Geology and Ground-Water Resources of Southern Ellis County and Parts of Trego and Rush Counties, Kansas

By

ALVIN R. LEONARD and DELMAR W. BERRY

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BULLETIN 149

GEOLOGY AND GROUND-WATER RESOURCES OF SOUTHERN ELLIS COUNTY AND PARTS OF TREGO AND RUSH COUNTIES, KANSAS

By ALVIN R. LEONARD and DELMAR W. BERRY
(U. S. Geological Survey)

Prepared as a part of the program of the Interior Department for the development of the Missouri Basin, and co-ordinated with the co-operative ground-water program of the United States Geological Survey, the State Geological Survey of Kansas, the Division of Water Resources of the Kansas State Board of Agriculture, and the Division of Sanitation of the Kansas State Board of Health.

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GEOLOGY AND GROUND-WATER RESOURCES OF SOUTHERN ELLIS COUNTY AND PARTS OF TREGO AND RUSH COUNTIES, KANSAS

By

ALVIN R. LEONARD and DELMAR W. BERRY

ABSTRACT

This report describes the geography, geology, and ground-water resources of an area about 4 to 13 miles wide and 37 miles long, containing approximately 365 square miles. The climate is subhumid, the mean annual precipitation is 22.90 inches, and the mean annual temperature is 54.7° F. Agriculture is the chief occupation in the area; wheat is the chief crop, but sorghum and alfalfa are grown along the principal streams where the water table is near the surface. Minerals produced in the area are oil, limestone, sand and gravel, silt and clay, and volcanic ash.

The exposed rocks range in age from Late Cretaceous to Recent. The Pleistocene alluvial deposits, which range in age from Nebraskan to Recent, are the principal aquifers in the area. The Dakota Formation (Cretaceous) supplies water for rural domestic and stock use in parts of the area. The shape and slope of the water table are illustrated by a map showing contours of the water table and depth to the water table in wells. Ground water in the Pleistocene alluvial deposits moves downstream and toward the principal streams. Ground water is recharged mainly from local precipitation; ground water is discharged chiefly by seepage into streams and by transpiration by plants.

In most of the area the ground water is suitable for domestic, stock, and municipal use. The water ranges from soft to hard and from moderately to strongly mineralized. Water in the Dakota Formation generally is of the sodium chloride type, has a large amount of dissolved solids, and is moderately hard. Most water from the Pleistocene deposits is of the calcium bicarbonate type and contains moderate to large amounts of dissolved solids. Water from most of the aquifers in the area is rated good to permissible for irrigation.

The hydrologic and geologic field data upon which this report is based include records of 141 wells, chemical analyses of water from 49 domestic and stock wells and from 5 municipal supplies, and logs of 50 test holes, 1 oil well, and 80 jetted test holes.

INTRODUCTION

PURPOSE OF INVESTIGATION

The investigation of this report area in Smoky Hill River valley in Trego, Ellis, and Rush Counties is a part of the program for the development of the Missouri River Basin by the United States Department of Interior. In Kansas, the ground-water investigations made under the Missouri Basin Program have been coordinated with those made under the co-operative ground-water program begun in 1937 by the United States Geological Survey, the State Geological Survey of Kansas, the Division of Sanitation of the Kansas State Board of Health, and the Division of Water Resources of the Kansas State Board of Agriculture. The present status of investigations resulting from these programs is shown in Figure 1.

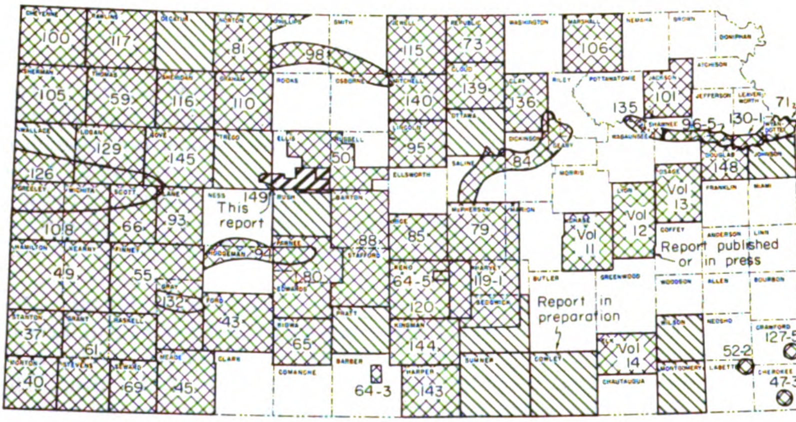

Fig. 1.—Index map of Kansas showing area discussed in this report and other areas for which ground-water reports have been published or are in preparation.

The purposes of this investigation were: To determine the natural occurrence and quality of the ground water before conditions were disturbed by irrigation developments; to determine the availability of ground water and its suitability for domestic, stock, municipal, and irrigation uses; to learn the geologic factors that control the occurrence of ground water; and to determine the chemical quality of the water in relation to geologic formations.

Location and Extent of Area

The area described in this report is a narrow strip extending from Cedar Bluff dam in southeastern Trego County to the eastern boundary of Ellis County. It includes the valleys of Smoky Hill River, Big Creek, and North Fork of Big Creek and the intervening and adjacent uplands. The area is about 37 miles long and ranges in width from 4 to 13 miles. It contains about 365 square miles.

Previous Investigations

The Cretaceous stratigraphy of Kansas has been a subject of interest to geologists since the railway explorations and the Hayden territorial surveys of the 1860's. Adams (1898) has given a historical summary of the early studies of the Cretaceous rocks in Kansas.

Many of the early field investigations and fossil collections were made by Mudge, who in 1878 presented the geologic outlines of western Kansas, using the stratigraphic classification set up by Meek and Hayden along Missouri River in Nebraska in 1862. Haworth (1897a) described the physiography of western Kansas and (1897b) the Tertiary rocks in Kansas. The Upper Cretaceous rocks were described by Logan (1897), who recognized several formations first described and named by Gilbert (1896) from exposures along Arkansas River in Colorado. Williston (1898, 1900) described the vertebrate paleontology of the Cretaceous rocks. In a report on the mineral waters of Kansas, Bailey (1902) presented analyses of water derived from Cretaceous rocks.

In 1913 Haworth described the occurrence of ground water in the Dakota Formation (p. 91-99) and in the Tertiary rocks (p. 57-68) of Kansas. Bass described the geology of Ellis County in detail (1926, p. 11-52) and included a short section on ground water. Frye and Brazil (1943) reported on ground water in the oil-field areas of Ellis and Russell Counties, which include the northeastern part of this area. Recent reports by Byrne, Coombs, and Bearman (1947, 1949) describe the occurrence of construction materials in this area.

Methods of Investigation

This project was started in the summer of 1946, as a part of the Missouri Basin program of the U. S. Department of Interior. Many wells were inventoried and an observation-well program was established in the eastern part of the area. During four months in the summer and fall of 1949, hydrologic and geologic data were collected in the area. The well inventory was completed, water levels were measured in many of the wells listed in Table 11, and the observation-well program was expanded to include the western part of the area. Depth to water was measured from a fixed point at the top of each well by steel tape graduated to hundredths of a foot. The altitude of the measuring point for each well was determined by level parties of the Bureau of Reclamation and the U. S. Geological Survey using a spirit level. The wells shown on Plate 2 were located by odometer, hence locations are accurate to about 0.1 mile.

In 1949, the geology was studied in the field, and the geologic map (Pl. 1) was prepared on aerial photographs made for the U. S. Department of Agriculture. Forty-nine test holes were drilled to determine the character, thickness, and extent of the water-bearing formations. These test holes penetrated the entire thickness of Pleistocene deposits and a few feet of the underlying bedrock (Pl. 3). The test holes were drilled with the hydraulic-rotary drilling machine owned by the State Geological Survey and operated by W. T. Connor, B. M. Yazza, and D. W. Berry. Samples of the drill cuttings collected in the field by D. W. Berry were examined with a binocular microscope in the office, and the field logs were modified as necessary. Additional data on the character and thickness of the water-bearing formations were obtained from field examination of outcrops and from residents in the area. In 1956, 80 test holes were jetted in Pleistocene deposits in and adjacent to Smoky Hill River valley in the western part of the area.

Chemical analyses of samples of water collected from 49 wells were made in the laboratory of the Quality of Water Branch at Lincoln, Nebraska. The analyses of the public water supplies for the cities of Hays and Victoria were made by the Division of Sanitation of the Kansas State Board of Health.

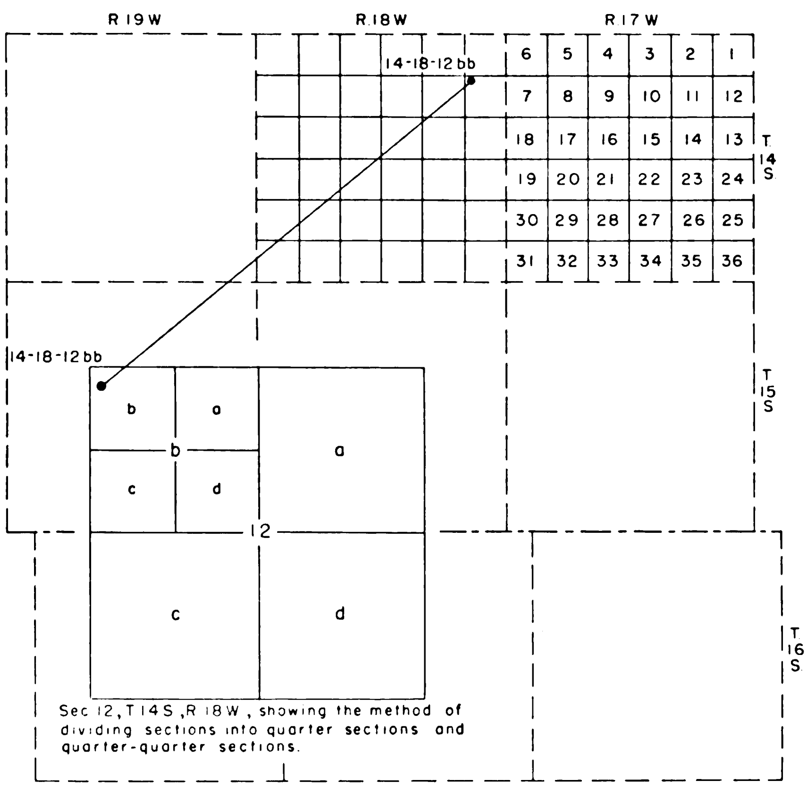

FIG. 2.—Sketch illustrating well-numbering system used in this report.

Well-Numbering System

The well-numbering system used in this report utilizes the General Land Office survey according to the following sequence: Township, range, section, quarter section, and 40-acre tract within the quarter section. The numbers used to designate the township, range, and section are those assigned in the General Land Office survey. The quarter sections and 40-acre tracts are lettered a, b, c, or d in a counterclockwise direction beginning with the northeastern quadrant. For example, well 14-18-12bb (Fig. 2) is in the NW¼ NW¼ sec. 12, T. 14 S., R. 18 W. If two or more wells or test holes are in the same 40-acre tract, they are numbered serially in the order in which they were inventoried; for example, 14-22-25da1, -25da2.

Acknowledgments

Appreciation is expressed to the residents of the area for providing information about ground-water supplies and for aiding in the collection of field data. Special thanks are given Ben Brungardt, city manager of Hays at the time this study was made, and to the water superintendents of Hays and Victoria for information about their city water supplies and the geology of the well fields.

The manuscript of this report has been reviewed critically by several members of the U. S. Geological Survey and the State Geological Survey of Kansas; by Robert V. Smrha, Chief Engineer, and George S. Knapp, Engineer, of the Division of Water Resources of the State Board of Agriculture; by Dwight F. Metzler, Director, and Willard O. Hilton, Geologist, of the Division of Sanitation of the Kansas State Board of Health; and by Robert L. Smith, Executive Secretary, and William E. Steps, Engineer, of the State Water Resources Board. Chemical analyses of water samples from the municipal supplies of Hays and Victoria were made by Howard Stoltenberg, Chemist, of the State Board of Health.

GEOGRAPHY

Topography and Drainage

Adams (1903) included this area in the Smoky Hills Upland division of the Great Plains physiographic province, and Schoewe (1949, fig. 22) classified it in the Smoky Hills and Blue Hills divisions of the Dissected High Plains. The area is characterized by gently rolling hills and undissected upland plains. The Greenhorn Limestone in southeastern Ellis County and the Fort Hays Limestone member of the Niobrara Chalk in southwestern Ellis County and southeastern Trego County form prominent escarpments, which rise 50 to 100 feet above the prominent terrace along Smoky Hill River. In southwestern Ellis County, long pediment slopes grade into the high terrace and mask the prominence of the Fort Hays escarpment. Smoky Hill River and its inner valley, entrenched 40 to 75 feet below the surface of the high terrace, are narrow inconspicuous features.

The maximum local relief exceeds 100 feet in two general localities only: Near the Cedar Bluff dam in sec. 18 and 19, T. 14 S., R. 21 W., in eastern Trego County, where the escarpment of the Fort Hays Limestone member rises abruptly about 140 feet above the flood plain of the river, and near Pfeifer where the bluff north of the river is formed by the Greenhorn Limestone. The total relief in the area is about 425 feet. The highest point is on the upland near the Cedar Bluff dam where the altitude is about 2,200 feet; the lowest point is along Smoky Hill River at the eastern side of Ellis County where the altitude is about 1,775 feet.

High terrace areas.—One of the most prominent physiographic features along Smoky Hill Valley is the nearly undissected high terrace, which ranges in width from 1 to 2½ miles (Pl. 4B). This terrace was named the Pfeifer Terrace by Leonard and Berry (Frye and Leonard, 1952) for the town of that name built on its surface. The surface of the Pfeifer Terrace lies at an elevation of 25 to 60 feet above the level of the flood plain and 60 to 120 feet below the general level of the upland. The terrace has an upland appearance and, although geomorphologically related to the stream, is separated from the inner valley nearly everywhere by bedrock bluffs. The principal tributaries to Smoky Hill River have eroded deep valleys across the Pfeifer Terrace, but in general the terrace has a coarse-textured drainage pattern, and many small undrained depressions are scattered over its surface.

A prominent well-developed terrace extends along Big Creek, especially on the north side. At Hays it is about 4 miles wide and extends on both sides of Big Creek. It attains a maximum width of about 7 miles in Ranges 16 and 17, where it extends from Big Creek to U. S. Highway 40 and beyond. This terrace is more rolling than the Pfeifer Terrace and its drainage pattern is better developed, although locally there are many small undrained depressions (Pl. 1). Loess is thicker and more widespread than on the Pfeifer Terrace, and the stream deposits underlying the loess probably represent several Pleistocene stages.

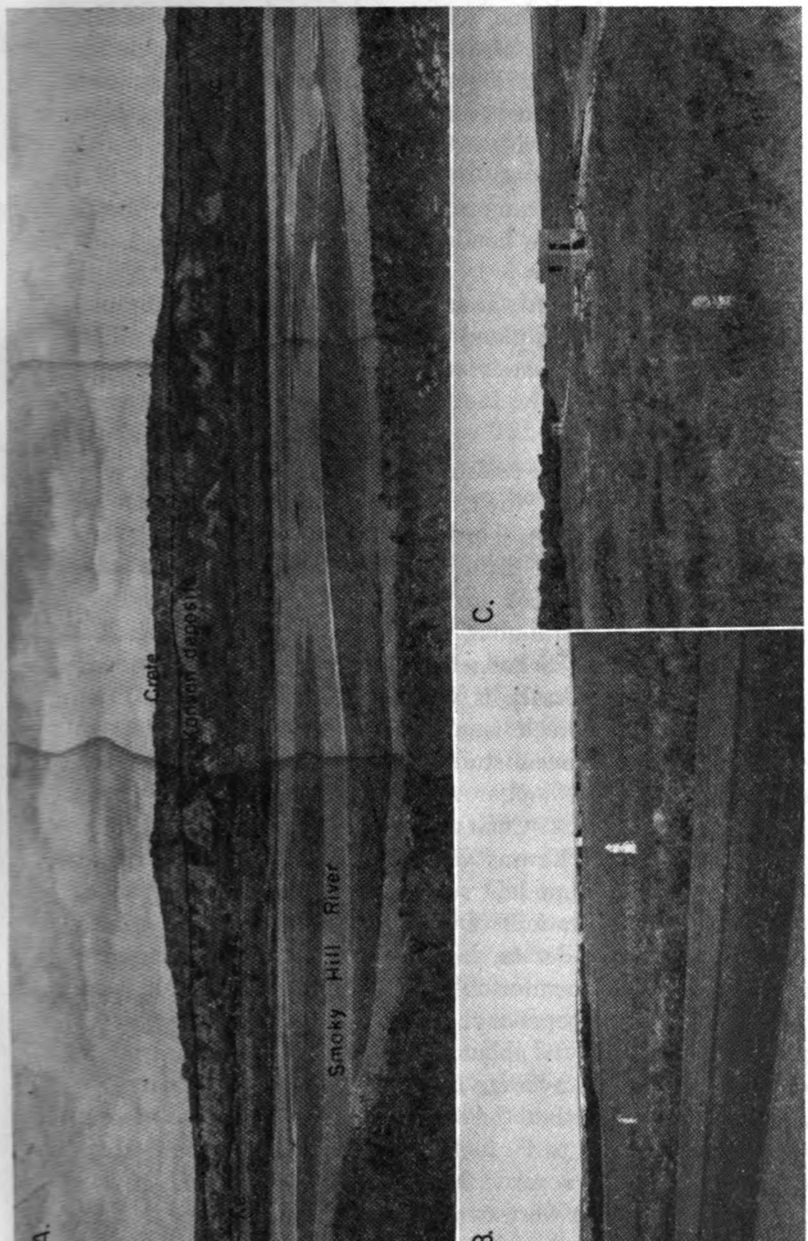

PLATE 4.—**A,** Pleistocene channel cut in Cretaceous rocks and filled with deposits of Kansan age, north bluff of Smoky Hill River in SE¼ sec. 28, NE¼ sec. 33, and NW¼ sec. 34, T. 14 S., R. 21 W., Trego County; **B,** Pfeifer Terrace, view looking northeast from Highway 183, east of Schoenchen; **C,** Scarp of Schoenchen Terrace and part of flood plain of Smoky Hill River in SE¼ sec. 28, T. 15 S., R. 18 W.

Pediment slopes.—Locally in southwestern Ellis County, pediment slopes, developed in the soft homogeneous Carlile Shale, descend from the escarpment of the Fort Hays Limestone member to the surface of the Pfeifer Terrace. They are smooth graded slopes that approximate perfect longitudinal stream profiles, and in places they are covered with a thin veneer of colluvium. The pediments blend into the terrace surface so imperceptibly that the upland edge of the terrace cannot be mapped precisely. In many places small streams, eroding headward, have cut gullies and dissected the pediments.

The divide area.—The divide area between Big Creek and Smoky Hill River is typical of the upland plains of the Blue Hills. This area is gently rolling, moderately well drained, and mantled by a thin layer of loess and, locally, Pleistocene stream deposits of sand and gravel.

Smoky Hill and Big Creek valleys.—The inner valleys of Smoky Hill River, Big Creek, and their principal tributaries consist of relatively narrow flood plains bordered by low terraces that are 15 to 25 feet above the flood plain and are as much as half a mile wide. In general, the terraces are gently sloping and moderately well drained. The discontinuous low terrace along Smoky Hill River is here named the Schoenchen Terrace for the village of Schoenchen, where the terrace is well developed (Pl. 4B). The low terrace along Big Creek is a more regular and continuous feature, but it has not been studied as much in detail as the Schoenchen Terrace.

Climate

The climate of central Kansas generally is classed as subhumid and is characterized by abundant sunshine, moderate precipitation, and a high rate of evaporation. During the summer, the days are hot, wind velocity is moderate, humidity is low, and the nights generally are cool and comfortable. The winters generally are moderate, having only occasional short periods of severe cold. Average annual snowfall is about 20 inches, and the ground is covered with snow for an average of about 25 days each year.

Trewartha (1941) described the subhumid prairie lands as having one to ten dry years (10 to 20 inches of precipitation) in twenty. Others (Russell, 1932) regard the climatic zone between the humid east and the desert west as a typical steppe. When precipitation is normal, the boundary between the steppe and the humid regions is west of the area, but during dry seasons the steppe shifts eastward and includes the area.

Normal conditions.—The following description of normal climate in this area is adapted from reports of the U. S. Weather Bureau.

The mean annual temperature at Hays is 54.7° F. The hottest month is July, which has a mean temperature of 80.6° F; the coldest month is January, which has a mean temperature of 29.6° F. The average length of the growing season is 168 days; the average date of the last killing frost in the spring is April 29, and the average date of the first killing frost in the fall is October 16.

The mean annual precipitation at Hays is 22.90 inches, of which 78 percent falls during the growing season, April to September. The largest precipitation generally falls during June (normal 4.27 inches) and the least in January (normal 0.46 inches). The annual precipitation was less than normal in 47 years in the 89-year period of record, and during 27 years was less than 20 inches. The smallest annual precipitation recorded was 9.21 inches in 1956; the greatest was 43.34 inches in 1951. The annual precipitation for the period of record and the cumulative departure from normal precipitation at Hays are shown in Figure 3. The graph for cumulative departure from the normal suggests that periods of abnormal precipitation may follow a cyclic pattern.

Drought conditions.—As previously stated, the mean annual precipitation for Hays is 22.90 inches, but actual precipitation has been less than that amount during 47 of the 89 years of record. Hoyt (1936, p. 2) suggested that drought effects are serious when precipitation is less than 85 percent of the mean. Periods of deficient precipitation frequently are accompanied by low humidity, high temperatures, and strong winds that sear the land and crops.

During 26 of the years since 1868, precipitation at Hays has been less than 85 percent of normal. During these drought years, the precipitation has averaged only 15.88 inches per year, or about 70 percent of normal. The three consecutive years of drought, 1893-95, was the most prolonged and severe drought period of record. During this period, the average annual precipitation was only 14.20 inches, about 62 percent of normal. Droughts of two consecutive years occurred in 1910-11, 1916-17, 1921-22, 1933-34, 1936-37. During the seven-year period 1933-39, precipitation was below normal each year, drought conditions occurred during five years of the period, and the seven-year average annual precipitation was only 17.99 inches, 78 percent of normal. During the period 1952-56 precipitation was below normal, and the annual precipitation in 1956 was only 9.21 inches, the lowest during the period of record.

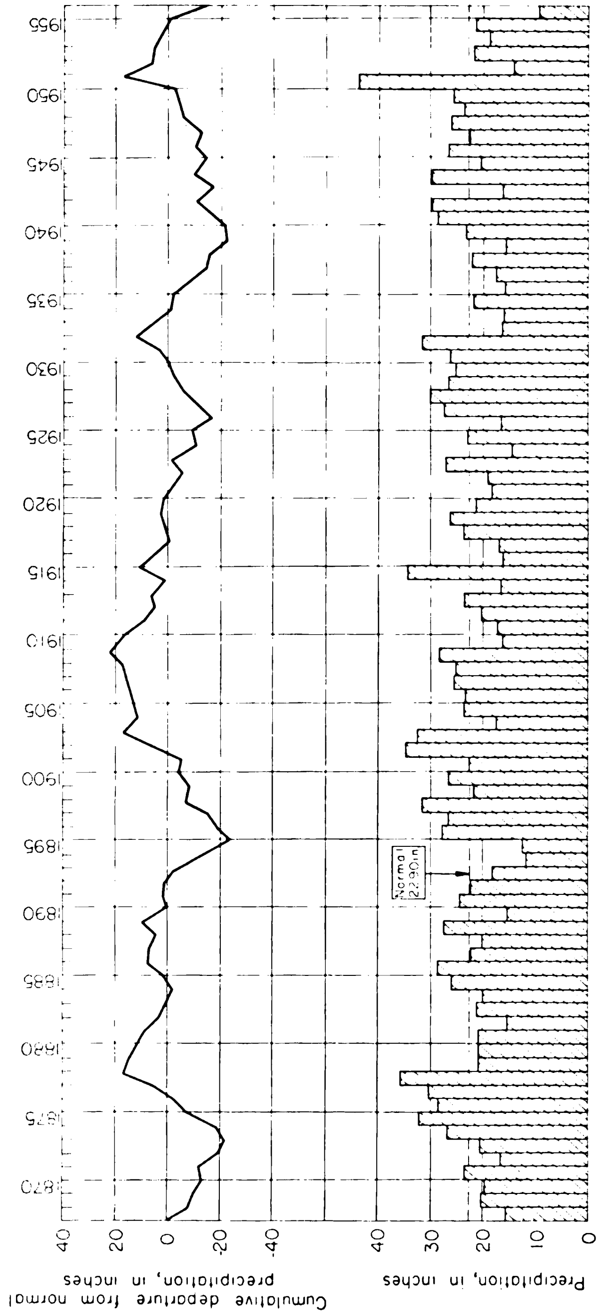

Fig. 3.—Annual precipitation and cumulative departure from normal precipitation at Hays.

The average annual precipitation during this five-year period was 16.68 inches. In general, however, periods of drought are balanced by periods of excessive precipitation; the 1893-95 drought was followed by three years during which the average precipitation was 28.66 inches, and the drought of the 1930's was followed by an eleven-year generally wet period, 1941-51, during which the average precipitation was 26.53 inches. During the 20-year period 1932-51, six drought years and eleven years of subnormal precipitation were recorded at Hays, yet the average precipitation for the period was 23.41 inches, 0.51 inch above normal.

Culture

Population.—According to the 1950 census, Ellis County had a population of 19,043, a rural population of 7,769, and a rural-population density of about 9 persons per square mile. The area studied during this investigation has a population of about 3,000, of which 170 live in Schoenchen and the others in the rural areas and in the unincorporated towns of Antonino, Munjor, and Pfeifer.

Transportation.—The northeastern part of this area is served by the main line of the Union Pacific Railroad, which passes through Victoria and Hays. U. S. Highway 40 parallels the Union Pacific Railroad, and U. S. Highway 183 traverses the center of the area in a north-south direction through Hays and half a mile east of Schoenchen (Pl. 1). Connecting with the main highways is a good system of hard-surfaced and graded county roads.

Agriculture

Agriculture is the chief occupation in the area. Wheat is the principal crop and is grown on more than half the area cultivated each year. Other crops are sorghums, grown for both grain and forage, and alfalfa. In general, sorghum and alfalfa are grown on the low terraces and flood plains along the principal streams where the water table is relatively near the surface. Less than 10 percent of the area shown on Plate 1 is pasture land; the larger pastures are along the escarpments of the Greenhorn Limestone and Fort Hays Limestone member and in the southwestern part of Ellis County south of Smoky Hill River.

Mineral Resources

Mineral resources, other than ground water, produced in this area are oil, limestone, sand and gravel, silt and clay, and volcanic ash.

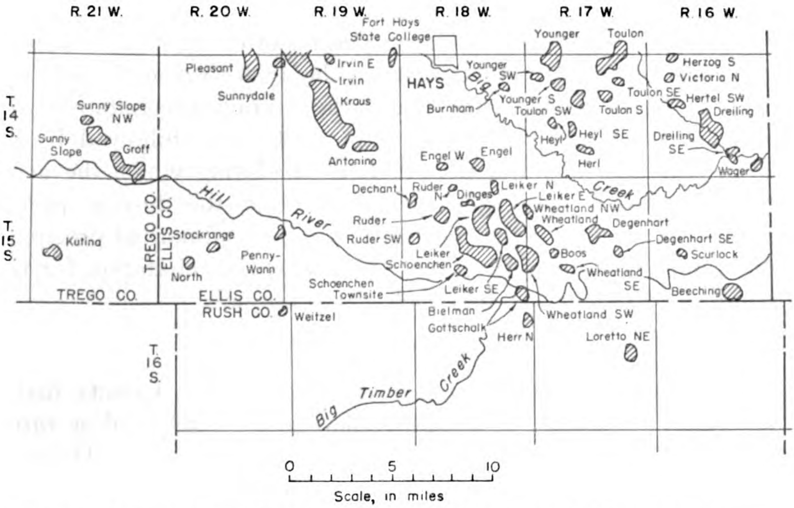

FIG. 4.—Locations of oil pools in the area. Abandoned fields are not shown.

Oil.—In central Kansas oil was first discovered in the Fairport Pool in northwestern Russell County in 1923 (Rubey and Bass, 1925, p. 13). In 1928 oil was discovered in Ellis County in the Shutts Pool (combined with Bemis to form Bemis-Shutts Pool in 1939) in T. 12 S., R. 17 W. (Ver Wiebe, 1938, p. 37-44; 1940, p. 24). Oil was first produced in the Smoky Hill Valley from the Ruder Pool, discovered in 1935. Production figures, wells drilled, and the history of development of the pools are given in the oil and gas reports of the State Geological Survey. Figure 4 shows the locations of producing oil fields in this area.

Limestone.—More than a score of quarries have been opened in the "Fencepost" Limestone bed of the Greenhorn Limestone in southeastern Ellis County (Pl. 1). Commonly, the quarries are 20 to 50 feet wide and follow the limestone outcrop along the contour of hills. Most of these quarries have supplied stone for both building stone and fence posts. Along the escarpments near Big Creek and Smoky Hill River, the "Fencepost" Limestone bed lies beneath a few feet of shale that is removed easily. The "Fencepost" bed, which is persistently 8 to 10 inches thick, is quarried for fence posts in blocks about 1 foot wide and 5½ to 6 feet long. On fresh exposures the limestone is chalky and can be sawed, cut with a knife, or penetrated with an ordinary drill. In hand quarries the limestone generally is wedged off after a series of holes have been drilled through it. Other holes, or notches, are drilled in the stone posts in order to fasten the wire to them. Stone posts are not quarried extensively at the present time, but in southeastern Ellis County thousands of them are still in use, and some farmsteads have few posts of any other kind. In 1897, Logan (p. 217) estimated that 50,000 stone posts were in use in Mitchell and Lincoln Counties, and stated that 5,000 were used in one township. In southeastern Ellis County it is estimated that 20,000 posts are used in a single township.

In addition to fence posts, the limestone has been used widely in southern Ellis County and elsewhere for foundations and buildings. Among the buildings constructed from this stone are the magnificent Catholic churches at Pfeifer, Victoria, and Liebenthal and the principal buildings at the Fort Hays State College in Hays. Newer buildings constructed from sawed blocks of this stone include the Methodist church and the Ellis County courthouse in Hays.

Rock quarried from the "Fencepost" Limestone bed has been used also for flagstone and crushed aggregate or road material. Elsewhere the limestones and intervening shales of the Greenhorn Limestone have been crushed and mixed and the material applied to county highways. Under moderate traffic the mixture becomes bonded into a serviceable all-weather road.

The Fort Hays Limestone member of the Niobrara Chalk also has been quarried for structural stone, although it is not as weather-resistant as the "Fencepost" Limestone bed. It is softer than the Greenhorn Limestone and spalls badly when used for foundation stone. Stone from the Fort Hays has also been crushed for road material, has been used in the manufacture of putty and Portland cement, and is suitable for agricultural lime, chalk, and the manufacture of lime.

Sand and gravel.—Gravel has been quarried in many localities for use as concrete aggregate, road material, and macadam. The quality of the sand and gravel has been discussed in detail by Byrne, Coombs, and Bearman (1947, 1949). The sand and gravel that is quarried most widely is from the Crete Formation, which forms the prominent high terrace along Smoky Hill River. Many pits, some very large, have been opened in this material. In general, the Crete Formation consists predominantly of fragments of quartz, granite, and dark igneous rocks; it contains a smaller amount of acid-feldspar and limestone fragments. The material is coarse, containing, in its lower part, many pebbles as much as 2 inches in diameter, and it contains very little silt and clay. Iron staining from a small content of limonite is common. The most extensive quarries are on the Mike Unrein and N. R. Werth farms in the SE¼ sec. 16, T. 15 S., R. 19 W., and the NE¼ sec. 29, T. 15 S., R. 18 W., respectively. More than 60,000 cubic yards of gravel is reported to have been quarried from the Unrein farm.

In addition to quarries in the Crete Formation along Smoky Hill River, several small quarries for gravel have been developed in the Nebraskan(?) deposits near Antonino and Victoria. In general, gravel from these deposits contains a much larger percentage of limestone pebbles and disseminated limy material than gravel from the Crete Formation.

Silt and clay.—Silt and clay for ceramic raw material, binder material, and fill for earthen dams are available from the Carlile Shale where it is weathered, from the wind-deposited silts of the Upper Pleistocene Subseries in the upland, and from the younger Pleistocene alluvial deposits. Plummer and Hladik (1948, p. 82, 86) have tested the Blue Hill Shale member of the Carlile Shale and report that it is suitable for the manufacture of light-weight aggregate. Silt from the alluvial deposits underlying the Schoenchen Terrace surface was the principal material used in construction of the earth-fill Cedar Bluff dam.

Volcanic ash.—Volcanic ash has been used as a constituent of ceramic glazes, of impervious concrete, and as mineral filler for bituminous-surfaced highways. A small pit has been opened in the volcanic ash in the Sappa Formation in the SW¼ sec. 36, T. 14 S., R. 21 W. Because the ash deposit is small, it has little commercial value.

GEOLOGY

Summary of Stratigraphy *

The rocks that crop out in the area are sedimentary and range in age from Early(?) Cretaceous to Recent. A generalized section of the geologic formations and their water-bearing properties is given in Table 1; the areal distribution of the geologic formations is shown on Plate 1, and their stratigraphic relations are shown on Plate 3.

The oldest rocks exposed in the report area are the sandstones of the Dakota Formation of Early(?) Cretaceous age. Overlying the Dakota is a series of marine rocks of Late Cretaceous age, classified in ascending order as the Graneros Shale, Greenhorn

* The geologic classification and nomenclature of this report follow the usage of the State Geological Survey of Kansas and do not conform in all respects to those of the U. S. Geological Survey.

