Northeast	10,042
Dillner	45,952
Donovan	50,220
Driscoll	15,445
Dubuque	179,864
Eichman	648,945
Fairfield	8,111
Fairfield, North	173,806
Fairport	15,015,970
Forest Hill	8,296
Gideon	40,515
Gorham	19,460,567
Greenvale	360,696
Greenvale, Northwest	15,904
Gustafson	2,334
Hall-Gurney	9,516,679
Karst	198,217
Lewis	7,154
Mahoney	24,398
Neidenthal	880,722
Rusch	30,663
Russell	4,810,729
Sellens	2,578,632
Steinert	39,972
Trapp	25,461,807
Trapp, West	95,197
Vaughn	1,007,874
Williamson	52,820

ELLIS COUNTY

The Shutts pool in T. 12 S., R. 17 W. is the oldest pool in Ellis county. The Phillips Petroleum Company drilled the No. 1 Shutts well in section 5 in November, 1928, and found oil in the Arbuckle limestone at a depth of 3,569 feet. The largest pool in Ellis county is the Bemis. The Roark No. 1 well, drilled in 1935 in sec. 16, T. 11 S., R. 17 W., was the discovery well for the Bemis pool. Oil was found in the Topeka limestone at a depth of 3,032 feet, but most of the wells in the Bemis pool are now producing from the Arbuckle limestone. Initial production from the Arbuckle ranged from 500 to 4,000 barrels.

The Burnett pool, discovered in 1937 in T. 11 S., R. 18 W., ranks second in production to the Bemis pool. Production is from the Arbuckle limestone at a depth of around 3,570 feet. The Walters pool, discovered in 1936 in T. 12 S., R. 18 W., ranks third in Ellis county in produced barrels of oil. Production is from the Topeka limestone at a depth of approximately 3,620 feet. The Ruder pool, in T. 15 S., R. 18 W., was discovered in August, 1935. The discovery well had an initial production of 818 barrels from the Kansas City-Lansing limestones at a depth of about 3,334 feet.

In 1942 there were 28 pools in Ellis county. The cumulative production from the principal oil pools in Ellis county to January 1, 1942, is given in table 2.

TABLE 2.—*Cumulative production from oil pools in Ellis county to January 1, 1942, in barrels*

(Data based on records of pipe-line runs)

Bemis	15,944,713	Kraus	58,938
Bemis, South	25,812	Marshall	653,741
Blue Hill	374,455	Penny-Wann	34,125
Burnett	5,446,052	Richards	81,145
Catherine	123,714	Ruder	692,968
Emmeram	64,535	Solomon	78,781
Hadley	58,562	Sugar Loaf	10,325
Haller	13,919	Sugar Loaf, Southeast,	2,935
Herzog	48,112	Toulon	173,923
High Spot	2,694	Ubert	155,040
Koblitz	132,726	Walters	1,398,565

GEOLOGIC FORMATIONS AND THEIR WATER-BEARING CHARACTERISTICS

The water-bearing formations exposed in the oil-field areas of Ellis and Russell counties consist of deposits of Cretaceous, Tertiary, and Quaternary age, and are listed in table 3. The oldest rocks exposed are classed as belonging to the Dakota formation and crop out along the sides of the major valleys in Russell county. The rocks dip gently toward the west, although there are many local deviations from this dip. Above the Dakota formation the following Cretaceous formations are exposed in ascending order: Graneros shale, Greenhorn limestone, Carlile shale, and Niobrara formation. The Kiowa shale and Cheyenne sandstone (also of Cretaceous age), although not exposed, are encountered in drill holes below the Dakota formation in Ellis county and parts of Russell county. These formations unconformably overlie Permian redbeds.

Tertiary deposits unconformably overlie the Cretaceous rocks in the uplands of Ellis county and parts of Russell county. Pleistocene terrace deposits occur along the major stream valleys, and Recent alluvium underlies the flood plains in most of the valleys. The physical characteristics and ground-water supply of these formations are discussed below.

The stratigraphic relationships of the several Cretaceous formations of this area are shown in the cross sections (fig. 2) plotted from test-hole and well-log data.

TABLE 3.—*Generalized section of geologic formations in Ellis and Russell counties*

System	Series	Subdivisions		Thickness (feet)	Physical character	Water supply
Quaternary	Recent	Alluvium		0–40	Gravel, sand, silt and clay underlying valley flats along major streams.	Yields abundant supplies of water to shallow wells. Water ranges in quality within wide limits.
	Pleistocene	McPherson (?) formation and younger and older beds.		0–75	Gravel, sand, silt, clay, and volcanic ash; locally cemented with calcium carbonate. Gravels contain igneous and limestone pebbles.	Where saturated with water, sand and gravel yield abundant supplies of water of good quality to shallow wells.
Tertiary	Pliocene (?)	Ogallala (?) formation.		0–50	Gravel, sand, silt, and clay; locally cemented by calcium carbonate.	Locally yields abundant supplies of water reported to be of good quality to shallow wells.
		Niobrara formation	Smoky Hill chalk member	150±	Limestone and chalky shale, gray to blue-gray.	Yields little or no water to wells.
			Fort Hays limestone member			
		Carlile shale	Codell sandstone member	300±	Shale, blue-gray, massive to thin-bedded. Codell sandstone member at top is about 20 feet thick.	Codell sandstone member yields small supplies of water; shale yields little or no water. Water reported to be of good quality.
			Blue Hill shale member			
			Fairport chalky shale member			

Table 3.—Generalized section of geologic formations in Ellis and Russell counties—*Concluded*

System	Series	Subdivisions		Thickness (feet)	Physical character	Water supply
Cretaceous	Gulfian*	Greenhorn limestone	Pfeifer shale member	85–110	Shale and limestone, interbedded. Shale is calcareous, tan to blue-gray; limestone is thin-bedded, fossiliferous, gray.	Limestones, where deeply weathered, yield meager supplies of potable water to shallow wells.
			Jetmore chalk member			
			Hartland shale member			
			Lincoln limestone member			
		Graneros shale		25–40	Shale, blue-gray, locally contains clay, siltstone, and sandstone. Contains selenite crystals and pyrite.	Yields little or no water to wells.
		Dakota formation*	Janssen clay member	200–300+	Clay, shale, siltstone, and sandstone interbedded and varicolored. Contains abundant siderite, hematite, limonite, and some lignite.	Sandstones yield abundant supplies of water having wide range in quality. Generally shallow wells yield good quality water and deep wells yield poor quality water.
	— ??? —		Terra Cotta clay member			
	Comanchean*	Kiowa shale (not exposed in area)		100–125	Shale, black, containing thin beds of sandstone and siltstone, and crystals of gypsum and pyrite.	Yields little or no water to wells.
		Cheyenne sandstone (not exposed in area)		0–200+	Sandstone, medium to fine-grained, gray, and some shale and siltstone.	Yields abundant supplies of highly mineralized water.
Permian	Leonardian*	Nippewalla group* (not exposed in area)			Siltstone, fine-grained sandstone, and shale; red and gray; loosely cemented	Highly mineralized water has been reported from wells.

* Classification of the State Geological Survey of Kansas.

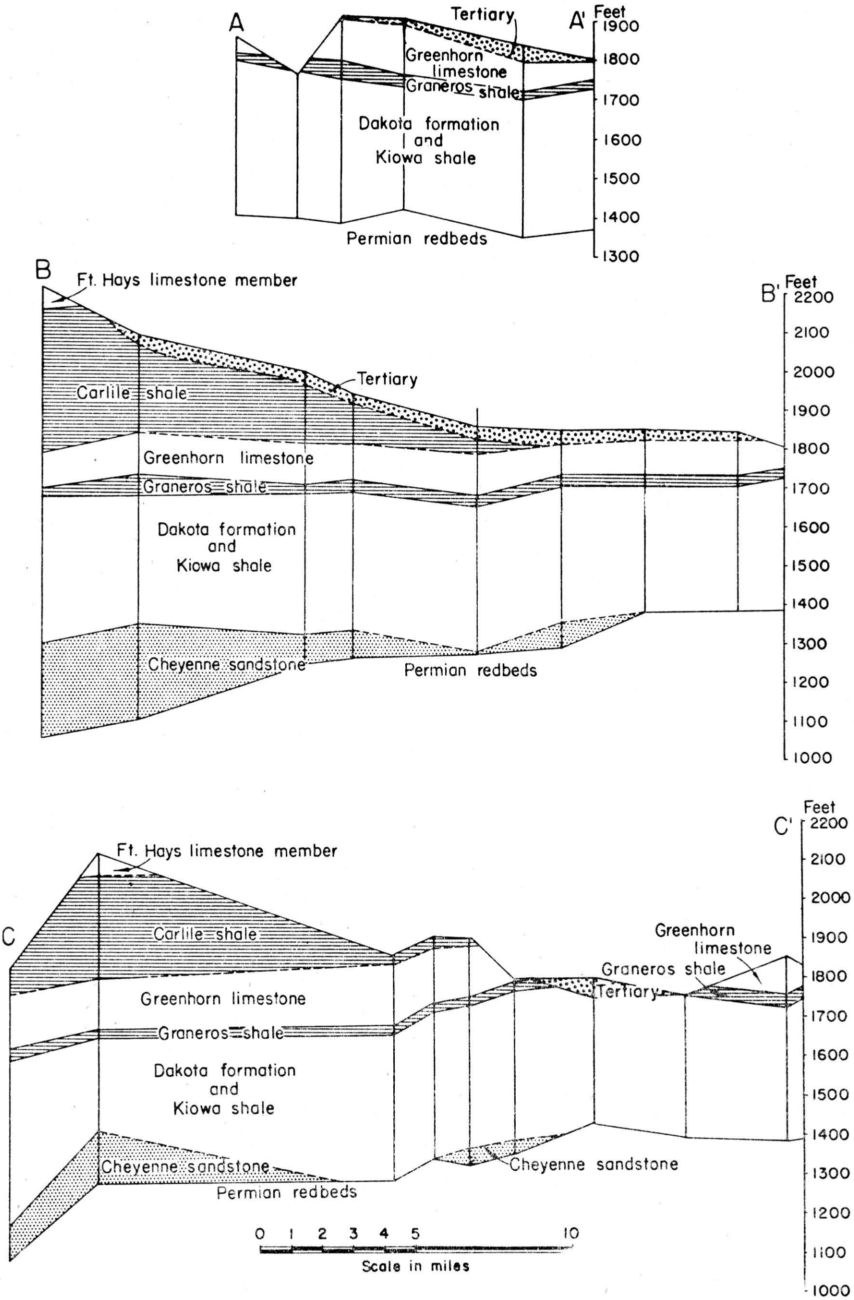

FIG. 2. Generalized cross sections plotted from logs of test holes and oil wells. Locations of cross sections are shown on plate 1.

The Cretaceous deposits below the Graneros shale becomes thicker across these counties toward the west. This thickening is shown by the several patterns in figure 3, which also shows by contour lines the configuration of the upper surface of the Permian rocks. The Cheyenne sandstone is thickest in the western part of the area and becomes thinner toward the east, being entirely absent east of central Russell county. The eastern margin of the Cheyenne standstone is shown in figure 3. The areal geology of this and other parts of Kansas is shown on the geologic map of Kansas published by the State Geological Survey of Kansas in 1937.

PERMIAN ROCKS

Character.—The oldest rocks penetrated in test holes put down during the investigation are Permian redbeds. These rocks have been classified by Norton (1939, pp. 1764-1765) as belonging to the Nippewalla group, and probably represent the Cedar Hills sandstone and Salt Plains formation (personal communication from R. P. Keroher). They consist of alternating beds of red and gray sandstone, red siltstone, and shale. The Permian rocks can be distinguished from the overlying Cretaceous beds in well cuttings by their distinctive brick-red color and the fine texture of the sandstones. The configuration of the upper surface of the Permian rocks is shown by contour lines in figure 3.

Water supply.—No water wells in this area obtain a water supply from the Permian rocks and water samples were not collected from test holes that penetrated these rocks. It is reported, however, that highly mineralized water has been encountered in the Permian redbeds where they have been penetrated by oil wells.

CRETACEOUS ROCKS

Rocks of Cretaceous age crop out or underlie the surface at shallow depths over the entire area under consideration. A general study of the Cretaceous rocks of Russell county was made by Rubey and Bass and published in Bulletin 10 of the State Geological Survey of Kansas (1925). A similar study of these rocks in Ellis county was made by Bass and published in Bulletin 11 of the State Geological Survey of Kansas (1926). Recently a critical study of the pre-Greenhorn Cretaceous rocks has been made in the area immediately east of Russell county by Plummer and Romary (1942). We have used these three reports freely, and much of the following discussion is quoted from them.

CHEYENNE SANDSTONE

Character and thickness.—The Cheyenne sandstone does not crop out at the surface anywhere in the area studied but it is an important formation in the subsurface as shown by well logs and cuttings from test holes. This formation was described by F. W. Cragin in 1889 from exposures at Cheyenne rock, near Belvidere in southeastern Kiowa county, Kansas. In the type area the Cheyenne sandstone attains a thickness of 40 feet, and is a cross-bedded loosely cemented sandstone interbedded with shale. The surface exposures of this formation nearest to the area discussed herein occur in the type area in Kiowa county. It seems probable that the Cheyenne sandstone occurring under this area has some of the same features that it possesses farther south. Sieve analyses of typical samples of Cheyenne sandstone from Kiowa county are given in table 7.

Well logs and test holes indicate that the Cheyenne sandstone underlying north-central Ellis county attains a maximum thickness in excess of 200 feet. It consists dominantly of moderately well-sorted quartz sand but contains a few beds of shale, and is light gray in color. This formation becomes thinner toward the east and is entirely absent east of central Russell county. The approximate eastern margin of the Cheyenne sandstone is shown on figure 3. This map also shows the thickness of the pre-Graneros Cretaceous rocks, the configuration of the Permian surface, and the well data upon which the map is based.

In 1895, Cragin classified the Cheyenne sandstone as a part of the Elk Creek beds, including the Stokes sandstone member at the top, the Lanphier beds, and the Corral sandstone member at the base. These units have never come into general use, and Twenhofel (1924, pp. 13, 14) has pointed out that they cannot be traced beyond a few square miles in southeastern Kiowa county, where the type localities are located. Minor divisions of the Cheyenne cannot be recognized in the subsurface. In this report the Cheyenne sandstone is used to include the beds designated by Cragin (1889, p. 65) and by Plummer and Romary (1942) as the nonmarine and near-shore deposits, consisting dominantly of quartz sand, unconformably overlying the Permian redbeds and overlain by the marine Kiowa shale.

Water supply.—Water from the Cheyenne sandstone is not used in this area for domestic, stock, or public supply, and has been pumped at only a few places as a water supply for drilling oil wells.

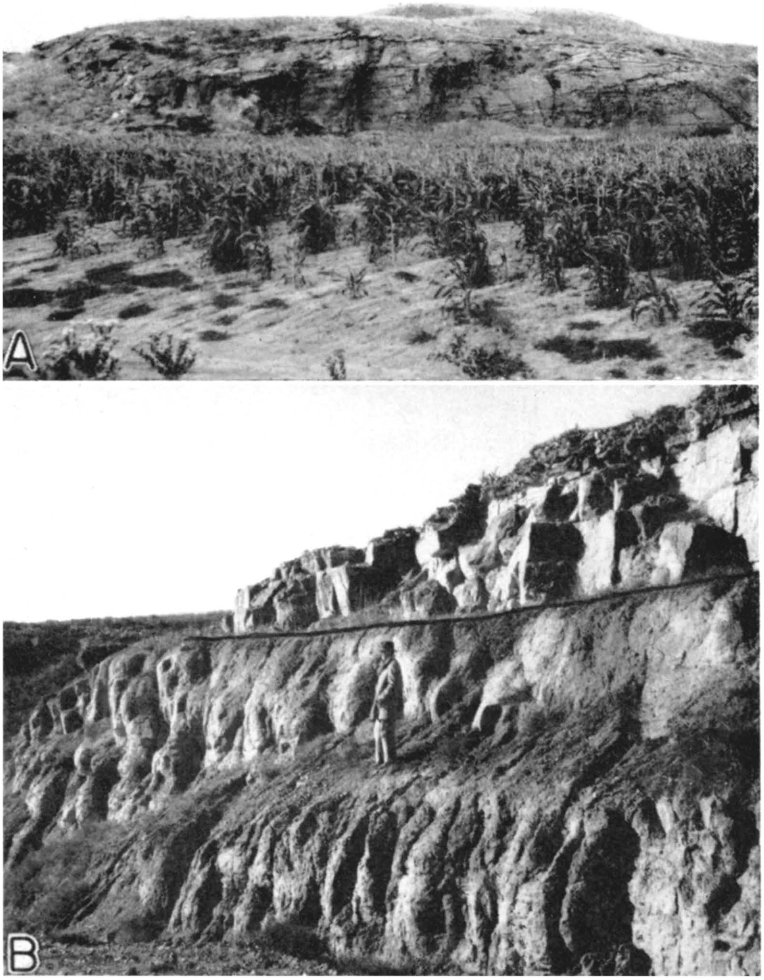

PLATE 2. *A,* Channel sandstone in the upper part of the Dakota formation, north side of Saline valley, north of Bunker Hill, Russell county. *B,* Codell sandstone member of the Carlile shale and the overlying Fort Hays limestone member of the Niobrara formation, north side of Saline valley, south of Codell, Ellis county. (Photographs by Frye.)

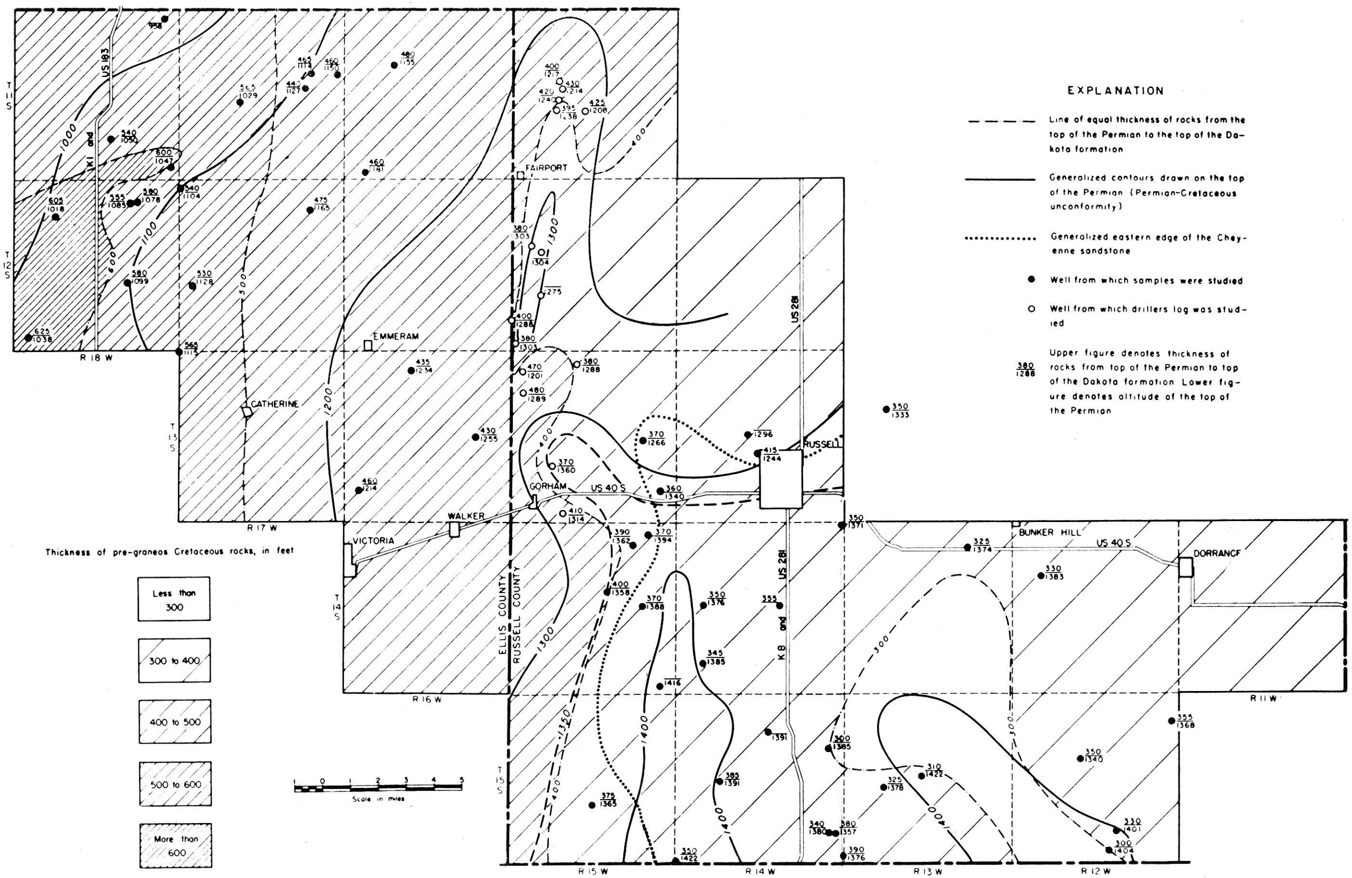

FIG. 3. Map of parts of Ellis and Russell counties, Kansas, showing changes in thickness of pre-Graneros Cretaceous rocks. The thinning of the pre-Graneros Cretaceous rocks is shown by contour lines and by shaded patterns. The configuration of the surface of the Permian rocks is shown by contours. The eastern margin of the Cheyenne sandstone is also shown.

Water from the Cheyenne sandstone is, for the most part, highly mineralized. This sandstone has been approved by the Kansas State Board of Health as a disposal horizon for oil-field brines. Many of the shallow disposal wells shown on plate 1 are being used for injecting brine into the Cheyenne sandstone.

KIOWA SHALE

Character and thickness.—The Kiowa shale was named in 1894 by F. W. Cragin (p. 49) and described as the dark- and light-colored fossiliferous shales overlying the Cheyenne sandstone or the Permian "redbeds," and overlain by brown sandstones of middle Cretaceous age, or by Tertiary or Pleistocene deposits. The name was derived from Kiowa county in southwestern Kansas. Although the Kiowa shale does not crop out in Russell or Ellis counties, it underlies the entire area under discussion. It overlies the Cheyenne sandstone and overlaps it to the east, and is overlain by the Dakota formation. Plummer and Romary (1942), who have studied the pre-Greenhorn Cretaceous rocks east and south of Russell county, describe the Kiowa as dark-gray fissile shale containing selenite crystals, bands of "ironstone," and cone-in-cone structures. They further state that the Kiowa also contains sandstone ranging in color from white to brown. These sandstone beds generally are fine-grained and horizontally thin-bedded. Some of them contain glauconite grains, pyrite, and lignite. Molds of marine fossils have been observed in these sandstones, and thin shell beds occur in the Kiowa in the type area. The Kiowa shale closely resembles the Graneros shale in superficial appearance. Plummer and Romary state that east and south of Russell county the maximum thickness of the Kiowa is 100 to 125 feet; available data indicate that under Russell and Ellis counties the thickness of the formation probably does not exceed this amount.

The available data indicate that the Kiowa shale is marine in origin. Many marine invertebrate fossils occur throughout the formation; plant fossils and lignite, common in both the Cheyenne sandstone and Dakota formation, are rare.

In the subsurface it is difficult to distinguish sharply the contact between the Kiowa shale and the overlying Dakota formation because they are seemingly conformable and gradational. Lithologic types prevalent in the lower part of the Dakota formation are also common in the upper part of the Kiowa shale, and the scattered marine fossils are not easily detected in cuttings. The Kiowa is distinguishable, after the transition zone has been passed through, by the absence of abundant siderite, the presence of gypsum and marine fossils, and the decreasing amount and finer texture of the sandstone beds. In the type area, thin limestones are also a distinguishing feature.

Water supply.—The Kiowa shale, which consists of shale, silt, and fine-grained sandstone, is a poor water-bearing formation. So far as is known no wells in the areas studied obtain water from this formation.

DAKOTA FORMATION

Character and thickness.—The term Dakota group was first applied to a stratigraphic unit by Meek and Hayden in 1862 (pages 419, 420), and was defined to include the sandstones, various colored clays, and lignite beds which underlie the "Benton group" in eastern Nebraska. The beds were named from exposures near Dakota City, in Dakota county, Nebraska. They were believed by Meek and Hayden to extend into northeastern Kansas. Since that time the terms "Dakota group," "Dakota sandstone," and "Dakota formation" have been used and misused in Kansas in a multiplicity of ways. In this report Dakota formation is used in the same sense as described by Plummer and Romary (1942) to include those dominantly continental and littoral deposits occurring stratigraphically above the marine Kiowa shale and below the marine Graneros shale in north-central Kansas. The Dakota formation attains a maximum thickness of more than 300 feet.

Many of the stratigraphic names that have been assigned to beds here included in the Dakota formation, such as Mentor beds, Marquette sandstone, and Rocktown channel sandstone, cannot be recognized with certainty from well cuttings and in many places cannot be correlated from one surface exposure to another outside of the type area. Plummer and Romary (1942) describe the Dakota formation as consisting of alternating beds of various colored clay, shale, siltstone, and sandstone (pl. 2A), in which lignite beds are prominent near the top and limonite, hematite, and siderite are abundant throughout. They subdivide the formation into two members, the Janssen clay member (upper) and the Terra Cotta clay member (lower), named from two railroad stations in Ellsworth county, Kansas. They have recognized and correlated these units extensively over the outcrop area, and in many places it is possible to recognize them from well cuttings.

In well cuttings the top of the Dakota formation is marked by the appearance of siderite (and/or ankerite), both in angular fragments with inclusions of fine sand and silt and in small globular or microbotryoidal concretions, and by the appearance of kaolin clay minerals. The Graneros shale above is a dark-gray fissile shale containing selenite crystals and pyrite, and the change to light-colored shale or clay, or in some places sandstone, and the appearance of siderite (and/or ankerite) make the contact between the Dakota and the Graneros fairly distinct. The top of the first sandstone cannot safely be taken as the top of the Dakota formation because in some places a prominent sandstone occurs in the Graneros shale and in other places the upper 10 to 40 feet of Dakota consists of shale. Except where displaced by one of the numerous medium- to coarse-grained channel sandstones, the Janssen member of the Dakota formation is composed of light-colored clay, shale, and sandy siltstone containing a recognizable amount of siderite. The Terra Cotta member of the Dakota formation contains a greater abundance of siderite concretions or pellets than the Janssen member, and an abundance of mottled red and gray clay and shale. Siltstone and channel sandstones are also present in the Terra Cotta member.

An excellent exposure of the upper part of the Terra Cotta member and of the Janssen member of the Dakota formation, the Graneros shale, and the lower part of the Greenhorn limestone, occurs along the road cut and the abandoned road cut south of Wilson near the Russell-Ellsworth county line. A measured section is given in table 4.

TABLE 4.—*Measured section (No. 9) of Cretaceous rocks exposed along the south side of Smoky Hill valley, south of Wilson, SW¼ sec. 31, T. 14 S., R. 10 W., Ellsworth county.* (Measured by John C. Frye and James J. Brazil.)

Bed No.		*Thickness (feet)*
Greenhorn limestone		
18.	Limestone, shale, and sandstone, interbedded. Shale is thin-bedded to fissile, gray to dark brown; sandstone is brown, calcareous. Limestone is irregularly bedded, nodular, cream to gray, and contains calcite veinlets at base. A thin band of light greenish-gray bentonite occurs immediately above the nodular limestone. Three thin bands of bentonite occur near top of interval	+ 15.0
17.	Sandstone, calcareous, and shale, interbedded; brown to light brown; contains a 4-inch bed of greenish-gray bentonite at top	2.0
Graneros shale		
16.	Shale, thin-bedded to fissile, dark gray to black, gypsiferous, containing interlaminations of fine-grained gray sand. Contains ochreous coloring along shale bedding	24.3
15.	Sandstone, medium-grained, well-sorted, thin-bedded, light brown to buff	1.4

14. Shale, carbonaceous, dark gray and brown, containing carbonized plant remains on bedding planes. Fine laminae of fine-grained gray sand distributed through interval; red-brown band of ironstone occurs in the middle	5.3
Dakota formation	
Janssen clay ~~member~~	
13. Siltstone, massive, calcareous, light lavender-gray weathering gray-buff, containing fragments of carbonaceous material. Contact between bed 13 and underlying lignitic bed 12 is irregular	1.4
12. Shale, fissile, black to dark brown, containing lignitic zones at middle and 1 foot below top. Differential compaction occurs in lignite where irregularities of bed 13 are extended downward	5.0
11. Shale, fissile, dark gray to black, containing light-brown partings near top and lignitic zone at middle. Bed is capped by thin, gray, silty limestone which contains "borings" or root molds	3.7
10. Shale, carbonaceous, fissile, dark brown to black, containing lignitic zone at middle, and limestone, silty, light gray to light buff, containing borings suggesting mollusks at top	3.4
9. Siltstone, sandy, finely laminated, gray on weathered surface, lavender-gray on fresh surface, containing partly filled borings throughout and some charcoal fragments	1.2
8. Shale, thin-bedded, dark gray to black, gypsiferous. Lower part thinly interbedded with light-brown to yellow-brown sandy siltstone	14.8
7. Shale, gray, containing irregular interlaminations of gray silty shale and fine gray sand. Thin band of red-brown iron-stained siltstone at top	5.3
6. Sandstone, iron-cemented, brown to light brown, containing thin streak of red-brown ironstone at middle	1.8
5. Shale, fissile, dark gray to black; mottled brown and gray at top	7.6
4. Sandstone, massive, fine-grained, well-sorted, gray, tan and yellow-orange, containing carbonaceous material along bedding planes. Lower 6 feet include sandstone concretions containing inclusions of shale and claystone. Thin zones of finely interlaminated gray silty shale and fine-grained gray sand occur approximately 8 feet from the top and from the base	29.4
Terra Cotta clay member	
3. Shale, irregularly bedded, gray at top and dark gray at base. Massive irregular bed of gray, yellow-brown, and reddish-gray sandy silt at middle containing bands of sandy siltstone nodules immediately above and below and numerous small concretions of hematite which give the weathered surface a sugary texture	12.1
2. Sandstone, fine-grained, massive, well-sorted, angular to subangular, light gray-buff	3.6
1. Shale, silty, massive, red to brick-red, gray and yellow-brown mottled; shot-like concretions of iron numerous on weathered surface	37.0
Covered interval	12.0
Total thickness	186.3

The evidence indicates that the sediments comprising the Dakota formation were deposited in a continental and littoral environment, probably including extensive coastal lagoons and tidal marshes. This environment is attested by the abundant plant fossils, lignite beds, and, in a few places, the remains of land vertebrates. The presence of abundant siderite (or ankerite) seems to indicate reducing waters, such as might be found in a lagoon or marsh environment. The fact that siderite and related minerals constitute the prevalent occurrence of iron in these deposits becomes evident only when well cuttings are examined. In many exposures the siderite seemingly has been weathered near the surface to limonite or hematite. The foregoing indicates that the arm of the sea which covered this part of Kansas during the time the Kiowa shale was being deposited withdrew temporarily during Dakota time. The re-advance of this sea is attested by the overlying marine Graneros shale and younger Cretaceous rocks.

Water supply.—As stated above, the Dakota formation consists dominantly of clay, shale, and siltstone containing beds of fine-grained sandstone and an interlacing network of channel sandstones (pl. 2A). Water can be obtained from some of the widespread and fairly persistent fine-grained sandstones, but the most abundant supplies are obtained from the coarser textured channel sandstones. Because of the discontinuous nature of these channel sandstones, the quantity of water obtainable at any locality cannot be determined with certainty without test drilling.

In Russell county many domestic and stock wells obtain water from one or more of the sandstones in the Dakota formation. Records of several of these wells are given in table 13. The quality of the water obtainable from these various sandstone lenses is quite variable; some wells yield water of usable quality, whereas water from other wells is too highly mineralized to be suitable for most uses. Analyses of water from sandstones in the Dakota formation are given in figure 9 and tables 10 and 11.

GRANEROS SHALE

Character and thickness.—The Graneros shale consists of 25 to 40 feet of dark-gray to blue-gray shale overlying the Dakota formation and overlain by the Greenhorn limestone. The Graneros shale is characterized by selenite, pyrite, and thin streaks of iron sulphate along bedding planes and joints, and locally contains thin beds of sandstone. The Graneros shale in Russell county has been described by Rubey and Bass (1925, pp. 51-54) and in Ellis county by

Bass (1926, pp. 35, 36). Locally, thin beds of limestone occur near the top of the formation and beds of iron-cemented siltstone occur near the base. From well cuttings the formation is known to consist wholly of sand in some places. It can be distinguished from the overlying Greenhorn limestone because it is dominantly noncalcareous and sandy, and it can be distinguished from the Dakota formation below on the basis of its color, the absence of abundant siderite and kaolin, and the presence of abundant selenite and pyrite.

Water supply.—The Graneros shale consists dominantly of shale, hence it generally yields little or no water to wells. In some localities where the formation is sandy it yields meager supplies of water, but even in such places the water is of poor quality. No wells were observed in the area that obtain water from this formation.

GREENHORN LIMESTONE

Character and thickness.—The Greenhorn limestone underlies most of the upland areas in central Russell county and dips below the bottoms of the deepest valleys in eastern Ellis county. The Greenhorn limestone has been studied in detail in Ellis county by Bass (1926, pp. 31-35) and in Russell county by Rubey and Bass (1925, pp. 45-51), who describe this formation in Russell county as follows:

> This formation crops out on both sides of the valleys of the tributaries of the three large streams that run eastward across Russell county—Smoky Hill and Saline rivers and Wolf creek. Hard chalk in beds less than a foot thick alternate with chalky shale in the upper three-fourths of the formation. The proportion of chalk to marl is highest about one-fourth of the way down from the top. The lower fourth of the formation contains, in addition to the chalk and chalky shale, thin beds of hard crystalline limestone. From several measurements it seems that the thickness of the Greenhorn limestone decreases from 105 to 110 feet in the northern part of Russell county, south-southeastward to 85 or 90 feet in the southern part.
>
> The great abundance of the fossil *Inoceramus labiatus,* the stratigraphic position, and the calcareous composition of the formation permit a close correlation of the formation with the Greenhorn limestone of parts of Colorado, Wyoming, and elsewhere. The name Greenhorn was given by Gilbert, in 1896 (p. 564), to corresponding beds in southern Colorado, which are typically exposed at Greenhorn station and on Greenhorn creek, south of Pueblo, Colorado. The formation in Russell county, Kansas, is divided into four members, here listed in descending order: (1) An upper unnamed member [Pfeifer shale] consisting of beds of chalky shale and fossiliferous chalk; (2) the Jetmore chalk member, which consists of regularly alternating beds of chalk and chalky shale; (3) an unnamed member of chalky shale [Hartland shale] containing few beds of chalk; and (4) the Lincoln limestone member, consisting of thin beds of crystalline limestone in a series of beds of chalk and chalky shale.

Well cuttings from this formation consist of fragments of dark-gray calcareous shale and limestone. The shale fragments are typically speckled with light-gray flakes of calcium carbonate. These characteristics make the cuttings easily distinguishable from the Graneros shale below, but less easily distinguishable from the overlying Fairport chalky shale member of the Carlile shale. It is difficult to recognize subdivisions of the Greenhorn from well cuttings owing to the nearly uniform nature of the rocks. The hard limestone beds are, for the most part, too thin to distinguish and are fairly evenly distributed throughout the formation.

Water supply.—At some localities in Russell county water for domestic and stock use is obtained from the near-surface weathered part of the Greenhorn limestone. Such wells are nearly all dug to shallow depths and are of relatively large diameter to afford maximum collecting and storage capacity. Water collects along bedding planes, joints, and fractures in the limestone, but in most places the quantity available from this formation is meager. Water is obtained only in the near-surface weathered part of the Greenhorn. The mantle rock that develops on the Greenhorn outcrops is more permeable than the mantle rock over the dominantly shale formations, because the thin limestone beds weather to angular pieces and so maintain somewhat of an open textured deposit through which ground water can circulate. Chemical analyses of water from the Greenhorn are given in figure 8 and table 10.

CARLILE SHALE

Character and thickness.—The Carlile shale underlies all of the uplands of Ellis county, and remnants of it cap the uplands of western Russell county. It has been described in Russell county by Rubey and Bass (1925, pp. 32-45), and in Ellis county by Bass (1926, pp. 26-31). Bass (p. 26) describes the Carlile shale in Ellis county as follows:

> Chalky and clay shale, about 300 feet thick, that contains thin beds of chalk near its base, numerous zones of septarian lime concretions in its upper half, and a unit of fine-grained sandstone at its top, constitutes the Carlile shale. The upper two-thirds is made up predominantly of gray-black fissile clay shale, and the lower third of chalky shale and thin beds of chalky limestone. In Ellis county it is separable into the Blue Hill shale member above and the Fairport chalky shale member below.

The Blue Hill shale member ranges in thickness from 175 to 215 feet. It is nonresistant on exposure and forms rounded slopes. The upper part of this member is typically sandy in these counties and was named the Codell sandstone bed (pl. 2B) by Bass (1926, p. 28).

In 1933, Dane and Pierce (1933) elevated Codell sandstone to the rank of a member at the top of the Carlile shale and restricted the Blue Hill shale member to the underlying part of the Blue Hill shale of previous reports. The Codell is referred to in this report as a member rather than a bed or zone of the Blue Hill shale because it is easily recognizable on the surface and in well cuttings by its distinctive lithology and color, and because it is widespread in western Kansas. In Kansas it ranges in thickness from a few inches to more than 20 feet. The Codell is well exposed in the bluffs along the north side of Saline valley west of the Russell-Ellis county line (see pl. 2). In this area the Codell sandstone member is about 20 feet thick, is very fine-grained, and is loosely cemented with calcium carbonate. In the type area this member is dominantly silt at the base and grades downward into silty shale.

In well cuttings the Fort Hays limestone member of the Niobrara formation is readily distinguishable from the underlying Codell sandstone member and the dark-gray, noncalcareous shale of the Carlile.. Where the Codell member is present it can be recognized as a silty, fine-grained sandstone, light gray to white in color. The Fairport chalky shale member can be distinguished from the Blue Hill shale member by its chalky character, but it is more difficult to distinguish the Fairport-Greenhorn contact.

Water supply.—Although a few shallow dug wells obtain meager supplies of water from the weathered near-surface part of the shale and mantle rock, it is, on the whole, not a good water-bearing formation. The Codell sandstone member is the only part of this formation that generally yields adequate supplies of water for domestic and stock use, and it is probable that none of the wells in the Codell will yield as much as 10 gallons a minute because of the fine texture of the sandstone. Many wells have been drilled and dug into the Codell in north-central Ellis county; records of some of these wells are given in table 14. The quality of the water obtained from this member is satisfactory for most uses. Analyses of water from the Codell sandstone member are given in figure 8 and table 11.

NIOBRARA FORMATION

Character and thickness.—The Niobrara formation crops out in the northwestern corner of Russell county and underlies much of the upland area of central and northern Ellis county. At no place in the area under consideration does the entire thickness of the formation occur, the upper part having been removed by erosion. The maximum thickness of the Niobrara formation exposed in this area is about 150 feet. Bass (1926, pp. 19-26) has described the occurrence and lithology of this formation in Ellis county, where it is divided into two members—the Smoky Hill chalk member (upper) and the Fort Hays limestone member (lower). The Smoky Hill member consists of marl beds alternating with beds of chalk and clay. The Fort Hays member (pl. 2B) is the better exposed in this area and has been described by Bass (1926, p. 24) as follows:

> Massively bedded cream-colored chalk or very chalky limestone, aggregating 55 feet in thickness, . . . The individual beds of chalky limestone range in thickness from 6 inches to 6 feet and average about 2½ to 3 feet; these beds are separated by thin layers, 1 to 4 inches thick, of light gray to dark gray chalky clay shale. The bedding is thinner toward the top of the member, and the upper beds commonly weather almost pure white. In contrast with the chalk of the overlying Smoky Hill member the rock of the Fort Hays member appears slightly coarser in texture and somewhat harder.

Water supply.—A quantity of water sufficient for domestic and stock use generally cannot be obtained from the Niobrara formation. None of the wells visited in Russell and Ellis counties obtained water from this formation. It is possible, however, that in certain localities some water has accumulated in the weathered near-surface part of this formation and shallow dug wells in such areas may yield sufficient water for some purposes.

TERTIARY ROCKS

OGALLALA (?) FORMATION

Character and thickness.—Deposits of Tertiary age are spread over the upland areas of much of northern Ellis county, and discontinuous areas of Tertiary deposits occur on the divides in western and central Russell county. Bass (1926, p. 16) correlated these deposits in Ellis county with the Ogallala formation of western Kansas and Nebraska and stated that they attain a maximum thickness of 75 feet. In Russell county east of the Fort Hays escarpment these upland deposits attain a maximum thickness of about 40 feet (Frye, Leonard and Hibbard, 1943, p. 34). They consist of gravel, sand, silt, and clay, and locally are cemented with calcium carbonate and contain nodules of calcium carbonate. These deposits range within wide limits in texture and lithology. In some places the sand and gravel consist dominantly of pebbles and grains of limestone, but elsewhere well-sorted quartz sand occurs, and sand and gravel containing abundant grains of feldspar and granite are exposed north of Gorham and at several places in Ellis county.

The age of these deposits east of the Fort Hays escarpment is in doubt. They are not continuous with the deposits overlying the Fort Hays member which were correlated by Bass with the Ogallala, but occur at a lower elevation. It is unlikely that two adjacent stream-laid deposits at different altitudes can be of the same age, even though erosion may have given some surface expression to the Fort Hays escarpment in pre-Ogallala time. It is probable that the upland deposits of Russell county and eastern Ellis county are younger than the Ogallala of Ellis county, and they are certainly older than the oldest Pleistocene terrace deposits along Smoky Hill and Saline river valleys. They are probably uppermost Pliocene or lowermost Pleistocene in age. No fossils have as yet been taken from these deposits.

Water supply.—In those areas where an appreciable thickness of Tertiary sand or gravel occurs, supplies of ground water generally have been found to be adequate for domestic and stock needs. Records of wells dug or drilled into these deposits are given in table 13. Many wells in the area north of Gorham in west-central Russell county obtain water from Tertiary(?) sand and gravel. A large well was drilled during 1941 in this area to obtain a water supply for the city of Gorham, but data on this well have not been made available. Water obtained from the Tertiary deposits is reported to be generally of good quality; typical analyses are given in figure 8 and table 10.

Pleistocene Deposits

Terrace deposits of presumed Pleistocene age were noted a number of years ago along the valleys of Smoky Hill and Saline rivers in Russell (Rubey and Bass, 1925, pp. 19-25) and Ellis (Bass, 1926, pp. 16-18) counties. Earlier, Logan (1897, pp. 218, 219) had described gravel beds in this area which he believed to be younger than the "Tertiary grit" (Ogallala formation) and referred to them as the "Salt Creek gravel beds." Recently a more detailed study has been made of these terrace deposits (Frye, Leonard, and Hibbard, 1943), particularly along Smoky Hill valley.

Character and thickness.—The Pleistocene terrace deposits consist of gravel, sand, silt, and clay; they underlie the surface of well-defined terraces along the Smoky Hill and Saline valleys and several of their major tributaries, particularly Big creek. The height above the present flood plain of the highest Pleistocene terrace gradually increases eastward across the area, reaching a maximum of nearly 150 feet in eastern Russell county. In this same part of the area the valley at the high terrace level attains a maximum width of 6 miles.

The high terrace where well preserved is characterized by a nearly flat upper surface underlain by 20 to 75 feet of gravel, sand, and silt. The boundary between the high terrace surface and outer slopes of the valley is not sharp except where it has been accentuated by recent erosion, but is marked by a gently sloping surface that rises to the upland level. The streamward margins of the terraces are marked in most places by distinct scarps.

It has been pointed out that these terrace beds probably were deposited during the early Pleistocene by streams flowing from the Rocky Mountain region (Frye, Leonard, and Hibbard, 1943). In some places the gravels consist largely of limestone pebbles derived from the near-by Cretaceous rocks, but in many places the sand and gravel consist dominantly of grains and pebbles of quartz, feldspar, granite, and other igneous rocks. Many Pleistocene vertebrate and invertebrate fossils occur in the silt and clay beds of the terrace deposits. The presence of Pleistocene fossils together with the fact that these terraces can be traced down Smoky Hill valley nearly to the type locality of the McPherson formation (restricted) (Lohman and Frye, 1940; Frye and Hibbard, 1941) indicates that the deposits are equivalent, at least in part, to the McPherson formation.

Water supply.—Many wells obtain water for domestic and stock use from the sand and gravel beds of the Pleistocene terrace deposits, particularly along the valleys of Smoky Hill and Saline rivers and Big creek. Records of typical wells in the Pleistocene deposits are given in table 13. In areas where the terraces have been extensively dissected these deposits contain only a small amount of water, or are dry, but under the broad undissected terrace areas large supplies of ground water generally are available. No large wells have been constructed in these deposits but it is possible that wells yielding as much as several hundred gallons a minute could be developed in a few places where the terrace gravels attain maximum thickness. Except in areas where this shallow ground water has been polluted by brine from disposal ponds, improperly cased wells, or seepage from polluted Cretaceous sandstones, the quality of water obtained from the Pleistocene deposits is satisfactory for most uses. Analyses of typical waters from the Pleistocene deposits are given in tables 10 and 11 and figure 8.

RECENT ALLUVIUM

Character and thickness.—Deposits of gravel, sand, silt, and clay of Recent age occur along the valleys and underlie the flood plains of the principal streams of this area, and occur also along the bottoms of some of the small stream valleys. The character and thickness of the alluvium range within wide limits, but in most places the alluvium contains some water-bearing sand or gravel. The alluvium exceeds 40 feet in thickness in only a very few places. The band of alluvium along the principal stream valleys attains a maximum width of about a half mile, but in most places it is less than a quarter mile in width.

Water supply.—Recent alluvium underlies only a small part of the total area; hence it does not constitute as important a source of ground-water supplies as does similar material in other parts of the state. It yields abundant supplies to wells along the major valleys, however, and yields meager supplies along the small stream valleys. Wells yielding as much as 500 gallons a minute might be obtained at the most favorable places in the alluvium. The water obtainable from the alluvium, although having considerable hardness, is satisfactory for most uses except in areas where it is contaminated by oil-field brine.

GEOLOGIC HISTORY

The known geologic history of this area started with the erosion of the pre-Cambrian basement rocks that occur below the Paleozoic sediments. This surface was submerged below sea level and marine sediments were deposited upon it. Throughout much of Paleozoic time the area was successively submerged and elevated. Marine sediments accumulated during periods when the surface was below sea level, and these sediments were subsequently eroded during periods of emergence. The lower Paleozoic rocks consist for the most part of marine limestone, shale, and sandstone.

According to Moore and Jewett (1942) an important structural event occurred in this area during post Devonian-preMississippian time. This consisted of a regional arching of the strata along a northwest-southeast axis and is indicated by the fact that pre-Mississippian erosion truncated the earlier Paleozoic rocks and stripped off all of the beds down to the Arbuckle limestone. This period of uplift and subsequent erosion is believed to have been followed by marine inundation and resulting deposition of the Mississippian strata over this part of Kansas. The rocks of northwestern Kansas were again uplifted and warped along this same general structural trend at the close of Mississippian time or during early Pennsylvanian time to form the structural feature now recognized as the Central Kansas Uplift. It is this structure that has localized the accumulation of oil produced from these counties. The Mississippian strata believed to have existed across the top of this structure were stripped away by early Pennsylvanian erosion. As some places along the Central Kansas Uplift this early Pennsylvanian erosion cut away the rocks to such a depth as to expose the pre-Cambrian basement. Coarse clastic deposits accumulated along the flanks of the Uplift as a result of this period of erosion, and it is believed that they may have been contemporaneous with the denudation deposits that were spread out toward the east from the ancestral Rocky Mountains.

The sea again invaded the area and marine deposits accumulated across all of northwestern Kansas during Pennsylvanian time. During the latter part of the Paleozoic, marine conditions were less prevalent and at times sediment accumulated on the surface of the land. Thus marine and nonmarine deposits occur alternately throughout rocks representing upper Pennsylvanian and Permian time. Desiccation and continental type sediments became more prevalent throughout Permian time, indicating an intermittent but progressive withdrawal of the seas.

The sea withdrew completely from the area by the close of Paleozoic time and the surface was eroded, uplifted, and warped. Erosion proceeded throughout much of Triassic and Jurassic time and it was over this eroded land surface that the Cretaceous deposits were spread.

The contact between the Cretaceous and Permian rocks, where it can be observed in adjacent areas, is characterized by a weathered zone at the top of the Permian. This zone is several feet thick, gray in color, and transgresses the bedding planes, indicating a relatively long period of weathering. At many places a zone of pebbles or cobbles has been observed at the base of the Cretaceous deposits. These pebbles consist of quartzite and igneous rocks and probably represent the first phase of continental deposition. This zone may be equivalent to the gravel that occurs at approximately the same stratigraphic position northeastward from Kansas. It has been observed in Kansas at the base of the Cheyenne, Kiowa, and Dakota where these formations immediately overlie the Permian.

During much of early Cretaceous time Ellis and Russell counties were still above sea level, whereas marine deposits were accumulating to the south and southwest. As the early Cretaceous sea encroached northward, clastic sediments accumulated at and near the shore line as beach deposits, deltas, and off-shore bars. These deposits, in addition to near-shore channel and flood-plain deposits, constitute the Cheyenne sandstone. In central Kansas they probably accumulated during a period of stable sea level or when the shore line was moving slowly northward, and the Kiowa shale, which overlies and overlaps the Cheyenne, represents the sediments deposited under marine conditions as the sea more rapidly advanced and inundated this region.

The close of early Cretaceous time is marked by the withdrawal of the sea. It was not a continuous retreat but was marked by minor readvances, and left interbedded marine and continental beds. Also it seems that the earth movements that occurred elsewhere at the close of Lower Cretaceous time may not have affected this area, because the Dakota formation, which is generally considered Upper Cretaceous in age, conformably overlies the Kiowa shale and is transitional with it. The Dakota formation is composed of continental and littoral beds deposited in channels, flood plains, beaches, lagoons and bars. Sand accumulated in stream channels or on beaches and bars, and clay, silt, and carbonaceous material were deposited on flood plains and in lagoons. The channel sandstones in general trend northeast, and the more evenly bedded bodies of sand that are believed to represent bar or beach deposits generally trend north or north-northwest. Thus the sandstones in the Dakota formation are elongate lenticular sand bodies interspersed through the clay and silt. This explains the fact that in some places one of two near-by wells will encounter several beds of sandstone and the other few or none. Also it can readily be seen why two near-by wells drilled into the Dakota sandstones yield water of different quality or water under a different hydrostatic head, and yet other wells more widely separated may have similar characteristics. This lattice work of lenticular sandstones is in part interconnecting, however, as shown by exposures where one lenticular sand body rests upon another.

Continental conditions existing throughout Dakota time again gave way to marine conditions and the upper part of the Dakota contains a larger percentage of even-bedded sand and silt suggesting beach or bar deposits. The sea completely transgressed the area for the last time and the Graneros shale and overlying marine formations of upper Cretaceous age were deposited.

Since the withdrawal of the Cretaceous sea this area has been continuously above sea level. It was subject to erosion during most of Tertiary time and was covered by a thin veneer of clastic sediments during the Pliocene. These sediments represent material eroded from the highlands to the west and transported to western Kansas by eastward flowing streams.

During the Pleistocene the major streams crossing this area from west to east cut wide valleys and spread a thick layer of gravel and silt over their valley floors. It was at this stage of valley development during the early Pleistocene that major changes occurred in the drainage pattern of central Kansas (Frye, Leonard and Hibbard, 1943). Wilson valley in western Ellsworth county, which formerly had carried the Saline river drainage into the Smoky Hill valley, was abandoned. Also, the McPherson valley, which carried this western drainage southward to its junction with the Arkansas valley, was abandoned, and the major drainage way was established to the eastward across the flint hills in the position of the present Kansas river valley. Several minor periods of valley cutting followed and gave rise to the series of terraces now to be seen along the major valleys of this area. The present valleys of the major streams are quite narrow and are cut below the level of the lowest Pleistocene terrace.

PHYSICAL PROPERTIES OF WATER-BEARING MATERIALS

Samples for sieve analyses and determinations of the coefficient of permeability were collected from surface exposures of the Dakota formation and the unconsolidated Tertiary and Quaternary deposits. Sieve analyses and determinations of the coefficient of permeability were made by Laurence P. Buck and us.

A sieve analysis of a sample of granular material consists of separating the grains of different sizes into groups by means of standard sieves and determining what percentage, by weight, each group constitutes. The unconsolidated samples required little or no treatment prior to analysis, but the samples of sandstone from the Dakota formation, which were cemented with iron oxide, had to be disaggregated by several methods described later. The samples were all "spot samples"; that is, they were collected from a small area of the exposure and are not composites of several adjacent beds. Where the field sample of unconsolidated material was too large for analysis, a representative sample of the desired size was obtained by repeated splitting using a modified Jones sample splitter. Carefully weighed samples ranging between 25 and 100 grams were put into a set of 3-inch sieves, the sieves were shaken vigorously for 25 minutes in a rotary shaker, and the fractions were weighed on a precision balance.

The permeability of a water-bearing material is its capacity for transmitting water under pressure. The coefficient of permeability, as determined in the field or laboratory, is expressed by O. E. Meinzer as the number of gallons of water a day, at 60° F., that is conducted laterally through each mile of water-bearing bed under investigation (measured at right angles to the direction of flow), for each foot of thickness of the bed, and for each foot per mile of hydraulic gradient (Stearns, 1927, p. 148). The coefficients of permeability given below were determined by means of a portable field apparatus designed by C. V. Theis of the Federal Geological Survey.