TABLE 1.—*Generalized section of outcropping geologic formations in southern Ellis County and parts of Trego and Rush Counties*[1]

System	Series	Subseries	Formation	Thickness, feet	Physical character	Water supply
Neogene	Pleistocene	Upper Pleistocene	Alluvium and terrace deposits	0–65	Silt, sandy silt, sand, and gravel, interbedded and stratified. Includes deposits underlying Schoenchen Terrace.	Yield abundant supplies of water along Smoky Hill River, large supplies along Big Creek, and moderate amounts along tributary streams.
			Loveland and Crete Formations	0–40	Upper part silt and clay, yellow; lower part well-sorted stratified sand and gravel (Crete Formation).	Yield moderate supplies of water for domestic and stock use except where thin and above the water table.
		Lower Pleistocene	Sappa and Grand Island Formations	0–55 ±	Silt, clay, volcanic ash, sand, and gravel; fills narrow bedrock channel along Smoky Hill River and underlies part of high terrace of Big Creek.	Yield moderate amounts of water for domestic and stock use to a few wells in the area.
			Nebraskan(?) deposits Unconformable on older deposits	0–25	Silt, yellow buff, and fine to coarse sand and gravel, occurring in a few areas.	Yield moderate supplies of water in Antonino area, in vicinity of Victoria, and in some places in eastern Ellis County. Elsewhere above water table.
	Pliocene		Ogallala Formation	0–5 ±	Sand, gravel, silt, and clay cemented with calcium carbonate.	Yields no water to wells.
Cretaceous	Upper		Niobrara Chalk	0–40	Upper chalky shale member removed by erosion in this area. Lower part consists of massive soft white limestone interbedded with paper-thin gray shale. Forms prominent escarpment.	Yields little or no water to wells.
			Carlile Shale	300	Shale, blue gray, noncalcareous, containing calcareous septarian concretions in upper part. Lower 100 feet is calcareous blue-gray to buff shale; contains thin concretionary chalky limestone and thin bentonite seams.	Yields little or no water to wells.
			Greenhorn Limestone	100	Shale, calcareous, blue gray, interbedded with thin chalky fossiliferous limestone; contains thin persistent seams of bentonite.	Weathered and fractured limestone yields meager supplies of water to a few wells in eastern Ellis County.
			Graneros Shale	40 ±	Shale, noncalcareous, blue black to brownish black. Contains selenite crystals, pyrite, thin coquinalike limestone and local sandstone lentils.	Yields little or no water to wells.
	Lower(?)		Dakota Formation	150–300	Clay, shale, siltstone, and sandstone, interbedded, lenticular, and varicolored. Contains lignite locally in upper part.	Sandstone lentils yield supplies of water having a wide range in quality and generally under artesian head (for domestic and stock use). Where formation is deeply buried, water may contain excessive chloride.

1. **Classification of State Geological Survey of Kansas.**

Limestone, Carlile Shale, and Niobrara Chalk. In the western part of the area, the divides north and south of Smoky Hill Valley are capped with remnants of the Ogallala Formation, of Neogene age.

Unconsolidated sediments, representing each stage of the Pleistocene, overlap and fill channels cut into the Cretaceous bedrock. These deposits are predominantly stream-deposited sand, gravel, and silt and are classified as deposits of Nebraskan(?) age, deposits of the Grand Island and Sappa Formations of Kansan and Yarmouthian age, the Crete and Loveland Formations of Illinoisan and Sangamonian age, terrace deposits and Peoria Formation (Fig. 6) of Wisconsinan age, and alluvium of Recent age. In most of the area the Pleistocene rocks are the principal sources of ground water.

GEOLOGIC FORMATIONS IN RELATION TO GROUND WATER

Cretaceous System

Dakota Formation

General description.—The term Dakota group (Meek and Hayden, 1862) was first applied to the sandstones, varicolored clays, and lignite beds that underlie the "Benton group" in exposures near Dakota City, Dakota County, Nebraska. As used in this report, the Dakota Formation includes that part of the Cretaceous section between the Kiowa Shale below and the Graneros Shale above (Moore and others, 1951, fig. 11, p. 25). The Dakota Formation as defined by the State Geological Survey of Kansas has been referred to variously as "Dakota group" (Meek and Hayden, 1862); "Dakota sandstone" (Prosser, 1897); "Dakota formation" (Twenhofel, 1924); "Rocktown channel sandstone member" (Rubey and Bass, 1925); "Cockrum sandstone" (Latta, 1941, p. 73); and "Omadi formation" (Condra and Reed, 1943, p. 14, 18).

Plummer and Romary (1942) described the Dakota Formation as about 75 percent varicolored clay containing irregular lenticular beds of siltstone and sandstone. In north-central Kansas thin lignite beds are present in the upper 25 feet of the Dakota Formation (Schoewe, 1952, p. 87, fig. 4), and pellets of iron in the form of siderite or ankerite and concretions of limonite seem to be a distinguishing characteristic of the formation (Plummer and Romary, 1942, p. 326-339). The Dakota Formation probably represents deposits formed in a dominantly continental and littoral environment, whereas the underlying and overlying shales were deposited in a marine environment. The sandstones are thin bedded to massive, generally crossbedded, and may be ripple marked. Fine-grained sandstone predominates, but the grain size ranges from silt (smaller than 0.062 mm) to very coarse sand (1.0 to 2.0 mm). The coarser-grained sandstones are the channel sandstones, which are somewhat more common in the upper part of the Janssen Clay member of the formation but may be found at any stratigraphic position. Many of the sandstone bodies are loosely cemented with limonite, some are uncemented, and others are tightly cemented with calcium carbonate, silica, or iron. Studies of surface exposures indicate that some of the sandstone lenses are small but others may be several square miles in extent. Many sandstones are not interconnected, as indicated by differences in hydrostatic pressure of the water that they contain. Frye and Brazil (1943, p. 53) reported that as many as six sandstones have been penetrated by one test hole, but it is also possible to drill through the entire thickness of the Dakota Formation without penetrating any sandstone.

Frye and Brazil (1943, table 3) gave the thickness of the Dakota Formation in Ellis and Russell Counties as 200 to 300 feet, Swineford and Williams (1945, p. 116) stated that in southwestern Russell County it is 213 to 300 feet thick, and Latta (1950, p. 61) indicated that it is 200 to 300 feet thick in the northern part of Barton County. Well cuttings from the Carl Ruder No. 1 oil well in the NE¼ NW¼ sec. 17, T. 15 S., R. 18 W., indicate that the Dakota Formation is about 155 feet thick in the central part of the area. The formation underlies all the area, but only the uppermost part is exposed, in the NW¼ sec. 35, T. 15 S., R. 16 W., where it arches over the axis of a northeastward-trending fold called the Pfeifer Anticline by Bass (1926, p. 36).

Water supply.—The Dakota Formation is the principal source of water in much of the upland of the report area. Many wells between Big Creek and Smoky Hill River in southeastern Ellis County, south of Smoky Hill River in southeastern Ellis County and northern Rush County, north of the Pfeifer Terrace west of Antonino, and west of the Smoky Hill School in southwestern Ellis County obtain moderate supplies of water for domestic and stock use from the Dakota. Information on 27 wells, ranging in depth from 108 to 350 feet, is given in Table 11. In addition, a few wells south of Smoky Hill River in southeastern Trego County are reported to obtain water for stock use from the Dakota Formation at depths exceeding 500 feet; however, these wells were not inventoried during this investigation.

No wells in the Dakota Formation in the area were reported to yield large supplies of water, but elsewhere wells penetrating thick sandstones in the Dakota Formation have large yields (Latta, 1950, p. 61, table 12). The sandstone lenses in the Dakota Formation contain ground water under artesian pressure, but differences in hydrostatic pressure from well to well indicate that the sandstone lenses may not be interconnected. For example, the water level in well 15-17-15dd has an altitude of 1,792 feet, whereas the water level in well 15-17-14dd, only a mile away, has an altitude of 1,826 feet. Some lenses may extend throughout several square miles (Fig. 5) as indicated by the close similarity of water levels in wells 15-16-9aa, 15-16-18ab, 15-16-18bb, 15-17-14dd, and 15-17-24dc. Possibly these wells penetrate a series of interconnected sandstones rather than a single lens of wide lateral extent, but the

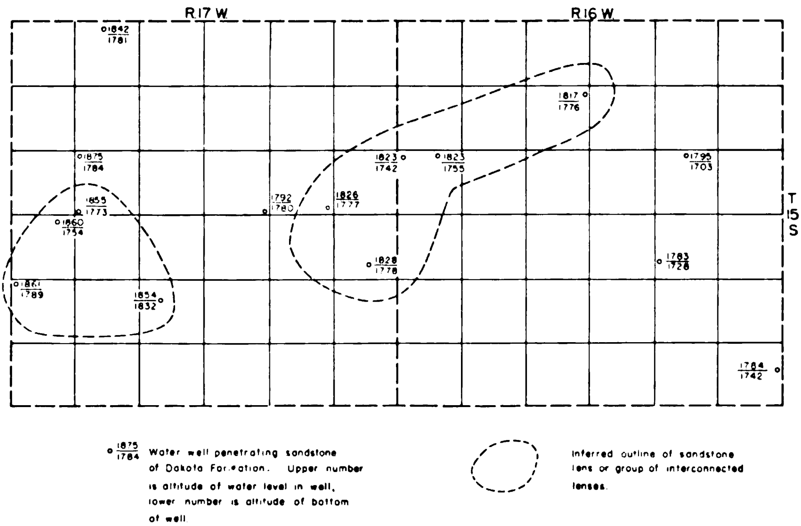

Fig. 5.—Inferred area of some lenses of sandstone in Dakota Formation in southeastern Ellis County.

relation of water levels suggests a connected hydrologic system among the wells. The source, movement, and occurrence of artesian water in the Dakota Formation are discussed more fully in the section on artesian conditions.

The quality of water from wells penetrating the Dakota Formation differs considerably from well to well. In general, water in the Dakota Formation is more mineralized than water in the unconsolidated rocks. The concentrations of iron, sodium, fluoride, and chloride generally are high, and in some places the concentration of sulfate is high, but generally the hardness is moderate. In 11 water samples collected from wells penetrating sandstones of the Dakota Formation, total dissolved solids ranged from 388 to 4,950 ppm (Tables 4, 7). In general, water from the deeper sandstones seems to be more mineralized than that from the shallower sandstones (Frye and Brazil, 1943, table 12). Some of the areas in which there are no wells (Pl. 2), as in southeastern and southwestern Ellis County, are areas in which water in the Dakota Formation is reported to be too mineralized for domestic and stock use. The quality of water in the Dakota Formation is discussed more fully in the section on chemical character of water.

Graneros Shale

The Graneros Shale was named by Gilbert (1896) from exposures along Graneros Creek 20 miles southwest of Pueblo, Colorado. The name was first used in Kansas by Logan (1897) for the noncalcareous beds at the base of the "Benton" group in central Kansas. The Graneros Shale was described and mapped in Russell County by Rubey and Bass (1925) and in Ellis County by Bass (1926). The Graneros Shale lies conformably between the Dakota Formation below and the Greenhorn Limestone above. The shale underlies all the area except part of the Smoky Hill Valley in southeastern Ellis County where the Dakota Formation crops out or lies directly beneath Pleistocene deposits.

The Graneros Shale consists of about 40 feet of noncalcareous blue-black to brownish-black shale. Generally it is thin bedded and where weathered has a fissile appearance. Thin layers of limonite, limonitic and pyritic concretions, flakes of ochre, and selenite crystals are common. Locally, coquina forms lenses near the top, and a prominent bentonite bed about 15 inches thick lies just below the top of the formation. Frye and Brazil (1943) noted sandstone lenses in the Graneros Shale, and some of the sandstone bodies may be of sufficient thickness and areal extent to yield water to wells. The Graneros Shale does not yield water to wells in this area, however.

The following section, measured along Smoky Hill River in Russell County east of the report area, illustrates the character of the Graneros Shale:

Measured section of Graneros Shale and upper part of Dakota Formation in SE¼ sec. 18, T. 15 S., R. 15 E., Russell County.

25. Lincoln Limestone member of Greenhorn Limestone

	Thickness, feet
GRANEROS SHALE	
24. Shale, noncalcareous, fissile, black	1.2
23. Bentonite, massive, creamy white	1.0
22. Limestone, composed of pelecypod shells	.2
21. Shale, noncalcareous, fissile, black	2.2
20. Coquina, brown, containing many fossil pelecypods and alternating with thin gray and brown shale beds	1.4
19. Shale, noncalcareous, fissile, dark gray; contains thin sandstone streaks	4.4
18. Ironstone and siltstone, hard, rusty; contains gypsum crystals	.5
17. Shale, noncalcareous, fissile, dark gray	2.4
16. Alternating thin beds of sandstone and shale, noncalcareous, gray.	3.7
15. Shale, noncalcareous, fissile, dark gray; contains many thin gray sandstone layers	2.8
14. Sandstone, gray and rusty brown; contains thin shale streaks and thin limestone layers	1.0
13. Shale, noncalcareous, fissile, dark gray	1.8
12. Shale, noncalcareous, fissile, dark gray; contains several silty "shell beds" containing many fossil pelecypods	2.5
11. Shale, noncalcareous, fissile, gray and black, containing lemon-yellow streaks	1.0
10. Sandstone, shaly, rusty, lemon yellow, and gray	0.4
9. Shale, noncalcareous, fissile, gray; contains some sand in lower part and selenite crystals throughout	4.8
8. Sandstone, iron cemented, gray and yellow, shaly in middle part; forms small ledge on slope	1.8
7. Shale, noncalcareous, fissile, slightly sandy, brown to black; contains selenite crystals	3.3
6. Sandstone, friable, gray; contains "ironstone" at top; 100 feet east thickens to 6 feet	.6
5. Shale, noncalcareous, fissile, brown, black, and maroon; contains thin streaks of sand in lower part and selenite crystals in upper part	3.3
Total measured thickness of Graneros Shale	40.3
DAKOTA FORMATION	
4. Sand, loose, gray, buff, and rusty; contains black carbonaceous streaks and thin "ironstone bands"	2.5
3. Shale, carbonaceous, fissile, brown to black; contains streaks of gray sand	.6
2. Sandstone, limonitic in upper part, gray to rusty yellow; contains black clay streaks	1.0
1. Clay, sandy, irregularly bedded, black and gray streaked; extends to Smoky Hill River flood plain	2.0
Total measured section	46.4

Greenhorn Limestone

General description.—Gilbert (1896) named the Greenhorn Limestone from exposures of interbedded limestone and shale near Greenhorn station and along Greenhorn Creek, about 15 miles south of Pueblo, Colorado. Tentative correlations of the Colorado section with central Kansas rocks referred to as "Benton" were made by Logan (1897, p. 232). Rubey and Bass (1925), in Russell County, were the first to use the Greenhorn Limestone as a mapping unit in Kansas. They subdivided the Greenhorn Limestone into four members in ascending order: The Lincoln Limestone member, an unnamed shale member, the Jetmore Chalk member, and an unnamed upper shale member. In 1926 Bass recognized the same subdivisions in Ellis County but named the lower shale member the Hartland Shale and the upper shale member the Pfeifer Shale. In central Kansas the uppermost unit of the Greenhorn Limestone is the "Fencepost" Limestone bed; the Greenhorn is bounded at the base by the noncalcareous shale beds of the Graneros Shale. The upper part consists chiefly of interbedded thin chalky limestone and calcareous shale and contains thin bentonite seams (Pl. 5A, B). The middle part of the formation is mainly calcareous shale containing a few concretionary limestone layers and thin bentonite seams. Calcareous shale interbedded with thin, dark, crystalline limestone containing shark teeth and other vertebrate remains also predominates in the lower part. The basal limestone beds are "petroliferous" and emit a strong petroleum odor when broken open. Bass (1926) gave the thickness of the Greenhorn Limestone as about 100 feet, but only the upper part is well exposed in much of the report area. The following section, measured in the SW¼ sec. 22 and SE¼ sec. 21, T. 15 S., R. 17 W., illustrates the character of the upper part of the Greenhorn Limestone:

Measured section of upper Greenhorn Limestone at type locality of Pfeifer Shale member in SW¼ sec. 22 and SE¼ sec. 21, T. 15 S., R. 17 W.

	Thickness, feet
CRETACEOUS—Gulfian	
Carlile Shale	
Shale, yellow; contains surficially chalky discoidal concretions	
Greenhorn Limestone—Pfeifer Shale member	
41. "Fencepost" Limestone bed, hard, dense; contains brown ironstain in center	0.8
40. Shale, calcareous, white and buff; contains bentonite streak 0.7 foot below top and concretionary limestone 1.3 feet below top	3.0
39. Limestone, concretionary	.3

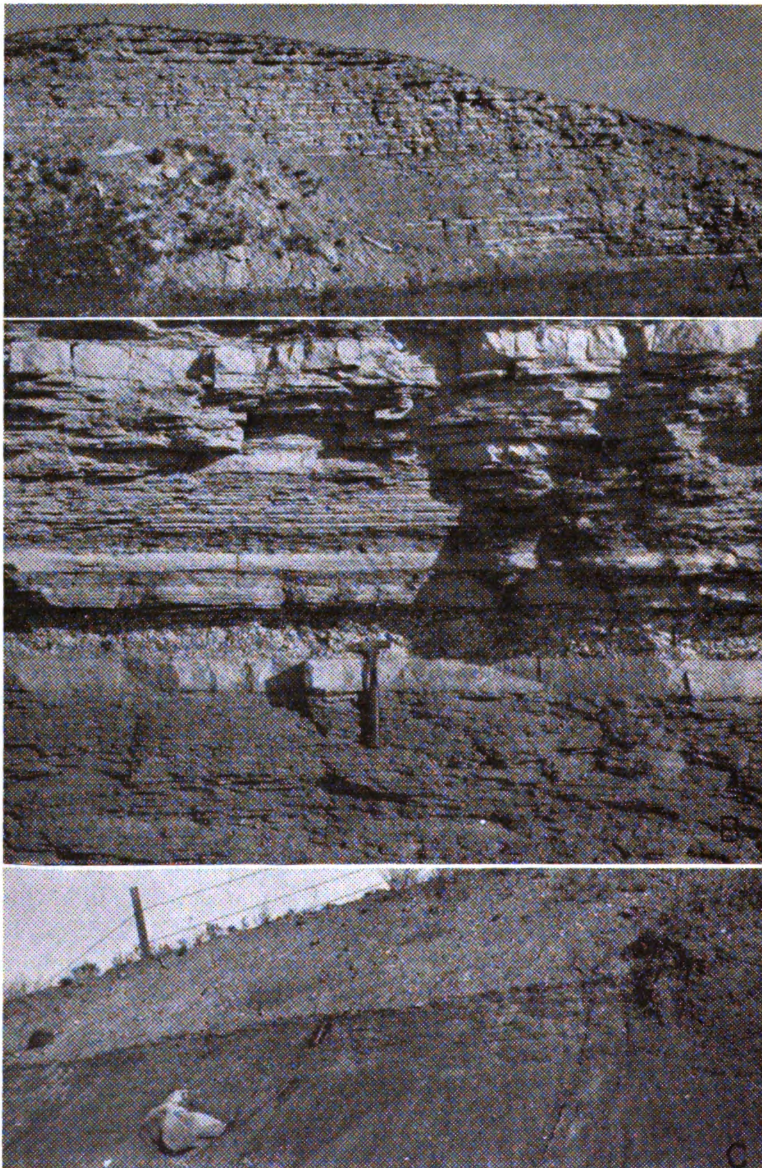

Plate 5.—A, Alternating limestone and calcareous shale of Jetmore Chalk and Hartland Shale members of Greenhorn Limestone in stream bank near NW cor. sec. 27, T. 15 S., R. 17 W.; **B,** Closeup of lower part of section shown in **A,** showing 6-inch layer of bentonite (marked by hammer head); **C,** Fissile noncalcareous shale of Blue Hill Shale member of Carlile Shale, containing large calcareous concretions, near NW cor. sec. 2, T. 15 S., R. 21 W.

		Thickness, feet
38.	Shale, calcareous, buff	1.3
37.	Limestone, dense, persistent, even bedded, gray buff, weathers chalky	.1
36.	Shale, calcareous, gray in upper part, buff in lower part; contains limonite in upper part and concretionary limestone at base	.95
35.	"Sugar sand"—calcite sand, white, buff, and orange; contains vertically oriented calcite prisms at base	.3
34.	Shale, calcareous; contains concretionary limestone layers 0.5 foot and 2.2 feet above base	4.0
33.	Limestone, concretionary; contains many shells	.4
32.	Shale, calcareous, gray, weathers white; contains zones of concretionary limestone containing shells 0.7 foot and 1.4 feet above base	2.3
31.	Limestone, chalky, gray buff, persistent; contains *Inoceramus* shells	.3
30.	Shale, calcareous, fissile, gray, weathers chalky and buff; contains limonitic zone at top and concretionary limestone layers 0.9 foot and 1.6 feet above base	3.1
29.	Limestone, concretionary, gray and orange; contains *Inoceramus* shells	.3
28.	Shale, fissile, calcareous, gray and white; basal part more massive, dark gray	3.5
Jetmore Chalk member		
27.	"Shell rock" limestone, white to light buff; upper surface irregular; contains many *Inoceramus* shells	1.0
26.	Shale, chalky; contains concretionary limestone layers 0.8 foot and 1.5 feet above base	3.0
25.	Limestone, hard; forms small ledge; contains shells	.35
24.	Shale, chalky, white	1.0
23.	Limestone, chalky, gray white, weathers orange; contains *Inoceramus* shells	.5
22.	Shale, calcareous, white, weathers chalky; contains bentonite streaks at base	.82
21.	Chalk, massive; contains *Inoceramus* shells	.4
20.	Shale, calcareous; contains 0.25-foot chalk bed 1.0 foot above base and bentonite streak 1.4 feet above base	2.05
19.	Chalk, weathers brown	.3
18.	Shale, chalky	.9
17.	Chalk, weathers rusty brown	.5
16.	Shale, calcareous	2.0
15.	Chalk, massive, gray	.4
14.	Shale, calcareous; contains 0.25-foot chalk bed in center	2.65
13.	Chalk, massive, hard, weathers orange	.4
12.	Shale, chalky, dark gray, weathers blue gray; contains 0.25-foot chalk bed in center	2.75
11.	Limestone, massive, gray, hard	.4
10.	Shale, calcareous, black	.2
9.	Bentonite, orange	.08

Hartland Shale member	Thickness, feet
8. Shale, chalky, gray; contains thin bentonite bed 0.7 foot above base and limonitic zone 3.1 feet above base	5.5
7. Limestone, chalky, gray	.4
6. Shale, chalky, gray	3.6
5. Shale, calcareous; contains limonitic zone in center and several thin chalky limestone beds	3.5
4. Limestone, chalky	.3
3. Shale, calcareous, white to gray	1.6
2. Bentonite, white and orange; contains limonitic concretions in center	.5
1. Shale, calcareous, thin bedded, gray; contains two chalky limestone beds 0.35 foot thick, one at top and one 0.8 foot above base. Down to level of small creek	3.6
Total measured thickness of Greenhorn Limestone	59.35

In southeastern Ellis County the uppermost layer of the Greenhorn Limestone, the "Fencepost" Limestone bed, has been quarried extensively to supply fence posts and building stone. In that area the "Fencepost" is massive, contains many *Inoceramus* shells, and has a faint ironstain through the center. It is about 10 inches thick and on fresh exposures is soft and chalky.

Water supply.—In general, the chalky limestone and shale that compose the Greenhorn Limestone are impervious and do not yield water to wells. Locally, where the upper part of the limestone lies at relatively shallow depth and is subject to weathering, it may contain openings large enough to hold small amounts of water. Although two or three wells in the area of this report may obtain water from the upper part of this limestone or from weathered shale (Carlile) overlying the limestone, the Greenhorn Limestone has little importance as an aquifer.

Carlile Shale

General description.—The Carlile Shale was named by Gilbert (1896) from exposures of gray argillaceous shale along Arkansas River near Carlile Station west of Pueblo, Colorado. Logan (1897, p. 232) compared Gilbert's section with the rocks lying below the Niobrara Chalk in Kansas and suggested their correlation. Rubey and Bass (1925) used the Carlile Shale as a mapping unit in Russell County where they separated it into two members, the Blue Hill Shale above and the Fairport Chalky Shale below. Bass (1926, p. 28) applied the same names to geologic mapping units in Ellis County; he also named and described the Codell Sandstone zone in the upper part of the Blue Hill Shale member from exposures along Saline River in northern Ellis County.

The Carlile Shale consists of about 300 feet of shale between the top of the "Fencepost" Limestone bed of the Greenhorn Limestone and the base of the overlying Niobrara Chalk. In general, the Carlile Shale is not well exposed, although parts of nearly all the section can be seen along the bluffs of Smoky Hill River in southwestern Ellis County. The lower 100 to 115 feet of the formation is calcareous and is classed as the Fairport Shale member. The lower part of the Fairport Shale member resembles the upper part of the Greenhorn Limestone and consists of alternating beds of calcareous shale and thin chalky or concretionary limestone containing thin bentonite seams in the basal 20 feet. The shale beds are bluish gray in fresh exposures but weather to a sticky yellow clay containing many *Ostrea* shells. "*Ostrea* Shale" was the term applied to this unit by Logan (1897). The Fairport Shale member underlies most of the broad plain between the valleys of Big Creek and Smoky Hill River in southeastern Ellis County.

The upper 175 feet of the Carlile is classed as the Blue Hill Shale member. Most of it is blue-gray fissile argillaceous shale that contains selenite crystals and flakes of bright yellow ochre. A lenticular sandstone or zone of sandy shale in the upper part is referred to as the Codell Sandstone zone (Moore and others, 1951, p. 24). Zones of calcareous concretions, both septarian and ordinary, characterize the upper 50 feet of the Blue Hill Shale member (Pl. 5C). The concretions may be spherical, ellipsoidal, or discoidal and contain intersecting veins of brown calcite that stand out in relief on weathering. They range in diameter from a few inches to as much as 3 feet and are in well-defined zones, which are well exposed on the steep slopes below the escarpment of the Niobrara Chalk. In the lower part of the member thin concretionary limestone beds and layers of rusty-brown discoidal concretions may occur. The Blue Hill Shale member is well exposed only on the steep slopes below the Niobrara escarpment where the shale has been eroded into "bad lands", such as the area south of Smoky Hill River in southwestern Ellis County.

Water supply.—In general, the Fairport Shale member is impervious chalky shale and yields little or no water to wells. In northwestern Ellis County the Codell Sandstone zone yields water to wells in an area of several square miles, but in the southern part of the county it is too thin and too argillaceous to serve as an aquifer. The Blue Hill Shale member is impervious and does not yield water to wells.

Niobrara Chalk

General description.—The Niobrara Chalk was named in 1862 by Meek and Hayden from exposures of chalky marl and shale along Missouri River near the mouth of Niobrara River in northern Nebraska. In 1897 Logan described the Niobrara Chalk in western Kansas and divided it into two members: the upper part, the *Pteranodon* beds, or Smoky Hill Chalk; and the lower part, the Fort Hays Limestone, named from a locality on the old Fort Hays military reservation just west of Hays. In 1925 the stratigraphy of the Niobrara Chalk in Russell County was described in detail by Rubey and Bass, and in 1926 Bass described and mapped the formation in Ellis County.

The lower 55 to 60 feet of the formation is a white massive chalk called the Fort Hays Limestone member in Kansas. It is resistant to erosion and forms a pronounced escarpment, which extends southward across Kansas from Jewell County to Arkansas River. This escarpment has been used to mark the boundary between the High Plains and the Dissected High Plains (Schoewe, 1949, fig. 22). In the area of this report, only the lower 30 or 40 feet of the Fort Hays Limestone member is present in the bluffs south of Smoky Hill River near Cedar Bluff dam. Just west of Hays, the Fort Hays Limestone member and the lower beds of the Smoky Hill Chalk member form the divide between Big Creek and Smoky Hill River. According to Landes and Keroher (1939, p. 13), the thickness of the Niobrara Chalk in Logan, Gove, and Trego Counties is about 700 to 800 feet, but all except the lower part has been removed by erosion in this area. An excellent exposure of the Fort Hays Limestone member may be seen in sec. 1, T. 15 S., R. 22 W., where the limestone was quarried for use in construction of the Cedar Bluff dam. Although it has been quarried at several localities for building stone, the Fort Hays stone may be somewhat inferior to the "Fencepost" for buildings.

Water supply.—The Niobrara Chalk is impervious and does not yield water to wells in this area.

Neogene System—Pliocene Series

Ogallala Formation

Tertiary rocks have been recognized in the western part of Kansas since the earliest geologic work in the state. Mudge (1878, p. 53) classed these rocks as Pliocene and described them briefly. Haworth

(1897b) also described their lithology and structure. In 1899 Darton named and described the Ogallala Formation in Nebraska from a locality that he later (1920, p. 6) stated was near Ogallala Station in southwestern Nebraska. Johnson (1901, 1902) described the geology and ground-water supply of the High Plains, including the western part of Kansas, and Bass (1926) mapped and described the Ogallala Formation in Ellis County.

Small remnants of the Ogallala Formation (Pliocene) lie unconformably on the Niobrara Formation in the western part of the area shown on Plate 1. In northern Ellis County the Ogallala Formation consists of about 75 feet of sand, gravel, silt, and clay loosely cemented in part with limy material to form "mortar beds" (Bass, 1926, p. 16). In southwestern Ellis County all except a few feet has been removed by erosion.

In the report area the Ogallala Formation lies above the water table and does not yield water to wells.

Neogene System—Pleistocene Series

Classification.—The Pleistocene classification system of the Kansas Geological Survey is based on the classification of glacial deposits developed in the Midcontinent region (Frye and Leonard, 1952, p. 28-52). The Kansas system deviates from other systems, however, by including the Recent as a stage within the Pleistocene instead of as a separate series. Although the nearest glacial deposits are more than 150 miles northeast of this area, excellent correlations have been made between the two areas. The eolian and alluvial deposits of the nonglaciated parts of Kansas and Nebraska have been correlated with the glacial section on the basis of continuous loesses and their included molluscan fauna, buried soil profiles, and petrologically distinctive volcanic ash (Condra, Reed, and Gordon, 1947; Frye, Swineford, and Leonard, 1948).

In the area of this report, stream deposits representing the Nebraskan(?), Kansan, Illinoisan, and Wisconsinan stages have been recognized near the Smoky Hill Valley. The undifferentiated Pleistocene deposits mapped near Big Creek valley (Pl. 1) are believed to include deposits of Nebraskan, Kansan, and Illinoisan age, but it was not feasible during this investigation to attempt to map them separately. Wisconsinan and Recent deposits occur along both Smoky Hill River and Big Creek, but were mapped together on Plate 1. Stream-deposited silt of Sangamonian age (Loveland Formation) borders the Smoky Hill Valley, and thin eolian silts of Sangamonian (Loveland) and Wisconsinan (Peoria) age are spread over upland areas. Because they are thin and discontinuous, the eolian silts were not mapped. The stream deposits fill channels cut into bedrock and form terraces along the principal streams. Successively younger deposits unconformably overlie or are channeled into older deposits. The classification of Pleistocene deposits in this area is given in Figure 6.

The classification of Pleistocene deposits used in this report has evolved mainly since 1948, although the terrace deposits of Pleistocene age were recognized much earlier in the area of this report. Rubey and Bass (1925, p. 19) and Bass (1926, p. 16) noted the broad terrace along Smoky Hill River and tentatively correlated the terrace deposits with the "McPherson Formation" of Pleistocene age.

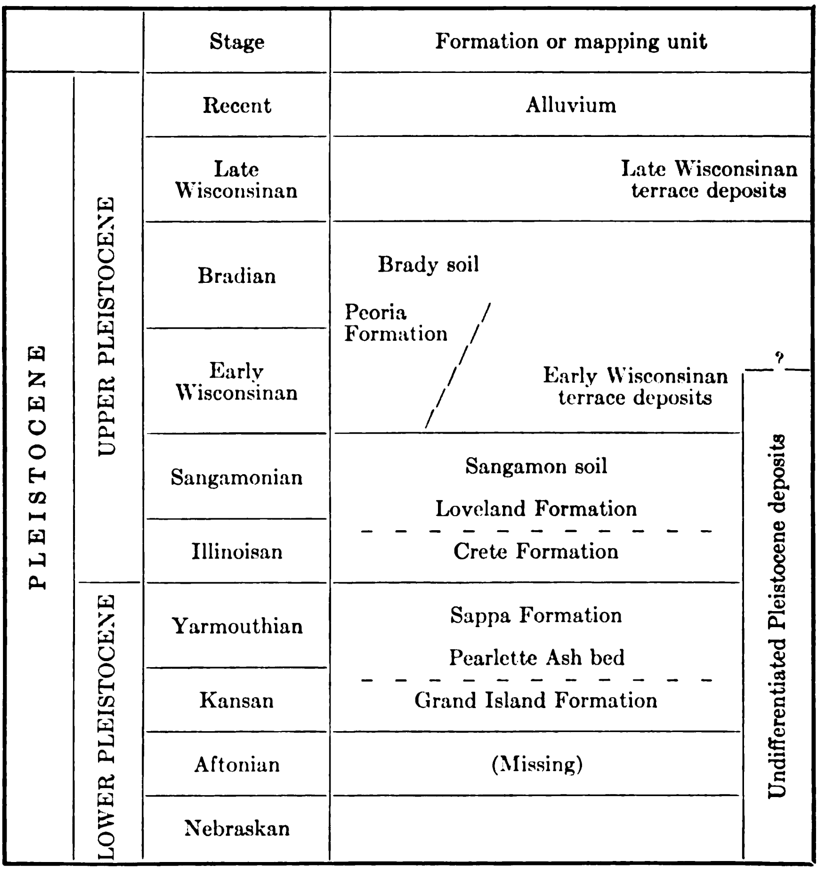

FIG. 6.—Chart showing classification of Pleistocene deposits in southern Ellis County and southeastern Trego County.

Frye, Leonard, and Hibbard (1943) studied in detail several exposures of the terrace deposits and decided the deposits were continuous with the "Equus beds" or the McPherson Formation of the McPherson region. In 1948, Frye, Swineford, and Leonard used the distinctive Pearlette Ash and associated snail fauna to extend the correlation of the midcontinent glacial section into the Great Plains. They showed that the deposits associated with the Pearlette volcanic ash, including the McPherson "Equus beds", part of the terrace deposits along Smoky Hill River, and other stream and basin deposits in Kansas were Late Kansan and Yarmouthian in age, and they applied the term "Meade Formation" to those deposits. The detailed field work for the present report produced evidence showing conclusively that the body of terrace deposits along Smoky Hill River is principally Illinoisan in age and that the Kansan and Yarmouthian deposits studied by Frye and others is only a very minor part of the deposits.