CONSOLIDATED DEPOSITS

Samples of sandstone of the Dakota formation were collected from exposures where stratigraphic sections were measured and were also collected from isolated exposures where the thickness of rocks exposed was not sufficient to encourage the measurement of a section. Thus the intervening samples are not placed precisely within the stratigraphic section, but they are all known to be from the upper part of the Dakota formation. The reader is referred to the measured sections given in this report for the exact stratigraphic position of samples from measured sections and for a description of the lithology of the bed sampled and of the intervening beds.

Most of the samples of sandstone from the Dakota formation were sufficiently indurated to require some special preparation and disaggregation before analyses could be made. Some of the light-gray friable sandstones were disaggregated mechanically by crushing the sample with a wooden roller on a soft wooden platform. It was necessary to disaggregate most of the samples chemically, however. The most satisfactory chemical method of disaggregation was found to be that of treating the sample with a solution of stannic chloride ($SnCl_4$) as described by Tester (1931). This solution was prepared by adding tin (Sn) to a slightly excess amount of hydrochloric acid (HCl). This treatment proved quite effective in removing the iron-oxide cement from the sandstone and thus disaggregating the sample prior to sieve analysis.

The determined physical properties of the samples of sandstone from the Dakota formation are given in tables 5 and 6. It will be noted that for most samples analyzed the major grade occurs in the sizes from medium sand (0.5—0.25 mm) to very fine sand (0.125—0.062 mm). In no sample is the major grade coarser than medium sand and the most common major grade is fine sand (0.25—0.125 mm). The major grade of a few samples is silt and clay (less than

TABLE 5.—*Physical properties of samples of sandstone collected from exposures described in the measured sections included in this report*

(Analyses by L. P. Buck, J. J. Brazil, and J. C. Frye)

No. of bed in measured section	Position of sample from within the described bed	Mechanical analysis (percent by weight)							
		Fine gravel (2.0-1.0 mm)	Coarse sand (1.0-0.5 mm)	Medium sand (0.5-0.25 mm)	Fine sand (0.25-0.125 mm)	Very fine sand (0.125-0.062 mm)	Silt and clay (less than 0.062 mm)	Solubility in $SnCl_4$ (percent)	Coefficient of permeability[1]
Measured section No. 1, NW¼ sec. 34, T. 12 S., R. 14 W., Russell county									
3	....	0.0	0.0	0.3	6.7	57.4	35.6	....	....
6	1 foot above base..........	0.0	tr.[2]	2.5	36.6	54.9	6.0	....	12
6	10 feet above base.........	0.0	tr.	0.4	17.8	64.4	17.4	....	4
6	16 feet above base.........	0.0	0.0	tr.	22.6	60.7	16.7	....	2
Measured section No. 2, NE¼ sec. 34, T. 12 S., R. 14 W., Russell county									
2	top of bed...............	0.0	tr.	12.0	35.5	43.8	8.7	....	13
4	....	0.0	0.0	0.5	2.9	71.8	21.3	3.5	....
9	do....................	0.0	0.0	0.0	40.7	22.4	28.1	8.8	....
11	1 foot below top of bed.....	0.0	0.2	13.7	68.3	12.4	3.4	2.0	....
11	top of bed...............	0.0	tr.	15.5	67.4	11.8	4.5	0.9	185

Measured section No. 3, SE¼ sec. 25, T. 12 S., R. 14 W., Russell county

9	1 foot above base..........	0.0	tr.	0.9	90.1	7.3	1.7	....	34
9	1 foot below top of base....	0.0	0.0	tr.	10.7	56.0	5.7	27.6	....
9	top of bed................	0.0	tr.	0.5	88.1	8.6	2.8	....	70

Measured section No. 4, SW¼ sec. 29, T. 12 S., R. 13 W., Russell county

2	base of bed...............	0.0	0.0	31.5	25.9	2.8	2.4	37.4	....
2	2 feet above base of bed....	0.0	tr.	14.2	56.0	14.1	3.3	12.4	....

Measured section No. 5, SE¼ sec. 9, T. 13 S., R. 12 W., Russell county

5	middle of bed.............	0.0	0.0	0.1	29.3	49.8	17.8	3.0	....
9	....	0.0	0.3	73.0	5.9	4.4	4.5	11.9	....
11	middle of bed.............	0.0	1.1	61.9	24.4	5.7	1.8	5.1	....
13	do....................	0.0	tr.	41.1	51.1	3.1	2.1	2.6	390
15	do....................	0.0	0.0	5.5	60.7	13.7	7.2	12.9	320
17	1 foot above base of bed....	0.0	tr.	19.7	62.4	14.2	2.0	1.7	170
19	....	0.0	tr.	6.2	84.8	3.4	1.2	4.4	....

Measured section No. 6, NE¼ sec. 12, T. 13 S., R. 12 W., Russell county

2	middle of bed.............	0.0	0.2	51.3	43.4	1.9	0.6	2.6	105
2	top of bed................	0.0	tr.	13.8	61.9	7.9	4.2	12.2	....
4	middle of bed.............	0.0	tr.	0.1	86.2	3.9	5.7	4.1	....
9	do....................	0.0	0.0	tr.	42.8	47.2	8.5	1.5	20
11	....	0.0	tr.	6.1	61.2	4.0	0.8	27.9	....

Table 5.—Physical properties of samples of sandstone collected from exposures described in the measured sections included in this report—*Concluded*

No. of bed in measured section	Position of sample from within the described bed	Mechanical analysis (percent by weight)							
		Fine gravel (2.0-1.0 mm)	Coarse sand (1.0-0.5 mm)	Medium sand (0.5-0.25 mm)	Fine sand (0.25-0.125 mm)	Very fine sand (0.125-0.062 mm)	Silt and clay (less than 0.062 mm)	Solubility in $SnCl^4$ (percent)	Coefficient of permeability[1]
Measured section No. 7, SE¼ sec. 23, T. 13 S., R. 11 W., Russell county									
1	base of bed	0.1	12.2	74.2	9.2	2.2	1.0	0.8	375
1	middle of bed	0.0	tr.	95.6	tr.	2.7	1.0	0.7	....
1	3 feet below top of bed	0.0	0.0	4.0	89.2	2.0	0.8	4.0	....
4	base of bed	0.0	tr.	24.8	67.0	6.4	1.2	0.6	....
4	top of bed	0.0	0.1	69.2	25.1	2.6	0.5	2.5	....
6	2 feet below top of bed	tr.	2.9	87.9	tr.	1.9	0.9	6.4	43
Measured section No. 8, NE¼ sec. 31, T. 14 S., R. 11 W., Russell county									
1	20 feet below top of bed	0.0	tr.	69.0	26.0	3.5	1.0	0.5	....
1	1 foot below top of bed	0.0	2.5	8.3	69.6	13.2	4.1	2.4	....
2	10 feet below top of bed	0.0	0.3	79.9	14.1	4.2	0.5	1.0	110
5	....	0.0	0.0	25.6	58.3	10.8	1.6	3.7	....

Measured section No. 9, SW¼ sec. 31, T. 14 S., R. 10 W., Ellsworth county

2	1 foot below top of bed.....	0.0	0.1	0.4	85.1	2.2	3.2	9.0	....
4	1 foot above base of bed....	0.0	tr.	4.3	59.0	16.4	2.4	17.9	....
4	19 feet above base of bed...	0.0	0.0	tr.	40.7	39.4	17.7	2.2	1
4	top of bed................	0.0	0.0	tr.	11.2	41.7	44.0	3.1	....
13	....	0.0	0.0	0.0	0.8	16.8	80.1	2.3	....

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1. Number of gallons of water a day, at 60° F., that is conducted laterally through each mile of water-bearing bed under investigation (measured at right angles to the direction of flow), for each foot of thickness of the bed and for each foot per mile of hydraulic gradient.

2. tr., trace (less than 0.1 gram).

TABLE 6.—*Physical properties of samples of sandstone collected from exposures of the Dakota formation*
(Analyses by J. C. Frye, J. J. Brazil, and L. P. Buck)

LOCATION	Position of sample	Mechanical analysis (percent by weight)							
		Fine gravel (2.0-1.0 mm)	Coarse sand (1.0-0.5 mm)	Medium sand (0.5-0.25 mm)	Fine sand (0.25-0.125 mm)	Very fine sand (0.125-0.062 mm)	Silt and clay (less than 0.062 mm)	Solubility in $SnCl_4$ (percent)	Coefficient of permeability[1]
SW sec. 22, T. 12 S., R. 13 W.	2 feet above road level	0.0	0.4	42.1	41.9	0.4	0.4	14.8	....
NW sec. 18, T. 12 S., R. 14 W.	Top of Saline river bank	0.0	0.0	42.5	45.7	3.0	2.2	6.6	....
NW sec. 18, T. 12 S., R. 14 W.	10 feet below top of Saline river bank	0.0	0.0	61.4	35.6	1.5	1.5	....	320
NW sec. 13, T. 12 S., R. 15 W.	1 foot above bottom of 8 foot bed,	0.0	0.0	tr.[2]	29.6	55.6	6.2	8.6	....
NW sec. 13, T. 12 S., R. 15 W.	Top of exposure	0.0	0.0	tr.	25.4	46.1	6.5	22.0	....
NE sec. 1, T. 13 S., R. 12 W.	West side of road	0.0	tr.	54.4	9.6	2.6	1.8	31.6	....
SW sec. 31, T. 14 S., R. 12 W.	South side of road	0.0	0.0	0.7	75.8	18.0	2.2	3.3	....
SE sec. 32, T. 14 S., R. 13 W.	East side of highway 281, 4 feet above base	0.0	tr.	68.9	29.9	0.6	0.6	....	630
SE sec. 32, T. 14 S., R. 13 W.	East side of highway, top of exposure	0.0	3.9	93.2	1.8	0.7	0.4	....	310
SW sec. 13, T. 15 S., R. 7 W.	Base of exposure in road cut	tr.	tr.	1.0	79.5	16.1	2.0	1.4	....
SW sec. 13, T. 15 S., R. 7 W.	Middle of exposure in road cut	0.0	0.0	0.4	80.4	17.0	1.2	1.0	....
NW sec. 21, T. 15 S., R. 9W.	Base of exposure, south side of road	0.0	tr.	11.5	47.5	20.5	6.4	14.1	....
NE sec. 5, T. 13 S., R. 13 W.	Top of exposure	0.0	tr.	1.3	13.6	69.3	15.8	....	4
NE sec. 5, T. 15 S., R. 13 W.	1.5 feet from base of exposure	0.0	tr.	80.6	15.1	tr.	0.4	3.9	....
NE sec. 5, T. 15 S., R. 13 W.	Middle of exposure, south side of road	0.0	tr.	70.8	13.3	0.7	0.3	15.0	....
NE sec. 1, T. 15 S., R. 14 W.	West side of road cut, top of exposure	0.0	0.0	1.0	88.0	3.8	7.2	....	13

NE sec. 1, T. 15 S., R. 14 W.	Base of exposure..............	0.0	0.0	tr.	2.6	64.5	32.6	0.3	....
SE sec. 3, T. 15 S., R. 14 W.	Middle of exposure along road cut.......................	0.0	tr.	0.2	18.4	69.8	7.3	4.3	....
NW sec. 21, T. 15 S., R. 19 W.	1 foot below top of exposure....	0.0	0.0	tr.	78.5	17.8	3.7	....	52
NE sec. 5, T. 16 S., R. 8 W.	4 feet below top of exposure....	0.2	13.9	73.2	3.9	1.0	1.9	5.9	....
NE sec. 5, T. 16 S., R. 8 W.	East side of road..............	tr.	2.2	44.5	49.0	3.4	0.8	0.1	....

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1. Number of gallons of water a day, at 60° F., that is conducted laterally through each mile of water-bearing bed under investigation (measured at right angles to the direction of flow), for each foot of thickness of the bed and for each foot per mile of hydraulic gradient.

2. tr., trace (less than 0.1 gram).

TABLE 7.—*Physical properties of samples of Cheyenne sandstone from exposures in the vicinity of the type locality, southeastern Kiowa county, Kansas*

(Collected by B. F. Latta; Analyzed by L. P. Buck)

LOCATION	Position of sample	Mechanical analysis (percent by weight)							
		Medium and coarse gravel (larger than 2.0 mm)	Fine gravel (2.0-1.0 mm)	Coarse sand (1.0-0.5 mm)	Medium sand (0.5-0.25 mm)	Fine sand (0.25-0.125 mm)	Very fine sand (0.125-0.062 mm)	Silt and clay (less than 0.062 mm)	Solubility in $SnCl_4$ (percent)
SW sec. 26, T. 30 S., R. 16 W.	14½ feet above base	10.7	15.4	17.5	40.6	14.4	0.9	0.1	0.5
SW sec. 26, T. 30 S., R. 16 W.	72 feet above base	0.0	0.0	0.0	0.2	88.8	10.2	0.5	0.3
SE sec. 9, T. 30 S., R. 16 W.	15 feet below "Champion shell bed"	0.0	0.0	tr.[1]	tr.	30.6	59.4	9.3	0.7
Sec. 8, T. 30 S., R. 16 W.	13 feet below "Champion shell bed"	0.0	0.0	0.0	0.3	89.1	9.1	0.5	1.0
Sec. 8, T. 30 S., R. 16 W.	4 feet above base	0.0	tr.	2.1	69.8	26.4	0.9	0.3	0.5

[1] tr., trace (less than 0.1 gram).

0.062 mm). The amount of soluble material contained in samples as cement and small concretions of iron oxide ranged from less than 1 to as much as 37.4 percent; however, most of the samples had a solubility of less than 10 percent in stannic chloride.

Due to the large amounts of cement irregularly distributed in some of the sandstones some of the determinations of coefficient of permeability of small samples may not be truly representative of a particular bed of sandstone or of the formation. It was possible, however, to determine the coefficient of permeability of many of the samples, the results of which are listed in tables 5 and 6. It will be noted that the coefficients of permeability of the sandstones generally are much lower than those of the unconsolidated sand and gravel given in table 8. The coefficient of permeability of 22 samples was determined, and the highest value obtained was 630. Of the 22 samples for which determinations were made, 10 had coefficients of more than 100; 8 had coefficients of 10 to 100; and 4 had coefficients of less than 10. This should not be considered completely representative, however, because only a few of the very fine-grained samples were analyzed. Concerning the relation of the permeability of water-bearing material to the yield of wells, Wenzel (1942, p. 11) states:

> Although there are many water-bearing materials of low permeability, most formations that are sufficiently water-bearing to be utilized by wells have coefficients that are whole numbers of two or more figures when expressed in Meinzer's units—that is, above 10. The yields of wells depend, of course, not only on the permeability of the formations they tap but also on the thickness of the formations, the draw-down of the water level, and the diameter and construction of the wells. For many places in the United States the physical and economic conditions are such that wells with moderate to high yields—100 gallons a minute or more—generally penetrate materials with coefficients of permeability of 100 or more.

Samples of Cheyenne sandstone were collected by B. F. Latta from near the type locality in Kiowa county, Kansas. The results of sieve analyses of these samples are given in table 7. Although these samples were collected some distance from this area, they may be considered typical of the composition of the Cheyenne sandstone. It should be noted that the range in major grade is from coarse sand to very fine sand.

UNCONSOLIDATED DEPOSITS

The laboratory determinations made on samples of the unconsolidated deposits collected from surface exposures in Russell county are given in table 8. The analyses are placed in three groups: (1)

TABLE 8.—*Physical properties of samples of unconsolidated deposits in Russell county*

(Analyses by John C. Frye and James J. Brazil)

LOCATION	Position of sample	Mechanical analysis (percent by weight)							
		Medium and coarse gravel (larger than 2.0 mm)	Fine gravel (2.0-1.0 mm)	Coarse sand (1.0-0.5 mm)	Medium sand (0.5-0.25 mm)	Fine sand (0.25-0.125 mm)	Very fine sand (0.125-0.062 mm)	Silt and clay (less than 0.062 mm)	Coefficient of permeability[1]
		Recent alluvium							
NW sec. 33, T. 14 S., R. 13 W.	Channel bar, Smoky Hill river. .	39.6	33.3	19.0	6.9	1.1	0.1	tr.[2]	9,000
NW sec. 33, T. 14 S., R. 13 W.	do.	37.1	28.7	15.4	13.6	4.7	0.1	0.4	2,500
NW sec. 33, T. 14 S., R. 13 W.	do.	3.8	19.6	61.1	14.7	0.5	0.1	0.2	3,300
NE sec. 36, T. 14 S., R. 13 W.	Bottom of flood plain slough. . . .	31.3	36.3	21.9	9.8	0.4	0.2	0.1	6,050
NE sec. 36, T. 14 S., R. 13 W.	do.	23.7	21.3	35.7	18.1	1.0	0.1	0.1	3,300
NE sec. 36, T. 14 S., R. 13 W.	do.	8.9	15.5	38.3	34.3	3.0	tr.	tr.	2,050
NW sec. 31, T. 15 S., R. 11 W.	Channel bar, Smoky Hill river. .	36.2	31.6	25.2	6.2	0.7	tr.	0.1	6,000
NW sec. 31, T. 15 S., R. 11 W.	do.	2.3	29.9	60.1	6.2	0.6	0.2	0.7	7,200
NE sec. 28, T. 14 S., R. 11 W.	do.	14.4	42.4	38.8	3.6	tr.	0.1	0.7	9,000
NE sec. 28, T. 14 S., R. 11 W.	do.	22.1	34.7	37.2	5.4	0.2	0.2	0.2	8,100
NE sec. 28, T. 14 S., R. 11 W.	Flood plain, Smoky Hill river. . .	0.0	0.0	tr.	1.5	8.5	34.2	55.8	. . . .

Pleistocene terrace deposits

SE sec. 3, T. 15 S., R. 14 W.	Basal terrace sand	2.4	12.3	44.2	34.4	6.3	0.3	0.1	2,000
NW sec. 33, T. 14 S., R. 13 W.	2 feet above base of terrace deposits	30.6	24.6	31.1	11.3	2.0	0.2	0.2	2,400
NW sec. 33, T. 14 S., R. 13 W.	8 feet above base of terrace deposits	35.9	28.7	21.4	11.1	2.1	0.3	0.5	620
NW sec. 33, T. 14 S., R. 13 W.	Silt near top of terrace deposits,	0.0	0.0	0.5	10.1	30.5	32.7	26.2	0.3
NE sec. 36, T. 14 S., R. 13 W.	Basal gravel of terrace deposits,	84.0	10.3	2.2	0.9	1.0	0.4	1.2	50,000
SW sec. 31, T. 14 S., R. 11 W.	High terrace deposits	tr.	1.5	26.4	63.0	7.3	0.9	0.9	180
SW sec. 31, T. 14 S., R. 11 W.	do	43.9	26.3	19.5	1.4	6.9	0.8	1.2	690
SW sec. 31, T. 14 S., R. 11 W.	do	1.2	10.9	43.4	40.1	3.3	0.5	0.6	640
NE sec. 28, T. 14 S., R. 11 W.	2 feet above base of terrace deposits	11.6	40.6	45.0	2.1	0.5	0.2	tr.	440
NE sec. 28, T. 14 S., R. 11 W.	6 feet above base of terrace deposits	7.7	14.0	52.1	20.0	5.1	0.6	0.5	430
NE sec. 28, T. 14 S., R. 11 W.	20 feet above base of terrace deposits	tr.	0.8	8.2	63.5	23.3	2.1	2.1	420
SW sec. 35, T. 15 S., R. 11 W.	Silt near top of terrace deposits	0.0	0.0	tr.	0.4	14.9	28.8	55.9	....

Upland Tertiary deposits

SW sec. 22, T. 12 S., R. 14 W.	Basal sand	7.7	14.5	36.8	28.2	8.1	2.5	2.2	20
SW sec. 22, T. 14 S., R. 12 W.	4 feet above base of 8 foot exposure	0.0	0.4	7.2	73.4	16.3	1.8	0.9	115

1. Number of gallons of water a day, at 60° F., that is conducted laterally through each mile of water-bearing bed under investigation (measured at right angles to direction of flow), for each foot of thickness of the bed and for each foot per mile of hydraulic gradient.

2. tr., trace (less than 0.1 gram).

Recent alluvium, (2) Pleistocene terrace deposits, and (3) upland Tertiary deposits. The 11 samples of alluvium were collected from the present channel, an abandoned channel, and from the flood plain of Smoky Hill river, and may be considered characteristic of the material underlying the narrow flood plain of that valley. With the exception of one sample from the flood plain, all of the samples of alluvium were found to have high coefficients of permeability. All had a coefficient greater than 2,000 and six had coefficients equal to or greater than 6,000. The major grade of most of the channel samples occurs in the gravel sizes.

The character and permeability of the Pleistocene terrace deposits range between wide limits. With the exception of two silt samples, the major grade of all of the samples of Pleistocene material occurs within the sand and gravel sizes. The coefficient of permeability of only three samples, however, was equal to or greater than 2,000 and that of five samples was less than 500. One sample of gravel had the very high coefficient of 50,000.

Only two samples of the upland Tertiary deposits were analyzed, so the resulting data are inadequate to justify any general conclusion. The two samples analyzed had coefficients of permeability of 20 and 115. These two analyses, in addition to field observations, indicate that the upland Tertiary deposits have a finer texture and are less permeable than the alluvium and the Pleistocene terrace deposits.

GROUND WATER

Principles of Occurrence

The following discussion on the occurrence of ground water has been adopted from Meinzer (1923, pp. 2-102), and the reader is referred to his report for a more complete discussion of the subject. A summary of ground-water conditions in Kansas has been made by Moore (1940) and published by the State Geological Survey of Kansas.

Ground water, or underground water, is the water that supplies springs and wells. The rocks that form the outer crust of the earth are at very few places solid throughout, but contain numerous open spaces called voids or interstices. These open spaces are the receptacles that hold the water that is found below the surface of the land and is recovered in part through wells and springs. There are many kinds of rocks and they differ greatly in the number, size, shape, and arrangement of their interstices and hence in their ability to hold and transmit water. Therefore, the character, distribution, and structure of the rocks of any region determine the occurrence of ground water.

The amount of water that can be stored in any rock depends upon the volume of the rock that is occupied by open spaces, that is, the porosity of the rock. The porosity is expressed as the percentage of the total volume of the rock that is occupied by interstices. A rock is said to be saturated when all its interstices are filled with water. The porosity of a sedimentary rock is controlled by (1) the shape and arrangement of the constituent particles, (2) the degree of assortment of its particles, (3) the cementation and compaction to which it has been subjected since its deposition, (4) the removal of mineral matter through solution by percolating waters, and (5) the fracturing of the rocks, resulting in joints and other openings. Well-sorted deposits of unconsolidated silt, sand, or gravel have a high porosity, but poorly sorted deposits have a much lower porosity because the small grains fill the voids between the large grains, thus reducing the amount of open space. The pore space in some well-sorted deposits of sand or gravel may gradually be filled with cementing material, thus reducing the porosity.

The capacity of a rock to hold water is determined by its porosity, but its capacity to yield water is determined by its permeability. The permeability of a rock may be defined as 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. Rocks that will not transmit water may be said to be impermeable. Some deposits, such as well-sorted silt or clay, may have a high porosity but because of the minute size of the pores will transmit water very slowly. Other deposits, such as well-sorted gravel containing large openings that communicate freely with one another, will transmit water very readily. Part of the water in any deposit is not available to wells because it is held against the force of gravity by molecular attraction—that is, by the cohesion of the water itself and by its adhesion to the walls of the pores.

Below a certain level, which in this area ranges from less than 10 feet to more than 100 feet below the surface, the permeable rocks are saturated with water. These saturated rocks are said to be in the zone of saturation, and the upper surface of this zone is called the water table. Wells dug or drilled into the zone of saturation will become filled with ground water to the level of the water table.

The permeable rocks that lie above the zone of saturation are said to be in the zone of aeration. As water from the surface percolates slowly downward to the zone of saturation, part of it is held in the zone of aeration by molecular attraction. In fine-grained material there is a moist belt in the zone of aeration just above the water table which is known as the capillary fringe. Although water in the zone of aeration is not available to wells, much of the water in the upper part of the zone may be withdrawn and discharged into the atmosphere by the transpiration of plants and by evaporation from the soil.

THE WATER TABLE

SHAPE AND SLOPE

The water table is defined as the upper surface of the zone of saturation except where that surface is formed by an impermeable body (Meinzer, 1923a, p. 32). It may also be regarded as the boundary between the zone of saturation and the zone of aeration. The water table is not a static, level surface, but rather it is generally a sloping surface which shows many irregularities caused by differences in permeability of the water-bearing materials or by unequal additions of water to the ground-water reservoir at different places.

The shape and slope of the water table in west-central Russell county are shown in figure 4. Water here occurs in Tertiary sediments that mantle the upland. The shape of the water table is largely controlled by the topography. Water moves outward from the divide area, at right angles to the contours, and is discharged along the sides of valleys as seeps in places where the base of the Tertiary deposits is exposed. In some places water probably moves out of the Tertiary deposits directly into alluvium which partly fills these small valleys, and thence through the alluvium to the valleys of Smoky Hill and Saline rivers. Water occurs under similar conditions in the Pleistocene terrace deposits along the major stream valleys and in alluvium, but in these areas data are lacking for the construction of contour maps.

FLUCTUATIONS

The water table does not remain in a stationary position, but fluctuates up and down much like the water in a surface reservoir. If the inflow to the underground reservoir exceeds the draft, the water table will rise; conversely, if the draft exceeds the inflow the water table will decline. Thus the rate and magnitude of fluctuations of the water table depend in large part upon the rate at which the underground reservoir is replenished or depleted.