The classification used in this report was adopted by the Kansas Geological Survey in 1959. The terms Grand Island, Sappa, Crete, and Loveland Formations have been used for deposits of the same ages in Nebraska for many years. These names have been used in Kansas reports to apply to deposits of identical ages for about 15 years, but were previously designated "members" (Frye and Fent, 1947; Frye and Leonard, 1949; Fent, 1950).

Deposits of Nebraskan(?) age

General description.—The oldest Pleistocene deposits in the area are remnants of stream-deposited channel fill tentatively classed as Nebraskan in age. About 15 feet of sand and gravel consisting of chalk pebbles, mortar-bed fragments, pebbles of "Algal limestone", and reworked crystalline material from the Ogallala Formation, loosely cemented with limy material, cap the elongated northwestward-trending ridge on which Antonino is built (Pl. 6B). Similar material, 3 to 7 feet thick, overlies the Carlile Shale and underlies late Pleistocene loess along U. S. Highway 183 in the north bluff of Smoky Hill River in the NW¼ NW¼ sec. 27 and NE¼ NE¼ sec. 28, T. 15 S., R. 18 W. Other stream deposits probably of Nebraskan age crop out north and northwest of Victoria (Pl. 6A). Those deposits have been mapped with the undifferentiated Pleistocene deposits.

The Nebraskan(?) deposits near Antonino contain a large amount of material derived from the Ogallala Formation and only a small

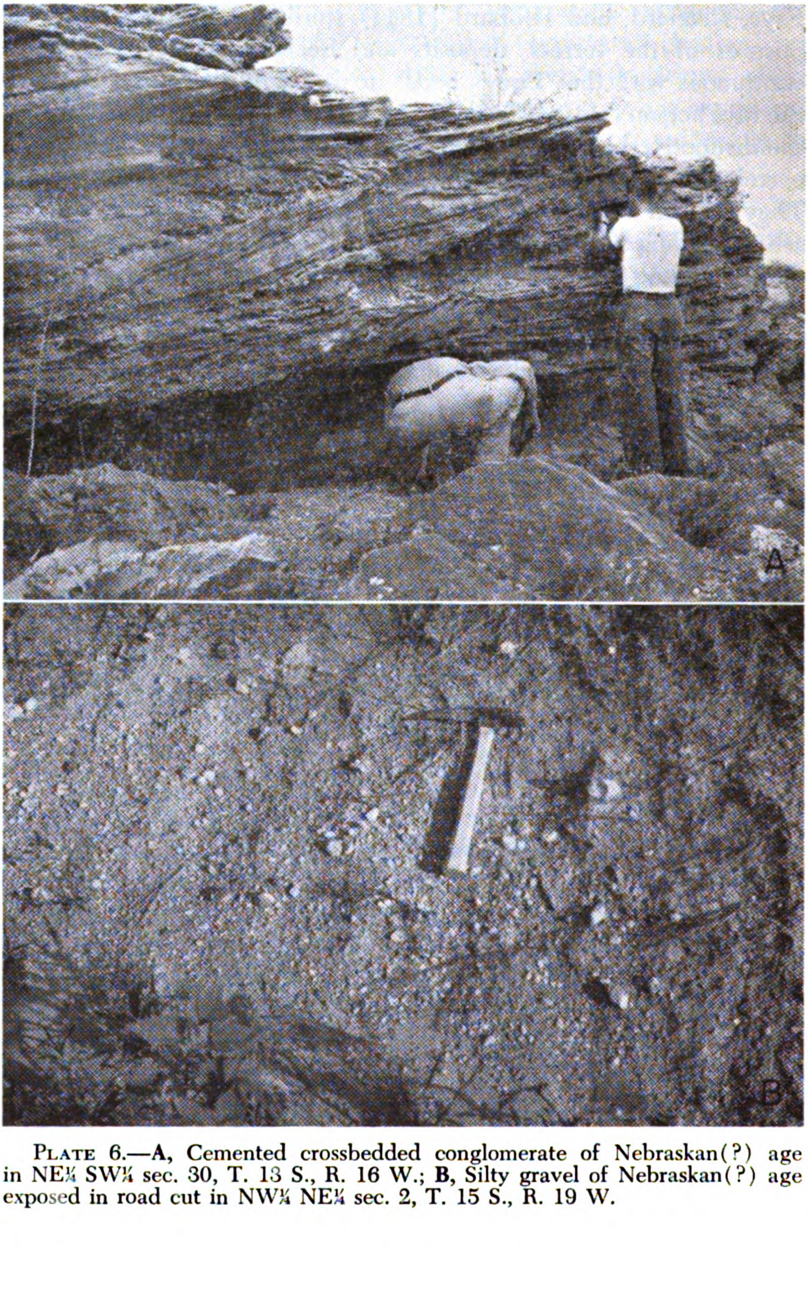

PLATE 6.—**A,** Cemented crossbedded conglomerate of Nebraskan(?) age in NE¼ SW¼ sec. 30, T. 13 S., R. 16 W.; **B,** Silty gravel of Nebraskan(?) age exposed in road cut in NW¼ NE¼ sec. 2, T. 15 S., R. 19 W.

amount of material derived from Cretaceous rocks. Some of the deposits northwest of Victoria contain a large percentage of locally derived chalk material, suggesting that they may have been deposited by small streams tributary to the main stream that deposited the main mass of sand and gravel, which is strongly crossbedded and locally in the lower part cemented with calcium carbonate (Pl. 6A). Nebraskan(?) deposits occupy a topographic position midway between the Ogallala Formation and Kansan deposits. Fragments of material from the Ogallala Formation contained in the Nebraskan(?) deposits indicate that they must be younger than the Ogallala Formation, and the calcium carbonate content helps to distinguish them from the Kansan deposits. Bass (1926, p. 16) recognized the Pleistocene age of material near Victoria, but Frye and Brazil (1943, p. 28) tentatively assigned it to the Tertiary System, although they noted that it was younger than the Ogallala Formation. No fossils have been found in the Nebraskan(?) deposits, and the tentative age assignment is based on its topographic position and relation to the formations for which definite age determinations have been made.

Water supply.—A shallow ground-water reservoir in Nebraskan(?) deposits along the Antonino ridge supplies many domestic water wells in Antonino and several wells along the ridge on each side of the village (Pl. 2, Table 11). The outcrops of the Nebraskan(?) deposits near Victoria may be one of the areas of local recharge to the main ground-water reservoir in the undifferentiated Pleistocene of the area. Well 15-16-21bd in southeastern Ellis County taps water from surficial materials that probably are of Nebraskan age.

Grand Island and Sappa Formations

General description.—The Grand Island and Sappa Formations, along Smoky Hill River in southeastern Trego County and southwestern Ellis County, are restricted to a narrow channel about one-fourth mile wide cut into the Carlile Shale (Pl. 4A). The location of this channel, which has a meander pattern much like that of the modern river, is shown in Figure 7 as plotted from surface exposures (Pl. 7B, C), test-holes and wells drilled into it, springs and seeps

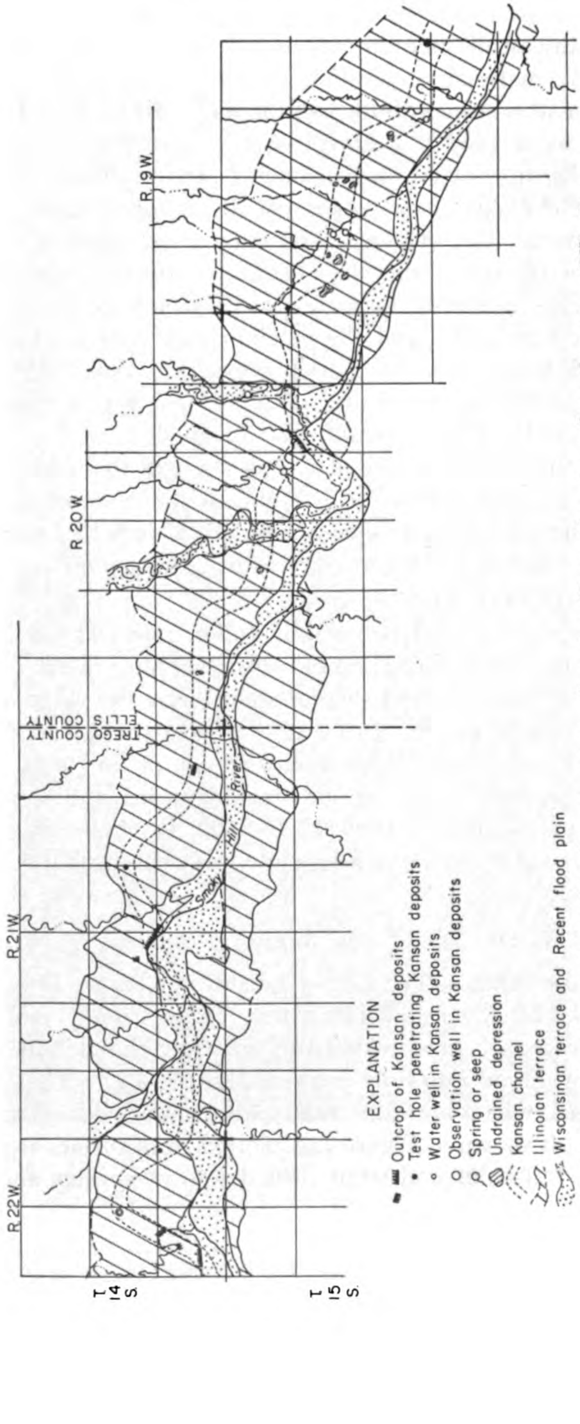

FIG. 7.—Kansan-age channel and terraces in southeastern Trego County and southwestern Ellis County.

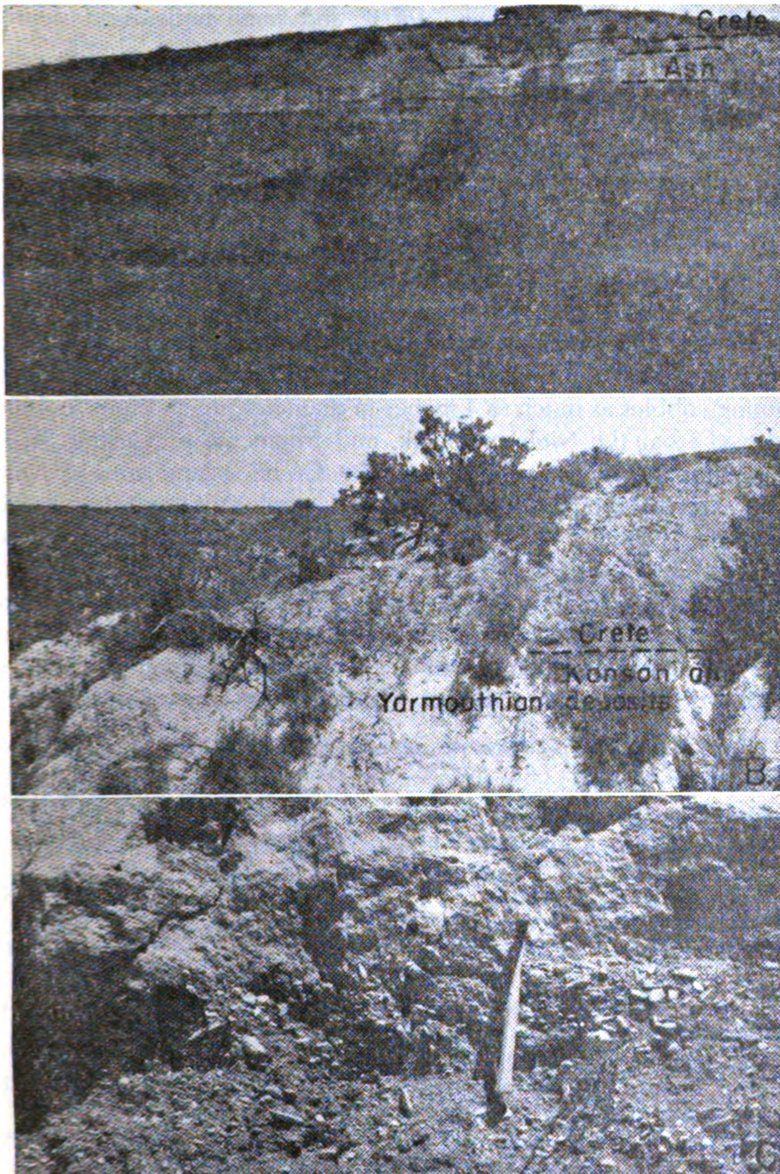

Plate 7.—A, Pleistocene deposits overlying Carlile Shale in SE¼ sec. 28, T. 14 S., R. 21 W. Several feet of sand and gravel of Crete Formation form top of deposit, beneath automobile. Light-colored wedge is volcanic ash in silt of Sappa Formation, which is separated from shale surface by a few feet of silt, sand, and gravel; **B,** Gravel of Crete Formation overlying Sappa silts in NE¼ sec. 33, T. 14 S., R. 21 W.; **C,** Light-gray silts of Sappa Formation overlying gravel of Grand Island Formation in NE¼ sec. 33, T. 14 S., R. 21 W.

where tributary streams intersect it, and small undrained depressions in the material overlying it. The base of this channel is a few feet below the level of the present river bed.

In this part of the Smoky Hill Valley these deposits represent channel fill of a single alluvial cycle and consist of gravel, sand, silt, and volcanic ash totaling about 50 feet in thickness. A test hole drilled at the SE cor. NE¼ sec. 27, T. 14 S., R. 21 W., penetrated 54 feet of these deposits. The lower 25 feet, the Grand Island Formation, consists of sand and gravel, and the upper part, the Sappa Formation, of white fine-grained silt containing near the top several feet of impure, fresh-water silty limestone. In surface exposures the Grand Island is composed of sand and gravel containing cobbles as much as 4 inches in diameter, many chalk pebbles derived from the Niobrara chalk, and fragments of Carlile Shale. The Sappa conformably overlies the Grand Island and consists of 25 to 30 feet of stratified silt and sandy silt containing thin lenticular stringers of gravel or sand and lenses of volcanic ash (Pl. 7A) identified as the Pearlette Ash bed. The silt is buff or gray buff when fresh, weathers white, and in many places contains snail shells identified by A. B. Leonard (personal communication) as a typical Yarmouthian (Sappa) fauna. The following measured section is typical of the Grand Island and Sappa Formations:

Measured section of Pleistocene deposits along north bank of Smoky Hill River in NE¼ sec. 33, T. 14 S., R. 21 W., Trego County.

	Thickness, feet
Neogene—Pleistocene	
18. Silt; contains some gravel; upper 1 foot in modern soil profile, lower 1 foot contains secondary limy material. To top of steep bluff	2.8
17. Silt, sandy, brown; contains clay; may be part of a soil profile	4.1
16. Silt, buff; contains sand and gravel in small lenses and some secondary limy material	3.0
Crete Formation	
15. Sand, silty, massive; contains gravel in lower part and snail shells throughout. Stands in vertical cliff	3.0
14. Gravel and sand, poorly stratified, brown; grades into underlying and overlying material	3.6
13. Gravel, medium to coarse, brown; contains many pebbles and cobbles in lower part, "clay balls" and fragments of concretions from Blue Hill Shale member; unconformable on Sappa member, but rests directly on Carlile Shale about half a mile southeast	10.4
Sappa Formation	
12. Silt, massive, buff; contains snail shells; upper 6 feet weathered yellowish buff	3.5

11. Silt, finely laminated, gray to light buff, weathers white; forms small bench	3.7
10. Sand, medium to coarse; contains very fine gravel; grades into overlying silt; lenticular, average thickness	.8
9. Silt, massive, light buff, weathers white; contains snail shells; composed chiefly of chalk-derived material	3.7
8. Silt, massive, gray buff; contains thin lenticular bodies of gravel	4.0
7. Gravel, predominately waterworn chalk pebbles and fragments; lenticular, grades laterally into silt and clayey silt,	2.7
6. Silt, well sorted, buff, weathers white; upper surface irregular and grades into bed 7	1.7
5. Silt, poorly sorted, buff, and fine to medium sand; contains several thin lenses of gravel and pebbles	3.8
4. Silt, massive, buff, weathers white; contains very fine sand and trace of gravel; forms a small bench	2.5
Grand Island Formation	
3. Gravel; contains cobbles as much as 3 inches in diameter and many rounded chalk pebbles and shale fragments	3.2
2. Silt and very fine sand, massive, buff, weathers white; forms small ledge; lenticular, average thickness	.6
1. Gravel; composed of cobbles as much as 4 inches in diameter, rounded chalk pebbles, fragments of Blue Hill Shale member, and medium to coarse sand; lower 3 feet covered to level of Smoky Hill River	5.9
Total measured section	63.0

The Grand Island and Sappa channel fill is truncated at the top by an erosional surface that bevels the shale on each side of the channel. Sand and gravel of the Crete Formation (Pl. 7B) unconformably rests on this surface and makes up most of the gravel deposits beneath the prominent high terrace surface in Trego and Ellis Counties.

The Pearlette Ash bed has been identified in association with silt deposits that underlie the high terrace along Big Creek near Yocemento, 6 miles northwest of Hays. The high terrace farther downstream between Hays and Victoria may be composed, in part, of deposits of Kansan and Yarmouthian age. It has not, however, been practical to attempt to subdivide the Pleistocene deposits along Big Creek; therefore, on the geologic map (Pl. 1) they are mapped as Pleistocene deposits undifferentiated.

Water supply. — In southeastern Trego County the Grand Island Formation is in contact with the alluvium, and the water table in the two formations is continuous (Pl. 2). Well 14-22-26ad at the Bureau of Reclamation construction office is the only well penetrating the Grand Island Formation in that area. Farther downstream, the ground-water body in the Grand Island extends into the overlying Crete Formation. Along Big Creek, the water table is continuous through the Nebraskan(?) deposits, Kansan deposits, Crete Formation, and alluvium.

Crete and Loveland Formations

General description.—Bass (1926, p. 16) described the distinct high terrace, 80 to 120 feet above the stream, along Smoky Hill River. He noted that the terrace was composed of coarse gravel including chalk fragments and material derived from the Ogallala Formation. On the basis of local deposits of volcanic ash of Kansan and Yarmouthian age that are associated with fossiliferous silt and clay, Frye, Leonard, and Hibbard (1943) and later Frye, Swineford, and Leonard (1948) correlated the high terrace deposits along Smoky Hill River with deposits of Kansan age in McPherson County and elsewhere in Kansas. But as already stated, in Smoky Hill Valley these older deposits are restricted to a narrow channel. The prominent gravel deposits of wide extent beneath the high terrace along Smoky Hill River are assigned to the Crete Formation; these deposits are believed to be Illinoisan in age because they unconformably overlie the Kansan and Yarmouthian deposits, and they grade upward into sandy silt containing Loveland-type fossil snails (A. B. Leonard, personal communication).

The high terrace is the most prominent feature of the Smoky Hill Valley in this area. It is more than 2½ miles wide in eastern Trego County and western Ellis County, narrows to about 1 mile near Schoenchen where the resistant Greenhorn Limestone constricts the valley walls, and widens to about 2 miles in eastern Ellis County. In many places the terrace is scarcely dissected, and locally there are undrained depressions on it. Mapping of the upland margin of the terrace is difficult because deposits of loess and colluvium locally overlie the terrace. The terrace surface slopes from an altitude of 2,130 feet near the Cedar Bluff dam in Trego County to an altitude of about 1,840 feet in southeastern Ellis County near the Russell County line. This surface, which is called the Pfeifer Terrace, has a gradient of about 10 feet per mile in the western part of this area, but eastward from Schoenchen the gradient is only about 6 feet per mile, because the resistant Greenhorn Limestone hindered downcutting by the stream that deposited the terrace material.

The Crete and Loveland Formations underlying the high terrace have a maximum thickness of about 40 feet. The lower 15 to 20

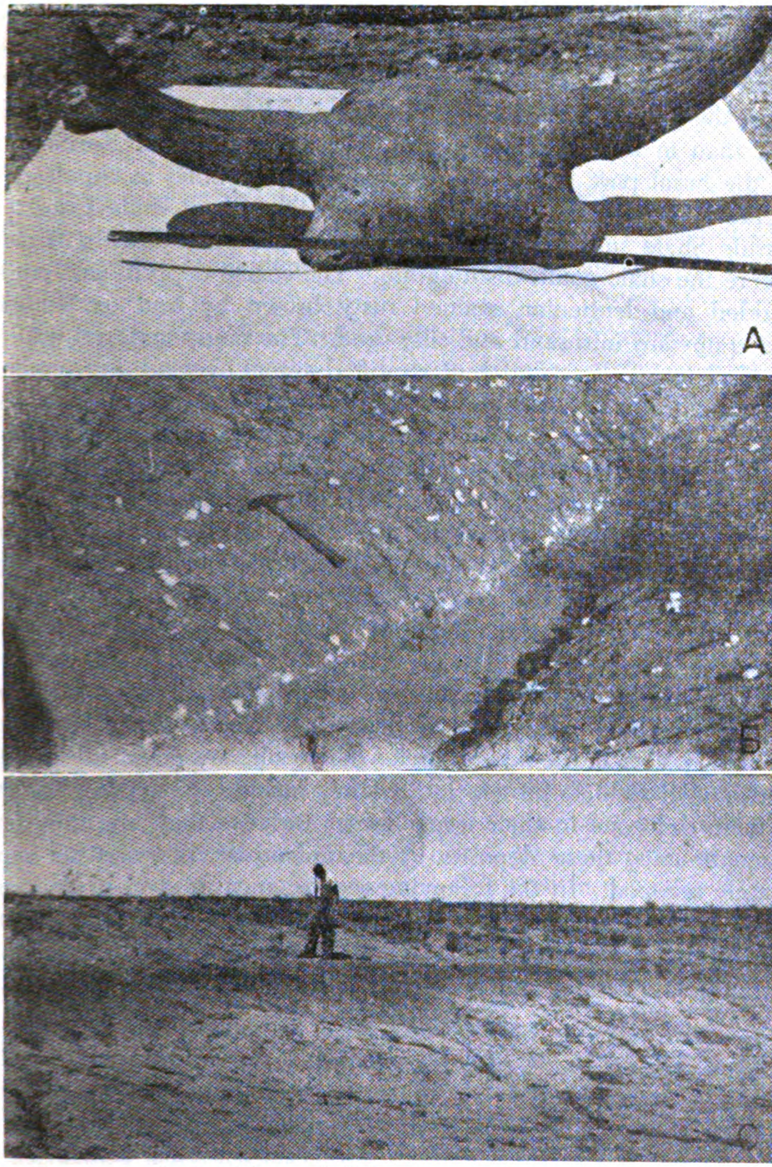

PLATE 8.—**A,** Fossil bison skull from terrace deposits at bottom of excavation for Cedar Bluff dam core trench; **B,** Caliche nodules in silt of Loveland Formation in road ditch in SE¼ SW¼ sec. 35, T. 14 S., R. 20 W.; **C,** Dark "bog" type paleosol developed in late Pleistocene silt in NE¼ sec. 3, T. 15 S., R. 21 W.

feet, the Crete Formation, consists of coarse well-sorted sand and gravel, predominantly crystalline material that was redeposited from the Ogallala Formation. A few chalk pebbles were derived from the Niobrara Formation, but the percentage of chalk is much less than in the sand and gravel of the Grand Island Formation. In the basal part, the gravel contains many cobbles as much as 4 inches in diameter. The presence of fragments of shale from the Carlile Shale suggests rapid deposition by a swift-flowing stream before the shale could disintegrate. The coarse deposits are cross-bedded and lenticular, stained rusty brown by iron oxide, and grade upward into sand and silty sand. The sandy material grades upward into yellow and buff stratified silt (Loveland Formation) containing thin lenses of sand and gravel and scattered sand grains. Locally, small concretions of secondary calcium carbonate (Pl. 8B) and accumulation of clayey material indicate the ancient development of a soil profile in the silt. Description of a typical section of Pleistocene deposits underlying the Pfeifer Terrace accompanies that of the Grand Island and Sappa Formations. Locally, thin deposits of loess of the Peoria Formation overlie the Loveland or Crete deposits, but they have not been mapped separately on Plate 1.

Thin, discontinuous deposits of eolian silt and sandy silt of the Loveland Formation overlie bedrock or Nebraskan(?) deposits at many places in the upland area. These silts are generally friable and buff or reddish brown; locally they include the typical Sangamonian soil zone in their upper part. Because they are thin and discontinuous, these deposits in the upland areas were not separately mapped. In the following section, measured in a road cut along U. S. Highway 183 half a mile north of Smoky Hill River, silt of the Loveland Formation lies between silt of the Peoria Formation and sand and gravel of Nebraskan(?) age.

Measured section of Upper Pleistocene and Nebraskan(?) deposits in SW¼ NW¼ sec. 27, T. 15 S., R. 18 W., Ellis County.

	Thickness, feet
NEOGENE—Pleistocene	
Peoria Formation	
3. Silt, gray buff; contains grains of sand and gravel and disseminated calcium carbonate; basal part in transition zone from soil below; upper 1.3 feet in modern soil profile. Thickens to north, minimum	4.6
Loveland Formation	
2. Silt, slightly sandy, noncalcareous, friable, reddish brown. Prominent soil zone in upper part	3.7

Nebraskan(?) deposits

1. Sand and gravel; basal part contains much calcium carbonate and fragments of Ogallala Formation and Carlile Shale; upper 4 feet contains red sandy silt and caliche nodules; upper contact indistinct 7.2

Total measured Pleistocene section 15.5

A large part of the deposits beneath the high terrace along Big Creek probably belongs to the Loveland and Crete Formations, but subdivision of those deposits was not feasible during this investigation.

Water supply.—The Crete Formation is a principal source of ground water for domestic and stock supplies in the area of the Pfeifer Terrace in southern Ellis County and along the northern edge of Rush County where the depth to water ranges from 10 to 50 feet. In most of southeastern Trego County and locally in southwestern Ellis County, most of the Crete Formation lies above the water table. At other localities small lenses of sand and gravel in the silty Loveland Formation contain bodies of perched water (Fig. 14). In the western part of the area, the water table in the Crete Formation is not connected with the water table in the Grand Island Formation and the alluvium. At many places eastward from Schoenchen, however, the water table is continuous from the Crete deposits to the alluvium (Pl. 2), and the flat surface of the Pfeifer Terrace may be an important recharge area.

Total dissolved solids in analyzed samples of water from wells penetrating the Crete Formation ranged from 332 to 1,180 parts per million. Because of the iron oxide present in the sand and gravel, the water contains more iron than that in the other Pleistocene rocks but not as much as the water from the Dakota Formation (Fig. 20, Table 8). The water is hard but is suitable for domestic and stock use.

Peoria Formation

Thin discontinuous patches of eolian silt of the Peoria Formation occur at many places in the uplands. These loess deposits generally are gray to gray buff, massive, and locally calcareous. In most places they are less than 5 feet thick, and at many places they are represented by only a few inches of silty material incorporated in the modern soil profile. In the western part of the area, deposits of Peoria have been reworked by slope processes and incorporated into the colluvium, or they have been deposited over colluvial material. Massive gray silt that locally overlies the buff stratified silt in the Pfeifer Terrace area may also be Peoria loess. Because it is thin and discontinuous, the Peoria was not differentiated on Plate 1.

The Brady soil has been tentatively identified as the soil zone (Pl. 8C) in the NE¼ sec. 3, T. 15 S., R. 21 W., that is overlain by a few feet of gray friable silt, which may be the Bignell Formation. Similar deposits were noted elsewhere in the area.

Alluvium and Terrace Deposits

General description.—Late Wisconsinan and Recent stream deposits along Smoky Hill River, Big Creek, and tributary valleys are mapped as alluvium and terrace deposits. The inner valley of Smoky Hill River, which is underlain by these deposits, is ¼ to ¾ mile wide, is cut about 50 feet below the level of the adjoining prominent Pfeifer Terrace, and in the western part of the report area is separated from the Pfeifer Terrace by a shale bluff. The alluvial material of the inner valley was deposited in two major alluvial cycles, one during late Wisconsinan time and the other in Recent time. The oldest part is the material of Wisconsinan age that fills a channel about ¼ mile wide cut about 50 feet below the level of the present stream. The upper part is late Wisconsinan, but the basal part may be of early Wisconsinan age. This channel meanders in the same manner as the present river; at one place it will correspond to the modern channel but at another will be against one wall of the inner valley (Pl. 3). The deepest part of the channel can be located only by test drilling, because there is no surface indication of its position. Test drilling indicates that the Wisconsinan deposits are as much as 65 feet thick in some places. The lower 30 to 50 feet is coarse sand and gravel derived principally from the older Pleistocene rocks and the Ogallala Formation, and the upper 10 to 30 feet is soft friable gray silt or sandy silt. During excavation of the core trench for Cedar Bluff dam a bison skull (Pl. 8A) and cedar logs were found at the base of these terrace deposits overlying the Carlile Shale. Uneroded remnants of these deposits form a low terrace 30 to 60 feet below the Pfeifer Terrace and 15 to 20 feet above the level of the river (Pl. 4C). We named it the Schoenchen Terrace from the village of that name built on it. In Ellis and Trego Counties the late Wisconsinan deposits have been extensively eroded so that only small remnants of the Schoenchen Terrace remain along Smoky Hill River (Pl. 1), but we recognized remnants of this terrace as far west as Logan County.

Recent deposits underlie the flood plain and channel of Smoky

Hill River. These rocks consist of about 10 to 15 feet of sand, gravel, and silt that overlie shale of Cretaceous age or are channeled into late Wisconsinan deposits (Pl. 3).

Along Big Creek and its principal tributaries the inner valley is characterized by a well-developed terrace and a narrow flood plain and channel. The terrace surface is 30 to 50 feet below the level of the broad high terrace along Big Creek and 20 to 25 feet above the level of the creek. The terrace is ½ to 1 mile wide along Big Creek and about ¼ to ½ mile wide along North Fork Big Creek. The terrace deposits (mapped with the alluvium on Pl. 1) are 30 to 50 feet thick, the lower 10 to 25 feet consisting of sand and gravel and the upper part of stratified silt and sandy silt. This terrace probably corresponds to the Schoenchen Terrace of the Smoky Hill Valley and to the late Wisconsinan terraces along Prairie Dog Creek and North Solomon River (Frye and Leonard, 1949; Leonard, 1952). The uppermost part of the terrace deposits is judged to be Recent in age because a wide area of the terrace surface in the vicinity of Hays was flooded in the summer of 1951.

During Recent time, the terrace deposits were eroded to form the flood plain and channel of Big Creek, and a thin layer of alluvial material was deposited over the eroded late Wisconsinan deposits. Recent deposits along Big Creek Valley are thin and of small lateral extent and have been mapped with the more widespread terrace deposits.

Water supply.—In eastern Trego County and western Ellis County as much as 50 feet of terrace deposits filling the late Wisconsinan channel adjacent to Smoky Hill River is saturated. In the eastern part of Ellis County about 35 feet of material is saturated (Pl. 3). These deposits are the only aquifer capable of yielding large supplies of water to wells, and the city of Hays has five wells (15-18-27ca, 15-18-27cb1, 15-18-27cb2, 15-18-28da1, 15-18-28da2) penetrating them. In June 1949, well 15-18-27cb1 had a drawdown of 26 feet when pumped at 844 gpm (gallons per minute) during a 48-hour pumping test, and well 15-18-28da2 had a drawdown of 24 feet when pumped at 860 gpm during a 24-hour pumping test. Although hard, the water is suitable for most purposes.

Moderate supplies of ground water are obtained from alluvial deposits of Big Creek valley and North Fork Big Creek valley. The thickness of saturated material and the permeability of these deposits are less than that in the Smoky Hill Valley and the yield of wells is much less. Hays formerly had 14 wells in the alluvium of Big Creek valley (Latta, 1948, fig. 3, table 1) that ranged in yield from 75 to 300 gpm and averaged about 140 gpm. The city of Victoria has five wells in the alluvium of North Fork Big Creek. The maximum yield of these wells reported by Latta (1948, table 4) was 70 gpm from a well in the NW¼ sec. 18, T. 14 S., R. 16 W., and this well was reported to pump dry in 3 hours. The alluvial deposits, however, supply moderate amounts of water suitable for domestic and stock use.

Undifferentiated Pleistocene deposits

General description.—Deposits classified as Pleistocene undifferentiated have been mapped (Pl. 1) in two areas: near Smoky Hill School in T. 15 S., R. 19 W., and in Big Creek valley eastward from Hays.

The deposits in the 4-square-mile area in T. 15 S., R. 19 W., underlie a relatively undissected terrace that borders an unnamed creek. The surficial material exposed in stream cuts is gray silt and sandy silt. The basal material is not exposed but is reported to be gravel. The deepest well inventoried in the area is 32 feet in depth and therefore the deposits are believed to have a maximum thickness of about 40 feet. The age of these deposits is unknown, but because the surface of the terrace is eroded only slightly, they must be relatively young. The terrace may correspond to either the Pfeifer or Schoenchen Terrace of the Smoky Hill Valley, and the deposits probably are Illinoisan or Wisconsinan in age.

The largest area of undifferentiated Pleistocene deposits shown on Plate 1 extends eastward from the vicinity of Hays. These deposits form a dissected "high terrace" adjacent to Big Creek valley, mostly north of the valley in the mapped area. The high terrace is about 5 miles wide at Hays but becomes nearly 7 miles wide near Victoria.

Test holes drilled into the high terrace along Big Creek penetrated 23 to 64 feet of Pleistocene deposits. The upper part consists of 15 to 55 feet of tan, brown, and buff calcareous silt and sandy silt that seems to be massive near the top but may be stratified in part. A large part of the silt probably belongs to the Loveland Formation, but the uppermost part may be loess of the Peoria Formation. Local deposits of light-colored silt associated with Pearlette volcanic ash are part of the Sappa Formation. The lower 6 to 30 feet of undifferentiated deposits consists of sand and gravel and locally contains thin stringers and layers of clay and silt. A few miles east of Ellis County the Big Creek high terrace is continuous with the high terrace of Smoky Hill River; therefore, most of the sand and gravel in the undifferentiated deposits probably is the Crete Formation. Exposures of sand and gravel north of Victoria have been identified tentatively as Nebraskan, and deposits known to be part of the Grand Island Formation have been noted elsewhere along Big Creek. The deposits beneath the Big Creek high terrace probably include stream deposits of Nebraskan to Sangamonian age and Wisconsinan loess.

Water supply.—The undifferentiated deposits rest on a surface of erosion developed on Cretaceous bedrock. This surface is irregular but slopes generally southward toward Big Creek (Pl. 3). The water table in the deposits slopes toward Big Creek and North Fork Big Creek. The saturated thickness of these deposits ranges from a few feet to nearly 40 feet (Pl. 3), but is not generally greater than 10 feet. The depth to water ranges from 12 to 54 feet and averages about 32 feet (Pl. 2). Water from these deposits is hard, but is generally suitable for most uses.

GEOMORPHOLOGY

Stream Development

The topographic features in the area of this report are the products of Pleistocene erosion and deposition. At the close of Pliocene time, the area from the Rocky Mountains to the Flint Hills was a nearly featureless aggradational plain crossed by streams flowing toward the east. During the formation of this plain in central Kansas the Cretaceous rocks were buried under a mantle of debris, which attained a thickness of 300 feet but thinned sharply toward its eastern margin. The remnants of the Ogallala Formation, which was deposited by these streams, cap the divides between the main streams in central Kansas.

In early Pleistocene (Nebraskan) time a drainage system developed on the Ogallala aggradational plain and erosion removed a large amount of these deposits. The main streams probably flowed south along the softer shales between the more resistant Cretaceous limestones that were uncovered by erosion. These streams cut valleys as much as 80 feet below the top of the Ogallala Formation (Fig. 8) and left alluvial deposits that now cap the ridge extending southeastward from Antonino and also left the unconsolidated deposits in a widespread area north of Big Creek in the vicinity of Victoria. Some of the deposits in the vicinity of Victoria may be colluvium overlying a surface graded to a terrace or

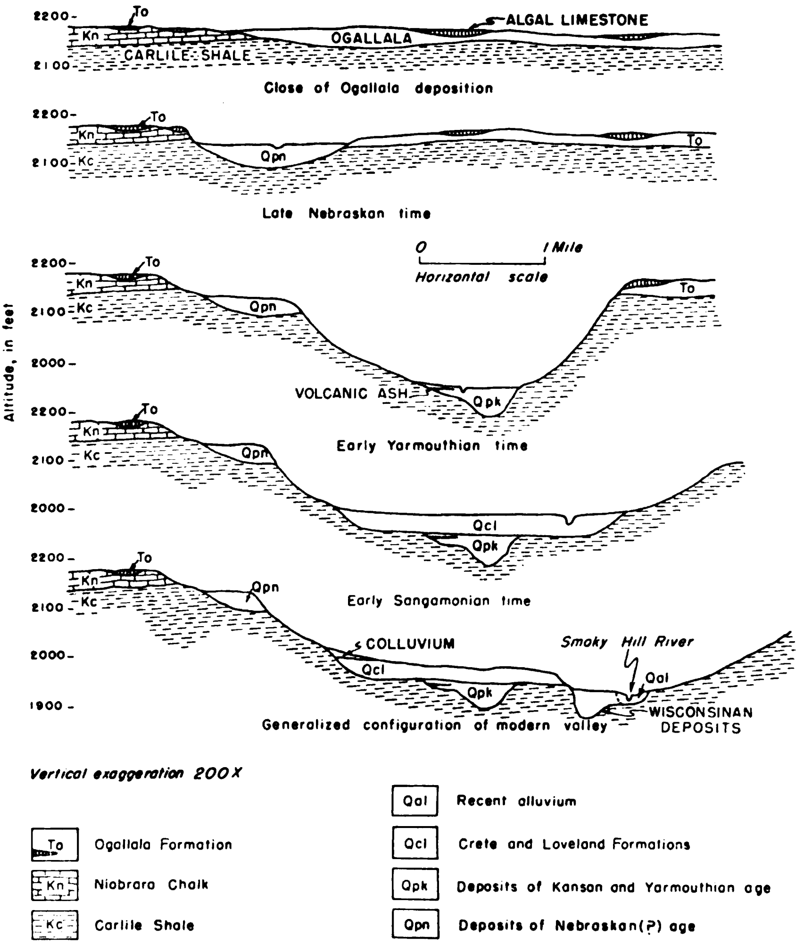

FIG. 8.—Stages in development of Smoky Hill Valley.

flood plain of the major early Pleistocene stream that flowed southward across this area. Stream deposits that may be a continuation of those in the Victoria and Antonino areas were noted at Galatia in northwestern Barton County by Latta (1950, p. 68). Little is known about the relief of the surface during the Nebraskan Stage.

By Kansan time erosion had removed much of the Ogallala deposits in the outcrop area of the Carlile Shale (Pl. 1), and the present drainage system was being established. At that time streams occupied Smoky Hill and Big Creek valleys, as shown by deposits of Pearlette volcanic ash in both valleys. In eastern Trego

County and western Ellis County the volcanic ash and associated deposits of the Sappa and Grand Island Formations fill a narrow channel, which was cut into the Carlile Shale and was covered by a widespread younger alluvial deposit. The stream that cut this channel may have been of the approximate size of the modern Smoky Hill River in southern Ellis County. Maximum depth of bedrock cutting during this interval was about to the level of the present river, nearly 300 feet below the top of the Ogallala Formation. Deposits of Pearlette volcanic ash west of Hays near Yocemento suggest that a stream of Kansan age occupied the approximate position of Big Creek. Volcanic ash in a locality in the southeastern part of sec. 17, T. 14 S., R. 19 W., is unrelated to either of the two major streams. This ash may be in a valley that was tributary to ancestral Smoky Hill River. Its location between two nearby escarpments of the Fort Hays Limestone member gives a good indication of the amount of erosion since the ash was deposited and the amount of escarpment retreat since Kansan time.

The events immediately following the cutting and filling of the narrow Kansan channel along Smoky Hill River are not entirely clear. During Illinoisan time a major stream flowing along the Smoky Hill Valley deposited the material underlying the widespread Pfeifer Terrace and overlapping the Kansan channel fill (Pl. 3, Fig. 7, 8). The broad shale surface beneath the Illinoisan deposits may have been beveled by the stream or it may have been a pediment surface graded to the Kansan channel during late Yarmouthian time and modified slightly as the Illinoisan rocks were deposited. The thick widespread sand and gravel deposits beneath the Pfeifer Terrace are correlated with the Crete Formation. In places these deposits grade upward into stratified silt, which is probably the lower part of the Loveland Formation. Thin discontinuous deposits of loess overlie Cretaceous rocks in the upland. The loess was carried into the area by winds from the flood plains of glacier-fed streams. Loess of Illinoisan and early Sangamonian age is widespread over north-central Kansas and extends as far south as Rice and McPherson Counties (Frye and Fent, 1947). In much of central Kansas, late Sangamonian time was a period of equilibrium when very little erosion took place and was ideal for the formation of the well-developed Sangamonian soil at the top of the Loveland Formation. Inasmuch as evidence of a soil of Sangamonian age has been noted at only a few localities in this area, erosion may have been the dominant physical process here at the time the Sangamonian soil was being developed elsewhere.

During early Wisconsinan time, silt from the flood plains of Platte and Republican Rivers was drifted over north-central Kansas by strong northwesterly winds (Swineford and Frye, 1951). Early Wisconsinan loess, the Peoria Formation, has been recognized only locally in the report area, and it is thinner and more discontinuous than in areas farther north and west (Frye and others, 1949, fig. 2).

During Wisconsinan time, Smoky Hill River intrenched its valley completely through the Illinoisan deposits and 60 to 80 feet into the underlying shale (Pl. 3, Fig. 8). It is not known whether downcutting took place throughout the Wisconsinan or mainly during one substage. After valley cutting, the alluvial deposits in the inner valley of Smoky Hill River were laid down and the Schoenchen Terrace was formed. The upper part of the deposits beneath this surface is late Wisconsinan, but some of the basal sand and gravel in the buried valley may be early Wisconsinan in age. Rapid accumulation of material during the early phase of deposition is indicated by cedar logs and limbs found in the lower gravel during excavation for the Cedar Bluff dam and by fragments of soft shale mixed with resistant rock materials.

The low terrace along Big Creek is probably of late Wisconsinan age also and was formed after an interval of valley cutting similar to the Wisconsinan interval in the Smoky Hill Valley. The record of events in the Big Creek valley is not as clear as in the Smoky Hill Valley because deposits of the various stages in the Pleistocene have not been differentiated. Downcutting during each interval of erosion was almost confined to earlier Pleistocene rocks, and intrenchment of the bedrock was not so pronounced as along Smoky Hill River. Pearlette volcanic ash in Big Creek valley indicates that the valley has been the site of a major stream since Kansan time. Probably the post-Kansan history of the valley is similar in most respects to that of the Smoky Hill Valley.

Although erosion has been the dominant process during Recent time, very little bedrock has been eroded and only a small amount of late Wisconsinan material has been removed from the valleys of Big Creek and Smoky Hill River. Locally, as much as 30 feet of material has been eroded during dissection of the Schoenchen Terrace. Accumulation of 10 to 15 feet of sand and gravel on the flood plain followed the period of erosion or occurred simultaneously with the later part of the erosion. Along Big Creek, Recent erosion was restricted to the silty part of the late Wisconsinan terrace deposits and was accompanied by the deposition of several feet of silty material on the flood plain. Modern floods such as those of 1951 have added a small amount of silt to the surface of the late Wisconsinan terrace of Big Creek.

Pediments

In 1942 Frye and Smith described pediment-like slopes in the High Plains along Cimarron River in Seward County and along Smoky Hill River in Logan and Gove Counties. In Logan County, these slopes are developed in the homogeneous nonresistant Smoky Hill Chalk member of the Niobrara Chalk and are graded to the terrace along Smoky Hill River. On the upland side in many places they blend imperceptibly into the valley walls, but locally they end abruptly at the foot of cliffs formed in resistant chalk beds. In western Ellis County and eastern Trego County similar slopes have developed in the Carlile Shale. They grade into the Pfeifer Terrace surface so imperceptibly that the boundary between the two features can not be determined precisely. On the upland side they locally grade into and mask the escarpment formed by the basal beds of the Niobrara Formation so that a graded slope is developed from the escarpment to the high terrace surface. At many places pediments are mantled by a thin layer of colluvium consisting of a mixture of loess, weathered shale, and chalk fragments. Locally, a pediment may be dissected by erosion and a series of smaller pediments graded to lower levels may be developed on the eroded part.

Plate 9 shows a remnant of a partly dissected pediment in southwestern Ellis County in sec. 8, 9, 16, and 17, T. 15 S., R. 20 W. This surface was graded to the escarpment of the Fort Hays Limestone member at the south and to the Pfeifer Terrace at the north. Erosion subsequent to pediment formation has formed a badland area about half a mile wide between the pediment remnant and the limestone escarpment, and downcutting of the Smoky Hill Valley has formed an escarpment between the pediment and the valley (Fig. 9). Late Pleistocene erosion has intricately dissected the shale on the south and east sides of the pediment remnant and formed badlands that are separated from the pediment by a pronounced escarpment. Although streams are beginning to erode the pediment, the surface at the south end is still relatively undissected and probably has been protected by the veneer of colluvium.

Frye and Smith (1942, p. 218) concluded that the High Plains pediments were formed by slope processes, especially erosion by closely spaced minor streams, sheet wash, and weathering creep.

PLATE 9.—Aerial view of central part of T. 15 S., R. 20 W., showing large pediment remnant, "badlands" developed on Carlile Shale, escarpment formed by Fort Hays Limestone member, and segment of Smoky Hill Valley. Arrow points north and is ½ mile long. (Features are labeled on Fig. 9.)

The grading of these surfaces to the Pfeifer and other terrace levels suggests that each pediment formed at the same time as the alluvial surface to which it is graded, or at least before extensive erosion of the terrace. The pediments in this area probably were formed

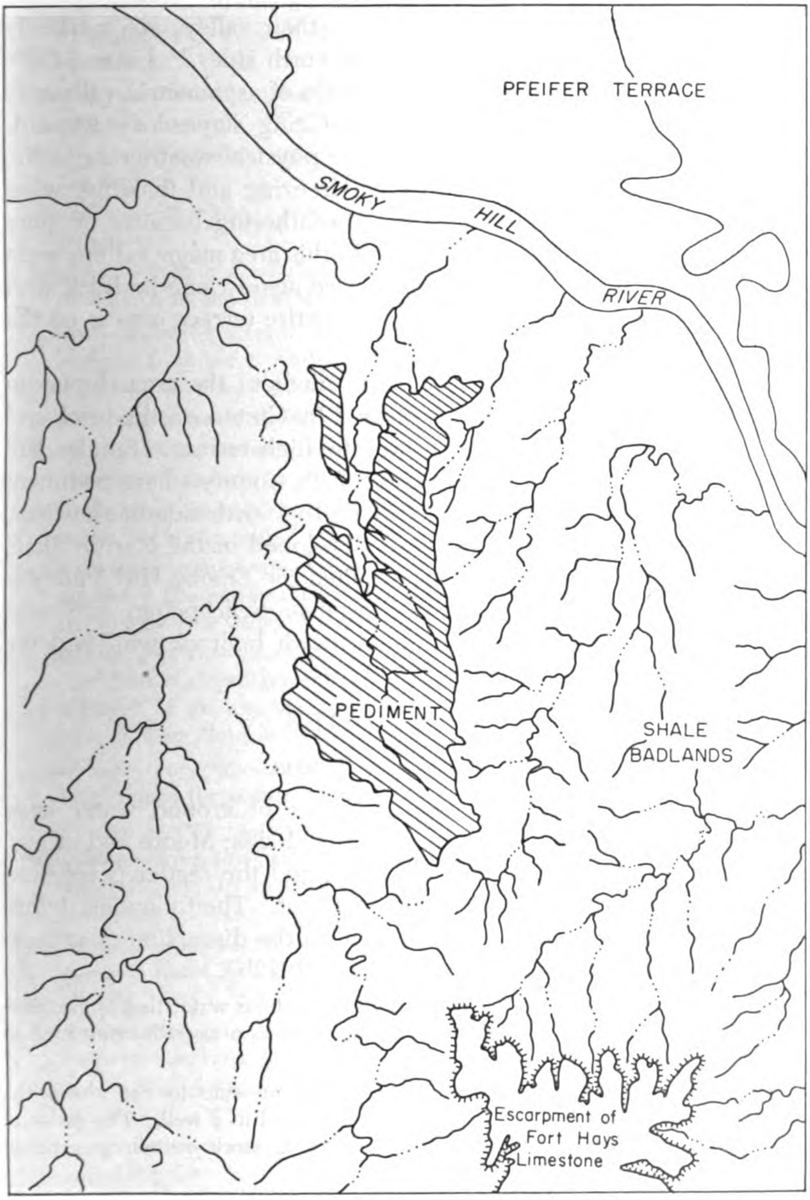

Fig. 9.—Map of area shown in Plate 9.

at different times during the Pleistocene, and the formation of multiple pediments has been a continuing process.

Asymmetric Valleys

Bass (1926, p. 13), in describing the topography of Ellis County, stated concerning the main streams: "—their valleys are markedly steeper on the south sides than on the north sides." Later (1929, p. 17-23), he discussed in detail the origin of asymmetric valleys in Kansas and concluded that the south-facing slopes of eastward-flowing streams were exposed to greater physical weathering in the form of alternate wetting and drying, freezing and thawing, wind action, and possibly greater chemical weathering because of more heating than the north-facing slopes. In this area major valleys seem to be asymmetric where their streams are against one bedrock wall for long stretches of the stream and the entire terrace area is on the other side of the stream.

Big Creek Valley is asymmetrical throughout the area shown on Plate 1 because the south wall is formed by Cretaceous bedrock and the north slope by the broad Pleistocene high terrace. Smoky Hill Valley is asymmetrical in southwestern Ellis County where pediment slopes grade into the Pfeifer Terrace on the north side of the river, and the bedrock slopes or badlands developed in the Carlile Shale form the south wall. East of Schoenchen the Smoky Hill Valley is almost symmetrical except locally, as near Schoenchen and near Pfeifer, where the river is against the north bedrock wall and the slope on the south side is gentle (Pl. 3).

GROUND WATER

Definition of Terms

The principles governing the occurrence of ground water have been discussed by many authors (Meinzer, 1923a; Moore and others, 1940, p. 11-32; Thomas, 1951, p. 15-34), and the reader is referred to their reports for a discussion of the subject. The following definitions of technical terms commonly used in the discussion of ground water are adapted chiefly from Meinzer (1923b).

aquifer—a rock formation, bed, or zone that contains water that is available to wells. An aquifer is sometimes referred to as a *water-bearing rock* or *water-bearing bed.*

artesian water—ground water under sufficient pressure to rise above the level at which the water-bearing rock is tapped in a well. The pressure is sometimes called *artesian pressure* and the rock containing artesian water is an *artesian aquifer.*

capillary fringe—that zone directly above the water table in which water is held in the pore spaces by capillary action.

cone of influence (or *cone of depression*)—a cone-shaped depression of the water table; it is developed in the vicinity of a well during pumping.

confined water—water under artesian pressure.

confining bed—generally a relatively less permeable rock layer that overlies or underlies an artesian aquifer and confines water in the aquifer under pressure.

connate water—water trapped in the openings in the rock at the time the rock was formed.

depression of the water table—lowering of the water table around a pumping well.

drawdown—depression of the water level in a well or in nearby wells during pumping.

discharge—term generally applied to *ground-water discharge,* the removal of water from the zone of saturation. (Meinzer, 1923b, p. 48-56).

effluent stream—a stream is generally said to be effluent if water is discharged from the ground-water reservoir to the stream, sometimes called a *gaining stream* (Fig. 10).

ephemeral stream—a stream that flows only in response to precipitation.

flowing well—an artesian well having sufficient head to discharge water above land surface.

ground water—as used in this report: water in the zone of saturation, or below the water table.

ground-water movement—the movement of ground water in or through an aquifer. The movement of ground water through rocks such as occur in the Smoky Hill Valley is extremely slow, probably less than 1 foot a day.

hydraulic gradient—gradient of the water table measured in direction of the greatest slope, generally expressed in feet per mile. The hydraulic gradient of an artesian aquifer is called the *pressure gradient* and is measured on the *piezometric surface.*

hydrologic properties—as used in this report: The properties of an aquifer that control the occurrence and movement of ground water.

hydrologic system—a series of interconnected aquifers.

hydrostatic pressure—pressure exerted by water at any point in a body of water at rest. In an artesian system the hydrostatic pressure is the artesian pressure.

impermeable rock—an *impervious* rock; that is, a rock through which movement of water under common subsurface pressure differentials is negligible.

infiltration—the process whereby water enters the surface soil and moves downward toward the water table.

inflow—movement of ground water into an area in response to a hydraulic gradient.

influent stream—a stream that contributes water to the ground-water reservoir (Fig. 10).

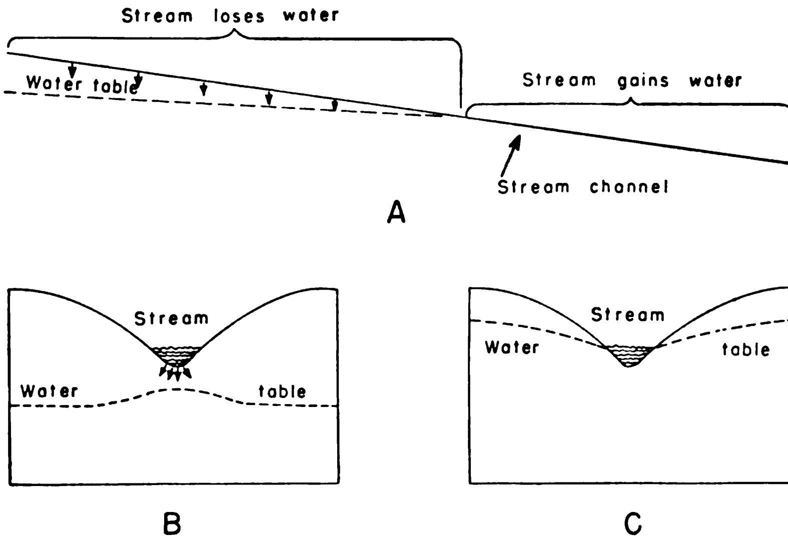

FIG. 10.—Diagrammatic sections showing influent and effluent streams.

intermittent stream—a stream that flows only at certain times following precipitation or when it receives water from springs, ground-water seepage, or melting of snow.

interstice—an opening or *void* in a rock. Interstices may be filled with air, gas, oil, water, or some other fluid. The interstices in an aquifer are filled with water (Fig. 11).

nonflowing artesian well—an artesian well in which the pressure is sufficient to cause the water to rise only part of the way toward the land surface.

perched water—ground water separated from the underlying water table by a zone of unsaturated rock. A perched water table is distinguished from the main water table.

perennial (or *permanent*) *stream*—a stream that flows continuously, such as Big Creek or Smoky Hill River in this report area.

permeable rock—a *pervious rock*, or a rock that has a texture permitting water to move through it readily under ordinary pressure differentials.

permeability—the capacity of rock to transmit water. The *field coefficient of permeability* of an aquifer may be expressed as the rate of flow of water at the prevailing temperature, in gallons a day, through a cross-sectional area having a thickness of 1 foot and a width of 1 mile for each foot per mile of hydraulic gradient.

piezometric surface—as generally used, the pressure-indicating surface of an artesian aquifer.

porosity—the porosity of a rock is its property of containing openings or interstices. Quantitatively, the porosity of a rock is the ratio (usually expressed as a percentage) of the volume of openings in the rock to the total volume of the rock.

recharge—the process by which water is absorbed and added to the zone of saturation. Also used to designate the quantity of water added to the ground-water reservoir.

runoff—the discharge of water through surface streams. It includes both surface-water runoff and ground-water runoff. Also used to designate the quantity of water discharged as runoff.

specific capacity—the yield of a well generally expressed in gallons a minute per foot of drawdown after a specified time of pumping.

specific yield—the specific yield of a saturated rock is the ratio of the volume of water it will yield by gravity to its own volume.

storage—water stored in openings in the zone of saturation is said to be in storage. Discharge of water not replaced by recharge from an aquifer is said to be from storage.

transmissibility—the transmissibility of a rock is its capacity to transmit water under pressure. The *coefficient of transmissibility* is the field coefficient of permeability multiplied by the saturated thickness, in feet, of the aquifer.

underflow or *subsurface movement*—underflow is the movement of ground water through a formation.

water table—the water table is the upper surface of the zone of saturation where that surface is not formed by an impermeable rock. The water table is not a plane surface, but has irregularities much like the land surface. The configuration of the water table is shown on Plate 2 by means of contours.

zone of aeration—the zone between the land surface and the water table.

zone of saturation—the zone of permeable rocks saturated with water under hydrostatic pressure.

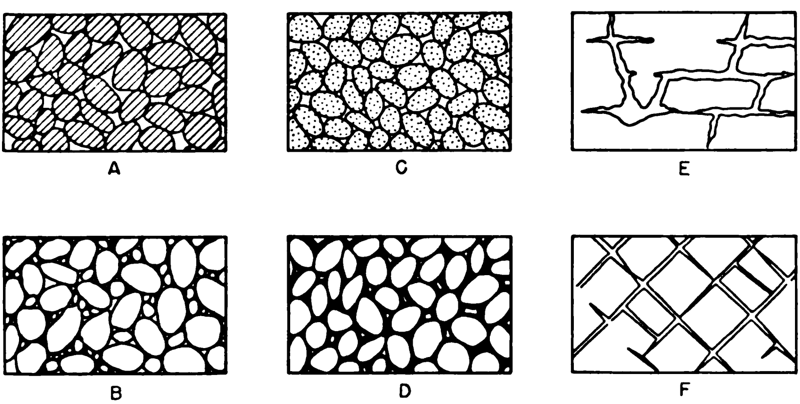

FIG. 11.—Diagram showing several types of rock interstices and the relation of rock texture to porosity. A, Well-sorted sedimentary deposit having high porosity; B, Poorly sorted sedimentary deposit having low porosity; C, Well-sorted sedimentary deposit consisting of pebbles that are themselves porous so that the deposit as a whole has very high porosity; D, Well-sorted sedimentary deposit whose porosity has been diminished by the deposition of mineral matter in the interstices; E, Rock rendered porous by solution; F, Rock rendered porous by fracturing. (From O. E. Meinzer.)

Water-Table Conditions

Movement of Ground Water

In southern Ellis County and southeastern Trego County, ground water is under water-table conditions in the Pleistocene rocks and, locally, in weathered zones in the Cretaceous rocks. The water-bearing characteristics of each of these rocks has been discussed in the section on geology. The source of ground water is precipitation on and upstream from the areas underlain by these rocks and infiltration from ephemeral streams that carry runoff from adjoining areas and cross the outcrops of these rocks. Throughout much of the upland both north and south of Smoky Hill River, the general water table is absent and small isolated bodies of ground water occur in alluvial deposits or in weathered zones in the Carlile Shale. Contours on the water table, where it can be contoured, are shown on Plate 2.

Movement of ground water is normal to the water-table contours, that is, in the direction of the greatest slope of the water table. Near Victoria the movement of ground water in the undifferentiated Pleistocene rocks is toward Big Creek and North Fork Big Creek. In the southeast part of T. 14 S., R. 17 W., the water table slopes toward Big Creek at about 17 feet per mile and just south of Victoria the slope toward North Fork Big Creek is about 25 feet per mile. Movement of ground water in the alluvium of Big Creek is downstream and the slope of the water table is about 8 feet per mile. In the alluvium along North Fork Big Creek the downstream slope of the water table is about 9 feet per mile. Big Creek and North Fork Big Creek are effluent streams and gain water from ground-water discharge in this area.

In southwestern Ellis County, the slope of the water table in the Crete Formation is about 22 feet per mile and ground-water movement is toward the river and downstream. In the alluvium of Smoky Hill River the slope of the water table is about 9 feet per mile in Trego County and about 7 feet per mile in southeastern Ellis County. Movement of ground water in the alluvium is principally downstream, but along the valley margins some movement is toward the center of the valley. Smoky Hill River is a gaining stream throughout its course in the report area (Pl. 2).

Interrelation of Precipitation, Runoff, and Recharge

In central Kansas the original source of all ground water is local precipitation. Part of the precipitation evaporates directly from the land surface on which it falls; part seeps into the soil and is absorbed by the roots of plants and transpired; part runs off in surface streams; and a part infiltrates the ground and percolates downward to the ground-water reservoir. Evaporation takes place whenever moisture is available and humidity, temperature, and air movement are suitable. Usually, air movement is adequate and humidity is low, hence moisture will evaporate whenever it is available at or near the land surface. During the growing season, plants transpire moisture whenever it is available in the soil or whenever the water table is shallow enough to be reached by the roots. During the precipitation, water seeps into the soil until the capacity of the soil to absorb water is satisfied, after which the excess runs off in surface streams. When precipitation falls at a rapid rate, a large proportion of the precipitation becomes runoff, and streams may flood their valleys. The amount of water that runs off a given area is measured by gaging the streams that drain the area. In Table 2 runoff is expressed in inches. Runoff is 1.00 inch when the amounts of water flowing from a drainage area would form a layer 1.00 inch deep if spread uniformly over the area.

The amount of water that runs off the area of this report is approximately the difference in the flow of Smoky Hill River between the Ellis and Russell gaging stations. Between these two stations, surface drainage flows into Smoky Hill River from the valley, valley slopes, and the drainage basins of Big Creek and Big Timber Creek. The area drained between these two stations is 1,335 square miles and includes all the area covered by this report. Table 2 gives the annual discharge in acre-feet of Smoky Hill River

TABLE 2.—*Discharge of Smoky Hill River near Ellis and Russell.**

Year	Annual discharge, acre-feet		Increment, Ellis to Russell, acre-feet	Runoff, Ellis to Russell, inches	Precipitation at Hays, inches	Percent of precipitation that is runoff
	Near Ellis	Near Russell				
1942......	78,110	191,200	113,090	1.59	29.61	5.4
1943......	12,300	21,400	9,100	.13	16.19	.8
1944......	67,640	191,300	123,660	1.74	29.70	5.9
1945......	12,000	65,830	53,830	.76	20.34	3.7
1946......	113,500	175,000	61,500	.86	26.48	3.3
1947......	32,710	97,250	64,540	.90	22.65	4.0
1948......	37,350	72,370	35,020	.49	26.19	1.9
1949......	129,400	228,100	98,700	1.39	23.62	5.9
Average..................................				0.98	....	3.9

* Records collected by Surface Water Branch and published in Water-Supply Papers, U. S. Geological Survey.

at the gaging stations near Ellis and near Russell, the increase in runoff between the two stations, the runoff in inches from the drainage area between the two stations, and the ratio of runoff to the precipitation at Hays for the period 1942-1949. During this period runoff ranged from 0.13 inch in 1943, when precipitation at Hays was 16.19 inches, to 1.74 inches in 1944, when precipitation was 29.70 inches. In general, runoff is greatest when precipitation is above normal and least when precipitation is below normal. The average runoff during this period was about 1 inch, or approximately 4 percent of the precipitation.

The amount of water available to recharge the ground-water reservoir is the amount in excess of that discharged by evaporation and transpiration and by surface runoff into the streams. Recharge takes place by infiltration of water from the soil, when it is saturated, downward to the water table; by the infiltration of water into deep cracks and other openings that extend below the zone from which plant roots obtain water that is transpired; and by seepage of water into the ground from streams that are above the water table. A large part of the recharge in the Smoky Hill Valley probably comes from precipitation falling on the nearly flat terrace surface where conditions are more favorable for infiltration than for runoff. Additional recharge is received from ephemeral streams that carry runoff across the terrace surface and have channels above the water table. Water seeps into the ground along the banks and beds of these streams and percolates to the water table. Normally, Smoky Hill River and Big Creek are lower than the water table and receive water from the ground-water reservoir, but during flood stages the streams may contribute a small amount of recharge to the zone of saturation by lateral seepage into the channel banks and by vertical infiltration into the alluvial material they overflow.

The hydrographs of several observation wells (Fig. 12) show the relation between precipitation and fluctuations of the water table. Wells 14-16-17cb and 15-18-1bb show that the water table rose in the summers of 1947 and 1949 following periods of heavy rainfall and declined in the fall of 1947 and 1948 following periods of light rainfall. The water table reached a high point several weeks after the period of excessive precipitation. The time interval represents the time required for percolation of ground water to the water table.

An approximation of the amount of recharge can be obtained by multiplying the magnitude of the rise of the water table by the specific yield of the water-bearing material. If the specific yield is assumed to be 15 percent, then the rise of the water level of well 14-16-17cb of 0.8 foot in June and July, 1947, and of 1.0 foot in May

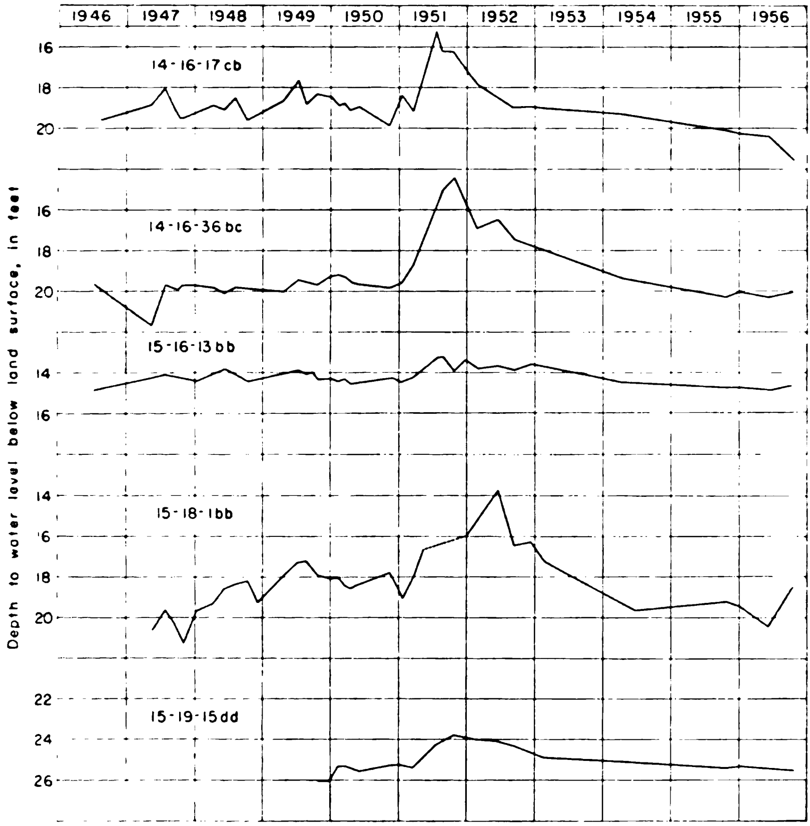

FIG. 12.—Hydrographs of five observation wells.

and June, 1949, indicates recharge in the vicinity of this well to have been 0.12 foot in June and July, 1947, and 0.15 foot in May and June, 1949. The effect of this recharge seemingly was offset by increased discharge of ground water into the channel of North Fork Big Creek. Generally, recharge is greater during periods of above-normal precipitation and less during periods of below-normal precipitation. Probably the average annual recharge over a long period of time is about 0.3 to 1 inch a year.

Fluctuations of the Water Table

The surface of the ground-water body is not stationary but fluctuates much like the water level in a lake or reservoir. Over a long period of time under natural conditions, a state of approximate equilibrium is attained between the amount of water added annually to ground-water storage and the amount discharged annually. The water table rises when recharge exceeds discharge and declines when discharge exceeds recharge.