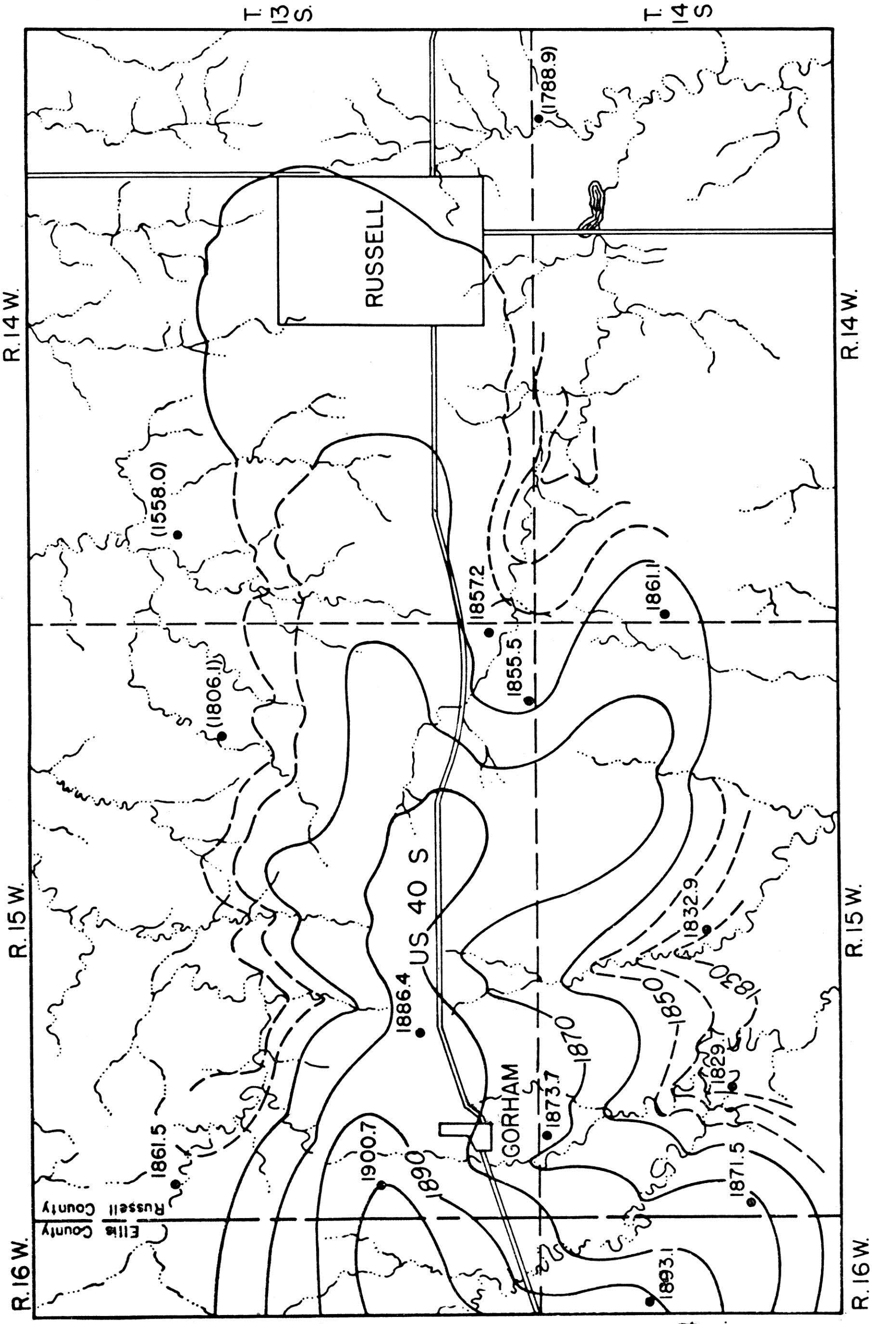

FIG. 4. Contour map showing configuration of the water table in Tertiary deposits west of Russell. Dots represent locations of wells; figures are altitudes of the water levels, in feet. Figures enclosed in parentheses indicate wells that end in alluvium. Contour interval 10 feet.

The principal factor controlling the rise or decline of the water table in the Tertiary deposits in this area is the amount of precipitation within the area that passes through the soil and descends to the water table. The fluctuations of the water table in the Tertiary deposits are also dependent upon the amount of water that percolates into them laterally from higher areas west of this area. The fluctuations of the water table in the Pleistocene terrace deposits and alluvium are controlled largely by local precipitation plus recharge from small streams and additions of water by percolation through these deposits from outside this area. All of these factors depend on precipitation either in or near this area. The relation between the amount of precipitation and the level at which the water stands in wells is complicated by several factors, however. After a long dry period, the soil moisture becomes depleted through evaporation and transpiration and when a rain does occur the soil moisture must be replenished before any water can descend to the water table. During the winter when the ground is frozen the water falling on the surface is hindered from reaching the water table, and during the hot summer months some of the water that falls as rain is lost directly into the air by evaporation. Where the water table stands comparatively far below the surface it generally fluctuates less in response to precipitation than it does where it is comparatively shallow.

The factors controlling the decline of the water table are the amount of water pumped from wells, the amount of water absorbed directly from the water table by plants (transpiration), the amount of water lost from the ground-water reservoir by direct evaporation, the loss of water from springs, and the amount of ground water passing beneath the surface into adjacent areas. All of these factors are important in Ellis and Russell counties, although the effect of pumpage from wells is slight.

Changes in the water levels in wells record the fluctuations of the water table or piezometric surface, which in turn record the recharge and discharge of the ground-water reservoir. In order to determine the character and magnitude of water-level fluctuations in this area, several wells were selected in both Ellis and Russell counties for observation, and periodic measurements of the depth to water level in them were begun in August, 1941. The wells were observed monthly through March, 1942, and thereafter were observed once every two or three months. Measurements were made by Gordon Shaffer from August, 1941, to May, 1942, and after that date by John McFarland. Complete records of these wells are published annually by the Federal Geological Survey, beginning in Water-Supply Paper 938 (Meinzer and Wenzel, 1943, pp. 59, 60, 130-132). The numbers of the observation wells previously published and the numbers used in this report are given in table 9.

TABLE 9.—*Observation wells in Ellis and Russell counties*

Well No. in this report	Well No. in Water-Supply Paper 938	Well No. in this report	Well No. in Water-Supply Paper 938
11	Russell county 95	89	Russell county 80
33	Russell county 126	90	Russell county 81
38	Russell county 116	108	Russell county 8
39	Russell county 117	131	Russell county 45
61	Russell county 152	163	Russell county 49
62	Russell county 151	164	Ellis county 215
63	Russell county 146	191	Ellis county 218
70	Russell county 148	196	Ellis county 225
83	Russell county 149	224	Ellis county 190

The fluctuations of the water level in six typical observation wells in Russell county and one in Ellis county are shown in figure 5, together with records of the monthly precipitation at Russell and Plainville and the average for the two stations. As shown in figure 5, the fluctuations of the water level in only a few of the wells show close correlation with the precipitation at Russell and Plainville, part of which results from the infrequency of measurements after March, 1942. The water levels in wells 11, 63, and 89 are relatively shallow, and hence might be expected to fluctuate in close accord with the precipitation. The water level in well 11 fluctuates in rather close accord with the precipitation, but there is less correlation between the water levels in wells 63 and 89 and the precipitation. The hydrograph of well 131 shows a rising water level during the spring of 1942 and a decline during the fall, which is in conformity with the precipitation record; however, the water level in this well rose during the fall and winter of 1941, which was a period of declining precipitation. The rather inadequate record of water level in well 196 seems to show a generally close correlation with the precipitation. The water levels in wells that end in the Dakota formation (Nos. 90 and 163) seem to show little or no correlation with the precipitation which is to be expected inasmuch as the water level in those wells lies at considerable depth and the area of outcrop of the Dakota is at a considerable distance from the wells.

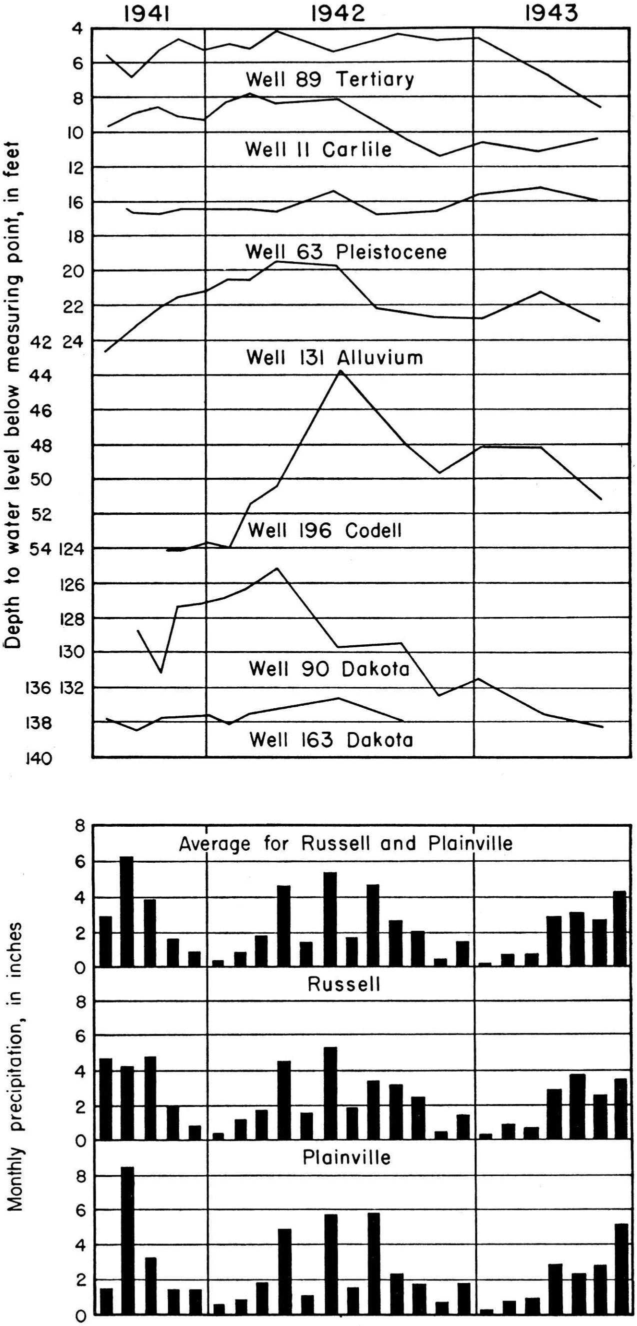

Fig. 5. Hydrographs of seven typical observation wells in Ellis and Russell counties and monthly precipitation at Russell and Plainville (precipitation data from U. S. Weather Bureau).

ARTESIAN WATER

OCCURRENCE

Artesian water is water that occurs in a pervious bed and is confined to its containing bed by impervious strata above and below. When a well is drilled into such a water-bearing formation, water will rise in the well above the level at which it is first encountered. Wells in this area that are drilled into sandstones in the Dakota formation.and into the Codell sandstone member of the Carlile shale encounter artesian water.

HEAD

Water occurring in these beds is confined under hydrostatic pressure; however, except at a few places, it does not rise above the general level of the water table and in many places the water level in wells tapping sandstones in the upper part of the Dakota formation is more than 100 feet lower than the water level in near-by wells that tap Tertiary, Pleistocene, or younger Cretaceous deposits at shallower depths. For example, the altitude of the water level in well 61, in Greenhorn limestone, is 1,767.01 feet, whereas in well 62, less than 50 yards distant and penetrating a sandstone in the Dakota formation, the altitude of the water level is only 1,625.83 feet (table 14). Similarly, the altitude of the water level in well 89, in Tertiary deposits, is 1,832.94 feet, whereas the altitude of the water level in near-by well 90, in a sandstone of the Dakota formation, is only 1,749.24 feet.

The artesian pressure of water in the Dakota formations varies in the different sandstone beds. This was determined in several of the test holes in which water-level measurements were made each time a different sandstone bed was encountered. These water-level measurements were made through a stem tester during the progress of drilling so all other water-bearing formations probably were effectively sealed off. The measurements were not made until the tester had been in place several hours so it can be assumed that the measurements represent approximately the true water level. In test hole 5, in west-central Russell county, it was found that water in a sandstone of the Dakota formation between depths of 134 and 160 feet rose to a level 67.35 feet below the surface; water in another sandstone between depths of 240 and 260 feet rose to a level 120.66 feet below the surface; and water in a sandstone between depths of 415 and 500 feet rose to within 18.20 feet of the surface. Similar conditions were encountered in test hole 2 in southwestern Russell county. In this test hole, water-level measurements were made in

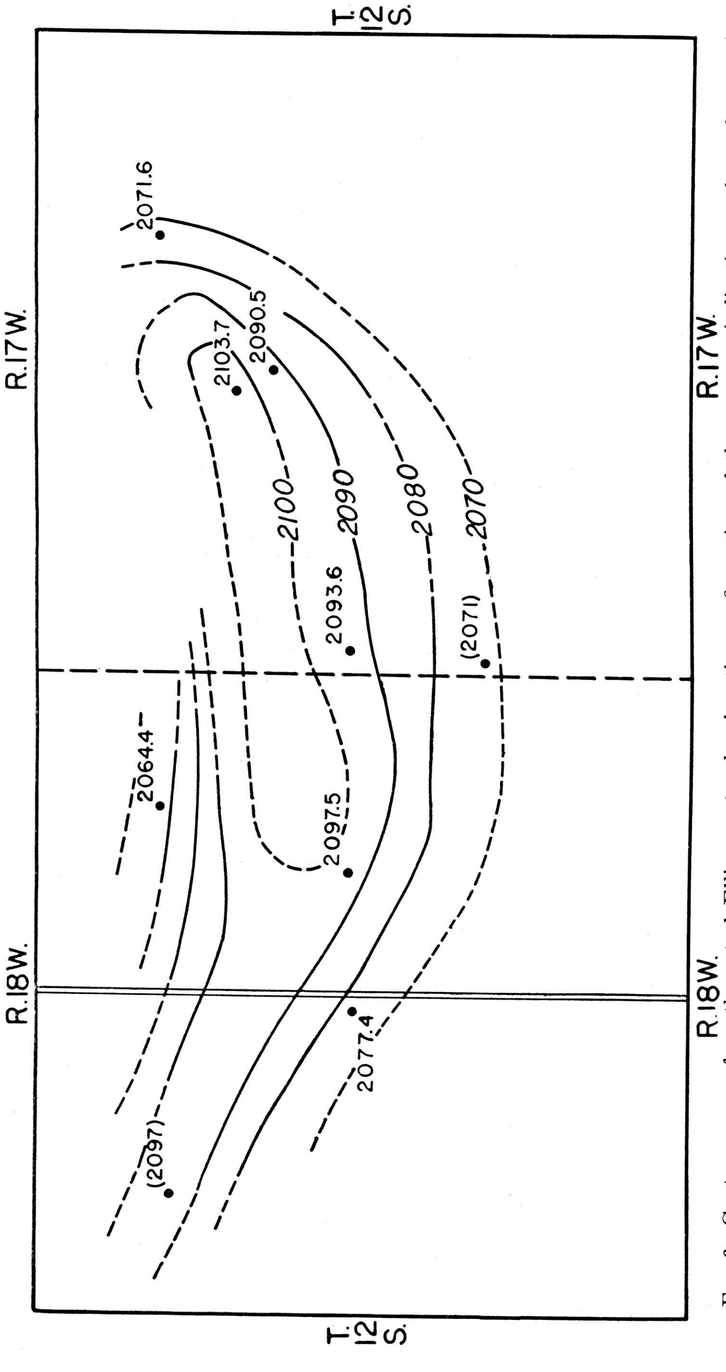

FIG. 6. Contour map of north-central Ellis county showing the configuration of the pressure-indicating surface of water in the Codell sandstone member of the Carlile shale. Dots represent locations of wells, and figures indicate altitudes of the water levels, in feet. Figures enclosed in parentheses are based on altitudes determined from topographic maps of the U. S. Geological Survey; others are based on instrumental levels. Contour interval 10 feet.

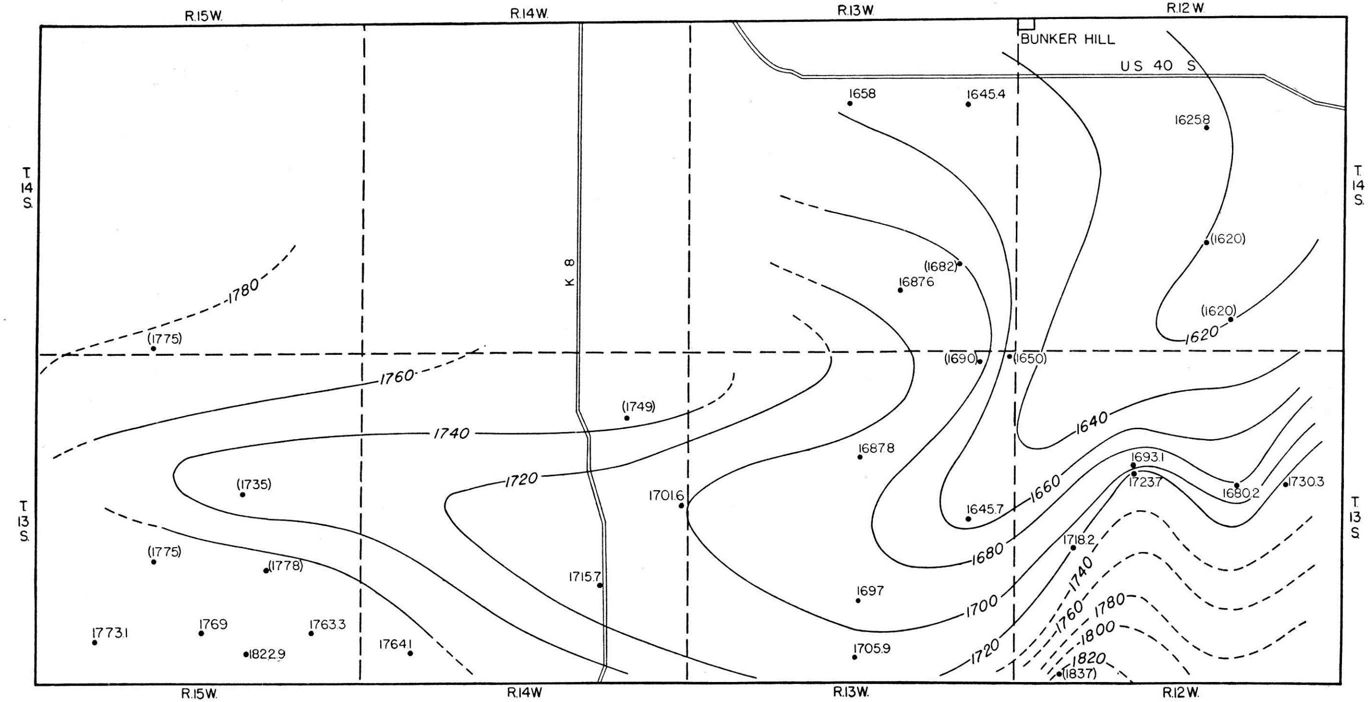

FIG. 7. Contour map of southern Russell county showing the configuration of the pressure-indicating surface of water in the uppermost sandstone beds of the Dakota formation. Dots represent locations of wells, and figures are altitudes of the water level, in feet. Figures enclosed in parentheses are based on altitudes determined from topographic maps of the U. S. Geological Survey; others are based on instrumental levels. Contour interval 20 feet.

six distinct sandstones at depths ranging from 200 to 533 feet and the levels of water encountered in the sandstones, in descending order, were as follows: 158.54, 158.78, 168.53, 161.31, 159.28, 164.35, and 28.65 feet. Seemingly in most places the water in the deeper sandstone beds is under much greater head than water in the shallower sandstone beds of the Dakota formation; however, this situation was not encountered in all test holes. All water-level measurements in test hole 3 in Ellis county indicated water levels of more than 230 feet below the surface. In test hole 1, east of Russell, the water levels in successively deeper sandstones were found at successively lower levels, and were as follows: 187.92, 190.45, and 242.04 feet.

Contour maps have been drawn in order to show the configuration of the pressure-indicating surface of water contained in the Codell sandstone and the upper sandstones of the Dakota formation (figs. 6 and 7). The map in figure 6 shows a dome on the pressure-indicating surface of water in the Codell sandstone. The dome is an area of recharge for this formation from which water is moving outward in all directions. The rate of movement of water through this sandstone is probably rather slow in spite of the steep hydraulic gradient shown locally by the contours, because the permeability of this sandstone is quite low. Figure 7 shows a distinct trough in the pressure-indicating surface of water in the Dakota sandstone. This is not a reflection of structure, as can be seen by comparison with the map in figure 3, and possibly can be accounted for by the supposition that it may represent a zone of greater than average permeability in the sandstones which thus allows more rapid movement of ground water along this zone toward a point of discharge east of this area.

RECOVERY

The following discussion on the principles of recovery of ground water has been adopted in part from Lohman (1938, pp. 54-56).

When water is withdrawn from a well there is a difference in head between the water inside the well and the water in the surrounding material at some distance from the well. The water table or pressure-indicating surface in the vicinity of a well that is discharging water has a depression resembling in form an inverted cone, the apex of which is at the well. This depression of the water table is known as the cone of influence or cone of depression, and the surface area affected by it is known as the area of influence. In any given well the greater the pumping rate the greater will be the draw-down (depression of the water level, commonly expressed in feet) and the greater will be the diameter of the cone of influence and of the area of influence.

The specific capacity of a well is its rate of yield per unit of draw-down and is generally stated in gallons a minute per foot of draw-down. When a well is pumped the water level drops rapidly at first and then more slowly, but it may continue to decline for several hours or days. In testing the specific capacity of a well, therefore, it is important to continue pumping until the water level remains approximately stationary. When the pump is stopped the water level rises rapidly at first, then more slowly, and may continue to rise long after pumping has ceased.

The character and thickness of the water-bearing materials have a definite bearing on the yield and draw-down of a well, and hence on the specific capacity of a well. Draw-down increases the height that the water must be lifted in pumping a well, thus increasing the cost of pumping. If the water-bearing material is coarse and of fairly uniform size it will readily yield large quantities of water to a well with a minimum draw-down; if the water-bearing material is fine and poorly sorted it will offer more resistance to the flow of water into a well, thereby decreasing the yield and increasing the draw-down. Other things being equal, the draw-down of a well varies inversely with the permeability of the water-bearing material.

WELLS IN CONSOLIDATED ROCKS

Most of the wells in these counties that obtain water from the sandstones of the Dakota formation or from the Codell sandstone member of the Carlile shale are drilled wells. Some of these wells penetrate consolidated rocks to depths of several hundred feet. Most of them have been drilled by the cable-tool method but in recent years a few have been drilled by the hydraulic rotary method. A few dug wells have been used to recover water from these water-bearings beds in places where the rocks occur close to the surface. In many places dug wells are used for obtaining water from the upper weathered part of the Greenhorn limestone. Many of the drilled wells in consolidated rocks are open-end wells—that is, wells that are cased only through the upper part of the hole so that water may enter the well along its uncased part wherever the rock is water-bearing. In many localities, however, the sandstones of the Dakota formation cave to such an extent that it is necessary to case the entire hole and place a screen or perforated casing opposite the water-bearing beds.

WELLS IN UNCONSOLIDATED DEPOSITS

Somewhat more than half of the wells visited in Russell and Ellis counties obtain supplies of water from unconsolidated deposits of Recent, Pleistocene, or Tertiary age. Most of the wells in these deposits are dug or drilled. Some of the dug wells in the unconsolidated deposits obtain water from rather poor water-bearing material, but because the diameter of the wells is large, a great infiltration area and considerable storage of water are provided. Because they generally extend only a few feet below the water table, dug wells are more apt to fail during dry seasons than deeper drilled wells. Also they generally are more subject to contamination than drilled wells. Some of the drilled wells in these deposits are cased to the bottom and receive water only through the open end of the casings. The intake area, and consequently the efficiency, of many of the drilled wells in unconsoliated deposits have been greatly increased by the use of well screens or perforated casings, some of which are gravel packed.

UTILIZATION OF WATER

Domestic and stock water supplies in the rural areas are, for the most part, obtained from wells. Of the 163 wells in Russell county for which records are given in table 13, 91 were used to supply water for stock, 23 supplied water for domestic use, 16 for both domestic and stock uses, and 33 wells were not in use when visited. Records of 69 wells in Ellis county are given in table 14, and of these 33 supplied water for stock, 19 for domestic use, 7 for both domestic and stock use, and 10 were not in use when visited.

DOMESTIC AND STOCK SUPPLIES

The domestic wells supply water in the homes for drinking, cooking, and washing, and in schools other than those supplied by municipal wells, and provide water for the irrigation of small gardens. The stock wells supply drinking water for livestock. Domestic and stock supplies are obtained from dug and drilled wells ranging in depth from less than 20 to more than 300 feet. The quality of this water is discussed in another section. In general, the ground waters in this area are reported to be of good quality, but some are too highly mineralized for most uses. Many of the wells for stock use are equipped with cylinder pumps and operated by windmills.

IRRIGATION SUPPLIES

Irrigation from wells has not been extensively practiced in Russell and Ellis counties. One well in alluvium along the Saline valley east of Fairport has been pumped for irrigation. For the most part, none of the water-bearing formations underlying this area will yield large quantities of water to an individual well. They do not have a sufficiently high permeability, saturated thickness, or recharge area to allow the extensive development of irrigation wells. Irrigation wells yielding as much as 500 gallons a minute might be obtainable in the narrow strips of alluvium along Smoky Hill and Saline rivers and Big creek, and possibly also in a few local areas underlain by upland Tertiary and Pleistocene deposits in the vicinity of Gorham and Dorrance. Owing to their low permeabilities, the sandstones of the Dakota formation, the Codell sandstone member of the Carlile shale, and the mantle rock developed on the Greenhorn limestone probably will not yield more than 100 gallons a minute to wells anywhere in this area. At most places the maximum yield of properly constructed wells in these formations probably will be much less than 100 gallons a minute, and at many places the maximum yield obtainable will probably be less than 10 gallons a minute.

MUNICIPAL SUPPLIES

Only three cities in or immediately adjacent to the area covered by this report have municipal water supplies. Of these, two obtain water from wells and one from surface sources.

Russell, the county seat of Russell county, had a population of 4,706 in 1940 according to the federal census. The city obtains its water supply from Smoky Hill river and Big creek, whence it is pumped to a reservoir on Fossil creek 1 mile south of the city. The pump at Smoky Hill river has a capacity of 700 gallons a minute; that at Big creek has a capacity of 350 gallons a minute. According to the Kansas State Board of Health, the city water plant has a rated capacity of 1,050,000 gallons a day. Storage is provided by an elevated tank having a capacity of 720,000 gallons.

Bunker Hill, in east-central Russell county, had a population of 249 in 1940 according to the federal census. The water supply is obtained from two 8-inch drilled wells in sandstone of the Dakota formation. The wells are reported to be 250 feet deep, and have perforated casing in the lower 10 feet. The water levels are reported to be 225 feet below land surface. Each well is equipped with an electrically driven plunger pump having a rated capacity of 18 gallons a minute, but one well is reported to pump dry after prolonged pumping at this rate. According to the Kansas State Board of Health, the water plant has a rated capacity of 40,000 gallons a day. Storage is provided by an elevated tank having a capacity of 50,000 gallons. A chemical analysis of the water is given in table 10.

Victoria, in east-central Ellis county, had a population of 858 in 1940 according to the federal census. Its water supply is obtained from four dug wells in unconsolidated deposits of Pleistocene or Tertiary age. The wells are reported to be 35 feet deep and are equipped with electrically driven pumps. According to the Kansas State Board of Health, the water plant has a rated capacity of 490,000 gallons a day. Storage is provided by an elevated tank having a capacity of 50,000 gallons. A chemical analysis of the water is given in table 11.

Although the city of Gorham in west-central Russell county had no municipal water supply, the construction of such a supply was started in 1941. One well was drilled in the unconsolidated sand and gravel of Tertiary age underlying the upland surface northeast of the city. When this well was visited in 1941, however, the well had not yet been test pumped, and no specific data were available.

Quality of Water

The chemical character of ground waters in this area is indicated by analyses in tables 10, 11, and 12, and in figures 8 and 9. The analyses were made by Howard Stoltenberg in the Water and Sewage Laboratory of the Kansas State Board of Health. Thirty-four samples of water were collected for chemical analysis from representative wells distributed as uniformly as possible within the area and among the water-bearing formations. Analyses of the water pumped from the municipal wells at Bunker Hill and Victoria also are given in tables 10 and 11. Fifteen other samples were collected from several sandstones of the Dakota formation encountered in the test holes. Samples of water for chloride analysis were collected from 158 of the 163 wells visited in Russell county, and from each of the 69 wells visited in Ellis county, the results of which are given in tables 10 and 11.

CHEMICAL CONSTITUENTS IN RELATION TO USE

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

Total dissolved solids.—The residue left after a natural water has evaporated consists of rock materials, with which may be included some organic material and a small amount of water of crystallization. Water containing less than 500 parts per million of dissolved solids generally is entirely satisfactory for domestic use, except for difficulties resulting from its hardness, and, in some areas, because of excessive iron corrosiveness. Water having more than 1,000 parts per million is likely to contain enough of certain constituents to produce a noticeable taste or to make the water unsuitable in some other respects.

The total dissolved solids in samples of water collected from private wells in this area ranged from 291 to 5,535 parts per million. The samples from six wells contained less than 500 parts per million, indicating waters suitable for most ordinary purposes. Nearly one-half of the samples contained between 500 and 1,000 parts per million, and the samples from 15 wells contained more than 1,000 parts per million.

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

In addition to the total hardness, the table of analyses indicates the carbonate hardness and the noncarbonate hardness. The carbonate hardness is that due to the presence of calcium and magnesium bicarbonate. It is largely removed by boiling. In some reports this type of hardness has been called temporary hardness. The noncarbonate hardness is due to the presence of sulphates or chlorides of calcium and magnesium, but it cannot be removed by boiling and has sometimes been called permanent hardness. With reference to use with soaps, there is no difference between the carbonate and noncarbonate hardness. In general, the noncarbonate hardness forms harder scale in steam boilers.

Water having a hardness less than 50 parts per million is generally rated as soft, and its treatment for removal of hardness under ordinary circumstances is not necessary. Hardness between 50 and 150 parts per million does not seriously interfere with the use of water for most purposes, but it does slightly increase the consumption of soap; its removal by a softening process is profitable for

TABLE 10.—*Analyses of water from typical wells in Russell county*

Analyzed by Howard Stoltenberg. Parts per million [1] and equivalents per million [2] (in italics)

Well No. on Plate 1	LOCATION	Depth (feet)	Geologic horizon	Date of collection, 1942	Temp. (°F)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium and Potassium[3] (Na+K)	Bicarbonate (HCO$_3$)	Sulphate (SO$_4$)	Chloride (Cl)	Fluoride (F)	Nitrate (NO$_3$)	Total dissolved solids[3]	Hardness (calculated as CaCO$_3$)		
																Total	Carbonate	Noncarbonate
4	*T. 11 S., R. 15 W.* SE sec. 8........	23.1	Pleistocene.....	May 8	58	0.68	209 *10.43*	24 *1.97*	59 *2.56*	439 *7.20*	183 *3.81*	58 *1.64*	0.4 *.02*	142 *2.29*	896	620	360	260
5	NE sec. 10......	31.4	Greenhorn......	May 8	58	3.4	81 *4.04*	19 *1.56*	86 *3.75*	185 *3.03*	49 *1.02*	40 *1.13*	.6 *.03*	257 *4.14*	629	280	152	128
14	*T. 12 S., R. 14 W.* SE sec. 10.......	15.2	Alluvium.......	May 8	53	.28	235 *11.73*	17 *1.40*	64 *2.78*	384 *6.30*	228 *4.74*	61 *1.72*	.2 *.01*	195 *3.14*	992	656	315	341
19	SE sec. 20.......	18.5	do..........	May 8	53	.96	156 *7.78*	9.6 *.79*	37 *1.63*	361 *5.92*	68 *1.41*	28 *.79*	.3 *.02*	128 *2.06*	608	428	296	132
22	SW sec. 34......	29.6	do..........	May 8	60	.73	199 *9.93*	24 *1.97*	62 *2.70*	360 *5.90*	340 *7.07*	43 *1.21*	.5 *.03*	24 *.39*	873	595	295	300
23	*T. 12 S., R. 15 W.* NW sec. 4.......	20.5	do..........	May 8	58	4.6	224 *11.18*	15 *1.23*	49 *2.12*	273 *4.48*	288 *5.99*	97 *2.74*	.5 *.03*	80 *1.29*	895	620	224	396
31	SW sec. 32......	25.6	Tertiary........	May 8	56	6.7	662 *33.03*	41 *3.37*	106 *4.63*	296 *4.85*	1,394 *29.00*	122 *3.44*	.8 *.04*	230 *3.70*	2,710	1,820	242	1,578
41	*T. 13 S., R. 14 W.* NW sec. 30......	183.7	Dakota........	May 21	58	5.2	39 *1.95*	42 *3.45*	2,027 *88.17*	496 *8.13*	550 *11.44*	2,610 *73.60*	4.5 *.24*	9.7 *.16*	5,535	270	270[4]	0
43	*T. 13 S., R. 15 W.* SE sec. 2........	30.6	Alluvium.......	May 8	60	9.6	403 *20.11*	33 *2.71*	95 *4.31*	277 *4.54*	959 *19.95*	82 *2.31*	.7 *.04*	7.1 *.11*	1,728	1,141	227	914
51	NW sec. 30......	25.0	Tertiary........	May 21	57	.12	84 *4.19*	10 *.82*	20 *.88*	248 *4.07*	27 *.56*	14 *.39*	.4 *.02*	53 *.85*	332	250	204	46
52	SW sec. 34......	23.1	do..........	May 21	52	.63	427 *21.31*	47 *3.86*	205 *8.93*	310 *5.08*	434 *9.03*	460 *12.97*	.5 *.03*	434 *6.99*	2,163	1,258	254	1,004

55	*T. 14 S., R. 11 W.* SW sec. 14......	44.2	Pleistocene.....	May 4	59	6.4	109 *5.44*	9.0 *.74*	24.0 *1.03*	280 *4.59*	40 *.83*	48 *1.35*	.2 *.01*	27 *.43*	404	309	230	79
58	NE sec. 30......	34.1	do.........	May 4	58	6.7	203 *10.13*	17 *1.40*	71 *3.09*	268 *4.40*	72 *1.50*	26 *.73*	.2 *.01*	496 *7.98*	1,026	576	220	356
A[5]	*T. 14 S., R. 12 W.* NE SW sec. 6....	250	Dakota..	Dec. 11	......	4.2	148 *7.38*	19 *1.56*	281 *12.20*	317 *5.20*	166 *3.45*	440 *12.41*	.7 *.04*	2.6 *.04*	1,270	447	260	187
61	SE sec. 10.......	30.8	Greenhorn......	May 4	55	.26	102 *5.09*	11 *.90*	29 *1.27*	228 *3.74*	63 *1.31*	22 *.62*	.6 *.03*	97 *1.56*	439	300	187	113
62	SE sec. 10.......	183.9	Dakota........	May 4	55	24	101 *5.04*	12 *.99*	29 *1.28*	227 *3.72*	65 *1.35*	23 *.65*	.6 *.03*	97 *1.56*	466	302	186	116
65	SE sec. 34.......	78.8	do.........	May 4	59	6.4	43 *2.14*	20 *1.64*	601 *26.15*	406 *6.66*	208 *4.33*	665 *18.75*	1.5 *.08*	7.1 *.11*	1,755	189	189[6]	0
68	*T. 14 S., R. 13 W.* SW sec. 12......	244.6	do.........	May 4	59	40.0	126 *6.29*	14 *1.15*	72 *3.11*	195 *3.20*	235 *4.89*	85 *2.40*	.7 *.04*	1.5 *.02*	672	372	160	212
77	*T. 14 S., R. 14 W.* NW sec. 1.......	19.5	Alluvium.......	May 4	53	1.9	118 *5.89*	11 *.90*	35 *1.51*	282 *4.62*	32 *.66*	91 *2.57*	.3 *.02*	27 *.43*	458	340	231	109
80	NE sec. 16......	24.3	Pleistocene.....	May 7	54	.95	197 *9.83*	15 *1.23*	198 *8.63*	320 *5.25*	67 *1.39*	260 *7.33*	.3 *.02*	354 *5.70*	1,252	553	262	291
85	SW sec .28......	61.1	do.........	May 6	60	31	188 *9.38*	30 *2.47*	144 *6.26*	341 *5.59*	526 *10.94*	52 *1.47*	1.8 *.09*	1.4 *.02*	1,145	592	280	312
92	*T. 14 S., R. 15 W.* NW sec. 12......	25.9	Greenhorn......	May 21	55	12	477 *23.80*	115 *9.45*	767 *33.36*	187 *3.07*	987 *20.53*	1,335 *37.65*	3.0 *.16*	323 *5.20*	4,112	1,662	154	1,508
95	NW sec. 29......	19.5	Pleistocene.....	May 6	58	.36	192 *9.58*	19 *1.56*	75 *3.28*	334 *5.48*	198 *4.12*	49 *1.38*	.5 *.03*	212 *3.41*	913	557	274	283
100	*T. 15 S., R. 12 W.* NW sec. 6.......	48.5	Pleistocene.....	May 4	58	4.3	141 *7.04*	11 *.90*	41 *1.78*	323 *5.30*	135 *2.81*	32 *.90*	0.3 *.02*	43 *.69*	569	397	265	132
111	SE sec. 31.......	244.5	Dakota........	May 4	61	8.5	42 *2.10*	29 *2.38*	1,163 *50.60*	458 *7.51*	345 *7.18*	1,420 *40.04*	3.0 *.16*	12 *.19*	3,252	224	224[7]	0
127	*T. 15 S., R. 14 W.* NE sec. 5.......	26.2	Pleistocene.....	May 6	55	.40	118 *5.89*	19 *1.56*	69 *3.02*	222 *3.64*	172 *3.58*	59 *1.66*	.5 *.03*	97 *1.56*	646	372	182	190
129	NE sec. 7.......	174.2	Dakota........	May 6	60	4.6	22 *1.10*	21 *1.73*	1,438 *62.57*	459 *7.53*	306 *6.36*	1,815 *51.18*	5.0 *.26*	4.2 *.07*	3,846	142	142[8]	0

Table 10.—Analyses of water from typical wells in Russell county—*Concluded*

Well No. on Plate 1	LOCATION	Depth (feet)	Geologic horizon	Date of collection, 1942	Temp. (°F)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium and Potassium[3] (Na+K)	Bicarbonate (HCO_3)	Sulphate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Total dissolved solids[3]	Hardness (calculated as $CaCO_3$)		
																Total	Carbonate	Noncarbonate
145	*T. 15 S., R. 15 W.* SE sec. 3........	11.5	Pleistocene.....	May 6	54	1.2	238 *11.88*	28 *2.30*	122 *5.30*	373 *6.12*	235 *4.89*	158 *4.46*	.3 *.02*	248 *3.99*	1,217	709	306	403
148	SW sec. 6.......	12.9	Alluvium.......	May 6	55	.62	179 *8.88*	13 *1.07*	119 *5.18*	350 *5.74*	71 *1.48*	131 *3.69*	.3 *.02*	261 *4.20*	949	498	287	211

1. One part per million is equivalent to 1 pound of substance per million pounds of water or 8.33 pounds per million gallons of water.
2. An equivalent per million (e. p. m.) is a unit chemical equivalent weight of solute per million unit weights of solution. Concentration in equivalents per million is calculated by dividing concentration in parts per million by the chemical combining weight of the substance or ion.
3. Calculated.
4. Total alkalinity, 406 parts per million; excess alkalinity, 136 parts per million.
5. Sample from north well of two similar wells that supply city of Bunker Hill.
6. Total alkalinity, 333 parts per million; excess alkalinity, 144 parts per million.
7. Total alkalinity, 376 parts per million; excess alkalinity, 152 parts per million.
8. Total alkalinity, 376 parts per million; excess alkalinity, 234 parts per million.

TABLE 11.—*Analyses of water from typical wells in Ellis county*

Analyzed by Howard Stoltenberg. Parts per million [1] and equivalents per million [2] (in italics)

Well No. on Plate 1	LOCATION	Depth (feet)	Geologic horizon	Date of collection, 1942	Temp. (°F)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium and Potassium[3] (Na+K)	Bicarbonate (HCO_3)	Sulphate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Total dissolved solids[3]	Hardness (calculated as $CaCO_3$)		
																Total	Carbonate	Noncarbonate
177	*T. 11 S., R. 18 W.* NE sec. 30......	65.3	Codell.........	May 21	58	89	102 *5.09*	43 *3.53*	134 *5.82*	273 *4.48*	157 *3.26*	92 *2.58*	0.9 *.05*	252 *4.06*	1,008	431	224	207
196	*T. 12 S., R. 17 W.* NW sec. 30......	61.0	do..........	May 21	59	6.3	87 *4.34*	11 *.90*	6.4 *.28*	295 *4.84*	7.9 *.16*	10 *.28*	.4 *.02*	14 *.22*	291	262	242	20
207	*T. 13 S., R. 16 W.* SE sec. 16.......	23	Tertiary........	May 21	54	.53	187 *9.33*	24 *1.97*	33 *1.42*	517 *8.48*	87 *1.81*	40 *1.13*	.1 *.01*	80 *1.29*	710	565	424	141
211	NE sec. 31......	23.8	do..........	May 21	58	.20	122 *6.09*	23 *1.89*	38 *1.64*	219 *3.59*	208 *4.33*	49 *1.38*	.9 *.05*	17 *.27*	568	399	180	219
215	*T. 13 S., R. 17 W.* NW sec. 7.......	29.3	Alluvium.......	May 21	57	5.4	153 *7.63*	17 *1.40*	45 *1.97*	416 *6.83*	60 *1.25*	40 *1.13*	.2 *.01*	111 *1.79*	640	452	341	111
219	NE sec. 28......	13.8	Pleistocene.....	May 21	58	2.0	230 *11.48*	39 *3.20*	79 *3.45*	446 *7.31*	463 *9.63*	40 *1.13*	.2 *.01*	3 *.05*	1,079	734	366	368
[4]B	*T. 14 S., R. 17 W.* Sec. 12..........	35	do..........	....	......	.10	112 *5.58*	11 *.90*	16 *.69*	339 *5.56*	35 *.73*	14 *.39*	.2 *.01*	30 *.48*	445	324	278	46

1. One part per million is equivalent to 1 pound of substance per million pounds of water or 8.33 pounds per million gallons of water.
2. An equivalent per million (e. p. m.) is a unit chemical equivalent weight of solute per million unit weights of solution. Concentration in equivalents per million is calculated by dividing concentration in parts per million by the chemical combining weight of the substance or ion.
3. Calculated.
4. Composite sample from four similar dug wells that supply city of Victoria.

TABLE 12.—*Analyses of water from test holes drilled into sandstones of the Dakota formation in Russell and Ellis counties*

Analyzed by Howard Stoltenberg. Parts per million [1] and equivalents per million [2] (in italics)

No. of test hole	LOCATION	Interval from which sample was collected	Date of collection	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium[3] (Na + K)	Bicarbonate (HCO_3)	Sulphate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Total dissolved solids[3]	Hardness (calculated as $CaCO_3$)		
														Total	Carbonate	Noncarbonate
1	NW sec. 6, T. 14 S., R. 13 W.	210–227	Nov. 1941	0.10	246 *12.28*	1.7 *.14*	898 *39.05*	0.0 *.0*	219 *4.56*	815 *22.98*	1.9 *.10*	0.0 *.00*	2,603	621	621[4]	0
2	SW cor. sec. 31, T. 15 S., R. 14 W.	383–395	Jan. 1942	.10	451 *22.50*	454 *37.32*	8,811 *383.29*	672 *11.02*	2,739 *56.97*	13,300 *375.06*	1.2 *.06*	.0 *.00*	26,092	2,991	551	2,440
2	do.	485–533	Jan. 1942	58.0	623 *31.09*	567 *46.61*	15,310 *665.96*	1,244 *20.40*	3,756 *78.12*	22,875 *645.08*	1.2 *.06*	.0 *.00*	43,812	3,885	1,020	2,865
3	SW cor. sec. 31, T. 12 S., R. 17 W.	513–555	Jan. 1942	.13	38 *1.90*	36 *2.96*	1,395 *60.69*	426 *6.99*	435 *9.05*	1,750 *39.35*	3.0 *.16*	.0 *.00*	3,870	243	243[5]	0
3	do.	593–630	Jan. 1942	.18	44 *2.20*	37 *3.04*	1,269 *55.20*	460 *7.54*	366 *7.61*	1,600 *45.12*	3.2 *.17*	.0 *.00*	3,549	262	262[6]	0
3	do.	702–730	Feb. 1942	58	435 *21.71*	746 *61.32*	9,811 *436.79*	1,952 *32.01*	2,592 *53.91*	15,000 *423.00*	.9 *.05*	53 *.85*	29,673	4,152	1,600	2,552
4	NW sec. 14, T. 12 S., R. 16 W.	224–250	Mar. 1942	.07	127 *6.34*	74 *6.08*	2,474 *107.64*	418 *6.86*	2,152 *44.76*	2,420 *68.24*	1.8 *.09*	7.1 *.11*	7,465	621	343	278
4	do.	388–420	Mar. 1942	.10	153 *7.63*	169 *13.89*	3,043 *132.39*	642 *10.53*	1,516 *31.53*	3,960 *111.67*	1.9 *.10*	5.3 *.08*	9,169	1,076	526	550
5	Middle east line sec. 20, T. 14 S., R. 15 W.	134–170	Mar. 1942	.96	94 *4.69*	52 *4.27*	2,062 *89.72*	418 *6.86*	453 *9.42*	2,910 *82.06*	2.5 *.13*	13 *.21*	5,796	448	343	105
5	do.	234–270	Mar. 1942	2.9	283 *14.12*	291 *23.92*	7,093 *308.54*	799 *13.10*	1,558 *32.41*	10,660 *300.61*	.7 *.04*	26 *.42*	20,314	1,902	655	1,247
5	do.	415–500	Apr. 1942	13	459 *22.90*	476 *39.13*	10,863 *472.56*	1,509 *24.75*	3,088 *64.23*	15,780 *445.0*	.6 *.03*	36 *.58*	31,470	3,102	1,238	1,864

6	SE sec. 14, T. 14 S., R. 15 W............	234–272	Apr. 1942	256	999 *49.85*	256 *21.04*	3,769 *163.96*	296 *4.85*	506 *10.52*	7,775 *219.26*	1.6 *.08*	8.8 *.14*	13,464	3,544	242	3,302
6	do................	417–500	Apr. 1942	9.0	765 *38.17*	488 *40.11*	10,724 *466.51*	888 *14.56*	2,787 *57.97*	16,720 *471.50*	.9 *.05*	44 *.71*	31,982	3,914	728	3,186
7	SE sec. 13, T. 14 S., R. 15 W............	267–320	May 1942	2.2	733 *36.58*	295 *24.25*	5,337 *232.15*	416 *6.82*	1,165 *24.23*	9,275 *261.56*	1.1 *.06*	19 *.31*	17,035	3,042	341	2,701
7	do................	407–520	May 1942	.33	1,101 *54.94*	354 *29.10*	6,280 *273.18*	305 *5.00*	1,103 *22.94*	11,660 *328.81*	.9 *.05*	26 *.42*	20,678	4,202	250	3,952

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1. 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.

2. An equivalent per million (e. p. m.) is a unit chemical equivalent weight of solute per million unit weights of solution. Concentration in equivalents per million is calculated by dividing concentration in parts per million by the chemical combining weight of the substance or ion.

3. Calculated.

4. Total alkalinity, 1,112 parts per million; excess alkalinity, 491 parts per million.

5. Total alkalinity, 350 parts per million; excess alkalinity, 107 parts per million.

6. Total alkalinity, 377 parts per million, excess alkalinity, 115 parts per million.

laundries or other industries using large quantities of soap. Water in the upper part of this range of hardness will cause considerable scale in steam boilers. Hardness exceeding 150 parts per million can be noticed by anyone; if the hardness is 200 or 300 parts per million it is common practice to soften water for household use or to install a cistern to collect soft rainwater. Where municipal water supplies are softened, an attempt is generally made to reduce the hardness to 60 or 80 parts per million. The additional improvement from further softening of a whole public supply is not deemed worth the increase in cost.

The hardness of samples of water collected from private wells in this area ranged from 142 to 1,820 parts per million. The softest water analyzed was from well 129 in a sandstone of the Dakota formation, and the hardest water was obtained from well 31 in Tertiary deposits. Four of the samples analyzed had a hardness between 100 and 200 parts per million, 5 had a hardness between 200 and 300 parts, 8 had a hardness between 300 and 400 parts, 15 had a hardness between 400 and 1,000 parts, and 4 had a hardness of more than 1,000 parts.

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

All of the samples of water from private wells in this area contained more than 0.1 part per million of iron, but four samples collected from test holes contained 0.1 part per million or less. Seventeen samples contained between 1 and 10 parts per million of iron and five samples (wells 62, 68, 85, 92, and 177) contained more than 10 parts per million.

Fluoride.—Although determinable quantities of fluoride are not as common as fairly large quantities of other constituents of natural waters, it is desirable to know the amount of fluoride present in water that is likely to be used by children. Fluoride in water has been shown to be associated with the dental defect known as mottled enamel, which may appear on the teeth of children who drink water containing excessive quantities of fluoride during the period of formation of the permanent teeth. It has been stated that waters containing 1 part per million or more of fluoride are likely to produce mottled enamel, although the effect of 1 part per million is not usually very serious (Dean, 1936). If the water contains as much as 4 parts per million of fluoride, 90 percent of the children exposed are likely to have mottled enamel and 35 percent or more of the cases will be classed as moderate or worse.

No samples of water collected in Ellis county contained as much as 1 part per million of fluoride, and only six of the samples collected in Russell county contained more than 1 part per million. The maximum fluoride content, 5 parts per million, was in a sample of water from well 129.

RELATION TO STRATIGRAPHY

The typical quality of water in the six principal water-bearing formations of this area is shown in figures 8 and 9, and is discussed below.

Cheyenne sandstone.—Water from the Cheyenne sandstone is not utilized in this area for domestic or stock supplies, but analyses of water obtained during the drilling of disposal wells indicate that the water in the Cheyenne sandstone is highly mineralized.

Dakota formation.—Water from wells in the various sandstones of the Dakota formation have a wide range in chemical composition; some are only moderately hard whereas others are highly mineralized. A sample of water from well 129 in a sandstone of the Dakota formation was the softest water of any of the 36 samples analyzed, having a hardness of only 142 parts per million, whereas a sample of water collected from a sandstone in the lower part of the Dakota formation penetrated in test hole 7 had a hardness of 4,202 parts per million. The fluoride content of about half the samples of Dakota waters was greater than 1 part per million, and the water from well 129 had the highest fluoride content of any sample analyzed—5.0 parts per million. The chloride is both the most variable and most objectionable constituent of many Dakota waters. A sample of water from well 62 had the lowest chloride content of any Dakota waters analyzed—23 parts per million. A sample obtained from test hole 2 at a depth of 485 to 533 feet had the highest chloride content of any Dakota waters analyzed—22,875 parts per million. The iron content of Dakota waters analyzed ranged from 0.07 part per million in test hole 4 to 256 parts per million in test hole 6.

Greenhorn limestone.—A few wells on the uplands in Russell

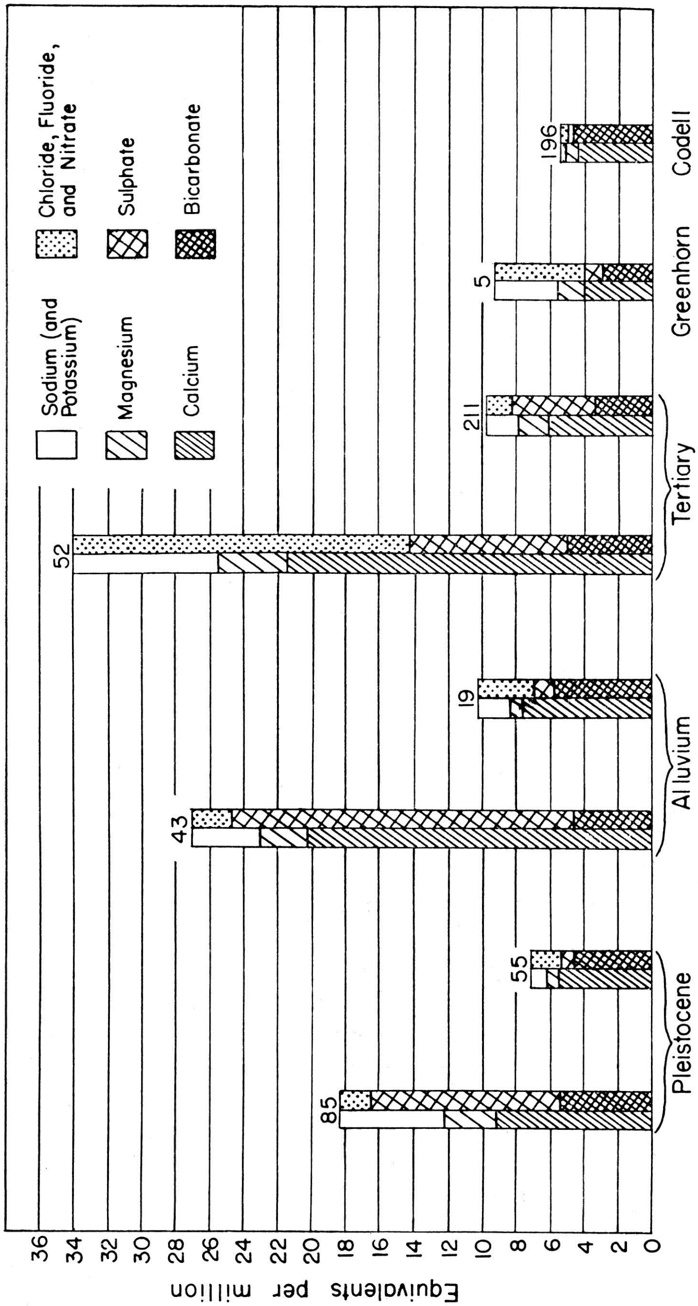

FIG. 8. Analyses of typical waters from five of the six principal water-bearing formations in Ellis and Russell counties.