In 1947, 14 wells were selected for observation wells, and the water levels in some of these wells have been measured periodically since that time. The descriptions of the wells and the measurements of water levels in them have been published in the annual water-level reports of the U. S. Geological Survey for the years 1947 through 1955. The measurements for 1956, 1957, 1958, and 1959 were published in Kansas Geological Survey Bulletins 125, 131, 141, and 146 and measurements for ensuing years will be published as bulletins. Figure 12 is a graphic representation of the changes in water levels in five of these wells. Precipitation and cumulative departure from normal precipitation at Hays are shown in Figure 3. A comparison of the hydrographs in Figure 12 with the precipitation records in Figure 3 shows a correlation between rise in water levels and periods of excessive precipitation, and decline in the water levels and periods of subnormal precipitation. The water levels in wells 14-16-17cb and 14-16-36bc rose about 4 and 5 feet, respectively, during the first half of 1951, owing to the heavy precipitation that caused the floods of May, June, and July, 1951. During the period from August 1946 to February 1952 the net rise in water level in well 14-16-17cb was 1.8 feet, in well 14-16-36bc was 2.8 feet, and in well 15-16-13bb was 1 foot. During this period, the net cumulative departure above the normal precipitation was 32.47 inches. During the period from February 1952 to October 1956 the net decline in water level in well 14-16-17cb was 3.8 feet, in well 14-16-36bc was 3.1 feet, and in well 15-16-36bb was 0.9 foot. During this period the net cumulative departure below the normal precipitation was 31.11 inches. During the period August 1946 to October 1956 water levels in wells 14-16-17cb and 14-16-36bc had a net decline of 2 feet and 0.3 foot, respectively, and in well 15-16-13bb a net rise of 0.1 foot. During the period the net cumulative departure below normal precipitation was 0.64 inch.

In general, the water table is high during wet periods and is low during dry periods. During wet seasons, more water is added to ground-water storage because recharge is greater, and more water is available in the soil for transpiration and evaporation. During dry seasons, more ground water is transpired by plants whose roots tap the water table; streams are so low that ground water is discharged into them; and recharge is at a minimum. Thus, ground-water levels tend to decline during periods of drought. In general, the fluctuations of the water table are approximately cyclic, just as are seasons of wet and dry weather.

The Ground-Water Reservoir

The main water table.—In the Smoky Hill Valley the main ground-water reservoir is in the alluvial materials adjacent to Smoky Hill River. In southwestern Ellis County and southeastern Trego County the alluvium is separated from the older Pleistocene deposits by shale walls that confine the ground-water reservoir to the narrow trough of the inner valley. The water table in the alluvium is higher than Smoky Hill River and ground water is discharged into the river except during flood stages. The water table in the alluvium of the valleys of the principal tributaries to the river is continuous with the water table in Smoky Hill Valley, and ground water moves down these valleys into Smoky Hill Valley. The depth to water in the alluvium of Smoky Hill Valley may be as much as 21 feet, but is less than 15 feet in many places. At the present time, the alluvium is tapped by only a few wells, but it is potentially the source of much greater supplies in this area. One of the Hays municipal wells has been test-pumped at a rate of 860 gallons a minute, and wells of large yield probably could be constructed at any place in the valley where the saturated part of the alluvium is thick.

In southeastern Trego County the main water table extends into the narrow meandering bedrock channel filled with deposits of Kansan age (Fig. 7, Pl. 2). Water from the alluvium moves down-

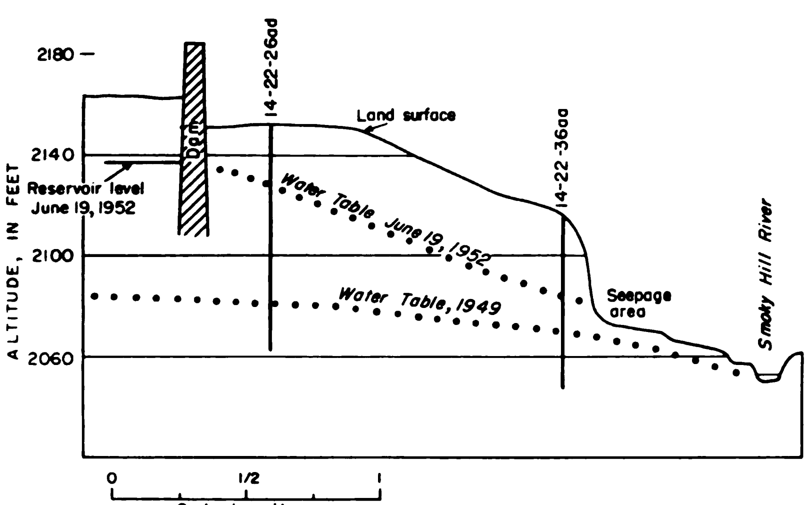

Fig. 13.—Water table in Pleistocene rocks near Cedar Bluff dam in 1949 and 1952.

stream through this channel and back into the alluvium again where the channel joins the alluvium. In 1949 the depth to water in the Kansan deposits was 71.86 feet in well 14-22-26ad and 42.65 feet in well 14-22-36aa. The maximum thickness of saturated material was about 32 feet. In June 1952 the water level in well 14-22-26ad was 25.49 feet below land surface, and in well 14-22-36aa was 30.52 feet below land surface. Figure 13 shows the relation of the water table in the Kansan deposits to the reservoir and river near the Cedar Bluff dam in 1949 and in 1952.

In southeastern Ellis County the main water table in the alluvium is continuous with the water table in the Crete deposits underlying the Pfeifer Terrace. In this area the depth to water ranges from 14 to 35 feet, being greatest in the terrace areas and least in the alluvium next to the river.

Along Big Creek the main water body extends through the undifferentiated Pleistocene deposits that underlie the broad high terrace north of the stream. The water table in these deposits is higher than the creek, which gains water from the ground-water reservoir along its course. In this area the depth to water ranges from 12 feet to 55 feet (Pl. 2). In the alluvium adjacent to Big Creek and North Fork Big Creek the depth to water is generally less than 20 feet. The depth to water is greatest in the uplands, the maximum depth being along the divide between Big Creek and North Fork Big Creek.

Along part of its course in Ranges 16 W. and 17 W., the south bank of Big Creek is formed by walls of relatively impervious shale in the Greenhorn Limestone. The shale beds isolate small bodies of ground water in the upland from the alluvium near the creek, but almost no ground water moves toward the creek from the shale outcrop areas.

Isolated water bodies.—Much of the ground water available to wells in the area of this report is in small ground-water bodies not connected to the main bodies along the principal streams. These water bodies occur in the Crete deposits under the Pfeifer Terrace, in the Nebraskan(?) deposits in the Antonino ridge, and in the alluvium of the upland. Figure 14 illustrates water tables in various ground-water reservoirs in southeastern Trego County.

Along much of the valley west of Schoenchen and locally in southeastern Ellis County, the terrace deposits of the Crete Formation are separated from the alluvium by shale bluffs, which form boundaries between the main water table adjacent to the river and the body of ground water in the Crete Formation. On Plate 2 the

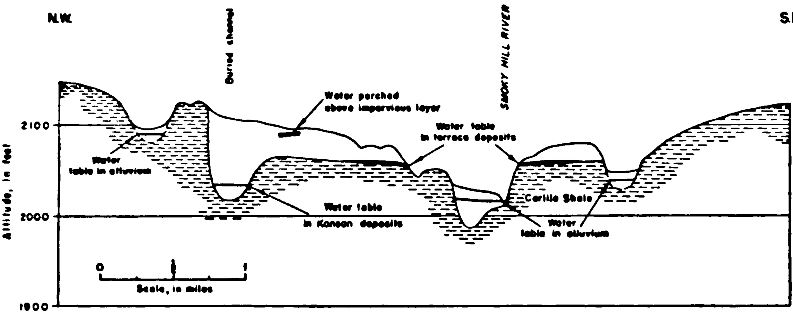

FIG. 14.—Water tables in Pleistocene rocks in southeastern Trego County.

water table in the Crete Formation has been contoured. Near Cedar Bluff dam the water table in the Crete deposits is 30 to 40 feet above the water table in the nearby alluvium, but the difference in altitude of the two water tables decreases downstream, and at Schoenchen they are only 20 feet apart.

Along the shale bluffs between the Pfeifer Terrace and Smoky Hill River Valley, locally along the upland margin of the terrace, and where tributary streams have cut through the Crete deposits and intrenched the underlying shale are small areas where the Crete deposits are dry. Seepage occurs locally along the shale bluffs during periods when the water table is high, and permanent springs flow where some of the major tributaries intersect the water table in the Crete Formation. In T. 15 S., R. 19 and 20 W., the channel cut into Kansan deposits is not deep enough for the water table in them to connect with the water table in the alluvium of Smoky Hill Valley. In this part of the area, the water body in the Crete Formation extends into the underlying Kansan deposits. Several permanent springs or zones of seepage mark the intersection of major tributary streams with this channel (Fig. 7).

Locally, clay lenses in the upper part of the upper Pleistocene deposits cause small zones of perched water several feet above the general water table in these deposits. Generally, these zones are wet-weather phenomena, and wells drilled into them go dry during dry seasons.

In general, the depth to water in the Crete deposits is about 17 to 53 feet and averages about 32 feet. Locally, along the margin of the terrace where springs occur, the depth to water is less than 10 feet, and several shallow wells have been constructed in such favored locations.

A small body of ground water occurs in the Nebraskan(?)

deposits under the narrow ridge extending southeastward through Antonino. These deposits are remnants of a channel fill overlying the eroded surface of the Carlile Shale. They are about 5 to 20 feet thick, and the depth to water on the ridge is generally between 10 and 15 feet. No wells penetrating these deposits are reported to yield large supplies, but the village of Antonino is supplied with water from several wells of small yield.

Locally, the alluvium along small streams in the upland contains small bodies of ground water, which supply many farm wells of small yield. Ground water moves down valley in the alluvium and eventually joins the main ground-water reservoir along the principal streams. The depth to water in the upland valleys is generally less than 20 feet and the thickness of saturated material may be as much as 20 feet.

The alluvial deposits near Smoky Hill School in the southwestern part of T. 15 S., R. 19 W., contain a body of water that extends under an area of several square miles and supplies water to several farm wells. The depth to water in these deposits is between 20 and 30 feet. The direction of ground-water movement is toward the northeast, and the gradient of the water table is about 20 feet per mile (Pl. 2).

Discharge

Natural discharge.—Before any wells were drilled, the ground-water reservoir in this area was in a state of approximate equilibrium; that is, the average annual recharge was balanced by the average annual discharge and the water table was moderately stable, except for fluctuations caused by seasons of excessive or abnormally low precipitation. Ground water was discharged principally by seepage into Smoky Hill River and its tributaries and by subsurface movement to the east. Small amounts of ground water are discharged by transpiration and by evaporation where the water table is shallow.

The principal methods by which ground water is discharged at the present time are by subsurface movement to the east in the alluvium, Crete deposits, and undifferentiated Pleistocene deposits along Big Creek, and by effluent seepage into Smoky Hill River, Big Creek, and other streams. Each of the principal streams in the area gains water from the ground-water reservoir (Pl. 2), and seepage is an important factor in maintaining the flow of the perennial streams.

Part of the ground water in the alluvial rocks in Smoky Hill and

Big Creek Valleys moves into the area from the west by lateral seepage in the subsurface. Likewise, part of the ground water leaves the area by lateral seepage to the east.

Some water is discharged from the ground-water reservoir through transpiration from plants whose roots penetrate the capillary fringe. Trees that line the banks of Big Creek along most of its course discharge a considerable amount of water during the growing season. Along Smoky Hill River, trees are less numerous and the discharge of ground water by transpiration is not so great. Locally, along Smoky Hill River and in some of the small upland valleys, deep-rooted crops such as alfalfa discharge ground water by transpiration, but because the areas of these crops are small, the amount of ground water transpired is not great.

Discharge from wells.—In 1951, there were no irrigation or industrial wells in the area of this report, and except for the Hays municipal wells near Schoenchen, no large quantities of ground water were discharged through wells in the Smoky Hill Valley. Hays had five municipal wells that tap alluvial deposits of Smoky Hill River. According to officials of the city of Hays, about 185 million gallons of water was pumped from these wells during 1950 and about 195 million gallons in 1951. The maximum daily amount used by the city was about 1.8 million gallons in 1950 and 2 million gallons in 1951. The amount of water pumped by the city probably was more than the total amount of water pumped by all other users in the report area.

Artesian Conditions

Occurrence of Artesian Water

Ground water in a permeable bed confined under pressure between two less permeable beds is regarded as artesian or confined water. When a well is drilled into the permeable water-bearing formation, water will rise in the well above the level at which it is first tapped. A flowing artesian well is one in which the water rises above the land surface. In the following discussion the term artesian is used for both nonflowing and flowing wells. In the classic artesian system the permeable bed dips from an outcrop area where recharge occurs toward the area of artesian flow (Fig. 15). Where the land surface is lower than the piezometric surface of the water in an artesian aquifer, flowing wells may be constructed.

In this area wells drilled into the Dakota Formation are artesian but do not flow. Twenty-seven of the wells shown on Plate 2

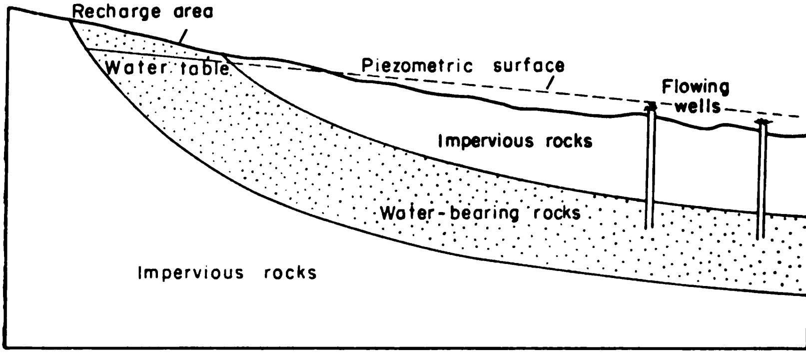

FIG. 15.—Diagrammatic section showing simple artesian system.

obtain water from the Dakota Formation in three general areas: (1) along the upland between Smoky Hill and Big Creek Valleys in southeastern Ellis County; (2) north of the Pfeifer Terrace west of Antonino, and (3) west of the Smoky Hill School in southwestern Ellis County. Water from wells in the Dakota Formation differs considerably in quality from place to place and the artesian head seems to differ to some extent, indicating that the sandstones penetrated by the wells are not necessarily interconnected.

Recharge of Artesian Aquifers

Several investigators have postulated different ideas concerning recharge to the Dakota artesian aquifers. Russell (1928) suggested that all water in sandstones of the Dakota is connate and that the formation receives no recharge. Others (Darton, 1909a, 1909b) have regarded the Dakota as a classic artesian system having elevated intake areas along the eastern front of the Black Hills and Rocky Mountains. Latta (1941, p. 40, pl. 5) indicated that the Dakota receives recharge in outcrop areas in southeastern Colorado.

If the Dakota aquifers received no replenishment, wells tapping them would record gradually diminishing hydrostatic head and the water supply would eventually be exhausted. Wells tapping the Dakota in central Kansas are known to produce water for many years without noticeable change in head. The water levels in wells that have been measured at different times show fluctuations of the piezometric surface that can be explained only by the addition of water to the artesian reservoirs. For instance, the piezometric surface in well 15-17-19ab was 1.1 feet higher in February 1950 than it had been in July 1946. Also, Frye and Brazil (1943, fig. 7) have shown that water was moving eastward in the upper sandstone of the Dakota in Russell County. This movement could occur only if water was being added to the aquifer.

Because the sandstone beds are lenticular and discontinuous, ground water could not move readily through the Dakota for the great distances from southeastern or central Colorado to central Kansas. Therefore, a recharge area near to the area of this report seems most likely. Sandstones of the Dakota are overlain by saturated Neogene rocks in a broad area less than 100 miles south and southwest of this area (Waite, 1942, pl. 5; McLaughlin, 1949, pl. 3). Those areas are relatively near the area of this report and the Dakota might receive recharge there. Another possibility is by recharge in the report area, or nearby, by the downward percolation of water through joints and fractures in the Cretaceous shale and chalk beds or by slow percolation through the shale, which is not wholly impervious. Small seeps issuing from joints in the shale and chalk have been noted, and if the joints extended deep enough, water could move through them to the sandstones of the Dakota.

Any explanation of the method of recharge to sandstones of the Dakota must account for the differences in hydrostatic head between different sandstone bodies and for the considerable variation in chemical quality from place to place. The ground water probably is replenished in a combination of ways and from a combination of sources. The water being added to the aquifer may be mixed with connate water or may dissolve mineral matter from local soluble rock material. The entire hydraulic system in the Dakota sandstones from the recharge area through conduits to the reservoirs tapped by wells is undoubtedly extremely complex.

Utilization of Ground Water

During the course of the investigation, information was obtained on 141 wells, of which 132 are domestic or stock wells, 6 are public-supply wells, 2 are industrial wells, and 1 is a municipal test well. The principal uses of ground water in this area are for domestic, stock, and public supplies.

Domestic and Stock Supplies

Water for domestic use is obtained almost entirely from wells, but in parts of the area a few cisterns are used. Domestic wells supply homes with water for drinking, cooking, and washing, and supply those schools not served by municipal wells. Stock wells supply water for livestock, principally cattle. Most of the water for livestock also is obtained from wells, but in recent years stock ponds have been constructed on dry water courses in areas where supplies of ground water are difficult to obtain. Although many wells obtain water from either the alluvium or terrace deposits at relatively shallow depths, some wells obtain water from the Dakota Formation at depths of as much as 200 feet.

Public Water Supplies

Hayes and Victoria are the only cities in the vicinity that have public water-supply systems. Brief descriptions of these systems are given below, and details of well construction are given in Table 11 at the end of this report.

Hays.—The city of Hays, on the terrace of Big Creek, obtains its water supply from wells in the valleys of Big Creek and Smoky Hill River. Prior to the summer of 1949, the water supply for Hays was obtained from 15 wells tapping the alluvium and terrace deposits of Big Creek. Owing to a need for additional water, the city in June 1949 constructed five gravel-packed wells in Smoky Hill Valley south of Hays. These wells obtain water from sand and gravel of terrace deposits that directly underlie the flood plain of Smoky Hill River. During 1950 and 1951 approximately 50 percent of the water supply for Hays came from the five wells in Smoky Hill Valley; locations are shown on Plate 2, and additional construction data are given in Tables 3 and 11.

In 1949 Hays had 2,105 water customers each using an average of 508 gallons a day. The city has a water storage capacity of 1,100,000 gallons. Consumption was 390,566,040 gallons of water during 1949, declined to 368,658,000 gallons in 1950, and rose again to 391,371,000 gallons in 1951. The water is chlorinated, aerated to remove the iron, and softened by use of lime and soda ash. Maximum daily consumption in 1951 was about 2 million gallons.

Victoria.—The city of Victoria, along North Fork Big Creek, obtains its water supply from five wells tapping the alluvium of tributaries of North Fork Big Creek. Data regarding these wells are given by Latta (1948, p. 153).

In 1949 Victoria had 266 water customers each using an average of 124 gallons a day. Victoria has a water storage capacity of 50,000 gallons and consumes about 11,650,000 gallons a year. In 1951 the only water treatment was chlorination.

TABLE 3.—*Data on Hays municipal wells in Smoky Hill Valley*

U. S. G. S. no.	City no.	Static water level, feet	Depth, feet	Length of screen, feet	Length of casing, feet	Yield, gpm	Drawdown, feet	Length of pumping test, hours
15–18–28da1	S–1	12.0	57	28	30	400	12.0	72
						450	14.0	
						500	16.5	
						550	18.3	
						600	22.0	
						650	25.0	
						700	27.0	
15–18–28da2	S–2	13.0	53	28	24	460	11.2	24
						600	13.9	
						800	20.6	
						830	21.0	
						860	24.0	
						600	15.0	
15–18–27cb1	S–3	11.5	51	28	24	250	16.0	48
						280	17.4	
						300	18.0	
						350	19.7	
						400	23.0	
						450	26.5	
						460	28.0	
15–18–27cb2	S–4	10.2	55	28	28	408	6.0	48
						589	11.0	
						672	16.0	
						760	21.5	
						805	23.0	
						844	26.0	
15–18–27ca	S–5	11.0	54	36	20	300	12.5	48
						400	16.0	
						500	18.5	
						560	28.0	
						590	30.0	

TABLE 4.—*Analyses of water from wells in southern Ellis County and parts of Trego and Rush Counties*

Dissolved constituents given in parts per million [a]

Well Number	Depth of well below land surface, feet	Geologic source	Date of collection	Temperature (°F)	Specific conductance (micromhos at 25°C)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na+K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids (residue on evaporation at 180°C)	Hardness as $CaCO_3$: Calcium, magnesium	Hardness as $CaCO_3$: Noncarbonate
14-16-10dd	17.6	Pleistocene undifferentiated	3-24-47	51	599	....	0.10[b]	90	9.8	18	272	24	21	0.6	30	361	265	42
14-16-16ab	24.7	(?)Greenhorn Limestone	10-31-49	56	934	32	.34	150	8.0	37	288	132	62	.2	32	610	408	172
14-16-17cb	24.0	Terrace deposits	3-24-47	53	631	....	.05[b]	103	9.2	9.0	282	38	28	.3	3.0	383	295	64
14-16-18bb2	34	do	11-15-46	....	....	28	.03	117	7.4	5.8	344	24	11	.1	15	397	322	40
•14-16-20dd	48.9	Pleistocene undifferentiated	3-24-47	58	584	....	.10[b]	97	8.7	4.0	296	21	13	.2	4.0	342	278	35
14-17-17bb	35.8	do	3-21-47	60	535	....	.00[b]	92	11	1.5	236	53	16	.2	8.0	340	275	81
14-17-25aa	28.0	do	3-24-47	56	3,160	....	.10[b]	478	48	72	219	51	930	.1	3.0	1,690	1,390	1,210
14-18-12bb	31.0	do	3-21-47	60	2,810	....	.00[b]	10	6.3	599	487	247	480	7.0	5.0	1,590	53	0
14-19-29dd	350	Dakota Formation	10-28-49	59	3,840	20	3.9	17	9.6	845	540	268	836	6.0	3.9	2,270	82	0
14-20-28ad	22.8	Carlile Shale or alluvium	10-29-49	57	691	32	.31	109	17	10	308	32	29	.1	46	430	342	89
14-20-32aa1	39.4	Crete Formation	10-22-49	57	634	35	.14	86	14	29	264	40	30	.2	42	422	272	56
14-20-32dd2	43.0	do	3-21-47	62	620	....	.00[b]	100	12	4.5	276	30	35	.1	2.0	391	299	110
14-20-35dc	19.5	do	3-21-47	62	649	....	.00[b]	108	9.2	1.0	296	26	18	.4	10	427	307	64
14-21-30ca	29.2	Alluvium	10-29-49	59	1,040	32	4.7	156	29	39	284	262	29	.7	55	772	508	275
14-21-31cd	13.2	do	10-29-49	62	1,210	39	.10	174	43	43	268	416	23	.6	22	938	611	391
14-21-34ba	20.9	do	10-29-49	58	1,980	36	.26	342	48	20	194	496	97	.4	348	1,480	1,050	891
14-21-35ca	19.1	Crete Formation	10-22-49	59	1,600	27	.26	214	38	101	224	538	78	.5	69	1,180	690	506
14-21-35cd	19.8	Terrace deposits	10-22-49	59	1,670	45	.77	226	78	81	374	648	41	.3	26	1,330	884	577
14-22-26ad	90.7	Grand Island Formation	10-29-49	....	510	35	.19	76	11	20	248	53	9.0	.4	9.0	368	235	32
15-16-6cb	56.9	Pleistocene undifferentiated	10-29-49	58	465	38	.39	86	4.8	4.8	268	7.2	8.0	.1	6.7	298	234	14
15-16-9aa	132.6	Dakota Formation	3-24-47	57	8,440	....	.05[b]	56	50	1,760	190	523	2,460	2.4	3.5	4,950	345	189
15-16-14ab	203.8	do	3-24-47	55	929	....	.10[b]	121	14	47	311	106	44	.7	40	571	359	104
15-16-18bb	188.1	do	3-24-47	58	4,430	....	.05[b]	92	25	858	359	411	1,030	3.2	20	2,610	332	38
15-16-21bd	18.3	Nebraskan(?) deposits	10-29-49	59	1,120	28	.19	88	15	147	340	140	91	1.0	55	730	291	2

15-16-25bb	19.4	Crete Formation	10-29-49	59	635	31	.04	96	6.8	17	268	16	28	.2	36	416	268	48
15-17-5ba	149.9	Dakota Formation	3-24-47	58	6,800	....	.10[b]	43	26	1,460	382	461	1,830	4.0	5.0	4,020	214	0
15-17-14dd	170.6	do.	3-24-47	57	5,590	....	.00[b]	87	35	1,120	460	556	1,300	.2	8.0	3,330	361	0
15-17-25bc	15.2	Crete Formation	3-24-47	50	501	....	.05[b]	90	5.5	5.2	232	29	6.5	.3	35	332	247	57
15-17-33dc	16.7	Terrace deposits	10-29-49	57	1,590	34	.24	258	38	9.4	326	632	55	.2	2.4	1,190	800	533
15-18-1bb	32.8	(?)Carlile Shale	10-31-49	56	3,100	29	9.5	627	68	148	396	1,570	144	1.0	1.7	2,780	1,840	1,520
15-18-9bb	269.5	Dakota Formation	10-31-49	59	3,640	38	....	562	89	341	280	1,780	298	1.0	4.1	3,250	1,770	1,540
15-18-13ab	26.7	(?)Carlile Shale	3-24-47	54	2,760	....	.10[b]	662	19	13	298	1,260	101	1.3	70	2,280	1,730	1,490
15-18-16bb	16.4	Alluvium	3-21-47	51	2,080	....	.00[b]	403	30	68	282	844	137	.5	20	1,660	1,130	899
15-18-20ab	23.5	do.	10-31-49	59	6,000	32	....	479	49	767	412	84	1,870	.1	.8	3,500	1,400	1,060
15-18-22bb	47.2	Nebraskan(?) deposits or (?)Greenhorn Limestone	10-31-49	56	2,710	42	20	624	54	41	364	1,460	33	1.0	1.6	2,440	1,780	1,480
[c]Hays municipal wells	[d]51-57	Terrace deposits	1- 5-53	....	....	17	2.0	116	18	39	203	230	28	.8	1.2	506	364	198
[c]15-18-28da1	57.0	do.	4-18-49	....	....	23	.25	157	25	43	235	340	26	.8	3.9	788	494	301
[c]15-18-28da2	53.0	do.	4- 5-49	....	....	23	2.8	155	26	40	226	347	22	.8	1.5	783	494	309
15-18-29dd1	18.8	do.	10-31-49	59	886	37	.04	139	21	30	196	296	19	.6	2.8	654	434	273
[c]15-18-29dd2	52	do.	9- 47	....	....	24	1.8	136	22	35	243	271	14	.8	4.4	705	430	231
15-18-30ab	13.6	Crete Formation	10-29-49	61	1,430	41	.20	206	30	78	336	296	42	.4	204	1,060	638	362
15-18-33ba	153.8	Dakota Formation	3-21-47	63	3,590	....	.00[b]	18	13	770	334	264	860	3.6	2.0	2,100	98	0
15-19-2aa	17.3	Nebraskan(?) deposits	10-21-49	60	1,320	37	.50	117	32	110	304	164	97	.5	130	904	424	175
15-19-4ad	290.2	Dakota Formation	10-28-49	58	1,430	23	4.7	77	25	208	304	306	125	1.4	.6	908	295	46
15-19-7ab	30.3	Crete Formation	10-22-49	58	498	47	.17	69	9.0	24	212	29	15	.3	45	338	209	35
15-19-10ad1	28.6	Alluvium	10-29-49	57	617	30	.04	104	13	8.3	296	29	16	.1	44	384	313	70
15-19-12aa	16.2	Nebraskan(?) deposits	10-21-49	59	785	40	.10	86	22	61	356	80	21	.4	41	520	305	13
15-19-27da	156.3	Dakota Formation	3-21-47	62	600	....	.00[b]	85	15	28	342	32	12	.4	4.0	388	274	0
15-19-28dd	26.5	Pleistocene undifferentiated	10-22-49	57	1,350	36	.15	148	26	125	260	346	95	.4	51	968	477	264
15-19-32cb	32.3	do.	10-22-49	58	1,210	43	.16	163	30	80	316	366	32	.7	20	880	530	271
15-20-7aa	18.7	Crete Formation	10-29-47	61	1,060	32	.64	156	25	46	294	250	38	.3	46	732	492	251
15-20-12ad	32.5	do.	10-21-49	58	913	29	3.1	130	14	18	244	8.0	45	.1	184	628	382	182
15-21-5ab	11.1	do.	10-29-49	63	1,050	36	.14	137	14	53	196	98	60	.1	208	780	400	239
16-18-10cb	168.2	Dakota Formation	10-29-49	59	3,830	18	3.2	21	12	792	344	268	886	5.0	.8	2,170	102	0

a. One part per million is equivalent to 1 pound of substance per million pounds of water or 8.34 pounds per million gallons of water.
b. In solution at time of analysis.
c. Analysis by laboratory of Kansas State Board of Health.
d. Composite from five wells (15-18-27ca, -27cb1, -27cb2, -28da1, -28da2).

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

Cation	Conversion factor	Anion	Conversion factor
Ca^{++}	0.0499	HCO_3^-	0.0164
Mg^{++}	.0822	SO_4^{--}	.0208
Na^+	.0435	Cl^-	.0282
K^+	.0256	NO_3^-	.0161
		F^-	.0526

CHEMICAL QUALITY OF THE GROUND WATER

The chemical quality of ground water in the report area is indicated by analyses of water from 49 representative farm wells and from 7 municipal wells (Table 4). Factors for converting analytical results reported in parts per million to equivalents per million are given in Table 5. The relations of the principal mineral constituents in the water are shown graphically in Figure 16. Water samples from the farm wells were analyzed in the laboratory of the U. S. Geological Survey Quality of Water Branch in Lincoln, Nebraska; the water samples from the municipal wells and systems were analyzed by Howard Stoltenberg in the Laboratory of the Kansas State Board of Health. W. H. Durum, chemist, Quality of Water Branch, has prepared a preliminary report on the chemical quality of ground water in the area (1951).

Chemical Constitutents in Relation to Use

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

Dissolved solids.—The residue left after a natural water has evaporated generally consists of mineral matter, some organic materials, and a small amount of water of crystallization. Except for difficulties resulting from hardness, water containing less than 500 ppm of dissolved solids generally is satisfactory for domestic use. Water having more than 1,000 ppm of dissolved solids is likely to contain enough of certain constituents to produce a noticeable taste or to make the water unsuitable in other respects. Figure 17, adapted from Wilcox (1948), indicates that water having dissolved solids equivalent to a specific conductance of 3,000 micromhos or more (about 1,800 ppm for bicarbonate or chloride waters) is unsuitable for irrigation.

Dissolved solids in samples of water from wells ranged from 298 to 4,950 ppm. Samples from 16 wells contained less than 500 ppm, 18 samples contained between 500 and 1,000 ppm, 15 samples con-

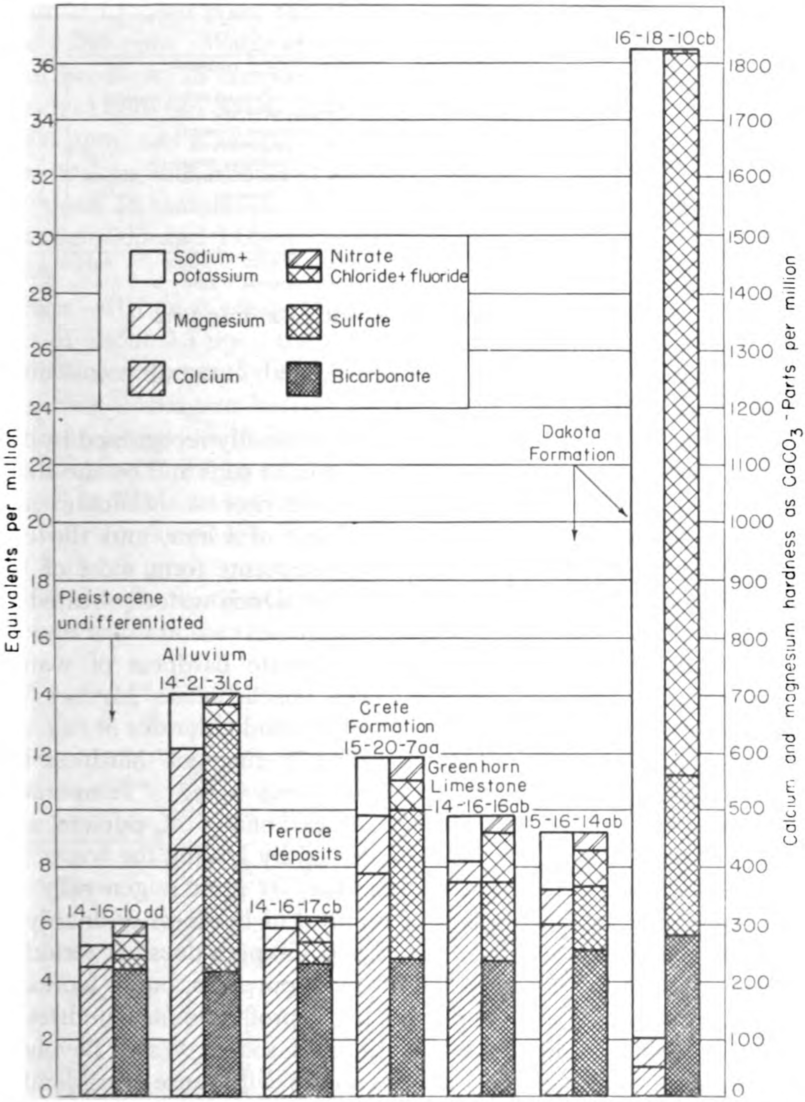

FIG. 16.—Graphic representation of chemical analyses of water from wells in principal water-bearing formations.

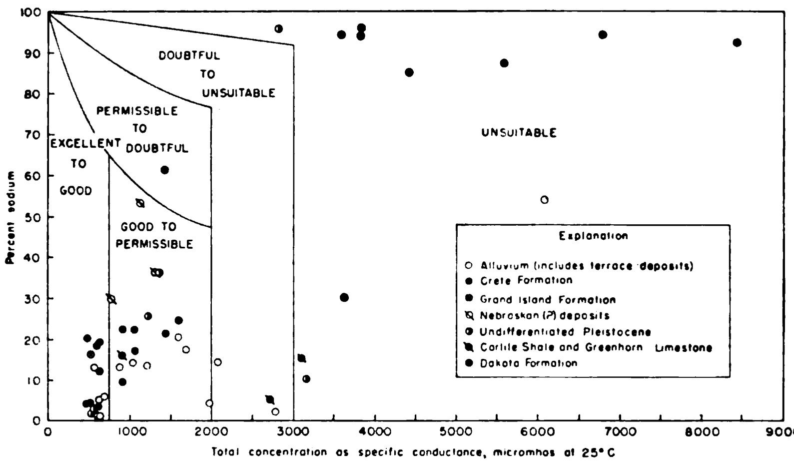

FIG. 17.—Classification of water for irrigation.

tained between 1,000 and 3,000 ppm, and 5 samples contained more than 3,000 ppm.

Hardness.—The hardness of water is generally recognized by the amount of soap needed to produce a lather or suds and by the curd-like scum that forms during the washing process. Calcium and magnesium cause nearly all the hardness of water, and the carbonate and sulphate salts of these constituents form most of the scale in steam boilers and other vessels in which water is heated or evaporated.

The total hardness and the noncarbonate hardness of waters analyzed are given in Table 4. The noncarbonate hardness of water is caused by the presence of sulfates and chlorides of calcium and magnesium and is sometimes called "permanent" hardness because it can not be removed by boiling the water. "Temporary" hardness, caused by the presence of carbonates of calcium and magnesium in the water, can be removed by boiling the water.

Water having a hardness of less than 50 ppm is generally regarded as soft, and treatment for removal of hardness ordinarily is not necessary. Hardness between 50 and 150 ppm does not seriously interefere with the use of water for most purposes, but it increases the consumption of soap, and softening is profitable for laundries or other industries using large quantities of soap. Water having a hardness in the upper part of this range will cause considerable scale in steam boilers. Hardness exceeding 150 ppm is noticeable, and if the hardness is 200 or 300 ppm, the water for household use commonly is softened or cisterns are installed to collect rain water. When municipal water supplies are softened, hardness is generally reduced to about 100 ppm. Additional softening of a public supply is often judged not worth the increase in cost.

Samples of water from the report area ranged in total hardness from 53 to 1,840 ppm, and the noncarbonate hardness ranged from 0 to 1,540 ppm. Water samples from 4 wells had less than 150 ppm total hardness, 15 samples had between 150 and 300 ppm, 20 samples had between 300 and 500 ppm, 7 samples had between 500 and 1,000 ppm, and 8 samples had more than 1,000 ppm; 7 water samples had no noncarbonate hardness, 18 samples had between 1 and 100 ppm, 18 samples had between 100 and 500 ppm, 5 samples had between 500 and 1,000 ppm, and 6 samples had more than 1,000 ppm.

Iron.—If iron is present in ground water in concentrations in excess of about 0.3 ppm, the excess will precipitate upon exposure to air. Water containing excess iron will have a noticeable discoloration and a disagreeable taste. Iron may be removed from most water by aeration and filtration.

The concentrations of iron in 34 samples of water that are reported in Table 4 ranged from 0.03 to 20 ppm. Water samples from 18 wells contained less than 0.3 ppm, 6 samples contained between 0.3 and 1.0 ppm, 9 samples contained between 1.0 and 10.0 ppm, and 1 sample contained 20 ppm. The areal distribution of iron in ground water in the area is shown in Figure 18.

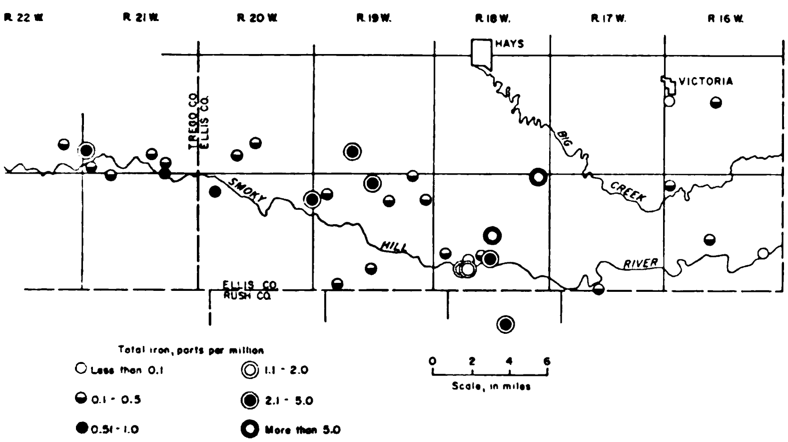

Fig. 18.—Map showing locations and limits of iron concentrations of selected water samples.

Chloride.—Chloride, an abundant constituent of sea water, is normally present in small to moderate amounts in water from wells. Chloride is dissolved from rock materials, derived from sewage and industrial wastes, or results from sea water entrapped in marine rocks. Locally in this area, some chloride is derived from brine that is pumped from oil wells and is allowed to contaminate shallow ground-water supplies. Small concentrations of chloride have little effect on the suitability of water for most uses, but water containing more than about 500 ppm may have a salty taste. Water containing much chloride is unsuitable for irrigation and generally is corrosive to pipes and steam boilers.

Concentrations of chloride in water samples collected for chemical analysis ranged from 6.5 to 2,460 ppm; 45 samples contained less than 500 ppm, 4 samples contained between 500 and 1,000 ppm, and 5 samples contained more than 1,000 ppm. The water in well 15-18-20ab has been contaminated by oil-field brine and the sample contained 1,870 ppm of chloride.

Fluoride.—Fluoride in concentrations of about 1.0 ppm helps prevent tooth decay, but fluoride in concentrations exceeding about 1.5 ppm may cause a discoloration known as "mottled enamel", which appears on the teeth of children who drink the water during the period when permanent teeth are forming. Fluoride in the water samples from wells in this area ranged from 0.1 to 7.0 ppm; 7 samples contained more than 1.5 ppm.

Nitrate.—Recent discoveries (Comly, 1945; Metzler and Stoltenberg, 1950) indicate that excessive amounts of nitrate in water used in the preparation of food for infants may cause infant cyanosis.

The Kansas State Board of Health judges that waters containing more than 45 ppm of nitrate as NO_3 are unsafe for use in infant feeding and that infant cyanosis is likely if the concentration of nitrate exceeds 90 ppm. Concentrations of nitrate in water samples from wells in the report area ranged from 0.6 to 348 ppm. Water samples from 12 wells contained more than 45 ppm nitrate and samples from 5 wells (14-21-34ba, 15-18-30ab, 15-19-2aa, 15-20-12ad, and 15-21-5ab) contained more than 90 ppm.

Some nitrate in ground water may be derived by solution of nitrate-bearing rocks, from the application of nitrate fertilizers, or from the growing of legumes in recharge areas, but strong concentrations may be due to seepage of surface water from a barnyard or other source of contamination. Table 6 is a comparison of the nitrate in water from 27 dug wells and 26 drilled or bored wells in the report area.

TABLE 6.—*Comparison of nitrate concentrations in water from dug and drilled wells*

Range in concentration of nitrate (ppm)	Dug wells		Drilled or bored wells	
	No.	Percent	No.	Percent
0–10	7	26	19	73
11–45	10	37	5	19
46–90	7	26	0	0
More than 90	3	11	2	8

Sodium.—For irrigation water the sodium content generally is expressed as the ratio of the concentration of sodium, in equivalents per million, to the total concentration of the cations (calcium, magnesium, sodium, potassium). This ratio, expressed as a percentage, is called "percent sodium". Water that has a large percent sodium, if used to irrigate certain types of soils, may deflocculate clays in the soil and cause the soil to become compacted. The percent sodium permissible in water for irrigation varies with the specific conductance, becoming smaller as the specific conductance increases (Fig. 17).

In the report area, water samples from wells ranged in percent sodium from 1 to 96. The percent sodium in 9 samples, including 8 from the Dakota Formation, was more than 60, but most of the water samples, except those from the Dakota Formation, are classed "excellent to good" or "good to permissible" for irrigation (Fig. 17).

Boron.—Water containing less than 1.0 ppm boron generally is considered satisfactory for irrigating even such boron-sensitive crops as citrus trees, melons, and nut trees. None of the water samples analyzed contained more than 1.0 ppm.

Chemical Quality of Water in Relation to Geologic Source

The chemical quality of the ground water in the water-bearing formations has a wide range. In some formations it also varies widely in quality from place to place. In general, water from the different Pleistocene formations is similar in type and in degree of mineralization but differs from the water in the Dakota Formation, which is principally of the sodium chloride type. The quality of water in the principal water-bearing formations, the Dakota Formation, undifferentiated Pleistocene deposits, Crete Formation, terrace deposits, and alluvium, is discussed below and is illustrated graphically by Figure 16. The number of water samples collected from the Carlile Shale, Greenhorn Limestone, Grand Island Formation, and Nebraskan(?) deposits was not sufficient to indicate the quality of water in these formations.

Dakota Formation.—Water from the Dakota Formation in this area generally is of the sodium chloride type, contains a large amount of dissolved solids, and is hard. A summary of several of the principal chemical constituents is given in Table 7. Total dis-

TABLE 7.—*Summary of concentrations of some chemical constituents in 11 water samples from wells in Dakota Formation*

Range in concentration (ppm)	Number of samples			Range in concentration (ppm)	Number of samples	
	Dissolved solids	Chloride	Total hardness		Nitrate	Fluoride
0–200	0	3	3	0.0–1.5	2	5
201–500	1	1	7	1.6–5.0	6	5
501–1,000	2	3	0	5.1–10	1	1
1,001–2,000	0	3	1	10.1–20	1	0
2,001–3,000	4	1	0	21–40	1	0
More than 3,000	4	0	0	More than 40	0	0

solved solids of 11 samples analyzed ranged from 388 to 4,950 ppm and averaged about 2,400 ppm. Except for well 15-18-9bb, which contained calcium sulfate type water, the total hardness ranged from 82 to 361 ppm and averaged 246 ppm, the lowest for the principal water-bearing formations. Six samples contained more than 1.5 ppm of fluoride, the greatest amount being 6.0 ppm from well 14-19-29dd. The fluoride concentrations of the 11 samples averaged 2.5 ppm.

Concentrations of chloride are considerably greater in samples from the Dakota Formation than in samples from the other aquifers. The concentrations ranged from 12 ppm for water from well 15-19-27da to 2,460 ppm for water from well 15-16-9aa. Only 2 water samples contained less than 100 ppm chloride, and 4 samples contained more than 1,000 ppm. The average of 11 samples was 880 ppm.

The concentrations of nitrate in the samples from the Dakota Formation are less than those from the other principal aquifers in the area, probably because most of the wells are drilled wells of small diameter, which are not as likely to be polluted by surface wastes as are larger diameter dug wells. Nine samples contained less than 10 ppm nitrate, and the greatest amount was 40 ppm.

Undifferentiated Pleistocene deposits.—Undifferentiated Pleistocene deposits yield water to wells in two parts of the area shown on Plate 1, in a small area in the southwestern part of T. 15 S., R. 19 W., near the Smoky Hill School and in a more extensive "high terrace" area along Big Creek east and southeast of Hays. Analyses of 8 water samples from these deposits were made, 2 from wells in the Smoky Hill School area, and 6 from wells in the Big Creek area. Water from well 14-17-25aa was of the calcium chloride type and had a dissolved solids concentration of 1,690 ppm and a hardness of 1,390 ppm. Water from well 14-18-12bb was of the sodium chloride type and had 1,590 ppm dissolved solids, 7 ppm fluoride, and 53 ppm hardness, the lowest hardness of the samples analyzed. Durum (1951, p. 25) suggested that the quality of this water might have been affected by intrusion of altered brine from one of the nearby oil fields. The other 6 samples were calcium bicarbonate type similar to the water from the other Pleistocene deposits in the area. For these 6 samples, dissolved solids ranged from 298 to 968 ppm and averaged 531 ppm, total hardness ranged from 234 to 530 ppm and averaged 343 ppm, and the fluoride content was low. Water from well 15-19-28dd contained 51 ppm nitrate; the nitrate concentrations of the other samples were less than 31 ppm.

Crete Formation.—Water samples from 11 wells tapping the Crete Formation in the "high terrace" area along Smoky Hill River were collected and analyzed. Water from wells 14-21-35ca, 15-18-30ab, and 15-29-7aa was of the calcium sulfate type and contained much bicarbonate. The sulfate is probably due to the solution of gypsum in the Carlile Shale in the vicinity of these wells. The other samples from the Crete Formation were of the calcium bicarbonate type and contained considerable hardness and dissolved solids but only a moderate amount of chloride and small amounts of fluoride and iron. Five samples contained more than 45 ppm of nitrate, and 2 samples contained more than 90 ppm. The 5 samples containing more than 45 ppm were from shallow wells ranging in depth from

TABLE 8.—*Summary of concentrations of some chemical constituents in 11 water samples from wells in Crete Formation*

Range in concentration (ppm)	Number of samples: Dis-solved solids	Number of samples: Total hard-ness	Range in concentration (ppm)	Number of samples: Chlo-ride	Number of samples: Ni-trate	Range in concentration (ppm)	Number of samples: Fluo-ride	Number of samples: Iron*
			0.0–5.0	0	1	0.0–0.1	4	1
300 or less	0	5	5.1–20	3	1	0.11–0.5	7	5
301–500	6	4	21–45	6	4	0.51–1.5	0	1
501–1,000	3	2	46–90	2	2	1.51–10	0	1
More than 1,000	2	0	More than 90	0	3	More than 10	0	0

* Total iron determined for only 8 samples.

12 to 33 feet, and the nitrate concentrations probably were caused by seepage from barnyards into the shallow aquifer. Table 8 is a summary of several of the principal chemical constituents in water from the Crete Formation.

Alluvium and terrace deposits.—Sixteen water samples from wells in the alluvium and associated late Pleistocene terrace deposits were collected for analysis. Four water samples were of the bicarbonate type; one sample of water (from well 15-18-20ab) contaminated with oil-field brine was of the chloride type; and 11 samples were of the sulfate type. Concentration of sulfate in water in the alluvium is most common in the western part of the area and in the Hays well-field area near Schoenchen. As in the Crete deposits, the sulfate is probably derived from gypsum in the adjacent Carlile Shale.

Water in the alluvium and terrace deposits is hard and relatively strongly mineralized. Except for well 15-18-20ab, the total hardness ranged from 295 to 1,130 ppm and averaged 564 ppm; dissolved solids ranged from 383 to 1,660 ppm and averaged 827 ppm. The fluoride and chloride contents were low, and the percent sodium was generally less than 20. The concentration of iron was excessive, only 3 samples out of 14 had less than 0.1 ppm iron, and 4 samples had more than 1.0 ppm. Water from wells 14-20-28ad (46 ppm nitrate), 14-21-30ca (55 ppm) and 14-21-34ba (348 ppm) contained more than 45 ppm nitrate. The nitrate concentrations in water from these wells may be the result of infiltration of water to the ground-water reservoir or well from barnyards or other sources of contamination.

A summary of the principal chemical constituents in water in the alluvium and terrace deposits is given in Table 9.

TABLE 9.—*Summary of concentrations of some chemical constituents in 16 water samples from wells in alluvium and terrace deposits*

Range in concentration (ppm)	Number of samples: Sulfate	Number of samples: Dissolved solids	Number of samples: Total hardness	Range in concentration (ppm)	Number of samples: Nitrate	Range in concentration (ppm)	Number of samples: Iron*
Less than 100	4	0	0	Less than 10	8	Less than 0.1	3
101–200	0	0	0	11–20	2	0.1–1.0	6
201–300	4	0	1	21–45	3	1.1–5.0	4
301–500	4	4	8	46–90	2	5.1–10.0	0
501–1,000	3	7	4	91–200	0	10.1–20	0
1,001–2,000	1	4	3	More than 200	1	More than 20	0
More than 2,000	0	1	0				

* Total iron determined for only 13 samples.

POLLUTION BY OIL-FIELD BRINES

Considerable brine is produced with crude petroleum pumped from the oil fields of the area. Some oil wells produce only a small amount, whereas others, especially old wells from which a large part of the recoverable oil has been pumped, may produce hundreds of barrels of brine daily. During the early period of oil field development, most of the brine was discharged into shallow earth "evaporation ponds". The principle of the evaporation pond was that the brine was removed from the pond by evaporation, which is relatively rapid in this area during the summer. Just how the mineral matter in the brine was to be removed is not clear, inasmuch as evaporation removes only the water and leaves the mineral matter behind in the increasingly concentrated brine. Frye and Brazil (1943) indicated that 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 rock, such as shale. Ponds are unsatisfactory for the disposal of brine where the near-surface materials are pervious and contain fresh water, as do the 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.

In the oil fields of this area, evaporation ponds have been constructed of shale and other impervious material, but in alluvial valleys many of the ponds are constructed of permeable alluvium. Brine may seep out of these ponds and contaminate the fresh water in the alluvium or flow away on the surface to contaminate the surface streams in the area. Figure 19 indicates the theoretical movement of brine from a pond of porous material into the ground-water body in the alluvium and into the surface drainage.

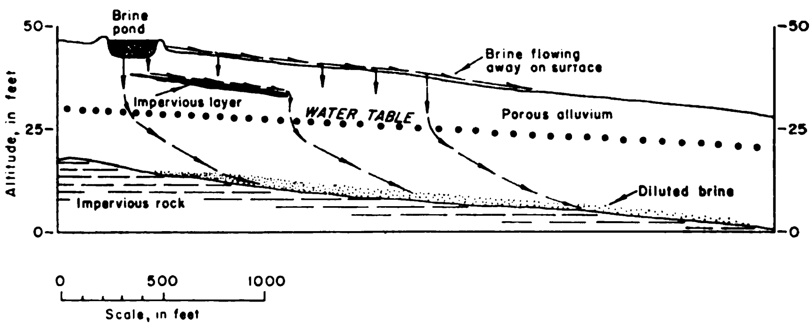

FIG. 19.—Diagrammatic section showing theoretical movement of oil-field brine.

Contamination in Ruder Creek valley.—Brine produced with oil in the Ruder oil pool in the central part of T. 15 S., R. 18 W. (Fig. 4), began to contaminate ground water in the alluvium of the valley soon after the field was put into production in 1936. By 1951, the alluvium for 2 miles below the oil pool was contaminated with brine, and contaminated ground water seemed to be moving down the valley toward Smoky Hill River. The water sample from well 15-18-20ab is an example of water that has been contaminated by oil-field brine. The contamination in this tributary valley was the result of the method formerly used for disposing of brine in shallow ponds from which it seeped into the alluvium, overflowed into surface streams, or seeped through the walls of the pond and flowed away on the land surface. Since 1951 brine pumped with the oil in the Ruder pool has been pumped into deep wells, and the contamination of the water in the alluvium gradually is decreasing as fresh water from precipitation flushes out the brine. Many years must elapse, however, before the effects of contamination disappear.

Possible contamination in other oil-field areas.—As previously quoted by Frye and Brazil, disposal of oil-field brines in surface ponds is safe only where the ponds are constructed of impervious materials. In the report area impervious clays are formed by weathering of the Carlile Shale and by soil formation in the late Pleistocene silts. Brine ponds constructed of these materials would probably not allow subsurface seepage or outflow through the pond walls and would be satisfactory in this respect. The mineral constituents that cause the contamination of water, however, will not be evaporated from any pond; therefore, such ponds are potential sources of ground-water contamination because of the possibility that they might overflow during periods of heavy precipitation and carry minerals into ground water during recharge. If they are abandoned, the concentration of mineral salts in the ponds will be left as potential sources of contamination.

Ground Water Regions and Areas

Ground-water regions and areas are shown on Figure 20, and the general availability of water in each region or area is given in Table 10. The report area is divided into three ground-water regions: the uplands, the Smoky Hill and Big Creek terraces, and the main valleys. Regions in which ground-water conditions are not uniform are divided into ground-water areas.

Upland Regions (U)

Three ground-water regions are of the upland type: the southeastern Ellis County upland, the southwestern Ellis County upland, and southeastern Trego County upland. In general, upland regions are areas of shale bedrock locally covered by thin layers of loess or colluvium. Water supplies are not abundant and generally are restricted to the alluvium of small valleys or to deep wells drilled into the Dakota Formation.

Southeastern Ellis County upland (U-1).—In the southeastern Ellis County upland the Cretaceous bedrock lies at or near the surface. The region is characterized by gently rolling hills, by relatively flat minor divides, and by steep bluffs where it borders Smoky Hill River and Big Creek valleys. The region is poorly supplied with ground water and in many places has no potable ground-water supplies. Locally, wells drilled nearly 200 feet to the sandstones

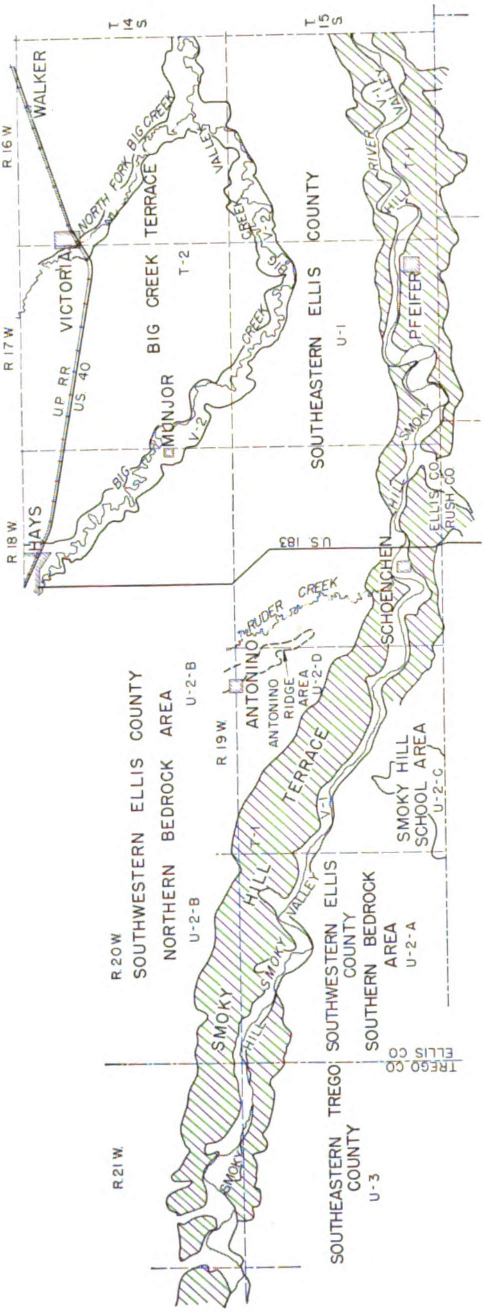

FIG. 20.—Ground-water regions and areas.

TABLE 10.—*General availability of ground water by areas*

Region and area	General availability of water	Principal geologic source	Depth to water, feet	General quality of ground water	Remarks
(U) Upland regions:					
(U-1) Southeastern Ellis County.	Small supplies.	Dakota Formation, alluvium.	Dakota: average 112. Alluvium: 18.	Dakota: moderately high in Na, Cl, Fl, Fe. Alluvium: hard.	Dakota: artesian conditions; average well depth, 190 feet.
(U-2) Southwestern Ellis County upland bedrock areas.					
(U-2-A) Southern bedrock area.	Small to moderate supplies.	Dakota Formation, alluvium.	Dakota: 300 or more. Alluvium: 30 or less.	No data.	Reported data only.
(U-2-B) Northern bedrock area.	Moderate supplies.	Dakota Formation, alluvium.	Dakota: average about 160. Alluvium: 30 or less.	Dakota: soft, high in Fl, Fe. Alluvium: hard.	
(U-2-C) Smoky Hill School area.	Moderate supplies.	Undifferentiated Pleistocene.	20 to 30.	No data.	Water-table conditions.
(U-2-D) Antonnio ridge area.	Moderate supplies.	Nebraskan(?) deposits.	15 or less.	Hard.	Alluvial deposits capping small ridge. Water-table conditions.
(U-3) Southeastern Trego County.	Small supplies locally.	Dakota Formation, alluvium.	Dakota: 300 or more. Alluvium: 20 or less.	No data.	Many areas without water supplies.
(T) High terrace regions:					
(T-1) Smoky Hill terrace.	Moderate supplies, except locally.	Crete Formation, alluvium.	10-50, average about 30.	Hard, high in Fe.	Shale bedrock locally above water table.
(T-2) Big Creek terrace.	Moderate supplies.	Undifferentiated Pleistocene deposits.	12-55, average about 30.	Hard, otherwise good.	Water-table conditions.
(V) Main valley areas:					
(V-1) Smoky Hill Valley.	Small to large supplies.	Terrace deposits and alluvium.	Generally less than 20.	Hard.	Yielded more than 700 gpm in tested wells.
(V-2) Big Creek Valley.	Small supplies.	Terrace deposits and alluvium.	20 to 30.	Hard.	

of the Dakota Formation yield small to moderate supplies of mineralized water. In many places, water in the Dakota Formation is too mineralized to be suitable for human or livestock use. Shallow wells of small yield have been constructed in the alluvium along some of the small streams, but these wells go dry during prolonged periods of drought, hence are not dependable sources of ground water. At a few places where the Greenhorn Limestone and Carlile Shale are deeply weathered, shallow wells obtain a small yield from these formations. In general, water supplies in the southeastern Ellis County upland are small, undependable, or strongly mineralized.

Southwestern Ellis County upland bedrock areas (U-2).—The southwestern Ellis County upland is the region that includes the strongly dissected upland south of Smoky Hill River in the southwestern corner of the county (U-2-A), and the shale slopes, pediment slopes, and gently rolling upland adjacent to the prominent terrace north of Smoky Hill River (U-2-B). Except for two small areas (C and D) discussed below, the region is not well supplied with ground water. Dependable wells of moderate yield may be drilled in the alluvium of the larger tributary streams, but in the alluvium of the smaller tributaries only small supplies can be obtained. Locally, wells 300 to 500 feet deep drilled to the Dakota Formation yield moderate supplies of ground water suitable for domestic and stock use. Elsewhere, areas of several square miles, such as the east-central part of T. 15 S., R. 20 W., are devoid of any potable ground-water supplies because the Dakota Formation contains strongly mineralized water and no alluvial deposits are present.

Smoky Hill School area (U-2-C).—Several farms and one rural school in an area of about 4 square miles in the southwestern part of T. 15 S., R. 19 W., Ellis County, and several square miles in northern Rush County are supplied from a body of ground water in undifferentiated Pleistocene alluvial deposits. The depth to water is 20 to 30 feet. Ground water moves northeastward at a hydraulic gradient of about 20 feet per mile. Yields are moderate and supplies are dependable.

Antonino ridge area (U-2-D).—Ground water is found at depths generally less than 15 feet in Pleistocene (Nebraskan?) alluvial deposits under the narrow ridge extending southeastward through Antonino to the center of sec. 18, T. 15 S., R. 18 W. Wells of small to moderate yields supply the residents of Antonino and several farms to the southeast. No large yields are reported, but the supply is dependable.

Southeastern Trego County (U-3).—Except for the valley area and the Smoky Hill terrace region, discussed below, southeastern Trego County is an upland region of flat-topped, steep-sided, strongly dissected hills underlain by the Niobrara Chalk. This region is almost devoid of ground-water supplies, except for a few wells that tap the Dakota Formation, reported to be more than 500 feet deep, and for wells of small yield tapping alluvial deposits in small tributary valleys.

High Terrace Regions (T)

Smoky Hill terrace (T-1).—The Smoky Hill terrace region is the flat to gently rolling, slightly dissected region adjacent to Smoky Hill River valley. It is underlain by the Crete Formation and locally by the Grand Island Formation and in many places is separated from the valley by shale banks. Except where the shale bedrock protrudes above the water table, moderate ground-water supplies are available from the Pleistocene deposits throughout the region. Ground water in the Crete Formation moves toward Smoky Hill River and downstream. The hydraulic gradient ranges from 20 to 40 feet per mile but averages about 35 (Pl. 2). Wells average about 30 feet deep, have small to moderate yields, and are dependable.

Big Creek terrace (T-2).—The Big Creek terrace lies principally north of Big Creek in east-central Ellis County; the surficial rocks are unconsolidated alluvial deposits. Moderate supplies of ground water under water-table conditions are found at shallow depths in the region. Depth of wells ranges from 12 to 55 feet and averages about 30 feet. The principal aquifers are stream-deposited sand and gravel of undifferentiated Pleistocene age. In general, ground water moves from the divides toward the principal streams, Big Creek and North Fork Big Creek. The hydraulic gradient ranges from about 12 to 50 feet per mile and averages about 25 feet per mile (Pl. 2). The ground water is hard but serves all domestic and farm uses.

Main Valley Areas (V)

The inner valley of Smoky Hill River, which is mapped as alluvium on Plate 1, and the valley of Big Creek are the two main valley areas.

Smoky Hill Valley (V-1).—The Smoky Hill Valley area, a flat area ¼ to 1 mile wide bordering the stream, generally is well supplied with ground water under water-table conditions. Alluvium and Wisconsinan terrace deposits are as much as 65 feet thick, and as much as 40 feet is saturated. The material generally is coarse sand and gravel sufficiently permeable to yield water readily to wells. Yields of more than 700 gallons a minute were reported during test-pumping of wells near the Hays municipal well field. Depth to water is generally less than 20 feet. Where the thickness of saturated material is less, yields are proportionately smaller.

Ground water moves downstream and toward the river and discharges into the stream. Generally the water contains iron and is hard but is used for domestic and farm purposes.

Big Creek Valley (V-2).—Big Creek Valley is the flat, terraced area adjacent to the creek. The width is ½ to 1 mile and averages about ¾ mile. Ground water occurs under water-table conditions in alluvial deposits adjacent to the stream. Ground water moves into these deposits from the high terrace deposits, principally north of the valley, and within the alluvial deposits it moves generally downstream. The alluvial deposits are principally sand, gravel, and silt; the lower saturated material consists principally of gravel locally intermixed with silt. The saturated thickness and permeability are not great, and yields of wells generally are small. The depth to water averages about 20 feet.

RECORDS OF WELLS AND TEST HOLES

Information pertaining to 41 test holes, 9 drilled observation wells, 80 jetted observation wells, and 141 wells is tabulated in Table 11. The 141 wells includes 132 domestic or stock wells, 6 public-supply wells, 1 industrial well, 1 well for oil-well drilling water, and 1 public-supply test well.