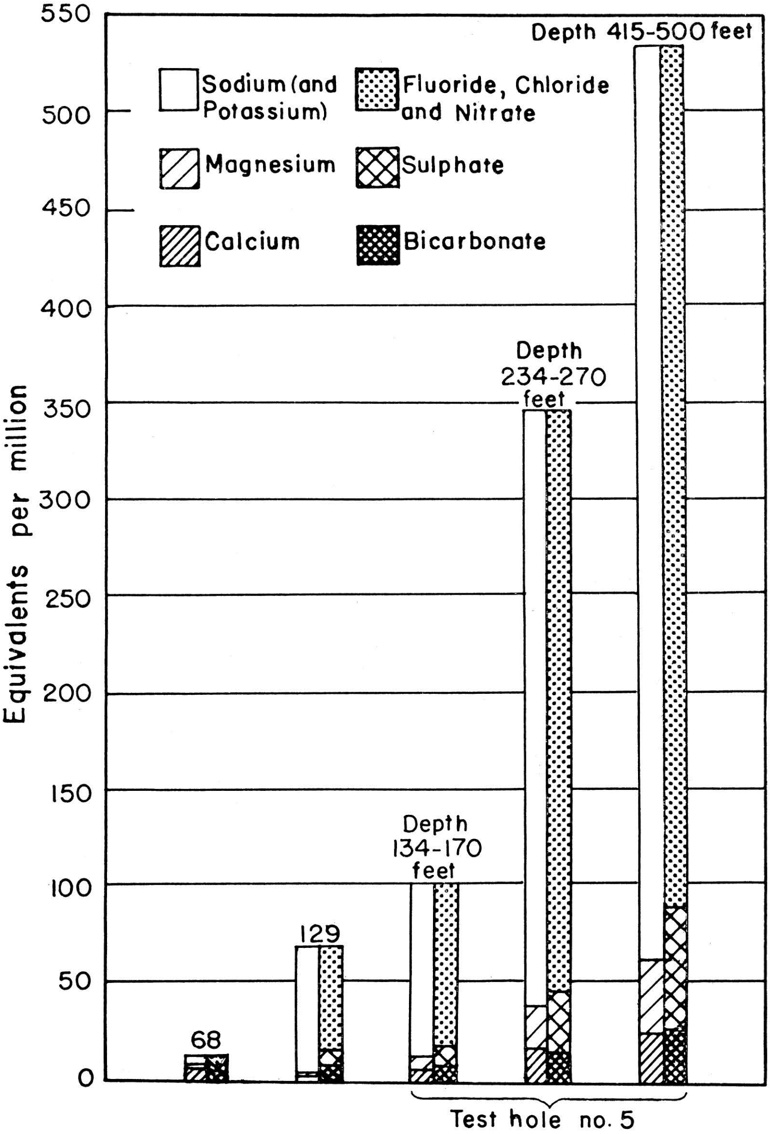

FIG. 9. Analyses of typical waters from sandstones of the Dakota formation in Russell county.

county obtain water from the near-surface fractured parts of the Greenhorn limestone. Only three samples of water from the Greenhorn limestone were analyzed (wells 5, 61, 92); they ranged in total solids from 439 to 4,112 parts per million, and in hardness from 280 to 1,662 parts per million.

Codell sandstone member of the Carlile shale.—The Codell sandstone member yields small quantities of water to wells in north-central Ellis county. Only two samples of water from the Codell sandstone member were analyzed (wells 177, 196) and they contained respectively 1,008 and 291 parts per million of total dissolved solids and 431 and 262 parts per million of hardness.

Tertiary deposits.—Sand and gravel of Tertiary age yield water to wells on the upland areas, particularly in west-central Russell county and east-central Ellis county. Five samples of water from the Tertiary were analyzed and their quality was found to range within wide limits. The total solids ranged from 332 to 2,710 parts per million, and the hardness ranged from 250 to 1,820 parts per million.

Pleistocene deposits.—Many stock and domestic wells obtain water from sands and gravels of Pleistocene age which occur as terrace deposits along the valleys of Smoky Hill and Saline rivers and Big creek. Ten samples of water from Pleistocene deposits were analyzed and were found to be generally of better quality than waters obtained from most of the other water-bearing materials.

The hardness of water obtained from Pleistocene deposits ranged from 309 to 734 parts per million, and the total dissolved solids ranged from 404 to 1,252 parts per million. Only one sample (85) contained more than 1 part per million of fluoride. The chloride ranged from 26 (well 58) to 260 parts per million (well 80).

Alluvium.—Wells obtain water from the alluvial deposits along the major valleys and also along minor tributary valleys. In many places water migrates from adjacent Tertiary and Cretaceous deposits into the alluvium, so water of different quality may be obtained from the alluvium in different valleys. These conditions give rise to considerable variation in the chemical character of waters obtained from the alluvium.

The hardness of samples of water from wells in the alluvium ranged from 340 to 1,147 parts per million, and the total dissolved solids ranged from 458 to 1,728 parts per million. In all the samples analyzed the fluoride was less than 1 part per million and the chloride was less than 100 parts per million.

SALT WATER DISPOSAL

The production and disposal of oil-field brines in Ellis and Russell counties were studied in detail by J. J. Brazil, then of the Kansas State Board of Health, who planned to include a discussion of the subject in this report. Because of his absence from Kansas on military service, however, this section of the report was not prepared. The data obtained by Brazil are on file in the office of the Kansas State Board of Health at Lawrence.

In general, salt water produced along with the oil in these two counties is disposed of in one of three ways: (1) by so-called evaporation ponds, (2) by shallow disposal wells drilled into the sandstones of Cretaceous age, and (3) by deep disposal wells drilled into porous rocks of Pennsylvanian age or older. The locations of disposal wells in the area in 1942 are shown in plate 1. Evaporation ponds are considered safe for the disposal of salt water only in areas where the material forming the sides and floor of the pond is impervious, such as shale; they are unsatisfactory for the disposal of brine where the near-surface materials are pervious and contain fresh water, such as alluvium or Pleistocene terrace deposits, because in such places the salt water percolates downward and laterally into the porous material and contaminates the fresh-water supply. Disposal of salt water by injection into wells drilled into sandstones of Cretaceous age is an adequate method of disposal where these sandstones do not contain fresh water and where they constitute stratigraphic traps so that the salt water cannot migrate into and contaminate other Cretaceous sandstones that contain fresh water. These conditions appear to be satisfied by the Cheyenne sandstone where it underlies this area. Disposal into deeper beds seems to be the best way to safeguard the fresh-water supplies.

The Section of Oil-Field Waste Disposal, Division of Sanitation of the Kansas State Board of Health, is charged with the responsibility of safeguarding the fresh underground-water supplies of the state from contamination by oil-field brines. It has been the policy of that agency to encourage the use of deep disposal wells in the pre-Cretaceous formations. They have approved the Cheyenne sandstone as a disposal horizon, and have discouraged the use of higher sandstones in the Dakota formation and the use of evaporation ponds. During the last few years the advisability of using the Cheyenne sandstone as a disposal horizon has been questioned. The facts presented in this report seem to substantiate their former decisions that disposal by means of properly cased and cemented wells into deeper pre-Cretaceous formations is the best method of safeguarding the fresh-water supplies, and also that the Cheyenne sandstone, which constitutes a stratigraphic trap, is a safe disposal horizon. The sandstones of the overlying Dakota formation have been determined to be in part an interconnecting series of channel and lenticular sandstones, hence brine injected into them would eventually migrate into other beds of sandstone, including those from which fresh-water supplies are obtained.

MEASURED SECTIONS IN RUSSELL COUNTY

The thickness of the exposed formations was measured by us at several places along Saline and Smoky Hill valleys in 1941. Descriptions of the beds exposed and their thickness and correlation are given in the following measured sections.

SECTION 1.—*NW¼ sec. 34, T. 12 S., R. 14 W. Measured from level of Saline river along scarp on east bank*

Bed No.		Thickness, feet
	Greenhorn limestone	
12.	Limestone and shale, thinly interbedded. Limestone is hard, gray weathering tan to buff, containing *Ostrea*. Shale is calcareous, thin-bedded, light buff	36.4
11.	Shale, light and dark gray interbedded, containing chalky shale, hard, thin-bedded, light gray to yellowish. A 2-foot bed of limestone, sandy, hard, thin-bedded, gray, containing teeth and scales of fish, occurs about 15 feet above the base	46.8
	Covered interval	31.2
	Graneros shale	
10.	Shale, fissile, papery, gypsiferous, black to dark gray, containing thin ochreous partings. Large crystals of selenite on weathered surface	20.8
	Dakota formation	
	Janssen clay member	
9.	Sandstone, fine-grained, iron-cemented, brown, tan, and purple, containing fragments of carbonized wood	0.2
8.	Silt, sandy, dark red-brown, containing carbonaceous and peaty material	2.8
7.	Ironstone, red-brown	0.5
6.	Sandstone, fine-grained, massive, mottled gray, tan, and yellow-orange, weathers to tan and buff. Three-foot zone of silty sandstone at top containing fragments of carbonized wood	17.2
5.	Shale, silty, gray, containing at base thin partings of fine-grained, yellow-tan sandstone, grading upward to gray, silty shale; also contains shot-like concretions of iron (mostly hematite)	3.4
4.	Shale, fissile, gypsiferous, gray to brown in lower half, gray in upper half, containing thin ochreous partings; carbonaceous in lower part.	2.4
3.	Siltstone, sandy, massive, mottled gray and yellow-tan, containing many fragments of carbonized wood and, at base, ochreous streaks	1.6
2.	Clay shale, silty, thin-bedded, becoming more regular at top, gray grading to darker gray at top	7.0
1.	Shale, silty, massive to blocky, brick-red in lower part grading to yellowish-tan and reddish-tan at top; contains numerous shot-like concretions of iron.	6.4
	Covered interval	11.8
		188.5

SECTION 2.—*NE¼ sec. 34, T. 12 S., R. 14 W. Measured from level of Saline river along Highway 281, approximately 4 miles north of Russell.*

Bed No.		Thickness, feet
Greenhorn limestone		
15.	Limestone and shale, thinly interbedded. Limestone is hard, gray, weathering tan to buff, containing *Ostrea*. Shale is thin-bedded, light buff, calcareous. Streak of dark-gray shale in lower third	15.6
Graneros shale		
14.	Shale, fissile, black; thin streaks of ironstone and siltstone occur in lower 8 feet. A bed of sandstone, fine-grained, finely laminated, gray, dark gray, and yellow, occurs at top. Laminae of sandstone are marked by fine particles of charcoal	31.3
Dakota formation, Janssen clay member		
13.	Ironstone, reddish-brown	0.7
12.	Shale, thin-bedded, black, gray and red. Thin beds of fine-grained, yellow sandstone throughout	4.2
11.	Sandstone, fine-grained, massive to thin-bedded, gray and yellow-orange mottled, weathering buff. Thin beds of ironstone in lower half and at top	20.8
10.	Shale, massive, carbonaceous, dark gray, gray and yellow brick-red, silty at top. Plant remains in lower one foot	3.6
9.	Siltstone, sandy, massive, light gray	1.4
8.	Shale, massive to blocky, gray, brown, brick-red, lavender, yellow, predominantly gray at top. Thin bed of clay-ironstone 2 feet above base. Botryoidal concretions of hematite and limonite throughout	13.9
7.	Shale, gypsiferous, blocky, irregularly bedded, dark gray, containing fragments of carbonized wood. Top 1.5 feet is very black shale with concentration of fragments of carbonized wood. Crystals of selenite weather out on the surface	5.3
6.	Sandstone, silty, fine-grained, mottled gray and yellow, containing many large (6 to 8 inches) botryoidal-shaped red-brown concretions of ironstone formed largely of iron-cemented coarse- to medium-grained sand	3.9
5.	Shale, silty, massive, mottled gray and yellow, containing nodules of hematite near top	5.5
4.	Sandstone, silty, irregularly bedded, mottled light gray and yellow-orange	1.7
3.	Silt, sandy, light gray	1.7
2.	Siltstone, sandy, massive, brown on weathered surface, yellow-buff when fresh, scattered speckles of brown iron stain	1.6
1.	Shale, blocky, light gray weathering to tan-gray	2.4
	Covered interval	8.9
		122.5

SECTION 3.—*SE¼ sec. 25, T. 12 S., R. 14 W. Measured from level of Saline river along north scarp*

Bed No.		Thickness, feet
	Greenhorn limestone	
15.	Limestone and shale, thinly interbedded. Limestone is sandy, hard, gray, containing *Ostrea;* shale is thin-bedded, calcareous, gray and yellow-tan	18.0
14.	Limestone, sandy, hard, gray, weathering to pinkish-tan, containing *Ostrea.*	0.7
	Graneros shale	
13.	Shale, fissile, rubbery, dark gray, brown to tan	5.0
12.	Shale, fissile, dark gray to black, containing thin partings of fine-grained, gray sandstone throughout. Bed of sandstone 10 feet above base and thin beds of red-brown ironstone 4 and 8 feet above base.	32.0
	Dakota formation	
	Janssen clay member	
11.	Ironstone, silt, and fine sand, red-brown; contains fragments of carbonized wood (and glauconite?)	0.8
10.	Shale, silty, gypsiferous, light gray, gray, blue-gray and yellow. Thin bed of sandstone, calcareous, fine-grained, light gray, 5 feet above base. Thin beds of ironstone in lower 5 feet. Large crystals of selenite on weathered slope	10.5
9.	Sandstone, fine-grained, thin- to medium-bedded, light gray and yellow, containing small concretions of hematite in upper 10 feet and two beds of ironstone at top	19.5
8.	Shale, irregularly thin-bedded, dark gray to black. Crystals of selenite and small nodules of pyrite on weathered surface	9.1
7.	Silt, sandy, light gray	6.5
6.	Shale, irregularly bedded, dark gray, weathering gray on surface	3.1
5.	Clay, massive to blocky, mottled gray, brick-red, yellow-tan	16.2
	Terra Cotta clay member	
4.	Clay, massive, mottled red, brick-red, tan and gray. Small concretions of hematite throughout and a thin zone of shot-like concretions of iron at top	6.3
3.	Clay, massive, mottled red, gray and brown. Shot-like concretions throughout. A one-half-inch zone of concretions of iron at base.	7.8
2.	Sandstone, calcareous, fine-grained, lenticular, light-gray. Sandstone pinches out 10 feet east	0.2
1.	Silt, sandy, dove-gray, mottled red-brown and ochreous	1.8
	Covered interval	13.1
		150.6

SECTION 4.—*SW¼ sec. 29, T. 12 S., R. 13 W. Measured from Saline river level along high scarp on east side of valley.*

Bed No.		Thickness, feet
Greenhorn limestone		
14.	Limestone and shale, thinly interbedded. Limestone, hard, gray, weathering to light buff, containing small concretions of iron in lower part; shale, calcareous, thin-bedded, dark gray. Fish teeth and scales in calcareous shales and limestone	19.6
13.	Shale, fissile, gray. Streaks of gray and light gray, calcareous shale, weathering to thin beds of white, sandy limestone throughout. Thin bed of concretions of ironstone and pyrite 2 to 3 feet from top	20.4
12.	Limestone, dirty-gray weathering dirty-white, scattered fragments of pyrite and carbonized wood	1.1
11.	Shale, interbedded calcareous and noncalcareous, thin-bedded, gray to dark gray	14.8
Graneros shale		
	Covered interval	22.0
10.	Shale, fissile, dark gray to gray, thin partings of buff to gray silty sandstone. Thin sandstone beds just below top; limestone, sandy, thin-bedded, gray, containing fragments of fish scales at top	10.5
9.	Sandstone, silty, fine-grained, well-sorted, buff to tan, locally iron cemented	1.0
8.	Shale, gypsiferous, thin-bedded, dark gray. Numerous large crystals of selenite on surface. Weathered surface has appearance of being wet, but discoloration does not permeate shale immediately underlying surface	4.4
Dakota formation		
	Janssen clay member	
7.	Sand and concretions of ironstone, sandy, irregularly cemented with iron, red-brown. Sand matrix, gray-brown and silty. Ironstone sandy, irregularly bedded, red-brown, containing numerous fragments of carbonized wood (and glauconite?) at top of bed	3.6
6.	Sandstone, shaly, thin-bedded, gray in upper half, fine-grained, well-sorted, light buff at top. Crystals of selenite on weathered surface. Clay shales, sandy, thin-bedded, dark gray in lower half,	35.0
5.	Shale, fissile, black to dark gray; contains thin bed of sandstone at top, reddish-brown, iron-cemented, containing numerous large fragments of carbonized wood	8.2
4.	Ironstone, containing inclusions of gray clay balls and fragments of pyritized wood in lower part	0.7
3.	Shale, silty, gray, interlaminated with yellow-brown silty, sandy shale. Thin bed of silty micaceous sandstone at base	2.2
2.	Sandstone, massive, locally cross-bedded, light gray-white to dirty tan-gray. Several thin beds of sand containing numerous small fragments of carbonized wood throughout	11.8
1.	Shale, silty, massive, brick-red, gray, purple mottled. Shot-like concretions of iron throughout	5.8
	Covered interval	21.6
		182.7

SECTION 5.—*SE¼ sec. 9, T. 13 S., R. 12 W., Russell county. Measured from creek level along road cut, approximately 5½ miles northeast of Bunker Hill.*

Bed No.		Thickness, feet
	Greenhorn limestone	
21.	Shale and limestone, interbedded; shale predominates and limestone occurs as thin beds. Shale, calcareous, thin-bedded, gray-buff; limestone, light pink to grayish-tan, containing fragments of fish scales	5.5
	Graneros shale	
20.	Covered. Road ditch material is clay shale, blue-black to black	26.0
19.	Sandstone, fine-grained, well-sorted, massive, gray-tan to yellow-orange, locally containing iron cement at base	5.0
18.	Shale, thin-bedded to fissile, dark gray, containing bed of dark-red fissile shale at base; contains streaks of limonitic shale throughout	10.1
	Dakota formation	
	Janssen clay member	
17.	Sandstone, fine- to medium-grained, well-sorted, angular to subangular, gray-tan to buff weathering to grayish-buff, containing iron cement in irregular patches. Thin bed of purple ironstone at top containing fragments of ironized and carbonized wood	5.3
16.	Shale and clay, massive, dark gray, containing thin beds of fine- to medium-grained, gray sandstone throughout	1.9
15.	Sand, fine-grained, well-sorted, unconsolidated, gray and gray-tan, containing thin streaks and interlaminae of limonitic claystone	3.9
14.	Shale, thin-bedded, dark gray, and sandstone, thin-bedded, fine-grained, well-sorted, gray; containing thin streaks of limonitic claystone throughout	2.3
13.	Sandstone, fine-grained, well-sorted, angular to subangular, tan to gray. Lower part is well cemented with iron. Upper part is cross-bedded and contains fragments of carbonized wood and elongated nodules of limonitic claystone	3.3
12.	Shale, clayey, dark gray, containing a few thin laminae of fine-grained, gray sandstone and small fragments of carbonized wood	1.0
11.	Sandstone, fine- to medium-grained, well-sorted, cross-bedded. massive at base, thin-bedded at top, iron-cemented, containing thin bed of gray to light-buff limestone at top	3.7
10.	Shale and sandstone, irregularly and thinly interlaminated. Shale is dark gray and contains small fragments of carbonized wood; sandstone is fine-grained, well-sorted, angular to subangular, and gray	2.1
9.	Sandstone and shale; containing scattered concretions of ironstone. Upper part is sandstone, well-sorted, coarse- to medium-grained, cross-bedded, light brown. Cross-bedding planes are marked with dark red-brown iron cement. Lower 2 feet composed of shale, carbonaceous, thin-bedded, dark gray, containing lenses of medium-grained, well-sorted, buff sandstone	3.1

8.	Shale, massive to blocky. Upper 15 feet alternating (2 to 3 foot zones) gray and buff shale and brick-red and buff mottled shale, lower part gray-brown shale. Small shot-like concretions of iron occur throughout	22.4
	Covered interval	2.9
7.	Sandstone, ironstone, and sandy shale, alternating in thin beds. Sandstone is silty, brown to buff, containing casts of wood and stems; ironstone is red-brown, containing inclusions of clay balls and fragments of pyritized wood; shale is sandy to silty, gray, containing large fragments of carbonized wood	2.6
6.	Shale and sandstone, gray and buff mottled. The lower 4 feet is shale, irregularly bedded, gray to grayish-pink, and sand, fine-grained, gray. Small shot-like concretions of iron and crystals of selenite prominent	12.5
5.	Sandstone, fine- to medium-grained, massive, gray to tan. Local cross-bedding in thin zones. Sandstone concretions near the top are light brown, iron-cemented, and average one-half inch in diameter	2.3
4.	Shale, massive to blocky, red, gray and buff mottled, containing numerous small concretions of brown ironstone in lower part	10.4
3.	Shale, silty, massive, gray, minor mottling of yellow-buff silty shale; containing small fragments of carbonized wood	3.0
2.	Sandstone, medium- to fine grained, iron-cemented, buff to tan, containing nodular sand near the top and displaying thin and irregular bedding in lower and middle parts	2.2
1.	Shale, clayey, massive, gray and red mottled	2.4
		133.9

Section 6.—*NE¼ sec. 12, T. 13 S., R. 12 W. Measured from creek level along low scarp on southeast bank approximately 5 miles north of Bunker Hill*

Bed No.		Thickness, feet
Greenhorn limestone		
18.	Shale, calcareous, thin-bedded, light buff-tan to gray-tan, containing fish scales. Limestone, thin, pinkish-tan	18.0
Graneros shale		
17.	Shale, thin-bedded to fissile, dark gray to black, ochreous, containing a few thin partings of fine-grained gray sand and small crystals of selenite	24.8
16.	Shale, dark gray and tan mottled; contains at top and bottom sandstone, fine-grained, iron-cemented, irregularly bedded, containing numerous veins of gypsum	3.7
15.	Shale, fissile, dark gray, scattered yellow-orange shale partings, containing crystals of selenite (3 inches by 5 inches largest)	3.7
14.	Shale, sandy, clayey, dark gray, containing beds of iron-cemented, soft, red-brown sandstone at top and bottom	1.5
13.	Shale, fissile, dark gray to black, containing thin ochreous partings and a few crystals of selenite	1.8

12.	Shale, sandy, dark gray, containing a thin bed of limonite-colored, iron-cemented sandstone at top	0.5
	Dakota formation	
	Janssen clay member	
11.	Sandstone, fine-grained, locally cross-bedded, light tan to brown, containing concretions of ironstone	1.7
10.	Sandstone, silty, thin-bedded, fine-grained, brown, containing partings of ironstone, and shale, sandy, thin-bedded, gray	6.9
9.	Sandstone, fine-grained, angular, cross-bedded, tan to gray, speckled with iron discoloration	3.3
8.	Sandstone and clay, thinly interbedded, gray. Sandstone, silty, fine-grained, containing a thin red-brown ironstone bed at the top and several bright yellow-orange sandstone laminae 2 feet above the base	3.9
7.	Ironstone, sandy, hard, dark red weathering purplish-black	0.8
6.	Sandstone, fine-grained, well-sorted, thin, irregularly bedded, gray and yellow-orange mottled	1.9
5.	Sandstone, silty, friable, dark buff, containing partings of red ironstone	1.2
4.	Sandstone, fine-grained, well-sorted, massive to medium-bedded, tan to gray weathering brownish-gray	6.7
3.	Sandstone, very fine-grained, soft, gray, containing partings of silt and shale and thin beds of fine-grained, buff sandstone. The buff sandstone is more prominent near the top	13.0
2.	Sandstone, fine-grained, well-sorted, angular to subangular, micaceous, thin- to medium-bedded, locally cross-bedded, gray, containing partings of gray shale along bedding planes	26.0
1.	Shale, massive to blocky, red, gray, yellow-buff, containing thin streaks of brown and limonite-colored ironstone. Weathered part is limonite-colored and is speckled with red-brown concretions of iron	25.3
	Covered interval	26.0
		169.3

SECTION 7.—*SE¼ sec. 23, T. 13 S., R. 11 W., Russell county. Measured from creek level*

Bed No.		Thickness, feet
	Greenhorn limestone and Graneros shale	
9.	Partially covered slope. Shale, thin-bedded, calcareous, buff to gray, and limestone, thin-bedded, sandy, gray, containing fish teeth and fish scales	60.0
8.	Covered slope. Long gentle slope suggests shale. Interval capped by limestone, sandy, gray, containing fish scales	25.0
7.	Covered interval. At the base is clay shale, gray and yellow-brown mottled. Top of interval is defined by thin bed of dark red-brown sandy ironstone which forms prominent bench	21.0

Dakota formation		
6.	Sandstone, fine- to medium-grained, well-sorted, massive, gray to brown; contains thin cross-bedded zones containing iron cement along planes of truncation	6.2
5.	Silt, light gray, overlying shale, massive to blocky, light gray and light lavender mottled	15.0
4.	Sandstone, fine-grained, well-sorted, angular to subangular, massive to thick-bedded, gray-tan to red-brown, containing a zone of cross-bedding near the top and a thin zone of limonite-colored, iron-cemented, fine-grained sandstone nodules at the base	25.0
3.	Shale, massive to blocky, dark blue-gray, containing a zone of thin partings of buff sandstone at the top, a zone of dark gray sandy shale at the bottom, and numerous fragments of carbonized wood.	12.0
2.	Shale, massive to blocky, dark gray; contains a zone of buff, fine-grained, silty sand containing a few partings of gray clay shale	6.0
1.	Sandstone, fine- to medium-grained, well-sorted, massive, gray-tan to yellow-buff, containing fragments of carbonized wood at the top and many zones of cross-bedding. Sand near the top is reddish-purple weathering to bright red, brick-red and red-brown	60.0
		230.0

SECTION 8.—*NE¼ sec. 31, T. 14 S., R. 11 W., Russell county. Measured from level of red shale exposure on floor of flood plain along south bluff of Saline river, approximately 4 miles south of Dorrance.*

Bed No.		Thickness, feet
Greenhorn limestone		
8.	Upper part of interval partly covered. Limestone, buff, containtaining *Ostrea* and *Inoceramus* shells and casts. Basal 2 feet is limestone, sandy, locally finely cross-laminated, wavy-bedded, gray and gray-brown	40.0
Graneros shale		
7.	Shale, fissile, dark gray to black, gypsiferous and ochreous, containing thin, irregular laminae of yellow, fine-grained sand. Top 3 feet is interlaminated, fine-grained, gray and yellow sandstone and dark-gray carbonaceous shale. A thin bed of nodular, partially iron-cemented, red and brown sandstone occurs 10 feet above the base	28.5
Dakota formation, Janssen clay member		
6.	Ironstone, dark red-brown, red, purplish, containing fragments of carbonized wood and nodules of iron-stained claystone. Crystals of selenite on weathered surface	0.3
5.	Shale, silty, thin-bedded, gypsiferous, slightly carbonaceous, gray to dark gray in upper half and mottled gray, brown, and yellow-orange in lower half	3.3

4. Sandstone, massive, yellow-buff weathering drab gray-brown to gray. Surface speckled with small concretions of iron. One-half inch bed of red-brown ironstone at the top	2.2
3. Shale, interbedded with fine-grained, micaceous, gray sand and carbonaceous, silty, gray shale. Upper part is shale, carbonaceous, fissile, gray	4.1
2. Sandstone, massive in upper part, thin- to medium-bedded in lower part, light gray to drab-buff weathering light gray to gray, containing charcoal at the top. Bedding planes of upper part are ripple marked. This sandstone thins to a bed a few feet thick one-half mile east and west	47.9
1. Shale, silty, thin-bedded to blocky, gray and yellow-orange mottled at base, gray at top, containing small concretions of iron on weathered surface	15.0
	141.3

RECORDS OF TYPICAL WELLS

Information pertaining to water wells in Russell and Ellis counties is tabulated on the following pages (tables 13 and 14). The numbers in the first column correspond to the well numbers on the map (pl. 1) and in the tables of analyses (tables 10 and 11). The wells are listed in order by townships from north to south and by ranges from east to west. Within a township the wells are listed in the order of the sections. All information classed as "reported" was obtained from the owner, tenant, or driller. Depths of wells not classed as "reported" are measured and given to the nearest tenth of a foot below the measuring point described in the tables, and depths to water level of wells not classed as "reported" are measured and given to the nearest hundredth of a foot.

Table 13.—*Records of typical water wells in Russell county, Kansas*

Well No.[1]	Location	Owner or tenant	Type of well[2]	Depth of well (feet)[3]	Diameter of well (in.)	Type of casing[4]	Principal water-bearing bed		Method of lift[5]	Use of water[6]	Measuring point			Depth to water level below measuring point (feet)	Date of measurement, 1941	Chloride in 1941 (parts per million)
							Character of material	Geologic subdivision			Description	Height above (+) or below (—) land surface (feet)	Height above sea level (feet)			
	T. 11 S., R. 14 W.															
1	SW NW sec. 7	Ruth Miller	Du	22.1	32	S	Sand	Alluvium	C, W	S	Top of casing, north side	+1.7	......	19.33	Sept. 5	35
2	SE SE sec. 33	E. Stielow	Du	8.9	60	S	do	do	N	N	Top of casing, west side	+2.5	......	7.6	Oct. 3	16
	T. 11 S., R. 15 W.															
3	NW NW sec. 6	Siwooganock Savings Bank	Du	21.1	32	S	Sand and shale	Pleistocene and Carlile	C, W	N	Top of casing, east side	+ .5	......	19.29	Sept. 1	25
(4)	SE SE sec. 8	J. C. Meier	Du	23.1	32	S	Sand	Pleistocene	C, W	S	Top of casing	+ .9	......	20.58	Sept. 1	58
(5)	SE NE sec. 10	C. Boedeker	Dr	31.4	6	GI	Limestone	Greenhorn	C, W	D	Top of casing, north side	+1.0	......	11.21	Sept. 1	40
6	NW NW sec. 12	G. H. Schwaoferger	Du	15.6	36	S	Sand	Alluvium	C, W	D	Top of casing, west side	+ .8	......	12.44	Sept. 1	35
7	SE SE sec. 14	C. Booth	Du	16.2	44	S	Shale	Carlile	C, W	S	Top of casing, east side	+ .1	......	14.39	Sept. 5	230
8	SW SE sec. 16	J. T. Howe	Du	12.1	36	S	Shale and sand	Carlile and Tertiary	C, H	S	do	+ .3	......	10.46	Sept. 5	115
9	SE NW sec. 18	Christopher Veh	Dr	29.1	8	GI	Sand and shale	Alluvium and Carlile	C, W	S	do	+ .5	......	28.30	Sept. 1	40
10	SE SW sec. 20	Ervin Miller	Du	18.4	36	S	Sand	Alluvium	C, W	S	do	+1.2	......	8.25	Sept. 5	25
11	SW NE sec. 28	G. J. Gobleman	Du	12.1	42	S	Shale	Carlile	N	N	Top of casing, north side	+ .5	......	9.78	Aug. 30	186
12	SW SW sec. 29	W. T. Musselman	Du	10.7	48	S	Sand	Alluvium	C, W	S	Top of casing, east side	+1.0	......	6.15	Sept. 5	350
	T. 12 S., R. 14 W.															
13	SE NE sec. 4	J. Kilian	Du	22.4	38	S	do	Pleistocene	C, W	D	do	+1.4	......	16.20	Sept. 6	150
(14)	SW SE sec. 10	S. Ottwein	Du	15.2	......	S	do	Alluvium	C, W	D, S	Top of casing, west side	+1.3	......	8.65	Sept. 6	61
15	NW NW sec. 11	Mary Fuller-Wallace	Du	16.8	40	S	do	Pleistocene	N	N	Top of casing, north side	.0	......	16.12	Sept. 6	30
16	NE NE sec. 12	J. Beor	Du	16.5	40	S	do	Alluvium	C, H	S	Top of casing, east side	+1.2	......	14.13	Sept. 6	130
17	NE SW sec. 14	R. Haferer	Du	20.8	40	S	do	do	C, W	S	Top of casing, east side	+1.1	......	7.42	Sept. 10	50
18	NE SE sec. 18	F. Boxberger	Du	19.1	32	S	do	do	C, H	S	Top of casing, west side	+1.0	......	13.33	Sept. 5	40
(19)	SE SE sec. 20	A. W. Schneider	Du	18.5	......	S	do	do	C, W	S	Top of casing, south side	+1.7	......	17.05	Sept. 5	28
20	SE NE sec. 23	W. Funk	Du	17.8	......	S	do	Tertiary	C, W	S	Top of casing, east side	+ .4	......	2.81	Sept. 10	40
21	NE SE sec. 33	C. Woelk	Du	22.1	42	S	do	Alluvium	C, W	D, S	Top of casing, south side	+ .8	......	14.65	Sept. 8	940
(22)	NE SW sec. 34	C. Claussen	Dr	29.6	6	GI	do	do	C, W	D, S	Top of casing, west side	+ .8	......	15.84	Sept. 6	43

	T. 12 S., R. 15 W.														
(23)	NW NW sec. 4	Otto Eulert	Dr	20.5	6	GI	do	do	C, W	D, S	Top of casing, east side	+ .2	....	11.86	Aug. 30	97
24	SE NE sec. 6	R. E. Tichener	Dr	26.8	6	GI	do	do	C, H	S	do	+ .7	....	18.21	Sept. 1	555
25	SW SW sec. 7	Loyd Oswald	Dr	35.1	6	GI	Limestone and sand	Greenhorn and alluvium	C, H	S	Top of casing, south side	+1.5	....	23.10	Aug. 30	27
26	SE NE sec. 14	F. J. Lindenberger	Du	26.1	36	S	Sand	Alluvium	C, W	S	Top of casing, west side	+2.4	....	22.64	Sept. 5	1,730
27	SW SW sec. 18	E. C. Deckoit	Du	12.9	48	S	Sand and limestone	Alluvium and Greenhorn	C, W	S	Top of casing, east side	+1.1	....	7.25	Aug. 30	65
28	SW NW sec. 25	W. E. Davis	Dr	149.8	6	GI	Sandstone	Dakota	C, W	S	Top of casing, west side	+ .5	....	89.88	Sept. 8	490
29	SW SW sec. 28	W. E. Keeney	Du	25.1	40	S	Limestone and alluvium	Greenhorn and alluvium	C, W	D, S	do	+ .8	....	12.11	Aug. 30	110
30	NE NW sec. 30	E. G. Deckart	Du	29.2	32	S	Shale	Carlile	C, W	S	do	+1.1	....	25.18	Aug. 30	70
(31)	NE SW sec. 32	J. Milke	Du	25.6	34	S	Sand	Tertiary	C, W	S	Top of casing, south side	+ .8	....	16.97	Aug. 30	122
32	SE SE sec. 34	H. H. Bender	Du	17.9	32	S	do	Alluvium	C, W	S	Top of casing, east side	+1.2	....	10.08	Sept. 8	50
	T. 13 S., R. 13 W.															
33	NW SW sec. 19	A. Ginther	Du	49.2	30	S	Limestone and sand	Greenhorn and Tertiary	C, W	S	Top of casing, south side	+0.2	....	35.32	Sept. 10	145
	T. 13 S., R. 14 W.															
34	SW NE sec. 2	F. J. Dumler	Du	23.4	36	S	Sand	Alluvium	C, W	S	Top of casing, west side	+ .2	....	18.03	Sept. 10	68
35	SE NW sec. 2	W. Waimaster	Du	32.2	30	S	do	do	C, W	S	do	+ .3	....	25.46	Sept. 10	35
36	SW NE sec. 6	Gustav Schenkel	Du	20.5	36	S	do	do	N	N	Top of casing, south side	+8.2	....	18.59	Sept. 8	2,810
37	NE SE sec. 16	G. Borrell	Dr	189.2	6	GI	Sandstone	Dakota	C, W	S	Top of casing, north side	+1.0	1,815.9	161.35	Sept. 6	....
38	NW NW sec. 16	G. P. Bender	Dr	178.9	6	GI	do	do	N	N	Top of casing, west side	+1.0	1,840.4	156.17	Sept. 6	....
39	SE NE sec. 18	W. H. New	Du	13.6	32	S	Sand	Alluvium	C, W	N	Top of casing, north side	+ .3	1,664.9	6.88	Sept. 8	5,800
40	SW SE sec. 24	George Holland	Dr	52.1	6	GI	Sand and limestone	Tertiary and Greenhorn	C, H	S	do	+ .3	....	8.05	Sept. 10	27
(41)	SE NW sec. 30	A. D. Jellison	Dr	183.7	6	GI	Sandstone	Dakota	C, W	S	Top of casing, west side	+ .4	1,870.1	163.42	Sept. 8	2,610
42	SE SE sec. 31	S. Brown	Du	22.4	36	S	Sand	Alluvium	C, W	S	do	+2.5	1,852.2	7.29	Sept. 12	105
	T. 13 S., R. 15 W.															
(43)	NE SE sec. 2	D. Rogg	Dr	30.6	6	GI	do	do	C, W	S	do	+1.2	....	18.76	Sept. 8	82
44	NE NE sec. 5	A. Pfeifer	Dr	35.9	4	GI	Limestone and sand	Greenhorn and alluvium	C, H	D, S	Top of casing, south side	+1.1	....	13.62	Aug. 30	444
45	SW SW sec. 8	J. P. Drieling	Du	21.4	44	S	Limestone	Greenhorn	C, H	S	Top of casing, west side	+2.3	....	16.38	Aug. 29	87
46	SE SE sec. 9	N. Brown	Du	14.2	48	S	Sand	Alluvium	C, H	S	do	+ .1	....	6.50	Aug. 29	73
47	SE SE sec. 14	M. J. Brungardt	Du	13.3	32	S	do	do	C, W	S	Top of casing, east side	+ .3	1,808.6	2.46	Sept. 8	30
48	SE NW sec. 18	A. Nowan	Dr	21.1	6	GI	do	Tertiary	C, H	S	Top of casing, west side	+ .3	1,871.2	9.69	Aug. 29	85
49	NW SE sec. 22	R. Johnson	Dr	223.5	6	GI	Sandstone	Dakota	C, W	S	Top of casing, north side	+ .2	1,884.9	133.67	Sept. 8	370
50	SE SE sec. 29	A. Dumler	Du	23.7	36	S	Sand	Tertiary	C, W	S	Top of casing, west side	+ .8	1,908.4	22,01	Aug. 29	16
(51)	SE NW sec. 30	A. Nowak	Du	25.6	48	S	Sand	Tertiary	C, W	S	Top of casing, north side	+ .8	1,924.4	23.66	Aug. 29	14
(52)	SW SW sec. 34	E. Mills	Du	23.0	40	S	do	do	C, W	D, S	do	+ .8	1,883.9	8.60	Aug. 29	460
53	SE SW sec. 36	Frank Dillner	Du	27.0	40	S	do	Alluvium	C, W	S	Top of casing, west side	+ .5	1,872.4	16.93	Sept. 12	190
54	NE SE sec. 36	S. Boxberger	Du	26.5	32	S	do	do	C, H	S	Top of casing, east side	+ .4	1,865.8	8.58	Sept. 12	30

Table 13.—Records of typical water wells in Russell county, Kansas—*Continued*

Well No.[1]	LOCATION	Owner or tenant	Type of well[2]	Depth of well (feet)[3]	Diameter of well (in.)	Type of casing[4]	Principal water-bearing bed		Method of lift[5]	Use of water[6]	Measuring point			Depth to water level below measuring point (feet)	Date of measurement, 1941	Chloride in 1941 (parts per million)
							Character of material	Geologic subdivision			Description	Height above (+) or below (—) land surface (feet)	Height above sea level (feet)			
	T. 14 S., R. 11 W.															
(55)	SE SW sec. 14	Tony Hvaik	Dr	44.2	6	GI	Sand	Pleistocene	C, W	S	Top ot casing, east side	+ .4	....	41.46	Sept. 20	48
56	NW NW sec. 17	C. M. Stoppel	Du	33.3	......	S	do	do	C, W	S	Top of casing, west side	+ .7	....	31.63	Sept. 22	27
57	SE SW sec. 21	Seymour Bunker	Dr	47.1	6	GI	Sand and sandstone	Alluvium and Dakota	N	N	Top of casing, north side	+1.0	....	17.36	Oct. 11	80
(58)	NE NE sec. 30	D. H. Heinze	Du	34.1	36	S	Sand	Pleistocene	C, H	N	do	+ .4	....	12.65	Oct. 11	26
	T. 14 S., R. 12 W.															
59	NE NW sec. 7	H. M. Baldridge	Du	21.3	30	S	do	Alluvium	C, H	N	do	+ .5	....	1.81	Oct. 3	5
60	SE SE sec. 10	M. J. Bohman	Du	32.6	38	S	do	Pleistocene	C, H	D	Top of casing, west side	+ .4	....	14.45	Sept. 20	132
(61)	SW SE sec. 10	D. D. Beisel	Du	30.8	32	S	Limestone	Greenhorn	C, H	N	Top of casing, south side	+ .8	1,794.3	27.25	Sept. 22	22
(62)	SW SE sec. 10	D. D. Beisel	Dr	183.9	6	GI	Sandstone	Dakota	C, W	N	Top of casing, east side	+ .5	1,796.2	170.33	Sept. 22	23
63	NW NE sec. 24	D. P. Steinle	Du	17.3	32	S	Sand	Pleistocene	C, H	N	Top of casing, north side	+ .6	....	16.40	Sept. 20	65
64	NE NW sec. 27	Fred Herbel	Dr	102.2	6	GI	Sandstone	Dakota	C, W	S	do	+ .4	....	44.07	Sept. 22	1,710
(65)	NE SE sec. 34	T. Madden	Dr	78.8	6	GI	do	do	C, H	S	Top of casing, south side	+1.0	....	60.23	Aug. 8	665
	T. 14 S., R. 13 W.															
66	NW NW sec. 3	D. J. Waymester	Du	20.1	48	S	Sand	Alluvium	C, H	S	do	+ .2	1,797.1	1.38	Oct. 11	10
67	NE SE sec. 9	Andrew Schultz	Dr	215.2	6	GI	Sandstone	Dakota	C, W	S	Top of casing, north side	+1.1	1,822.7	164.70	Oct. 11	465
(68)	NW SW sec. 12	George Shearer	Dr	244.6	6	GI	do	do	C, W	D	Top of casing, west side	+ .2	1,853.5	208.10	Oct. 9	85
69	NE NE sec. 13	C. Best	Du	12.2	42	S	Sand	Alluvium	C, W	S	Top of casing, east side	+1.8	....	6.02	Oct. 3	....
70	NE SE sec. 13	John Penix	Du	11.6	36	S	do	Pleistocene	C, W	D, S	Top of casing, south side	+1.3	....	9.18	Sept. 20	60
71	NW NW sec. 22	John Bond	Du	25.3	60	S	do	do	C, H	N	do	+2.9	....	6.22	Oct. 10	10
72	NE SE sec. 26	R. S. Hall	Dr	131.6	6	GI	Sandstone	Dakota	C, H	D	Top of casing, west side	+ .8	....	33.42	Oct. 9	205
73	SE SE sec. 27	John Letsch	Dr	27.8	6	GI	Sand	Pleistocene	C, H	D	Top of casing, south side	+1.2	....	18.75	Oct. 10	160
74	SE SE sec. 27	John Letsch	Dr	82.9	6	GI	Sandstone	Dakota	N	N	Top of casing, west side	+1.2	1,705.4	17.85	Oct. 9	50
75	NE NE sec. 29	Mary Carter	Dr	58.8	6	GI	Limestone	Greenhorn	C, W	S	Top of casing, north side	+1.3	1,708.5	44.53	Oct. 6	70
76	NW NE sec. 34	John Letsch	Du	39.9	38	S	Sand	Pleistocene	C, W	N	Top of casing, east side	+ .2	....	26.50	Oct. 9	120

	T. 14 S., R. 14 W.													
(77)	NW NW sec. 1	A. H. Forthmeyer	Du	19.5	48	S	do.	Alluvium	C, W	S	do.	+ .2	1,799.0	10.12	Oct. 13	91
78	SE SW sec. 3	Henry Boxberger	Du	23.5	36	S	do.	Pleistocene	C, W	S	Top of casing	+ .7		19.57	Oct. 6	140
79	SW NW sec. 7	H. B. Milberger	Du	30.4	36	S	do.	Alluvium	C, W	S	Top of casing, south side	+ .2	1,868.0	6.89	Sept. 13	5
(80)	NE NE sec. 16	S. Boxberger	Du	24.3	48	S	do.	Pleistocene	C, H	D	Top of casing, north side	+ .7		13.83	Sept. 6	260
81	NE NW sec. 17	F. H. Krug	Du	30.7	36	S	do.	Alluvium	C, W	S	Top of casing, east side	+ .9		22.09	Sept. 13	60
82	SE NE sec. 20	George Crissman	Du	25.6	42	S	Sand	Pleistocene	C, W	S	Top of casing, south side	+ .8		23.36	Sept. 13	415
83	NE NE sec. 22	G. Boxberger, Jr	Du	23.1	36	S	Limestone	Greenhorn	C, H	N	Top of casing, west side	+1.3		22.16	Sept. 20	50
84	SW SE sec. 25	Nadine Hickey	Du	18.4	30	S	Sand	Alluvium	C, H	S	Top of casing, south side	+ .1		7.32	Oct. 6	218
(85)	SW SW sec. 28	Alex Flegler	Dr	61.1	6	GI	do.	Pleistocene	C, H	S	Top of casing, north side	+1.0		31.57	Sept. 13	52
86	NW NW sec. 31	J. C. Rexroot	Dr	38.1	6	GI	do.	do.	M	N	Top of casing, south side	+ .5		24.79	Aug. 28	10,060
	T. 14 S., R. 15 W.															
87	NE NE sec. 6	Sarah Stafford	Du	13.8	36	S	do.	Tertiary	C, W	S	do.	+ .6	1,879.7	6.04	Aug. 29	555
88	SE SW sec. 8	Joseph Jacobs	Du	40.6	36	S	do.	do.	C, W	D	Top of casing, east side	+ .1	1,868.7	38.97	Aug. 29	165
89	SE SE sec. 9	Jos. Forthermyer, Jr.	Du	15.1	72	S	do.	do.	N	N	do.	+ .8	1,838.5	5.51	Aug. 29	11,740
90	SE SE sec. 9	Joseph Forthermyer	Dr	224.1	6	GI	Sandstone	Dakota	C, W	S	Top of casing, west side	+ .3	1,851.4	102.15	Aug. 29	4,100
91	SW SE sec. 12	Geo. Boxberger, Jr	Dr	201.4	6	GI	do.	do.	C, W	S	Top of casing, east side	+ .5		112.30	Sept. 13	1,780
(92)	NE NW sec. 12	R. W. Peterson	Du	25.9	38	S	Limestone	Greenhorn	C, W	S	Top of casing, north side	+ .2	1,855.0	7.15	Sept. 13	1,335
93	SW SW sec. 14	W. J. Smith	Du	7.4		S	Sand	Pleistocene	C, H	N	Top of casing, east side	+ .2		5.31	Sept. 28	25
94	NW SW sec. 18	Albert Kurz	Du	18.8	48	S	do.	Tertiary	C, W	S	do.	+1.9	1,885.0	13.48	Aug. 28	9
(95)	NE NE sec. 29	E. D. Gorham	Du	19.5	48	S	do.	Pleistocene	C, H	D	do.	+4.5		17.43	Aug. 28	49
96	NE NW sec. 30	Michael Baumrusker	Du	37.3	48	S	do.	do.	C, W	D	Top of casing, south side	+ .1		34.60	Aug. 28	22
97	SW SW sec. 33	S. Rouback	Dr	155.1	6	GI	Sandstone	Dakota	C, W	S	Top of casing, north side	+ .1		124.34	Aug. 27	1,245
	T. 15 S., R. 12 W.															
98	SE SW sec. 1	F. C. and A. Ptacek	Dr	299.1	6	GI	Sandstone	Dakota	C, W	S	Top of casing, west side	+ .6		193.02	Aug. 8	2,330
99	NW NW sec. 2	Emma Ney	Du	33.2	36	S	Sand	Pleistocene	C, H	D	Top of casing, east side	+1.0		29.70	Aug. 8	85
(100)	NE NW sec. 6	S. K. Steinert	Dr	48.5	6	GI	do.	do.	C, H	D	Top of casing, south side	+ .1		7.9	Aug. 11	32
101	NE NW sec. 6	S. K. Steinert	Du	33.5	28	S	do.	do.	C, W	S	Top of casing, east side	+1.0		32.51	Aug. 11	40
102	NE NE sec. 8	A. F. Major	Du	19.9	30	S	do.	Alluvium	C, W	N	Top of casing, south side	.0		10.17	Aug. 8	23
103	SW SW sec. 8	E. Brock	Du	21.2	36	S	Sand and limestone	Alluvium and Greenhorn	C, W	S	Top of casing, east side	+ .7		5.55	Aug. 8	27
104	NW NE sec. 10	Charles Kaufman	Dr	54.7	6	GI	Sandstone	Dakota	C, W	S	Top of casing, north side	+1.0		29.50	Aug. 8	200
105	SW NW sec. 14	Henry Kastrup	Dr	71.9	6	GI	do.	do.	N	N	Top of casing, south side	+ .6	1,733.1	70.80	Aug. 9	220
106	SW NW sec. 14	Henry Kastrup	Dr	132.1	6	GI	Sandstone	Dakota	C, W	S	Top of casing, south side	.0	1,751.1	70.85	Aug. 9	367
107	SE NE sec. 14	W. Koetkemeyer	Dr	194.2	6	GI	do.	do.	C, W	D	Top of casing, north side	+ .5	1,840.0	109.70	Aug. 9	700
108	NW NW sec. 16	F. C. and A. Ptacek,	Dr	220.1	6	GI	do.	do.	N	N	Top of casing, east side	+ .3	1,820.7	97.00	Aug. 8	472
109	NW NW sec. 16	F. C. and A. Ptacek,	Dr	262.8	6	GI	do.	do.	C, W	D, S	Top of casing	+ .7	1,815.2	122.03	Aug. 8	960
110	SW NW sec. 20	Emile Hilgenberg	Dr	215.5	6	GI	do.	do.	C, W	S	Top of casing, east side	+ .7	1,839.1	120.85	Aug. 11	1,975
(111)	SE SE sec. 31	N. G. Nye	Dr	244.5	6	GI	do	do.	C, G	S	Top of casing, north side	+ .7		53.00	Aug. 11	1,420
112	NE SE sec. 34	C. Klusener	Du	19.5	48	S	Sand	Alluvium	C, W	D	Top of casing, east side	+ .7		12.40	Aug. 9	170
	T. 15 S., R. 13 W.															
113	NE NE sec. 1	W. C. Ruby	Dr	76.6	6	GI	Sandstone	Dakota	N	N	Top of casing, west side	+ .7		47.90	Aug. 11	140
114	SE NE sec. 1	C. Fisher	Dr	104.6	6	GI	do.	do.	C	N	Top of casing, south side	+ .5		91.60	Aug. 11	
115	SE SE sec. 2	R. Lipprand	Du	15.9	48	S	Sand	Tertiary	C, W	S	Top of casing, east side	+ .8		6.71	Aug. 12	15
116	SW SW sec. 10	C. Anschutz	Dr	183.8	6	I	Sandstone	Dakota	N	N	Top of casing, west side	+ .7	1,866.3	178.53	Aug. 14	
117	NW NE sec. 16	A. Schultz	Du	31.9	36	S	Sand and Limestone	Tertiary Greenhorn	N	N	do.	+ .7	1,873.8	11.57	Aug. 14	80

Table 13.—Records of typical water wells in Russell county, Kansas—*Concluded*

Well No.[1]	LOCATION	Owner or tenant	Type of well[2]	Depth of well (feet)[3]	Diameter of well (in.)	Type of casing[4]	Principal water-bearing bed		Method of lift[5]	Use of water[6]	Measuring point			Depth to water level below measuring point (feet)	Date of measurement, 1941	Chloride in 1941 (parts per million)
							Character of material	Geologic subdivision			Description	Height above (+) or below (—) land surface (feet)	Height above sea level (feet)			
	T. 15 S., R. 13 W.															
118	SW SE sec. 16	G. W. Meharg	Du	27.8	36	S	Limestone	Greenhorn	C, W	S	Top of casing, east side	+ .5	1,876.7	10.13	Aug. 14	15
119	SW NW sec. 20	E. W. Hill	Du	17.4	34	S	Sand	Alluvium	C, W	D, S	Top of casing, south side	+ .2	....	15.43	Aug. 14	60
120	SE SE sec. 22	Tom Sellens	Du	31.7	34	S	Sand and limestone	Tertiary and Greenhorn	C, W	S	Top of casing, east side	+ .5	1,834.1	18.71	Aug. 13	265
121	NW NE sec. 23	W. H. Berrick	Du	24.0	48	S	Sand	Alluvium	C, W	S	do	+ .2	....	13.96	Aug. 13	34
122	NW SW sec. 24	do	Dr	147.4	6	GI	Sandstone	Dakota	C, W	S	do	+ .5	1,773.1	127.35	Aug. 9	420
123	NW SW sec. 27	W. H. Berry	Dr	224.3	6	GI	do	do	C, W	S	Top of casing, south side	+ .5	1,886.6	189.56	Aug. 25	1,910
124	SE NE sec. 30	W. E. Boomhower	Dr	22.2	6	GI	Sand	Alluvium	C, H	S	Top of casing, north side	+ .5	....	15.23	Aug. 14	440
125	NE SE sec. 34	Peter Eichman	Du	15.9	36	S	Limestone	Greenhorn	C, W	D	Top of casing, west side	+ .3	....	14.24	Aug. 13	2,630
126	NW SW sec. 34	Ruth C. Weeks	Dr	204.1	8	GI	Sandstone	Dakota	C, W	S	do	+ .5	1,877.8	171.93	Aug. 13	1,840
	T. 15 S., R. 14 W.															
(127)	NW NE sec. 5	L. J. Phinney	Du	26.2	36	S	Sand	Pleistocene	C, W	D, S	Top of casing, east side	+ .5	....	19.93	Sept. 13	59
128	SW SW sec. 6	P. G. Vonfelt	Du	17.9	36	S	do	do	C, H	N	Top of casing, west side	+2.6	....	14.80	Sept. 13	1,220
(129)	NW NE sec. 7	George Krug	Dr	174.2	6	GI	Sandstone	Dakota	C, W	N	Top of casing	+ .5	....	159.92	Sept. 13	1,815
130	NW NE sec. 11	Jacob Flegler	Dr	92.4	6	GI	do	do	C, W	S	Top of casing, east side	+ .7	....	31.23	Aug. 20	1,140
131	NW NW sec. 11	do	Du	27.2	32	S	Sand	Alluvium	C, H	S	do	+ .7	....	24.98	Aug. 20	60
132	SE SE sec. 13	Fred D. Krug	Dr	190.2	6	GI	Sandstone	Dakota	C, W	S	do	+ .3	1,871.5	169.90	Aug. 20	1,580
133	NE SW sec. 16	Gottfried Stricker	Du	6.9	48	S	Sand	Alluvium	C, W	S	Top of casing, north side	.0	....	5.94	Aug. 18	35
134	NW SW sec. 17	F. Dietz	Du	18.1	48	S	do	do	C, H	D	Top of casing, east side	+ .7	....	9.58	Aug. 18	170
135	SW SE sec. 25	W. Michaelis	Du	20.9	30	S	Sand and limestone	Alluvium and Greenhorn	C, W	S	do	+ .7	....	8.98	Aug. 18	140
136	SE SW sec. 25	F. Podszus	Du	34.9	40	S	Limestone	Greenhorn	C, H	S	Top of casing, north side	+ .3	....	23.31	Aug. 18	735
137	NE NW sec. 26	D. H. Bender	Du	29.4	34	S	do	do	C, W	S	Top of casing, east side	+ .8	....	12.03	Aug. 18	620
138	NE NW sec. 26	do	Dr	221.3	6	GI	Sandstone	Dakota	C, W	S	do	+ .7	1,897.3	181.66	Aug. 18	1,725
139	SE SE sec. 28	H. P. Nuss	Du	15.1	32	S	Sand	Alluvium	C, W	N	Top of casing, south side	+ .7	....	7.11	Aug. 18	30
140	SW NW sec. 29	J. Ernest	Du	18.4	34	S	do	Pleistocene	C, H	D	Top of casing, west side	+ .5	....	14.58	Aug. 18	55
141	NE SE sec. 31	L. Elasser	Dr	62.4	7	GI	Sandstone	Dakota	C, H	D	Top of casing, east side	+ .7	1,860.7	22.51	Aug. 21	45
142	NE SE sec. 31	L. Elasser	Dr	170.9	6	GI	Sandstone	Dakota	C, H	S	Top of casing, south side	+ .3	1,867.5	103.33	Aug. 21	785
143	NE NW sec. 32	E. Becker	Du	24.1	32	S	Sand	Alluvium	C, H	D	Top of casing, east side	+ .7	....	20.09	Aug. 18	90
144	NE NE sec. 36	R. Deines	Dr	38.3	6	GI	Sand and limestone	Tertiary and Greenhorn	C, H	D	Top of casing, north side	+ .8	....	11.04	Aug. 18	70