TABLE 11.—*Record of wells and test holes in southern Ellis County and parts of Trego and Rush Counties, Kansas*

WELL NUMBER (1)	Owner or tenant	Type of well (2)	Depth of well below land surface, feet (3)	Diameter of well, inches	Type of casing (4)	Principal water-bearing bed: Character of material	Principal water-bearing bed: Geologic source	Method of lift (5)	Use of well (6)	Height of land surface above mean sea level, feet	Depth to water level below land surface, feet (7)	Date of measurement	REMARKS (Yield given in gallons a minute; drawdown in feet)
13-16-31cc	Kansas Geological Survey	Dr	28.0	4	N	Sand and gravel	Pleistocene undifferentiated	N	N	1,973.3	15.65	11- 5-49	Test hole. Log included in report.
13-17-36aa	do	Dr	26.0	4	N	Silt, sand, gravel	do	N	N	1,991.9	11.50	11- 5-49	do
14-16-6cb	do	Dr	30.0	4	N	Gravel	do	N	N	1,949.0	19.38	11- 5-49	do
14-16-7bc	do	Dr	28.0	4	N	Sand and gravel	Terrace deposits	N	N	1,909.6	24.57	11- 5-49	do
14-16-7cc	do	Dr	35.0	4	N	do	do	N	N	1,902.3	18.80	11- 5-49	do
*14-16-10dd		Du	17.6	30	R	Limestone gravel	Pleistocene undifferentiated	Cy, W	N	1,904.5	13.52	5-10-42	Abandoned stock well.
											14.05	9-26-49	
14-16-11cc	H. H. Robben	Du	13.1	54	R	Sand and gravel	do	Cy, W	S	1,900.1	10.62	8- 2-46	
											12.35	9-26-49	
14-16-12bb	F. H. Schulte	Du	17.0	28	R	Sand	do	Cy, H	D	1,908.8	14.48	9-26-49	
14-16-13dd	J. M. Rome	B	30.4	6	GI	do	do	Cy, H	N	1,886.9	25.60	9-26-49	Abandoned stock well.
*14-16-16ab	Wm. H. Bevens	Du	24.7	42	R	Weathered limestone	Greenhorn Limestone(?)	Cy, W	D, S	1,889.8	21.46	9-27-49	
*14-16-17cb	J. M. Schippern	Du	24.0	60	R	Sand and gravel	Terrace deposits	Cy, W	S, O	1,886.2	19.16	9-26-49	Observation well.
14-16-18bb1	A. G. Wagner	Du	30.7	42	R	Silt, sand, gravel	do	Cy, W	D	1,902.1	25.38	9-26-49	
*14-16-18bb2	City of Victoria	Du	34	180	Br	do	do	T, E	P		25	1946	Victoria well no. 1.
14-16-18cb	Kansas Geological Survey	Dr	40.0	4	N	do	Pleistocene undifferentiated	N	N	1,941.8			Test hole. Log included in report.
14-16-19bb1		Du	39.5	34	R	Sand and gravel	do	Cy, W	S	1,924.4	35.52	9-27-49	
14-16-19bb2	Kansas Geological Survey	Dr	40.0	4	N	do	do	N	N	1,929.2	38.50	11- 5-49	Test hole. Log included in report.
14-16-19cc	do	Dr	40.0	4	N	do	do	N	N	1,944.0	28.45	11- 4-49	do
*14-16-20dd	D. Smithberger	Dr	48.9	10	GI	do	do	Cy, W	S	1,903.8	43.40	7-17-46	
											41.74	9-26-49	
14-16-21cb	P. A. Dreiling	Du	37.0	36	R	do	do	J, E	D	1,891.4	32.50	9-26-49	
14-16-22aa	V. G. Tholen	Du	27.6	36	R	do	do	Cy, W	S	1,884.0	21.42	9-26-49	
14-16-22cb		Du	18.4	36	R	do	do	Cy, W	S	1,856.4	14.85	9-27-49	
14-16-26ac	B. J. Wagner	Du	29.5	42	R	Gravel	Terrace deposits	Cy, W	D, S	1,837.7	25.62	9-26-49	
14-16-28cd	Dan J. Braun	Du	52.7	42	R	Limestone	Greenhorn Limestone(?)	Cy, W	D, S	1,892.0	50.87	9-27-49	
14-16-30cc	Kansas Geological Survey	Dr	68.0	4	N	Sand and gravel	Pleistocene undifferentiated	N	N	1,938.1	55.10	11- 4-49	Test hole. Log included in report.
14-16-31cc	do	Dr	65.0	4	N	Gravel and sand	do	N	N	1,928.9	43.50	11- 4-49	do

14-16-31dd	M. Dinkle	Du	36.2	48	R	Sand and gravel	do	Cy, W	S	1,887.2	34.31	9-27-49	
14-16-32ab		Du	50.9	27	R	do	do	Cy, W	N	1,805.2	49.30	7-12-46	Abandoned stock well.
											49.02	9-27-49	
14-16-34ba		B	15.6	6	GI	do	Terrace deposits	Cy, H	D	1,839.1	14.57	9-28-49	
14-16-36bc	Tony Wagner	Du	29.0	43	R	Sand	do	Cy, W	S	1,836.1	19.77	7-17-46	Observation well.
											19.48	7- 6-49	
14-16-36dd		Du	13.2	36	R	do	Carlile Shale(?)	N	N	1,907.1	9.60	9-27-49	Abandoned stock well.
14-17-12da	Kansas Geological Survey	Dr	30.0	4	N	Gravel and sand	Terrace deposits	N	N	1,904.8			Test hole. Log included in report.
14-17-16ad		Du	19.1	42	R	Sand and gravel	Pleistocene undifferentiated	Cy, W	S	1,993.9	16.96	8- 2-46	
											15.80	9-26-49	
*14-17-17bb	Leo Dellva	Du	35.8	36	R	do	do	Cy, W	D, S	1,986.0	31.10	7-30-46	
											29.40	9-27-49	
14-17-19bb	Hilarius Gabel	B	40.0	6	GI	do	do	J, E	D	1,973.2	34.23	9-27-49	
14-17-20dd	Mrs. Stecklein	Dr	49.1	6	GI	do	do	Cy, W	N	1,953.4	26.00	7-16-46	Abandoned stock well.
											24.95	9-27-49	
14-17-23ba		Du	30.9	36	R	do	do	Cy, W	N	1,969.5	29.15	9-27-49	do
*14-17-25aa	Robert Goetz	Du	28.0	36	R	do	do	Cy, W	S	1,936.6	24.89	7-12-46	
											24.80	9-27-49	
14-17-27aa		Dr	30.0	6	GI	do	do	Cy, W	S	1,957.2	25.00	7-16-46	
14-17-27cc		Dr	65.5	5	GI	do	do	N	N	1,957.9	46.29	9-30-49	Abandoned stock well.
14-17-31aa	John Ruder	Dn, B	25.2	6	GI	Gravel	Terrace deposits	Cy, W	D, S	1,930.5	19.11	8- 9-46	
14-17-32bb	A. N. Pfannenstiel	Du	24.5	42	R	do	do	Cy, W	D, S	1,930.2	20.30	9-27-49	
14-17-34cc		B	37.4	5	GI	Sand	Pleistocene undifferentiated	Cy, W	S	1,935.6	34.11	9-28-49	
14-17-36bb	Frank Dinkel	B	50	5½	GI	Sand and clay	do	J, E	D	1,929.6	35.95	9-27-49	
14-18-9aa	Kansas Geological Survey	Dr	45.0	4	N	Sand and gravel	Terrace deposits	N	N	1,981.5	31.57	10-28-49	Test hole. Log included in report.
14-18-9ad	do	Dr	30.0	4	N	Gravel and sand	do	N	N	1,979.7	18.79	10-28-49	do
14-18-9bb1	do	Dr	53.0	5	N	Sand and gravel	Pleistocene undifferentiated	N	N	2,011.5	46.85	10-27-49	do
14-18-9bb2	do	Dr	65.0	5	GI	do	do	N	O	2,017.6	51.72	10-28-49	Recorder observation well. Log included in report.
14-18-9da	do	Dr	60.0	4	N	Gravel	do	N	N	2,011.6			Test hole. Log included in report.
14-18-9dd	do	Dr	60.0	4	N	Sand and gravel	do	N	N	2,007.4			do.
*14-18-12bb	J. Brull	Du	31.0	48	R	do	do	Cy, W	D, S	1,991.1	24.33	8-22-49	Observation well.
14-18-16da	Kansas Geological Survey	Dr	58.0	4	N	do	do	N	N	1,993.6	32.40	10-31-49	Test hole. Log included in report.
14-18-21aa	do	Dr	33.0	4	N	Gravel	do	N	N	2,005.5	22.85	10-31-49	do
14-18-25aa	Al Rohr	B	27.6	6	GI	Sand	Terrace deposits	J, E	D	1,944.7	23.12	8- 5-46	
											22.60	9-27-49	
14-18-26aa	F. J. Befort	Du	24	48	R	do	do	Cy, W	D, S	1,957.1	18.97	8-22-49	Observation well.
14-18-27cb	A. A. Dechant	Dr	345	7	GI	Sandstone	Dakota Formation	N	N	2,058.8	158.87	7-22-46	Unused stock well.
											158.87	10- 3-49	
14-18-29bb		Du	26.3	48	R	Sand and gravel	Alluvium(?)	Cy, W	S	2,066.9	21.45	7-26-46	
*14-19-29dd	Jacob M. Haas	Dr	350	6	GI	Sandstone	Dakota Formation	Cy, W	S	2,103.6	179.08	8-23-49	
14-19-31bc	Kansas Geological Survey	Dr	10.0	4	N	Silt and clay	Colluvium	N	N	2,085.0			Test hole. Log included in report.
14-19-31cc	do	Dr	40.0	1¼	GP	Sand and gravel	Crete Formation	N	O	2,062.5	31.79	10-22-49	Observation well. Log included in report.
14-19-32cb	do	J	16.7	¾	GP	do	Colluvium	N	O	2,077.4	Dry	9-27-50	Log included in report.
14-19-32cc	do	J	23.0	¾	GP	Silt and sand	Loveland Formation	N	O	2,071.0	16.90	9-16-50	do

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TABLE 11.—*Record of wells and test holes in southern Ellis County and parts of Trego and Rush Counties, Kansas—Continued*

WELL NUMBER (1)	Owner or tenant	Type of well (2)	Depth of well below land surface, feet (3)	Diameter of well, inches	Type of casing (4)	Principal water-bearing bed: Character of material	Principal water-bearing bed: Geologic source	Method of lift (5)	Use of well (6)	Height of land surface above mean sea level, feet	Depth to water level below land surface, feet (7)	Date of measurement	REMARKS (Yield given in gallons a minute; drawdown in feet)
14-19-34ba	Joe Feitz	Dr	217.5	6	GI	Sandstone	Dakota Formation	N	N	2,122.1	197.91	8-15-49	Unused stock well.
14-19-35dd	Kansas Geological Survey	Dr	30.0	4	N	Gravel	Nebraskan(?) deposits	N	N	2,108.4	....	....	Test hole. Log included in report.
14-20-25cc1	do	J	14.0	¾	GP	Sand and gravel	Alluvium	N	O	2,076.6	Dry	9-27-50	Log included in report.
14-20-25cc2	do	J	18.0	¾	GP	do	do	N	O	2,067.9	Dry	9-26-50	do
•14-20-28ad	Florence Solomon	Du	22.8	26	R, C	Silt, sand, gravel	Carlile Shale and alluvium	Cy, W	D, S	2,137.0	15.12	8-15-49	
14-20-30dd	Kutina Estate	B, Dn	30.8	5	GI	Sand and gravel	Crete Formation	Cy, W	D, S	2,087.5	30.55	10-10-49	
14-20-31aa	Kansas Geological Survey	J	28.5	¾	GP	Sand	do	N	O	2,083.0	Dry	8- 9-50	Log included in report.
14-20-31cc	do	J	18.0	¾	GP	Sand and gravel	Terrace deposits	N	O	2,018.1	8.20	9-16-50	do
•14-20-32aa1	Clarence Groff	Du	39.4	42	R	do	Crete Formation	Cy, W	D, S	2,088.6	27.75	10- 4-49	
14-20-32aa2	Kansas Geological Survey	Dr	41.0	1¼	GP	do	do	N	D, S	2,089.1	35.43	10-21-49	
14-20-32aa3	do	Dr	48.0	4	N	do	do	N	N	2,089.4	....	....	Test hole. Log included in report.
14-20-32ad	do	J	23.0	¾	GP	Sand	do	N	O	2,079.2	Dry	8-16-50	Log included in report.
14-20-32bb	do	J	29.0	¾	GP	Sand and gravel	do	N	O	2,089.7	Dry	8-19-50	do
14-20-32dd1	do	J	26	¾	GP	do	do	N	O	2,056.4	22.30	9-15-50	Observation well. Log included in report.
•14-20-32dd2	School District	Dr	43.0	8	GI	do	do	Cy, W	D	2,068.1	35.65	7-18-46	
											35.58	8-15-49	
14-20-34bb	Kansas Geological Survey	J	22.5	¾	GP	Sand	Colluvium	N	O	2,089.9	15.66	9-27-50	Log included in report.
14-20-34bc	do	J	27.0	¾	GP	do	Loveland(?) and Crete Formations	N	O	2,079.7	13.94	9-27-50	do
14-20-34cd	....	Du	45.4	30	C	Sand and gravel	Crete Formation	Cy, H	S	2,063.2	40.11	8-22-49	
14-20-35bb	Kansas Geological Survey	J	7.5	¾	GP	Clay	Colluvium	N	O	2,084.1	Dry	9-22-50	Log included in report.
14-20-35bc	do	J	18.8	¾	GP	Silt and gravel	Loveland and Crete Formations	N	O	2,071.9	9.05	9-27-50	do
14-20-35cc	do	J	25.4	¾	GP	Silt and sand	do	N	O	2,051.0	11.39	9-22-50	do
•14-20-35dc	F. A. Pfannenstiel	Du	19.5	72	R	Sand and gravel	Crete Formation	Cy, H	D	2,029.4	14.27	8-22-49	Formerly an observation well.
14-20-36dd	Kansas Geological Survey	J	21.5	¾	GP	Silt	Loveland Formation	N	O	2,072.9	16.26	9-16-50	Log included in report.
14-21-25cc	do	J	16.0	¾	GP	Sand and gravel	Crete Formation	N	O	2,073.4	12.90	9-15-50	do
14-21-25dd	do	J	27.0	¾	GP	Silt	Loveland Formation	N	O	2,106.2	12.20	9-15-50	do
14-21-26da	do	J	19.0	¾	GP	do	do	N	O	2,100.6	Dry	9- 7-50	do
14-21-27ad	do	Dr	95.0	4	N	Gravel	Grand Island Formation	N	N	2,108.4	76.70	10-19-49	Test hole. Log included in report.
14-21-27dd	do	J	30.0	¾	GP	Sand	Crete Formation	N	O	2,099.5	27.30	9-15-50	Log included in report.

14-21-28cb	do	J	27.1	¾	GP	do	do	N	O	2,118.4	Dry	8-3-50	do
14-21-28cc	do	J	25.0	¾	GP	do	do	N	O	2,096.7	12.50	8-3-50	do
14-21-29dc	Geo. Snyder	B	28.1	5½	GI	Sand and gravel	Alluvium	Cy, W	S	2,068.8	16.76	10-29-49	
•14-21-30ca	Tony Aschenburner	Du	29.2	42	C	do	do	Cy, W	D, S	2,071.8	18.48	10-29-49	
14-21-30cd	Kansas Geological Survey	J	16.8	¾	GP	Sand	Terrace deposits	N	O	2,065.4	13.08	7-14-50	Log included in report.
14-21-30da	do	J	21.0	¾	GP	do	Crete Formation	N	O	2,122.7	Dry	9-15-50	do
14-21-30dd	do	J	14.0	¾	GP	do	do	N	O	2,112.9	Dry	7-19-50	do
•14-21-31cd	Dave Yanda	Du	13.2	36	R	Sand and gravel	Alluvium	Cy, W	D	2,072.1	9.88	10-29-49	
14-21-32ad	Kansas Geological Survey	J	21.0	¾	GP	Sand	do	N	O	2,049.1	6.50	8-3-50	Log included in report.
14-21-33bb	do	J	28.0	¾	GP	do	do	N	O	2,057.7	7.90	8-3-50	Observation well. Log included in report.
14-21-33cc	Jake Augustine	Du	11.2	33	C	Sand and gravel	do	Cy, W	D, S	2,088.9	7.88	10-18-49	
14-21-34aa	Kansas Geological Survey	Dr	37.0	1¼	GP	do	Crete Formation	N	O	2,095.4	Dry	10-22-49	Log included in report.
14-21-34ad	do	Dr	26.0	4	N	do	do	N	N	2,087.3			Test hole. Log included in report.
•14-21-34ba	J. F. Wanamaker	Du	20.9	33	R	do	Alluvium	Cy, W	D, S	2,045.3	12.81	10-12-49	
14-21-34da	Kansas Geological Survey	Dr	68.0	4	N	do	Terrace deposits	N	N	2,041.4	16.90	10-13-49	Test hole. Log included in report.
14-21-34dd	do	Dr	18.0	4	N	do	Alluvium	N	N	2,028.4			do
•14-21-35ca	C. S. Holtzinger	Du	19.1	60	C	do	Crete Formation	Cy, W	D, S	2,076.3	17.35	8-15-49	
14-21-35cb	Kansas Geological Survey	J	11.0	¾	GP	Sand	Terrace deposits	N	O	2,047.4	Dry	8-4-50	Log included in report.
14-21-35cc	do	J	20.0	¾	GP	do	do	N	O	2,033.7	12.20	9-15-50	do
•14-21-35cd	C. S. Holtzinger	B	19.8	6	GI	Sand and gravel	do	Cy, W	D, S	2,037.8	15.04	8-15-49	
14-21-36bc	Kansas Geological Survey	J	20.0	¾	GP	do	Crete Formation	N	O	2,073.8	Dry	9-7-50	Log included in report.
14-22-25da1	do	J	8.1	¾	GP	do	Alluvium	N	O	2,103.3	6.90	9-15-50	do
14-22-25da2	do	J	7.1	¾	GP	do	do	N	O	2,098.9	5.25	9-15-50	do
•14-22-26ad	U. S. Bureau of Reclamation	Dr	90.7	6	GI	do	Grand Island Formation	J, E	D	2,151.8	71.86 25.49	10-29-49 6-19-52	Observation well.
14-22-36aa	Kansas Geological Survey	Dr	74.5	1¼	GP	do	do	N	O	2,114.7	42.65 30.52	10-19-49 6-19-52	Observation well. Log included in report.
14-22-36ad	do	J	24.4	¾	GP	do	Alluvium	N	O	2,069.2	6.95	9-15-50	Log included in report.
14-22-36da	do	J	17.4	¾	GP	do	do	N	O	2,068.3	6.50	9-15-50	do
14-22-36dd	do	J	11.6	¾	GP	do	do	N	O	2,063.4	3.85	9-15-50	do
15-16-2bb	C. D. Wagner	Du	35.1	46	R	do	Terrace deposits	Cy, W	D, S	1,860.8	34.23	9-27-49	
15-16-5aa	Leo Rajewski	Dr	21.3	7	GI	do	do	Cy, W	D	1,857.7	15.02	9-28-49	
•15-16-6cb	Louis Leiker	B	56.9	6	GI	do	Pleistocene undifferentiated	Cy, W	D	1,914.7	54.06	9-27-49	
15-16-6dd	Ted Tholan	Du	29.1	48	R	do	Terrace deposits	Cy, W	D, S	1,876.4	23.04	9-27-49	Observation well.
•15-16-9aa	H. Huser	Dr	132.6	6	GI	Sandstone	Dakota Formation	Cy, W	S	1,908.4	91.78	9-27-49	
15-16-12da	M. L. Gorham Co.	Du	13.4	48	R	Sand	Carlile Shale(?)	Cy, H	D	1,904.5	10.93 10.53	7-17-46 9-27-49	
15-16-13bb	Ethel M. Witt	Du	16.0	48	R	Limestone	Carlile Shale, Greenhorn Limestone	Cy, W	D, S	1,921.4	14.00	9-27-49	Observation well.
•15-16-14ab		Dr	203.8	6	GI	Sandstone	Dakota Formation	Cy, W	S	1,906.7	112.19	7-17-46	
15-16-16aa	Alfred Dreiling	Du	18.9	45	R	Sand and gravel	Alluvium	Cy, W	S	1,887.3	11.85	9-30-49	
15-16-18ab	Ed F. Schulte	Dr	177.0	6	GI	Sandstone	Dakota Formation	Cy, W	S	1,932.0	109.49	7-17-46	
•15-16-18bb	D. Vonfeldt	Dr	188.1	6	GI	do	do	Cy, W	D, S	1,930.3	109.60 107.28	7-26-46 9-28-49	
•15-16-21bd	John Kruger	Du	18.3	96	R	Gravel	Nebraskan(?) deposits	Cy, H	D	1,941.4	15.44	9-28-49	
15-16-23cb		Dr	107.9	5	GI	Sandstone	Dakota Formation	Cy, H	N	1,835.7	53.10	9-28-49	Unused stock well.

TABLE 11.—*Record of wells and test holes in southern Ellis County and parts of Trego and Rush Counties, Kansas—Continued*

Well number (1)	Owner or tenant	Type of well (2)	Depth of well below land surface, feet (3)	Diameter of well, inches	Type of casing (4)	Principal water-bearing bed: Character of material	Principal water-bearing bed: Geologic source	Method of lift (5)	Use of well (6)	Height of land surface above mean sea level, feet	Depth to water level below land surface, feet (7)	Date of measurement	REMARKS (Yield given in gallons a minute; drawdown in feet)
15-16-25aa	....	B	26.2	10	GI	Sand and gravel...	Terrace deposits........	Cy, W	S	1,798.8	14.04	9-29-49	
*15-16-25bb	Loren Truan........	Du	19.4	72±	R	do........	Crete Formation........	Cy, W	S	1,834.8	16.98	9-29-49	
15-16-29ad	G. E. Scurlock........	B	22.2	6	GI	do........	Terrace deposits........	Cy, W	D, S	1,825.2	20.73	9-28-49	
15-16-30cc	Kansas Geological Survey	Dr	50.0	4	N	do........	Alluvium........	N	N	1,843.2	....	....	Test hole. Log included in report.
15-16-31bb	do........	Dr	60.0	4	N	do........	Terrace deposits........	N	N	1,860.6	22.30	1-14-44	do
15-16-32cc	John J. Dome........	Du	16.1	30	R	do........	Crete Formation(?)........	Cy, W	D, S	1,869.0	14.90	9-28-49	
15-16-33ca	D. G. Meier........	Dr	80.0	6	GI	Limestone(?) Gravel(?)	Greenhorn Limestone(?) Crete Formation(?)	Cy, W	D, S	1,867.2	58.02	9-29-49	
15-16-34db	....	Du	9.1	44	R	Sand and gravel...	Crete Formation(?)........	N	N	1,825.7	4.66	9-29-49	Abandoned stock well.
15-16-36ad	J. Edward Boxberger....	Dr	179.9	6	GI	Sandstone........	Dakota Formation........	Cy, W	S	1,921.9	137.59	9-29-49	
15-17-1dd	Kansas Geological Survey	Dr	29.0	4	N	Gravel........	Terrace deposits........	N	N	1,881.1	....	....	Test hole. Log included in report.
15-17-2cd	....	Du	37.1	36	R	Sand and gravel...	Pleistocene undifferentiated	Cy, W	S	1,916.3	35.49	8- 7-49	
*15-17-5ba	Alois Gross........	Dr	149.9	6	GI	Sandstone........	Dakota Formation........	Cy, W	S	1,931.1	99.80 88.70	8- 9-46 8- 7-49	
15-17-6ad	....	Dr	93.7	5	GI	Limestone(?)......	Greenhorn Limestone(?)....	Cy, W	N	1,988.5	36.06	9-29-49	Abandoned stock well.
15-17-7bb	....	Du	28.6	24(?)	R	do........	do........	Cy, W	D, S	1,981.4	22.52	9-29-49	
15-17-12aa	Kansas Geological Survey	Dr	27.0	4	N	Gravel........	Terrace deposits........	N	N	1,884.6	22.67	11- 4-49	Test hole. Log included in report.
*15-17-14dd	Christina Roth........	Dr	170.6	6	GI	Sandstone........	Dakota Formation........	Cy, W	S	1,947.1	124.10 121.40	7-20-46 9-29-49	
15-17-15dd	J. Degenhardt........	Dr	190.8	6	GI	do........	do........	Cy, W	S	1,970.8	178.68	9-29-49	
15-17-17bb	S. Leiker........	Dr	181.5	6	GI	do........	do........	Cy, W	S	1,965.3	112.40 90.10	7-15-46 8- 7-49	
15-17-17cc	Paul Leiker........	Dr	221.4	6	GI	do........	do........	Cy, W	S	1,994.4	139.45	8-14-49	Well pumping a few minutes before measurement.
15-17-19ab	A. B. Leiker........	Dr	246.3	6	GI	do........	do........	N	N	2,000.0	139.66	8-22-49	Formerly an observation well. Abandoned stock well.
15-17-24dc	Geo. Mader........	Dr	151.2	6	GI	do........	do........	Cy, W	D, S	1,929.4	115.16 101.94	7-15-46 9-30-49	
*15-17-25bc	do........	Du	15.2	36	R	Gravel........	Crete Formation........	Cy, W	D, S	1,871.5	11.90	8-22-49	Formerly an observation well.
15-17-28bd	Frank Rejewki........	Dr	131.7	6	GI	Sandstone........	Dakota Formation........	Cy, W	N	1,963.8	110.20	10- 3-49	Abandoned stock well.
15-17-28dd	J. P. Jacobs........	Du	39.6	33	R	Gravel........	Crete Formation........	Cy, W	N	1,887.7	35.33	9-30-49	do

15-17-30bb	C. Unrein	Dr	195.2	5	GI	Sandstone	Dakota Formation	Cy, W	S	1,984.4	123.59	9-30-49	
15-17-31ab	E. P. Stecklein	B	31.9	5½	GI	Sand and gravel	Crete Formation	Cy, W	D, S	1,926.6	29.38	9-30-49	
*15-17-33dc	Anthony Jacobs	Du	16.7	36	R	do.	Terrace deposits	B, H	D	1,865.0	14.35	9-30-49	
15-17-35cd		Du	20.5	24	R	Gravel	Crete Formation	N	N	1,895.4	18.21	9-30-49	Abandoned stock well.
*15-18-1bb	Mat Rohr	Du	32.8	24	R	Limestone	Carlile Shale(?)	Cy, W	S	2,004.7	17.98	10-22-49	Observation well.
15-18-2cb	Alex B. Leiker	Dr	232.3	6	GI	Sandstone	Dakota Formation	Cy, W	D, S	2,014.6	26.85 23.89	7-27-46 10- 3-49	
15-18-7bb	Kansas Geological Survey	J	12.0	¾	GP	Clay	Nebraskan(?) deposits	N	O	2,065.7	6.80	7-14-50	Log included in report.
15-18-7cc	do.	J	9.0	¾	GP	Gravel	do.	N	O	2,069.9	7.55	7-14-50	Log included in report.
*15-18-9bb	Mermis Trust	Dr	269.5	5	OW	Sandstone	Dakota Formation	Cy, W	S	2,004.3	137.20	10- 3-49	
15-18-11cc		Du	16.0	36	R	Sand and gravel	Alluvium	Cy, H	S	1,987.3	11.93 8.47	7-12-46 10- 3-49	
*15-18-13ab	S. S. Leiker	Du	26.7			do.	Carlile Shale(?)	Cy, W	S	1,991.1	15.30	7-16-46	
*15-18-16bb	T. W. Wolf	Du	16.4	40	R	do.	Alluvium	B, H	D, S	1,980.9	8.18	8-22-49	Observation well.
15-18-17ba		Dr	805.0							1,982.0			Palmer Oil Corporation No. 1 Carl Ruder well; log included in report.
15-18-18cc	Kansas Geological Survey	J	12.6	¾	GP	Sand	Colluvium(?)	N	O	2,014.8	11.50	9-15-50	Log included in report.
*15-18-20ab	Geo. Klaus	B	23.5	6	GI	Sand and gravel	Alluvium	Cy, W	N	1,963.2	21.40	10-31-49	Abandoned stock well contaminated with oil-field brine.
15-18-21aa	Kansas Geological Survey	Dr	26.0	4	N	Gravel	Nebraskan(?) deposits, Carlile Shale(?)	N	N	2,036.5	10.50	11- 2-49	Test hole. Log included in report.
*15-18-22bb	Joe B. Zimmerman	Dr	47.2	6	GI	Limestone and gravel	Nebraskan(?) deposits, Greenhorn Limestone(?)	Cy, H	D	2,035.1	33.98	10- 3-49	
15-18-23ab		Dr	256.2	6	GI	Sandstone	Dakota Formation	Cy, W	S	1,960.5	91.80 88.80	7-25-46 9-29-49	
15-18-26bb	E. F. Madden	Dr	242.5	8	OW	do.	do.	Cy, G	Ind	1,993.7	115.44	8-19-49	Water for oil field.
15-18-26da	Henry S. Leiker	Du	16.8	34	R	Sand and gravel	Alluvium	Cy, W	D, S	1,905.9	14.11	10- 3-49	
*15-18-27ca	City of Hays	Dr	54	30-17	C	do.	Terrace deposits	T, E	P	1,904.7	11	6- 49	Hays well S-5. Composite sample; see Table 4.
*15-18-27cb1	do.	Dr	51	30-17	C	do.	do.	T, E	P	1,907.3	12	6- 49	Hays well S-3. Composite sample; see Table 4.
*15-18-27cb2	do.	Dr	55	30-17	C	do.	do.	T, E	P		10	6- 49	Hays well S-4. Composite sample; see Table 4.
15-18-27cb3	Kansas Geological Survey	Dr	50.0	1¼	GP	do.	do.	N	O	1,907.9	9.32	11- 2-49	Observation well. Sand point set at 37 feet. Log included in report.
15-18-27cb4	do.	Dr	63.0	4	N	Gravel	do.	N	N	1,919.4	22.40	11- 5-49	Test hole. Log included in report.
15-18-27cc	do.	Dr	30.0	4	N	Sand and gravel	do.	N	N	1,911.3	15.00	11- 2-49	do
*15-18-28da1	City of Hays	Dr	57.0	30-17	C	do.	do.	T, E	P	1,909.8	12	6- 49	Hays well S-1. Composite sample; see Table 4.
*15-18-28da2	do.	Dr	53.0	30-17	C	do.	do.	T, E	P	1,909.9	13	6- 49	Hays well S-2. Composite sample; see Table 4.
*15-18-29dd1	N. R. Werth	Dn, B	18.8	6	GI	do.	do.	C, G	S	1,925.4	11.07	8-17-49	
*15-18-29dd2	City of Hays	Dr	52	16-30	GI	do.	do.	N	N				Hays test well.
*15-18-30ab	Roy Thomas	B	13.6	5	GI	do.	Crete Formation	Cy, W	S	1,956.2	9.85	10- 5-49	

TABLE 11.—*Record of wells and test holes in southern Ellis County and parts of Trego and Rush Counties, Kansas—Continued*

WELL NUMBER (1)	Owner or tenant	Type of well (2)	Depth of well below land surface, feet (3)	Diameter of well, inches	Type of casing (4)	Principal water-bearing bed: Character of material	Principal water-bearing bed: Geologic source	Method of lift (5)	Use of well (6)	Height of land surface above mean sea level, feet	Depth to water level below land surface, feet (7)	Date of measurement	REMARKS (Yield given in gallons a minute; drawdown in feet)
15-18-33ad	Kansas Geological Survey	Dr	39.0	4	N	Sand and gravel	Crete Formation	N	N	1,951.4	32.40	11- 2-49	Test hole. Log included in report.
•15-18-33ba	Frank Werth	Dr	153.8	6	GI	Sandstone	Dakota Formation	J, E	D, S	....	35.33	8- 6-46	
											35.98	8-17-49	
15-18-34cb	Kansas Geological Survey	Dr	37.0	4	......	Gravel	Crete Formation	N	N	1,955.5	....	....	Test hole. Log included in report.
15-18-35cd	....	B	13.4	5	GI	Sand and gravel	Crete Formation(?)	Cy, W	S	1,981.8	12.27	10- 4-49	
•15-19-2aa	Alfred Haas	Du	17.3	24	R	do	Nebraskan(?) deposits	Cy, W	D, S	2,102.2	14.14	8-24-49	
15-19-2cc	Kansas Geological Survey	J	21.0	¾	GP	do	Alluvium	N	O	2,011.2	Dry	8- 1-50	Log included in report.
•15-19-4ad	Carl Pfannenstiel	Dr	290.2	6	GI	Sandstone	Dakota Formation	Cy, W	D, S	2,061.7	136.98	8-23-49	
15-19-4cb	Kansas Geological Survey	J	21.0	¾	GP	Sand	Loveland and Crete Formations	N	O	2,054.3	6.90	9-16-50	Log included in report.
15-19-4da	do	J	13.0	¾	CP	Silt	Alluvium	N	O	2,064.1	7.94	9-16-50	do
15-19-5cb	do	J	34.8	¾	GP	Sand	Crete Formation	N	O	2,041.5	31.10	9-16-50	do
15-19-5da	Merril Moore	Dr	64.7	6	GI	Sand and gravel	do	N	N	2,052.4	47.23	8-17-49	Abandoned stock well.
15-19-6aa	Aug. Leiker	Dr	....	6	GI	do	do	Cy, H	D	2,059.9	53.12	8-22-49	Observation well 1946-1949.
•15-19-7ab	Peter M. Younger	B	30.3	6	GI	Sand	do	Cy, W	D, S	2,023.7	27.17	8-15-49	
15-19-7ad	Kansas Geological Survey	J	17.5	¾	GP	Sand and gravel	Alluvium	N	O	2,003.8	10.80	9-27-50	Log included in report.
15-19-7bc1	do	Dr	36.0	4	N	do	Crete Formation	N	N	2,030.1	....	....	Test hole. Log included n report.
15-19-7bc2	do	J	22.2	¾	GP	do	do	N	O	2,029.1	9.65	9-16-50	Log included in report.
15-19-7dd	do	J	22.9	¾	GP	do	do	N	O	2,018.8	Dry	9-27-50	do
15-19-8bb	do	J	22.0	¾	GP	do	do	N	O	2,020.7	21.80	9-16-50	do
15-19-9bb	do	J	34.8	¾	GP	Sand	do	N	O	2,015.1	26.30	9-16-50	do
15-19-9cb	do	J	32.0	¾	GP	do	do	N	O	2,027.2	Dry	9- 6-50	do
15-19-9cc	do	Dr	60.0	1¼	GP	Gravel and sand	Crete Formation and Grand Island Formation	N	O	2,017.5	33.01	10-24-49	Observation well. Log included in report.
15-19-10ab	do	J	15.0	¾	GP	Clay	Colluvium(?) or Carlile Shale(?)	N	O	2,044.3	7.40	9-15-50	Log included in report.
•15-19-10ad1	Alec Gross	Du	28.6	24	R	Sand and gravel	Alluvium	Cy, W	S	2,025.0	20.38	8-24-49	
15-19-10ad2	Kansas Geological Survey	J	16.0	¾	GP	Sand	do	N	O	2,021.1	13.85	9-15-50	Log included in report.
15-19-10bb	do	J	23.0	¾	GP	Sand and gravel	do	N	O	2,043.1	5.80	9-15-50	do
15-19-10bc	Frank A. Worth	Du	15.3	42	R, C	do	do	Cy, W	S	....	8.42	9-29-50	
15-19-10cb	Kansas Geological Survey	J	33.0	¾	GP	Sand	Crete and Loveland Formations	N	O	2,032.4	21.95	9-15-50	Log included in report.
•15-19-12aa	Walter Urban	B	16.2	6	GI	Sand and gravel	Nebraskan(?) deposits	Cy, W	S	2,083.2	13.50	8-17-49	
15-19-13ab	Pete Wolfe	Du	12.0	48	R	Sand	Alluvium	Cy, G	S	2,027.7	7.25	8-22-49	Formerly an observation well.