	T. 15 S., R. 15 W.														
145)	SW SE sec. 3	Jacob Streck	Du	11.5	60	S	Sand	Pleistocene	C, E	S	Top of casing, south side	+ .8		10.04	Aug. 23	158
146	NW SW sec. 5	Oscar Mitchell	Du	40.1	38	S	do.	do.	C, W	D	Top of casing, east side	+ .4		37.36	Sept. 13	275
147	SW SW sec. 5	Joseph J. Krause	Dr	17.4	84	S	do.	Alluvium	C, W	S	Top of casing, west side	+ .3		14.09	Aug. 23	45
(148)	SE SW sec. 6	Albert Yoxall	Du	12.9	48	S	do.	do.	C, H	S	Top of casing, north side	+ .8		10.67	Aug. 23	131
149	NE SW sec. 7	Sherman Weidle	Du	18.5	42	S	do.	Pleistocene	C, W	S	Top of casing, east side	+ .7		17.75	Aug. 22	100
150	NW SW sec. 11	Henry Dietz	Du	10.7	40	S	do.	do.	C, H	S	Top of casing, north side	+ .2		9.67	Aug. 23	30
151	SE NE sec. 15	Henry Weideman	Dr	72.4	6	GI	Sandstone	Dakota	C, W	S	Top of casing, north side	+ .7		45.12	Aug. 23	900
152	SE NE sec. 18	Marie B. Bushell	Du	15.5	50	S	Sand	Pleistocene	C, H	D	Top of casing, east side	+1.2		14.52	Aug. 22	70
153	NW NE sec. 21	F. Steinert	Dr	17.1	6	GI	do.	do.	C, H	N	Top of casing, west side	+ .2		13.79	Aug. 27	43,200
154	NW SW sec. 21	Lydia Steinert	Dr	70.8	6	GI	Sandstone	Dakota	C, W	D, S	Top of casing, east side	+ .5		69.05	Aug. 22	20
155	SE SW sec. 23	J. R. Dumler	Dr	198.4	6	GI	do.	do.	C, W	S	Top of casing, west side	.0		142.84	Aug. 21	1,520
156	SE NW sec. 27	G. R. Dumler	Du	13.3	70	S	Sand	Alluvium	C, H	D, S	Top of casing, south side	+3.7		11.22	Aug. 22	30
157	NE NW sec. 30	John Maier	Dr	80.3	6	GI	Sandstone	Dakota	C, W	S	Top of casing, north side	+ .2		31.21	Aug. 22	1,085
158	SW NW sec. 32	Phillip Funk	Dr	154.9	6	GI	do.	do.	C, W	S	do.	+ .5	1,888.3	115.19	Aug. 22	930
159	NW NW sec. 34	Honis Michaelis	Dr	199.4	6	GI	do.	do.	C, W	N	Top of casing, east side	+ .3	1,915.6	146.50	Aug. 22	
160	NE SE sec. 34	do.	Dr	184.2	6	GI	do.	do.	C, W	S	Top of casing	+1.6	1,951.1	128.22	Aug. 21	950
161	NE SE sec. 34	do.	Du	38.5	60	S	Sand and limestone	Tertiary and Greenhorn	C, H	N	Top of casing, north side	+2.2		32.80	Aug. 21	230
162	SE NE sec. 35	B. Boxberger	Du	27.1	60	S	Limestone and sand	Greenhorn and Tertiary	C, W	S	Top of casing, east side	+ .8		17.52	Aug. 21	25
163	NW NW sec. 36	do.	Dr	175.9	6	GI	Sandstone	Dakota	C, W	D, S	Top of casing, west side	+ .5	1,900.3	137.99	Aug. 21	1,365

1. Well number in parentheses indicates that analysis of water is given in table 10.
2. Dr, drilled; Du, dug.
3. Measured depth below the measuring point.
4. GI, galvanized iron; I, iron; S, stone.
5. C, cylinder pump; E, electric motor; G, gasoline engine; H, hand-operated; N, none.
6. D, domestic; N, none; S, stock.

TABLE 14.—*Records of typical water wells in northeastern Ellis county, Kansas*

Well No.[1]	LOCATION	Owner or tenant	Type of well[2]	Depth of well (feet)[3]	Diameter of well (ins.)	Type of casing[4]	Principal water-bearing bed		Method of lift[5]	Use of water[6]	Measuring point			Depth to water level below measuring point (feet)	Date of measurement, 1941	Chloride in 1941 (parts per million)
							Character of material	Geologic subdivision			Description	Height above (+) or below (—) land surface (feet)	Height above sea level (feet)			
	T. 11 S.. R. 16 W.															
164	NE NW sec. 7	A. H. Romine	Du	20.0	36	S	Sand	Pleistocene	C, W	S	Top of casing, south side	+2.1	....	16.42	Nov. 13	40
165	SW SW sec. 16	Flora Finch	Dr	18.9	6	GI	do	Alluvium	C, H	S	Top of casing, east side	+1.0	....	15.70	Oct. 30	10
166	NE NE sec. 24	Central Life Ins. Co.	Du	31.8	36	S	do	do	C, W	S	Top of casing, south side	+ .1	....	15.94	Oct. 30	60
167	SE SE sec. 26	W. Shaw	Du	29.0	36	S	do	do	C, W	S	Top of casing, north side	+ .6	....	25.95	Oct. 30	105
	T. 11 S., R. 17 W.															
166	SE NE sec. 1	J. Gillis	Dr	19.6	6	GI	do	Pleistocene	C, W	S	Top of casing, east side	+1.8	....	14.87	Nov. 14	35
169	SE SE sec. 3	Harry Simpson	Du	26.0	36	S	Sandstone	Codell	C, W	D, S	Top of casing, north side	+ .2	....	25.75	Nov. 13	15
170	NW NW sec. 14	C. E. Simpson	Du	16.6	36	S	Sand	Alluvium	C, W	S	Top of casing, east side	+ .3	....	12.32	Nov. 13	95
171	NE NE sec. 18	J. Cormichael	Dr	25.4	6	GI	do	do	C, H	D	Top of casing, north side	+ .2	....	21.25	Nov. 13	20
172	SW SW sec. 26	S. and F. Hall	Dr	43.9	6	GI	do	Pleistocene	N	D	Land surface, east side	....	....	40.80	Nov. 13	50
	T. 11 S., R. 18 W.															
173	SE SE sec. 7	Park E. Salter	Dr	42.5	6	GI	....	....	C, W	S	Top of casing, south side	+2.5	....	24.81	Dec. 3	8
174	NW NW sec. 10	T. Moistrell	Dr	16.1	6	GI	....	....	N	N	Top of casing, north side	+ .2	....	12.55	Dec. 3	38
175	NW NW sec. 14	H. B. Conrad	Dr	33.5	6	GI	....	....	C, H	D	Top of casing, south side	+ .3	....	17.86	Dec. 4	14
176	NE NE sec. 16	W. J. Madden	Dr	25.0	6	GI	....	....	C, H	D	Top of casing, east side	+ .6	....	14.31	Dec. 3	10
(177)	NE NE sec. 30	T. W. McNeeley	Du	65.3	36	S	Sandstone	Codell	C, W	D	Top of casing, north side	+ .7	....	56.10	Dec. 5	92
178	SW SW sec. 32	W. Johnson	Dr	32.1	6	GI	....	....	C, W	S	Top of casing, east side	+ .4	....	18.1	Dec. 4	8
179	SW SW sec. 36	C. Meier	Dr	43.2	6	I	....	....	N	N	Top of casing, west side	+1.7	....	9.91	Dec. 3	145
	T. 12 S., R. 16 W.															
180	NW NE sec. 2	D. F. Oswald	Du	29.0	36	S	Sand	Alluvium	C, H	S	Top of casing, north side	+ .2	....	9.40	Oct. 2	45
181	SW SW sec. 8	H. J. Huff	Du	16.9	36	S	do	do	C, W	S	do	+ .2	....	8.62	Oct. 28	55
182	SE SE sec. 12	C. L. Smith	Du	27.2	36	S	do	do	C, H	S	Top of casing, west side	+ .5	....	18.08	Oct. 30	38
183	NE NE sec. 16	E. Jantzen	Du	16.8	36	S	do	do	C, W	S	Top of casing, south side	+1.0	....	4.40	Oct. 28	115
184	NE NE sec. 25	K. Franis	Du	16.0	84	S	do	do	C, W	S	Top of casing, west side	+ .7	....	5.58	Oct. 28	42
185	SW SW sec. 31	B. P. Brungardt	Du	20.6	36	S	do	do	C, W	S	Top of casing, east side	+ .3	....	9.20	Oct. 28	20
186	SE SE sec. 34	F. J. Froelich	Du	27.9	36	S	do	do	C, H	S	do	+2.6	....	14.50	Oct. 28	10

	T. 12 S., R. 17 W.														
187	NE SE sec. 6	A. E. Korlin	Dr	518.3	6	GI	Sandstone	Dakota	N	N	Top of casing, south side	+ .4	2,152.9	306.1	Dec. 29	3,100
188	NE NE sec. 8	M. Dreiling	Du	15.3	48	S	Sand	Pleistocene	C, W	D, S	do	+1.5	2,068.0	10.73	Nov. 15	15
189	Center SE¼ sec. 9	V. N. Rohleder	Dr	99.3	6	GI	Sandstone	Codell	N	N	Top of casing, east side	—4.7	2,175.9	72.20	Nov. 14	65
190	NW NW sec. 11	P. M. Rohleder	Dr	62.1	6	GI	do	do	C, W	D, S	Top of casing, south side	+1.2	2,119.9	48.30	Nov. 15	10
191	NE NE sec. 16	W. W. Bemis	Du	82.6	36	S	do	do	C, H	S	do	+ .3	2,144.7	54.24	Nov. 14	22
192	SW SW sec. 18	E. Schmeidler	Dr	57.0	6	GI	do	do	C, W	D	Top of casing, west side	+ .4	2,129.5	35.95	Nov. 15	20
193	NE NE sec. 24	F. Kinderknecht	Du	34.0	48	S	Sand	Pleistocene	C, W	S	do	+ .3	....	27.83	Nov. 15	60
194	SE SE sec. 25	M. Brungardt	Dr	20.2	8	GI	do	do	C, H	D	do	+ .4	....	7.58	Nov. 15	30
195	SE SE sec. 28	A. Schmeidler	Du	19.7	36	S	do	do	C, W	S	Top of casing, east side	+ .4	....	3.50	Nov. 14	8
(196)	NW NW sec. 30	Ray Smith	Dr	61.0	6	GI	Sandstone	Codell	N	N	Top of casing, west side	+ .3	....	54.22	Nov. 15	10
	T. 12 S., R. 18 W.														
197	SW NW sec. 8	A. Kreutzer	Dr	62.2	6	GI	....	....	C, H	D	Top of casing, south side	+0.8	....	13.16	Dec. 5	20
198	NE NE sec. 11	A. V. Stabb	Dr	73.9	6	GI	Sandstone	Codell	C, W	S	Top of casing, north side	+ .3	2,118.4	53.97	Dec. 4	30
199	SW SW sec. 14	H. W. Joy	Du	42.6	48	S	do	do	C, W	S	Top of casing, east side	+2.3	2,113.9	16.42	Dec. 4	10
200	SE SE sec. 16	A. M. Cole	Dr	87.9	6	GI	do	do	C, H	D	Top of casing, west side	+ .4	2,153.1	75.67	Dec. 16	45
201	NE NW sec. 24	H. W. Byers	Dr	99.5	6	GI	do	do	C, W	D, S	do	+1.8	....	63.48	Dec. 5	18
202	SW SW sec. 30	P. Fisher	Du	23.5	48	S	....	....	C, W	S	Top of casing, south side	+ .5	....	16.75	Dec. 4	1,400
203	NE NE sec. 32	P. J. Schmidt	Du	26.2	48	S	....	....	C, W	S	Top of casing, west side	+1.2	....	9.10	Dec. 4	70
204	SW SW sec. 34	J. J. Saunders	Du	19.3	48	S	....	....	C, W	S	Top of casing	.0	....	10.65	Dec. 5	10
205	NE NE sec. 35	Hans Jenson	Du	29.3	......	S	....	....	H	D	Top of casing, west side	— .8	....	23.5	Dec. 5	70
	T. 13 S., R. 16 W.														
206	SW NE sec 5	J. J. Brungardt	Du	20.1	36	S	Sand	Alluvium	C, W	S	Top of casing, east side	+ .3	....	13.80	Oct. 14	15
(207)	SE SE sec. 16	J. Scheck	Du	23.0	48	S	do	Tertiary	C, W	S	do	+1.0	....	8.61	Oct. 14	87
208	NW NW sec. 18	J. M. Kuhn	Du	24.2	48	S	do	Alluvium	C, W	S	Top of casing, west side	+ .3	....	16.48	Oct. 14	8
209	NW SW sec. 20	A. P. Dreiling	Du	23.0	24	S	do	Tertiary	C, W	S	do	+ .3	....	20.62	Oct. 14	30
210	SE NE sec. 25	Brungardt et al	Du	13.9	48	S	do	do	C, W	D	Top of casing, south side	+ .2	1,906.3	10.97	Oct. 14	40
(211)	SE NE sec. 31	A. P. Brungardt	Du	23.8	36	S	do	do	C, W	D	do	+ .8	....	23.8	Oct. 14	49
212	SE NE sec. 34	Peter Mermis	Du	29.5	36	S	do	do	C, W	D	Top of casing, east side	+ .4	....	28.03	Oct. 14	35
	T. 13 S., R. 17 W.														
213	NE SE sec. 1	P. Leiker	Du	20.4	36	S	do	do	C, W	S	Top of casing, west side	+ .3	1,908.4	9.08	Oct. 17	45
214	NW NE sec. 3	A. Schmidt	B	12.0	6	GI	do	Alluvium	C, W	D, S	do	—4.6	....	2.24	Oct. 17	50
(215)	NW NW sec. 7	A. Staab	Dr	29.3	6	GI	do	do	C, H	D	Top of casing, north side	+ .2	....	19.67	Oct. 17	40
216	SE SW sec. 9	P. Schmidt	Dr	42.8	6	GI	do	Pleistocene	N	N	do	+ .3	....	40.43	Oct. 17	110
217	NE NE sec. 14	A. P. Graff	Dr	29.6	6	GI	Sandstone	Codell	N	N	Top of casing, east side	+ .6	....	26.30	Oct. 17	20
218	NW NW sec. 17	F. M. Putman	Du	13.9	48	S	Sand	Alluvium	C, W	N	do	+2.3	....	12.9	Oct. 17	30
(219)	NW NE sec. 28	K. Bissing	Du	31.8	24	S	do	Pleistocene	C, W	S	Top of casing, south side	.0	....	26.57	Oct. 17	40
220	SE SE sec. 31	A. A. Weisner	Du	18.4	36	S	do	Alluvium	C, W	S	Top of casing, east side	+ .3	....	12.60	Oct. 17	20
221	SE NE sec. 33	F. J. Krentze	Du	28.6	60	S	do	Tertiary	C, W	S	Top of casing, north side	+ .3	....	17.46	Oct. 17	10
222	SE SW sec. 36	M. Kuhn	Du	25.6	36	S	do	Pleistocene	C, W	S	Top of casing, south side	+ .4	....	22.92	Oct. 17	20

Table 14.—Records of typical water wells in northeastern Ellis county, Kansas—*Concluded*

Well No.[1]	LOCATION	Owner or tenant	Type of well[2]	Depth of well (feet)[3]	Diameter of well (ins.)	Type of casing[4]	Principal water-bearing bed		Method of lift[5]	Use of water[6]	Measuring point			Depth to water level below measuring point (feet)	Date of measurement, 1941	Chloride in 1941 (parts per million)
							Character of material	Geologic subdivision			Description	Height above (+) or below (—) land surface (feet)	Height above sea level (feet)			
	T. 14 S., R. 16 W.															
223	SW NW sec. 5	A. M. Kuhn	Du	17.8	36	S	Sand	Tertiary	C, W	D, S	Top of casing, west side	+ .5		15.28	Oct. 16	38
224	NE NE sec. 8	Ben Schulte	Du	17.9	24	S	do.	do.	C, W	N	do.	+ .2		14.0	Oct. 16	360
225	NE NE sec. 10	Polcyn et al	Dr	153.7	6	GI	Sandstone	Dakota	N	N	Top of casing, north side	+ .3		151.05	Oct. 16	522
226	NW NW sec. 12	F. H. Schulte	Du	17.3	36	S	Sand	Tertiary	C, H	D	Top of casing, west side	+ .3	1,909.1	15.97	Oct. 16	22
227	SE SE sec. 15	W. Berens	Du	25.4	36	S	Limestone	Greenhorn	C, W	D	Top of casing, east side	+ .3		20.60	Oct. 14	30
228	NW NW sec. 18	A. G. Wagner	Du	34.3	40	S	Sand	Pleistocene	C, W	D	Top of casing, south side	+1.6		26.07	Oct. 16	40
229	NW SW sec. 21	P. A. Dreiling	Du	37.8	36	S	do.	Tertiary	C, H	D	Top of casing, east side	+ .3		33.54	Oct. 16	25
230	NE NE sec. 26	B. M. Wagner	Du	29.7	36	S	do.	Pleistocene	C, W	D	Top of casing, north side	+ .2		26.95	Oct. 16	20
231	SW SW sec. 28	J. Broun	Du	53.0	36	S	Limestone	Greenhorn	C, W	D, S	Top of casing, east side	+ .5		50.5	Oct. 16	28
232	SE SE sec. 31	M. Dinkle	Du	37.5	48	S	Sand	Pleistocene	C, W	S	Top of casing, north side	+ .6		30.84	Oct. 16	10

1. Well number in parentheses indicates that analysis of water is given in table 11.
2. B, bored; Dr, drilled; Du, dug.
3. Reported depths below the land surface are given in feet; measured depths, in feet and tenths below measuring points.
4. GI, galvanized iron; I, iron; S, stone.
5. C, cylinder pump; H, hand-operated; N, none; W, windmill.
6. D, domestic; N, none; S, stock.

LOGS OF TEST HOLES DRILLED IN ELLIS AND RUSSELL COUNTIES

During the course of the field work seven test holes were drilled with the portable hydraulic-rotary drilling machine owned by the State and Federal Geological Surveys, and operated by Ellis Gordon, driller, Leroy Fugitt and James Cooper. Samples were collected at the rig and a log was prepared in the field by James Cooper. The samples were later examined with a binocular microscope by Frye and the following logs were prepared:

1.—*Log of test hole 1, 185 feet east and 55 feet south of NW corner sec. 6, T. 14 S., R. 13 W., Russell county. Surface altitude, 1,849 feet.*

	Thickness, feet	Depth, feet
Greenhorn limestone		
Shale and limestone, interbedded, gray	110	110
Graneros shale		
Shale, sandy, black	20	130
Dakota formation and Kiowa shale		
Shale and clay; blue-black, plastic	10	140
Shale, sandy, and clay; containing siderite and pyrite	30	170
Shale, sandy, light gray and yellow, containing concretions of siderite	30	200
Sandstone, containing thin beds of shale, gray and pink, and carbonaceous material	40	240
Shale, silty, gray-white and red	19	259
Shale, mottled gray-white and red, containing small concretions of siderite	26	285
Shale, silty, gray, containing small concretions of siderite	35	320
Shale, sandy, mottled red and gray	10	330
Shale, sandy, dark gray, containing siderite	30	360
Shale, silty, gray, containing pyrite and siderite	20	380
Shale, sand, and siderite	40	420
Shale, silty, sandy, light to medium gray	10	430
Shale, sandy, blue-gray and red, containing some siderite	20	450
Shale, sandy, gray	28	478
Permian redbeds		
Shale and sandstone; gray and red	12	490
Shale, silty, red	10	500

2.—*Log of test hole 2, 21 feet east and 45 feet north of SW corner sec. 31, T. 15 S., R. 14 W., Russell county. Surface altitude, 1,919 feet.*

Tertiary(?)	Thickness, feet	Depth, feet
Soil and mantle rock		
Clay, silt, and sand, light tan to dark gray, containing grains of quartz and feldspar	13	13
Greenhorn limestone		
Limestone, pale yellow to tan	12	25
Shale, calcareous, gray, containing thin beds of limestone	79	104
Limestone and shale; interbedded	20	124
Graneros shale		
Shale, brown-black, containing pyrite and thin beds of sand	26	150
Dakota formation and Kiowa shale		
Shale, sandy, dark gray	5	155
Shale and sandstone; brown and gray; containing siderite	17	172
Shale, soft, black to gray-black	6	178
Sandstone and shale; buff to gray; containing siderite	26	204
Sandstone, fine-grained, and shale, gray to buff; interbedded	17	221
Clay, sandy, gray, containing siderite	19	240
Shale, sandy, gray to brown, containing siderite	10	250
Shale, silty, gray, containing carbonaceous material	10	260
Clay, sandy, massive to concretionary, gray to brown	30	290
Sandstone, fine-grained, gray to white, containing loosely cemented siderite	10	300
Clay and sandstone, fine-grained, white; containing siderite	20	320
Sandstone and shale, sandy; gray	30	350
Shale, sandy, and sandstone; containing siderite	33	383
Sandstone, medium to coarse, gray	11	394
Shale and clay; blue-gray to gray; containing siderite and charcoal	51	445
Shale, gray and red, containing pyrite and fragments of shell	5	450
Shale, fissile, black and gray	20	470
Shale, sandy, gray and red, containing pyrite	7	477
Sandstone, fine to coarse, gray to white	20	497
Permian redbeds		
Sandstone, silty, brick-red	43	540

3.—*Log of test hole 3, 80 feet north and 12 feet east of SW corner sec. 31, T. 12 S., R. 17 W., Ellis county. Surface altitude, 2,081 feet.*

	Thickness, feet	Depth, feet
Tertiary(?)		
Soil and mantle rock		
Clay and silt, containing grains of limestone, pyrite, quartz, and feldspar	36	36
Carlile shale		
Blue Hill shale member		
Shale and clay; noncalcareous; gray to dark gray	124	160
Fairport chalky shale member		
Shale, calcareous, gray to black	88	248
Greenhorn limestone		
Shale and limestone; gray and brown; interbedded	102	350
Graneros shale		
Shale, sandy, and sandstone, black and gray	20	370
Shale, fissile, dark gray and black	30	400
Dakota formation and Kiowa shale		
Shale, sandy, and sandstone, gray and brown	30	430
Sandstone, gray	35	465
Shale and clay; sandy; mottled red and gray; containing small concretions of siderite	65	530
Shale, sandy, and sandstone, light gray and yellow	25	555
Shale, mottled red, gray, and yellow	29	584
Shale, sandy, brown and gray, containing siderite and thin beds of sandstone	36	620
Sandstone, fine-grained, and shale, sandy, gray and tan	50	670
Sandstone, fine-grained, gray and red, containing fragments of charcoal	40	710
Shale, sandy, light gray, containing pyrite	7	717
Sandstone and shale, sandy; gray and light gray	23	740
Shale, dark gray-black and gray	20	760
Cheyenne sandstone		
Sandstone, well-sorted, light gray to white	190	950
Sandstone, poorly sorted, gray, and silt, red	16	966
Permian redbeds		
Siltstone, sandy, red	14	980

4.—*Log of test hole 4, 1,870 feet south and 9 feet east of NW corner sec. 14, T. 12 S., R. 16 W., Ellis county. Surface altitude, 1,880 feet.*

	Thickness, feet	Depth, feet
Top soil	4	4
Carlile shale		
Shale and clay, gray-brown	28	32
Shale, calcareous in lower part, black	72	104
Greenhorn limestone		
Shale and limestone in thin alternating beds, gray and dark gray, containing foraminifera	106	210
Graneros shale		
Shale, in part sandy, blue-gray	5	215
Shale and sandstone, thin-bedded, black	33	248
Dakota formation		
Shale and clay; gray-white, pink, and yellow; containing a few sandy beds and siderite	62	310
Shale, red and gray, containing siderite	20	330
Shale and sandstone; gray	34	364
Shale and clay; red and gray; containing sandstone and siderite	31	395
Sandstone, gray, containing pyrite, siderite, and charcoal,	45	440

5.—*Log of test hole 5 in roadway at center E. line sec. 20, T. 14 S., R. 15 W., 12 feet east and 30 feet south of one-half mile post of sec. 20, Russell county.*

	Thickness, feet	Depth, feet
Soil	5	5
Tertiary		
Clay, black and brown, containing quartz grains	5	10
Gravel and sand; containing clay and fragments of limestone	17	27
Greenhorn limestone		
Shale and limestone; dark gray	20	47
Limestone, gray	2	49
Shale and limestone; dark gray	3	52
Graneros shale		
Shale, blue-black, containing sandstone, pyrite, and glauconite	38	90
Dakota formation and Kiowa shale		
Shale and sandstone, gray, containing clay and siderite	10	100
Shale, light gray, containing streaks of brown and red siderite	34	134
Shale, light gray, and sandstone, brown and gray	27	161
Clay shale, gray and red, containing siderite and a few thin beds of fine sandstone	79	240
Sandstone and shale; brown and gray; containing charcoal and siderite	20	260
Clay shale, gray to brown, containing siderite and beds of sandstone	120	380
Shale and sandstone; gray and tan; containing pyrite	10	390
Shale, gray and tan, containing pyrite	25	415
Cheyenne sandstone (?)		
Sandstone, very fine, silty, white	62	477
Permian redbeds		
Sandstone, fine-grained, pink and red	23	500

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