15-19-13cb	Kansas Geological Survey	J	30.5	¾	GP	do	Crete Formation	N	O	2,004.0	Dry	7-25-50	Log included in report.
15-19-14aa	do	J	9.0	¾	GP	do	Alluvium	N	O	2,017.8	4.35	9-15-50	do
15-19-15aa	do	J	25.8	¾	GP	do	Crete Formation	N	O	2,007.5	Dry	7-28-50	do
15-19-15ad	do	J	25.0	¾	GP	do	Alluvium	N	O	2,002.1	12.61	7-28-50	do
15-19-15bc	do	J	25.6	¾	GP	do	Crete Formation	N	O	2,001.2	23.40	9-15-50	do
15-19-15dd	do	Dr	51.5	1¼	GP	Sand and gravel	Crete and Grand Island Formations	N	O	1,993.0	26.07	10-29-49	Observation well. Log included in report.
15-19-16aa	do	J	32.0	¾	GP	Sand	Crete Formation	N	O	2,023.1	Dry	8-18-50	Log included in report.
15-19-16cb	do	J	31.0	¾	GP	Sand and gravel	do	N	O	2,008.8	27.70	9-16-50	do
15-19-16dc	Mike Unrein	B	12.5	6	GI	Gravel	do	N	N	1,984.0	9.87	8-15-49	Abandoned stock well.
15-19-16dd	Kansas Geological Survey	J	18.8	¾	GP	Sand	do	N	O	1,997.4	Dry	8- 7-50	Log included in report.
15-19-18bb	do	Dr	68.5	4	N	Gravel	Terrace deposits	N	N	1,990.9	20.10	10-24-49	Test hole. Log included in report.
15-19-18bd	....	B	18.7	5	GI	Sand and gravel	do	Cy, H	S	1,977.3	16.96	10- 5-49	
15-19-18da	Kansas Geological Survey	J	21.0	¾	GP	do	do	N	O	1,975.8	8.68	9-19-50	Log included in report.
15-19-20ab	Tom Bieler	B	16.2	6	OW	do	do	N	N	1,963.8	8.30	10- 6-49	Abandoned stock well.
15-19-21ad	Kansas Geological Survey	J	6.2	¾	GP	Sand and limestone	Crete Formation and Greenhorn Limestone	N	O	1,978.2	Dry	8- 7-50	Log included in report.
15-19-22ad	do	J	18.7	¾	GP	Sand	Crete Formation	N	O	1,982.4	16.10	9-15-50	do
15-19-22dd	do	J	21.3	¾	GP	do	Terrace deposits	N	O	1,965.5	16.25	9-15-50	do
15-19-24bc	do	J	15.2	¾	GP	Sand and gravel	Alluvium	N	O	1,969.1	9.05	9-15-50	do
15-19-24cd	do	J	28.4	¾	GP	do	Crete Formation	N	O	1,975.8	22.40	7-24-50	do
15-19-25aa	do	J	18.5	¾	GP	do	do	N	O	1,967.7	16.20	7-24-50	do
15-19-25bb	do	J	13.5	¾	GP	Sand	do	N	O	1,975.8	Dry	9-15-50	do
15-19-27aa	Andrew Gross	B	19.9	6	GI	Sand and gravel	Terrace deposits	Cy, W	S	1,955.0	14.14	8-17-49	
5-10-27da	Martin Dreher	Dr	156.3	6	GI	Sandstone	Dakota Formation	Cy, W	D, S	1,996.2	75.34	8- 5-46	
15-19-28dd	Fred F. Werth	Du	26.5	36	R	Sand and gravel	Pleistocene undifferentiated	Cy, W	D, S	2,018.8	22.33	10- 6-49	
•15-19-32cb	Alfred J. Werth	Du	32.3	30	R	do	do	Cy, W	D, S	2,064.6	22.41	8-18-49	
15-19-32da	J. K. Zimmerman	Du	31.8	....	R	Gravel	do	Cy, W	D, S	2,047.6	27.59	8-18-49	
15-19-35aa	J. Zimmerman	Dr	152.2	6	GI	Sandstone	Dakota Formation	Cy, G	S	1,982.1	63.69	8-22-49	Formerly an observation well.
15-20-1bb	Kansas Geological Survey	J	26	¾	GP	Sand and gravel	Terrace deposits	N	O	2,034.4	22.10	9-16-50	Observation well. Log included in report.
15-20-1da1	do	Dr	46.0	4	N	Gravel	Crete Formation	N	N	2,043.0	36.05	10-22-49	Test hole. Log included in report.
15-20-1da2	do	J	31.9	¾	GP	Sand and gravel	do	N	O	2,041.6	Dry	9-12-50	Log included in report.
15-20-2bc	do	J	25.2	¾	GP	do	Loveland and Crete Formations	N	O	2,057.9	8.74	9-21-50	do
15-20-2da	do	J	12.5	¾	GP	do	Alluvium	N	O	2,015.7	9.49	9-20-50	do
15-20-4aa	do	J	28.5	¾	GP	do	do	N	O	2,054.0	7.12	9-23-50	do
15-20-4cc1	do	J	20.0	¾	GP	do	do	N	O	2,004.5	8.30	9-15-50	do
15-20-4cc2	do	J	30.0	¾	GP	Sand	Terrace deposits	N	O	2,024.8	23.90	9-15-50	do
15-20-4da	do	J	23.0	¾	GP	Sand and gravel	Crete Formation	N	O	2,040.7	18.90	9-20-50	do
15-20-5ad	do	J	30.0	¾	GP	do	do	N	O	2,053.5	Dry	8-15-50	do
•15-20-7aa	Ernest J. King	Du	18.7	45	GI	do	do	Cy, W	D, S	2,054.6	16.85	10-29-19	
15-20-8ab	Chester Meserve	Du	18.1	60	R	do	Alluvium	Cy, W	N	2,020.0	11.05	10-10-49	Abandoned stock well.
15-20-9aa	Kansas Geological Survey	J	23.0	¾	GP	do	do	N	O	2,014.6	5.30	9-20-50	Log included in report.
15-20-11ad	do	J	17.0	¾	GP	do	Crete Formation	N	O	2,001.5	11.13	9-16-50	do
15-20-12aa	do	Dr	60.0	1¼	GP	do	Crete and Grand Island Formations	N	O	2,038.4	39.23	10-22-49	Observation well. Log included in report.

TABLE 11.—*Record of wells and test holes in southern Ellis County and parts of Trego and Rush Counties, Kansas—Concluded*

Well Number (1)	Owner or tenant	Type of well (2)	Depth of well below land surface, feet (3)	Diameter of well, inches	Type of casing (4)	Principal water-bearing bed: Character of material	Principal water-bearing bed: Geologic source	Method of lift (5)	Use of well (6)	Height of land surface above mean sea level, feet	Depth to water level below land surface, feet (7)	Date of measurement	REMARKS (Yield given in gallons a minute; drawdown in feet)
*15-20-12ad	Alphonse Dechant	Dn, B	32.5	6	GI	Sand and gravel	Crete Formation	Cy, W	D, S	2,030.4	31.50	8-23-49	
15-20-12bb	Kansas Geological Survey	J	33.6	¾	GP	do	do	N	O	2,043.3	Dry	9-13-50	Log included in report.
15-20-28bc	....	Du	7.7	54	R	do	Alluvium	Cy, N	S	....	3.78	8-23-49	
15-21-2bb	Kansas Geological Survey	Dr	14.0	4	N	do	do	N	O	2,031.4	....	....	Test hole. Log included in report.
15-21-3ad	do	Dr	34.0	4	N	do	Crete Formation	N	O	2,100.7	....	....	do
15-21-3dd	do	Dr	10.0	4	N	Silt and clay	Loveland Formation(?)	N	O	2,148.8	....	....	do
*15-21-5ab	A. B. Engel	Du	11.1	18(?)	C	Sand and gravel	Crete Formation	Cy, W	D, S	2,090.4	9.00	10-18-49	Penetrated shale at 9 feet.
15-22-1ab	Kansas Geological Survey	J	15.5	¾	GP	Sand	Alluvium	N	O	2,068.6	8.30	7-14-50	Log included in report.
16-17-1bb1	....	Du	21.6	36	T	Sand and gravel	Crete Formation	Cy, W	D, S	1,881.9	19.77	9-28-49	
16-17-1bb2	Kansas Geological Survey	Dr	27.0	4	N	do	do	N	N	1,887.7	19.90	11- 3-49	Test hole. Log included in report.
16-17-1bc	do	Dr	28.0	4	N	do	do	N	N	1,896.9	24.80	11- 3-49	do
16-17-6bb	....	Du	22.2	60	R	do	Alluvium	Cy, W	S	1,892.2	18.40	9-30-49	
16-18-3bc	....	B	33.8	6	OW	do	Crete Formation	Cy, W	S	1,952.3	29.14	10- 4-49	
*16-18-10cb	Wm. Legleiter	Dr	168.2	5	GI	Sandstone	Dakota Formation	Cy, W	D, S	1,963.4	69.32	10- 4-49	
16-19-2ba	....	Du	32.3	30	R	Sand and gravel	Terrace deposits	Cy, W	N	2,009.2	27.15	8-17-49	Abandoned stock well.

1. Well-numbering system, described in text, indicates location.
2. B, bored; Dn, driven; Dr, drilled; Du, dug; J, jetted.
3. Reported depths below land surface are given in feet; measured depths below land surface are given in feet and tenths.
4. Br, brick; C, concrete; GI, galvanized iron; GP, galvanized pipe; N, none; OW, oil-well casing; R, rock; T, tile.
5. Method of lift: B, bucket; C, centrifugal; Cy, cylinder; J, jet; N, none; T, turbine. Type of power: E, electric; G, gasoline engine; H, hand; W, wind.
6. D, domestic; Ind, industrial; O, observation; P, public supply; S, stock; N, none.
7. Reported depths to water are given in feet; measured depths are given in feet, tenths, and hundredths.

* Chemical analysis given in Table 4.

LOGS OF TEST HOLES

Given on the following pages are logs of 41 drilled test holes, 9 drilled observation wells, 80 jetted observation wells, and 1 oil well. The logs are arranged by township from north to south and by range from east to west. Within a township they are arranged by section number. An explanation of the numbering system is given on page 13 and a diagram is shown in Figure 2. Two test holes were drilled by the State Geological Survey in 1944, 39 test holes and 9 observation wells were drilled in 1949, and 80 observation wells were jetted in 1950. Samples of the materials penetrated in the test holes and observation wells were examined in the field by geologists who supervised the drilling and prepared the logs. The samples subsequently were studied microscopically by D. W. Berry and A. R. Leonard. General locations of the test holes are shown on Plates 2 and 3. Logs of test holes 2, 5, 6, 7, 39, 40, 41, 44, and of Hays wells 3, 15, and 20 on cross section C-C′ of Plate 3 are given by Latta (1948).

13-16-31cc.—Sample log of drilled test hole in SW SW sec. 31, T. 13 S., R. 16 W., 45 feet north and 12 feet east of center of crossroads, Ellis County. Surface altitude, 1,973.3 feet; water level, 15.65 feet, November 5, 1949.

	Thickness, feet	Depth, feet
NEOGENE—Pleistocene		
Undifferentiated		
Silt, compact, brown	3	3
Silt, compact, light gray	3	6
Silt, slightly calcareous, buff	3	9
Silt, medium compact, slightly sandy, brown	2	11
Silt, tan; contains medium to coarse sand and gravel	3	14
Silt, sandy, light gray	2	16
Sand and gravel, medium to coarse; cemented layer at 18.5 to 19 feet	4	20
Sand and gravel, fine to coarse	6	26
CRETACEOUS		
Carlile Shale—Fairport Shale member		
Clay and shale, compact, calcareous, yellow to gray	2	28

13-17-36aa.—Sample log of drilled test hole in NE NE sec. 36, T. 13 S., R. 17 W., 75 feet west and 10 feet south of center of crossroads, Ellis County. Surface altitude, 1,949.0 feet, water level, 19.38 feet, November 5, 1949.

	Thickness, feet	Depth, feet
Silt, dark brown; contains sand and gravel (road fill)	2	2
NEOGENE—Pleistocene		
Undifferentiated		
Silt, medium compact, sandy, brown	2	4
Silt, medium compact, sandy, tan	3	7
Silt, slightly sandy	3	10

	Thickness, feet	Depth, feet
Silt, buff to white; contains some caliche	3	13
Silt, limy cement, tan and white to cream color; contains some caliche	4	17
Silt, cemented, sandy and clayey, cream color to white,	4	21
Clay and gravel, medium to coarse quartz in calcareous clay	2	23
CRETACEOUS		
Carlile Shale—Fairport Shale member		
Shale and clay, compact, calcareous, yellow to gray	3	26

14-16-6cb.—Sample log of drilled test hole in NW SW sec. 6, T. 14 S., R. 16 W., 0.3 mile north of corner and 9 feet east of center of road, Ellis County. Surface altitude, 1,949.0 feet; water level, 19.38 feet, November 5, 1949.

	Thickness, feet	Depth, feet
Silt, gray, dark gray, brown (road fill)	3	3
NEOGENE—Pleistocene		
Undifferentiated		
Silt, sandy, calcareous, dark brown	4	7
Silt, medium compact, sandy, calcareous, buff	1	8
Silt, tan; contains sand, gravel, and caliche	2	10
Silt, sandy, tan; contains caliche	4	14
Gravel, coarse, quartzose; contains fragments of limestone and shale and some cream-color to tan silt	6	20
Gravel and silt, tan silt and coarse quartz gravel, limy cement	3	23
CRETACEOUS		
Carlile Shale—Fairport Shale member		
Clay and shale, yellow to gray	7	30

14-16-7bc.—Sample log of drilled test hole in SW NW sec. 7, T. 14 S., R. 16 W., 0.4 mile south of corner and 8 feet east of center of road, Ellis County. Surface altitude, 1,909.6 feet; water level, 24.57 feet, November 5, 1949.

	Thickness, feet	Depth, feet
Silt, compact, dark gray; contains some sand and gravel (road fill)	3	3
NEOGENE—Pleistocene		
Terrace deposits		
Silt, medium compact, sandy, tan	4	7
Silt, compact, slightly sandy, brown	3	10
Silt, medium compact, sandy, tan	7	17
Silt, sandy, buff; contains some coarse sand and caliche	5	22
Silt, sandy, buff; contains small amount of sand and gravel	2	24
CRETACEOUS		
Carlile Shale—Fairport Shale member		
Clay, sandy, calcareous, buff, yellow	2.5	26.5
Shale, compact, sandy, calcareous, dark gray	1.5	28

14-16-7cc.—Sample log of drilled test hole in SW SW sec. 7, T. 14 S., R. 16 W., 80 feet east and 10 feet north of center of crossroads, Ellis County. Surface altitude, 1,902.3 feet; water level, 18.80 feet, November 5, 1949.

	Thickness, feet	Depth, feet
NEOGENE—Pleistocene		
Terrace deposits		
Silt, compact, brown	4	4
Silt, sandy, light brown	3	7
Silt, medium compact, sandy, brown	3	10
Silt, sandy, tan to brown	4	14
Silt, slightly sandy, gray brown; contains some gravel,	6	20
Silt, sandy, dark gray to gray; contains fragments of shells	5	25
Gravel, coarse, quartzose; contains many locally derived pebbles and some quartz sand	5	30
Gravel, very coarse; contains many locally derived pebbles	3	33
CRETACEOUS		
Greenhorn Limestone		
Shale, very compact, calcareous, dark gray	2	35

14-16-18cb.—Sample log of drilled test hole in NW SW sec. 18, T. 14 S., R. 16 W., 38 feet south of half-mile line and 16 feet east of center of road, Ellis County. Surface altitude, 1,941.8 feet.

	Thickness, feet	Depth, feet
Silt, compact, dark brown	4	4
NEOGENE—Pleistocene		
Undifferentiated		
Silt, medium compact, slightly sandy, brown	5	9
Silt, calcareous, sandy, rust color to buff; contains caliche	8	17
Silt, compact, calcareous, buff; contains caliche	6	23
Silt, very sandy, calcareous, tan to buff	7	30
Silt, medium compact, sandy, buff	3	33
Silt and gravel	1.5	34.5
CRETACEOUS		
Carlile Shale—Fairport Shale member		
Clay and shale, compact, chalky, white to cream color; contains limestone	5.5	40

14-16-19bb2.—Sample log of drilled test hole in NW NW sec. 19, T. 14 S., R. 16 W., 70 feet south and 15 feet east of center of crossroads, Ellis County. Surface altitude, 1,929.2 feet; water level, 38.50 feet, November 5, 1949.

	Thickness, feet	Depth, feet
Silt, dark brown; contains sand and gravel (road fill)	2.5	2.5
NEOGENE—Pleistocene		
Undifferentiated		
Silt, compact, sandy, slightly calcareous, gray	3.5	6
Silt, slightly calcareous, dark rusty brown; contains sand	4	10

	Thickness, feet	Depth, feet
Silt, sandy, calcareous, rusty brown; contains caliche	4	14
Silt, calcareous, slightly sandy, tan; contains caliche	4	18
Sand and tan silt; contains gravel	2	20
Gravel and tan silt; contains shell fragments	5	25
Silt, medium compact, sandy, calcareous	2	27
Gravel, medium to coarse, quartzose, stained black; contains some coarse sand	2	29
Silt, compact, brown	3	32
CRETACEOUS		
Carlile Shale—Fairport Shale member		
Clay, silty, soft, calcareous, buff	4	36
Chalk and shale, calcareous, cream color to light gray and white	4	40

14-16-19cc.—Sample log of drilled test hole in SW SW sec. 19, T. 14 S., R. 16 W., 60 feet north and 18 feet east of center of crossroads, Ellis County. Surface altitude, 1,944.0 feet; water level, 28.45 feet, November 4, 1949.

	Thickness, feet	Depth, feet
Silt, dark brown; contains sand and gravel (road fill),	2	2
NEOGENE—Pleistocene		
Undifferentiated		
Silt, compact, calcareous, sandy, gray	2	4
Silt, compact, sandy, brown	3	7
Silt, compact, sandy, dark brown	2	9
Silt, calcareous, sandy, rusty brown	8	17
Silt, calcareous, buff to cream color; contains caliche and some gravel and sand	3	20
Silt, buff, and sand; contains fine to medium gravel	4	24
Sand, coarse, quartzose; contains fine to coarse gravel	3	27
Gravel, coarse, and chalk pebbles; contains a 6-inch layer of white silty caliche at 27 feet	5	32
CRETACEOUS		
Carlile Shale—Fairport Shale member		
Limestone, compact, chalky	8	40

14-16-30cc.—Sample log of drilled test hole in SW SW sec. 30, T. 14 S., R. 16 W., 75 feet east and 7 feet north of center of crossroads, Ellis County. Surface altitude, 1,938.1 feet; water level, 55.10 feet, November 4, 1949.

	Thickness, feet	Depth, feet
Silt, compact, sandy, brown (road fill)	2	2
NEOGENE—Pleistocene		
Undifferentiated		
Silt, compact, sandy, calcareous, tan	2	4
Silt, sandy, calcareous, brown	2	6
Silt, sandy, calcareous, rusty brown	2	8
Silt, compact, sandy, calcareous, tan; contains caliche,	7	15
Silt, compact, slightly sandy, calcareous, tan to buff	5	20

	Thickness, feet	Depth, feet
Silt, sandy, calcareous, buff	6	26
Clay, cream color to white; contains some caliche and sand	2	28
Silt, slightly sandy, calcareous, buff	4	32
Silt, calcareous, buff; contains some caliche	4	36
Silt, slightly sandy, calcareous, buff	6	42
Silt, compact, calcareous, gray buff; contains some sand	4	46
Silt, sandy, calcareous, buff; contains some gravel and sand	4	50
Silt, sandy, calcareous, tan; contains medium to fine gravel	4	54
Silt, sandy, calcareous	3	57
Gravel and silt, sandy; contains some shale fragments,	7	64
CRETACEOUS		
Greenhorn Limestone		
Clay and shale, calcareous, gray to yellow; contains shell fragments and some sand	2	66
Shale, calcareous, dark gray	2	68

14-16-31cc.—Sample log of drilled test hole in SW SW sec. 31, T. 14 S., R. 16 W., 80 feet east and 7 feet north of center of crossroads, Ellis County. Surface altitude, 1,928.9 feet; water level, 43.50 feet, November 4, 1949.

	Thickness, feet	Depth, feet
Silt, compact, dark brown (road fill)	2	2
NEOGENE—Pleistocene		
Undifferentiated		
Silt, slightly sandy, dark brown	3	5
Silt, sandy, brown	3	8
Silt, sandy, light rusty brown; contains caliche at 9 feet	6	14
Silt, sandy, calcareous, buff; contains caliche	6	20
Silt, compact, calcareous, sandy, buff	5	25
Silt, calcareous, buff to cream color	5	30
Silt, compact, calcareous, sandy, cream color to white	10	40
Silt, calcareous, buff, and fine to coarse gravel and sand	8	48
Gravel, coarse, and interbedded silt; contains some coarse sand	12	60
Gravel, fine to coarse; contains shell fragments	3	63
CRETACEOUS		
Greenhorn Limestone		
Clay, compact, light gray to white	1	64
Limestone and shale, very solid and medium solid layers interbedded, gray to dark gray	1	65

14-17-12da.—Sample log of drilled test hole in NE SE sec. 12, T. 14 S., R. 17 W., 0.26 mile north of corner and 60 feet north and 40 feet east of U. S. Highway 40 stop sign, Ellis County. Surface altitude, 1,904.8 feet.

	Thickness, feet	Depth, feet
Silt, dark brown; contains gravel (road fill)	4	4
NEOGENE—Pleistocene		
Terrace deposits		
Silt, compact, calcareous, brown	4	8
Silt, compact, slightly sandy, calcareous	4	12
Silt, calcareous, tan; contains some calcium carbonate particles	5	17
Silt, compact, calcareous, iron stained, tan to gray	5	22
Silt, sandy, iron streaks, tan; contains some shell fragments	3	25
Gravel, coarse to very coarse; contains some coarse sand	3.5	28.5
CRETACEOUS:		
Greenhorn Limestone		
Shale, compact, sandy, dark gray	1.5	30

14-18-9aa.—Sample log of drilled test hole in NE NE sec. 9, T. 14 S., R. 18 W., 35 feet west of fourth power-line pole south of Big Creek and 45 feet east of city pipe line in field, Ellis County. Surface altitude, 1,981.5 feet; water level, 31.57 feet, October 28, 1949.

	Thickness, feet	Depth, feet
Soil, friable, silty, brown	2.5	2.5
NEOGENE—Pleistocene		
Terrace deposits		
Silt, plastic, dark gray to brown; contains clay layer at 5 feet	4.5	7
Sand, fine to coarse; contains fine gravel and brown silt	3	10
Sand, very fine and fine; contains small amount of coarse sand and gravel and caliche	10	20
Sand, fine to coarse, and fine to coarse gravel; contains quartz and granite pebbles as much as ½ inch in diameter and shale and limestone pebbles	8	28
Clay, plastic, blue gray, and brown silt	2	30
Gravel, fine to coarse, pebbles as much as ½ inch in diameter; contains coarse sand	10	40
Gravel, medium to coarse; contains pebbles of chert, limestone, and granite as much as 1 inch in diameter	3.5	43.5
CRETACEOUS		
Carlile Shale—Fairport Shale member		
Limestone, hard, black, and calcareous shale	1.5	45

14-18-9ad.—Sample log of drilled test hole in SE NE sec. 9, T. 14 S., R. 18 W., 10 feet north of third telephone pole SE of crossing of power line and telephone line, Ellis County. Surface altitude, 1,979.7 feet; water level, 18.79 feet, October 28, 1949.

	Thickness, feet	Depth, feet
Soil, friable, silty, dark brown	2	2
NEOGENE—Pleistocene		
Terrace deposits		
Silt, black, and fine sand	1	3
Clay, compact, stiff, gray; contains some gravel and sand and caliche at 7 to 10.5 feet	7.5	10.5
Clay, friable, gray; contains caliche nodules as much as ½ inch in diameter	6.5	17
Clay, silty, gray; contains some caliche	3	20
Gravel and sand, fine to coarse; contains many pebbles of limestone and shale as much as ¾ inch in diameter	5	25
CRETACEOUS		
Carlile Shale—Fairport Shale member		
Shale, hard, calcareous, black	5	30

14-18-9bb1.—Sample log of drilled test hole in NW NW sec. 9, T. 14 S., R. 18 W., NE corner of field, Ellis County. Surface altitude, 2,011.5 feet; water level, 46.85 feet, October 27, 1949.

	Thickness, feet	Depth, feet
Soil, friable, dark gray	1.5	1.5
NEOGENE—Pleistocene		
Undifferentiated		
Silt, calcareous, tan; contains some sand and gravel	2.5	4
Silt and clay, calcareous, buff; contains some sand and gravel	5	9
Clay, plastic, tough, calcareous, gray to cream color	5	14
Silt, buff, interbedded with sand and gravel	6	20
Sand, very fine, and silt, tan; contains some caliche	6	26
Sand, fine to coarse; contains gravel and clay	11	37
Sand and gravel, fine to coarse; contains caliche, shell fragments, and pebbles of chalk	7	44
Gravel, fine to coarse, and chalk pebbles as much as ¾ inch in diameter; contains small amount of blue plastic clay and fine sand	6.5	50.5
CRETACEOUS		
Carlile Shale—Fairport Shale member		
Shale, hard, calcareous, black	2.5	53

14-18-9bb2.—Sample log of drilled observation well in NW NW sec. 9, T. 14 S., R. 18 W., 0.25 mile east and 0.23 mile south of NW corner at east end of terrace in field south of Hays Experimental Station buildings, Ellis County. Surface altitude, 2,017.6 feet; water level, 51.72 feet, October 28, 1949.

	Thickness, feet	Depth, feet
NEOGENE—Pleistocene		
Undifferentiated		
Silt, brown; contains some sand and gravel	4	4
Clay, plastic, gritty, calcareous, buff	8	12
Clay, hard, stiff, buff; contains a few pebbles and caliche fragments	10	22
Silt, compact, buff; contains sand, caliche, and limestone fragments	11	33
Silt, calcareous, buff; contains caliche and sand	6	39
Sand, fine to medium, and clay; contains coarse sand and gravel	8	47
Gravel and sand, coarse to ¼-inch pebbles; contains many limestone pebbles	11.5	58.5
CRETACEOUS		
Carlile Shale—Fairport Shale member		
Shale, hard, calcareous, blue black	6.5	65

14-18-9da.—Sample log of drilled test hole in NE SE sec. 9, T. 14 S., R. 18 W., 0.3 mile north of corner and 20 feet west of center of road, Ellis County. Surface altitude, 2,011.6 feet.

	Thickness, feet	Depth, feet
NEOGENE—Pleistocene		
Undifferentiated		
Silt, friable, slightly sandy, brown	1	1
Silt, compact, sandy, buff	1.5	2.5
Silt, sandy, rusty brown; contains caliche	2.5	5
Silt, compact, sandy, tan	5	10
Silt, medium compact, sandy, buff	4	14
Silt, sandy, buff; contains caliche	9	23
Silt, sandy, buff; contains caliche and some sand	8	31
Silt; contains some caliche and gravel	4	35
Gravel, coarse; contains some sand and some pebbles as much as ¼ inch in diameter	8	43
Gravel, medium, buff; contains silt layer at 45 to 48 feet	7	50
Gravel, medium to coarse, well sorted, quartz and limestone pebbles	5.5	55.5
CRETACEOUS		
Carlile Shale—Fairport Shale member		
Shale, compact, black to blue black	4.5	60

14-18-9dd.—Sample log of drilled test hole in SE SE sec. 9, T. 14 S., R. 18 W., 40 feet north and 27 feet west of center of road intersection, Ellis County. Surface altitude, 2,007.4 feet.

	Thickness, feet	Depth, feet
Soil, silty, gray buff; contains few pebbles	2.5	2.5
NEOGENE—Pleistocene		
Undifferentiated		
Silt, friable, reddish brown; contains some gravel	5.5	8
Silt, sandy, brown; contains caliche	3.5	11.5
Sand, very fine to fine	5.5	17
Clay, plastic, buff to tan; contains caliche	1	18
Sand, very fine to fine; contains some medium to coarse sand and fine gravel	0.5	18.5
Silt, plastic, buff, reddish; contains some sand and some caliche nodules as much as ½ inch in diameter,	18.5	37
Silt, plastic, gray to dark brown	3	40
Silt, tough, plastic, tan to buff	12	52
Gravel and sand, fine to coarse; contains pebbles ⅜ inch in diameter	6.5	58.5
CRETACEOUS		
Carlile Shale—Fairport Shale member		
Shale, calcareous, hard, black	1.5	60

14-18-16da.—Sample log of drilled test hole in NE SE sec. 16, T. 14 S., R. 18 W., 0.1 mile south of half-mile line and 8 feet west of center of road, Ellis County. Surface altitude, 1,993.6 feet; water level, 32.40 feet, October 31, 1949.

	Thickness, feet	Depth, feet
Silt, compact, gray; contains limestone (road fill)	3	3
NEOGENE—Pleistocene		
Undifferentiated		
Silt, sandy, rusty brown	4	7
Silt, very sandy, loose; contains fine sand at 9 feet	6	13
Sand and tan silt; contains medium to coarse sand	4	17
Silt, compact, buff	5	22
Silt, sandy, iron stained, buff; contains some gravel	4.5	26.5
Sand, medium to coarse; contains some coarse gravel	6.5	33
Gravel, coarse, quartz and limestone pebbles	7	40
Gravel, medium to coarse, quartz and limestone pebbles; contains some coarse sand	5	45
Gravel, coarse, quartz and limestone pebbles	9.5	54.5
CRETACEOUS		
Carlile Shale—Fairport Shale member		
Shale, chalky, black	3.5	58

14-18-21aa.—Sample log of drilled test hole in NE NE sec. 21, T. 14 S., R. 18 W., 0.2 mile south of corner and 6 feet west of center of road, Ellis County. Surface altitude, 2,005.5 feet; water level, 22.85 feet, October 31, 1949.

	Thickness, feet	Depth, feet
Silt, gray; contains gravel (road fill)	2.5	2.5
NEOGENE—Pleistocene		
Undifferentiated		
Silt, slightly sandy, gray brown	2.5	5
Silt, sandy, rusty brown	3	8
Silt, fairly loose, buff	2	10
Silt, iron stained, slightly sandy, gray buff	4	14
Gravel, coarse	2	16
Clay, sandy, calcareous, gray yellow	5	21
Gravel, coarse, quartzose	1.5	22.5
CRETACEOUS		
Carlile Shale—Fairport Shale member		
Shale and clay, calcareous, weathered, gray yellow	7.5	30
Shale, platy, yellow to blue gray; contains selenite crystals	3	33

14-19-31bc.—Sample log of drilled test hole in SW NW sec. 31, T. 14 S., R. 19 W., 25 feet north of half-mile line and 8 feet east of center of road, Ellis County. Surface altitude, 2,085.0 feet.

	Thickness, feet	Depth, feet
Silt, friable, sandy, dark brown (road fill)	1.5	1.5
NEOGENE—Pleistocene		
Colluvium		
Silt, calareous, buff	1.5	3
Clay, chalky, calcareous, creamy white; contains caliche and sand grains	3	6
CRETACEOUS		
Carlile Shale—Fairport Shale member		
Shale (weathered), calcareous, gray to tan	1	7
Shale, plastic, calcareous, gray to light blue gray	3	10

14-19-31cc.—Sample log of drilled observation well in SW SW sec. 31, T. 14 S., R. 19 W., 300 feet north and 20 feet east of center of road intersection, Ellis County. Surface altitude, 2,062.5 feet; water level, 31.79 feet, October 22, 1949.

	Thickness, feet	Depth, feet
NEOGENE—Pleistocene		
Colluvium		
Silt, compact, sandy, dark brown and black	2	2
Clay, compact, gray	2	4
Clay, compact, light gray	3	7
Silt, iron stained, gray brown; contains some gravel	5	12
Loveland Formation		
Silt, compact, sandy, rusty brown	13	25
Silt, iron stained at base, sandy, buff	5	30

	Thickness, feet	Depth, feet
Crete Formation		
Sand, medium to coarse, and fine gravel	6	36
Gravel, coarse, quartzose; contains some coarse sand	1	37
CRETACEOUS		
Carlile Shale—Fairport Shale member		
Clay and shale, calcareous, weathered, yellow to light gray	1.5	38.5
Shale, plastic, calcareous, blue gray	1.5	40

14-19-32cb.—Sample log of jetted well in NW SW sec. 32, T. 14 S., R. 19 W., Ellis County. Surface altitude, 2,077.4 feet; dry, September 27, 1950.

	Thickness, feet	Depth, feet
NEOGENE—Pleistocene		
Colluvium		
Silt, dark gray	1	1
Silt, clayey, sandy, gray	1	2
Silt, sandy, brown, and fine sand	6	8
Silt, very hard, slightly sandy, tan to brown	6	14
Sand, very coarse, and silt; contains some limestone gravel and white to brown caliche at base	2.7	16.7

14-19-32cc.—Sample log of jetted well in SW SW sec. 32, T. 14 S., R. 19 W., Ellis County. Surface altitude, 2,071.0 feet; water level, 16.90 feet, September 16, 1950.

	Thickness, feet	Depth, feet
NEOGENE—Pleistocene		
Loveland Formation		
Soil, silty, black	1	1
Silt, clayey, plastic, calcareous, tan	4	5
Silt, hard, blocky, calcareous, dark brown	5	10
Silt, sandy, and fine sand, loose, calcareous, brown	10	20
Silt, sandy, clayey, tight, plastic, calcareous, brown	3	23

14-19-35dd.—Sample log of drilled test hole in SE SE sec. 35, T. 14 S., R. 19 W., 6 feet south and 4 feet west of inside corner of sidewalk, Ellis County. Surface altitude, 2,108.4 feet.

	Thickness, feet	Depth, feet
NEOGENE—Pleistocene		
Nebraskan(?) deposits		
Silt, plastic, sandy, brown	4	4
Silt, tan, coarse quartz sand, and gravel cemented by calcium carbonate; contains caliche	3	7
Gravel, coarse to 1-inch pebbles, and fine to coarse sand; contains small amount of intermixed clay	8.5	15.5
Clay, compact, sandy, noncalcareous, gray; contains coarse gravel	10.5	26.0
CRETACEOUS		
Carlile Shale—Blue Hill Shale member		
Clay, very stiff, and weathered shale, noncalcareous, blue gray; contains selenite crystals	4	30

14-20-25cc1.—Sample log of jetted well in SW SW sec. 25, T. 14 S., R. 20 W., Ellis County. Surface altitude, 2,076.6 feet; dry, September 27, 1950.

	Thickness, feet	Depth, feet
NEOGENE—Pleistocene		
Alluvium		
Silt, sandy, hard, tan	1	1
Silt; contains medium and fine sand and much limestone gravel	7	8
Gravel, limestone, medium to coarse; contains much light-brown silt	1	9
Silt, sandy, light brown, and medium limestone gravel,	3	12
Sand, coarse to very coarse, mixture of igneous and limestone pebbles	2	14

14-20-25cc2.—Sample log of jetted well in SW SW sec. 25, T. 14 S., R. 20 W., Ellis County. Surface altitude, 2,067.9 feet; dry, September 26, 1950.

	Thickness, feet	Depth, feet
NEOGENE—Pleistocene		
Alluvium		
Silt, gray	1	1
Silt, slightly sandy, loose, gray to brown	5	6
Sand, medium, and hard brown silt	8	14
Gravel, fine, igneous and limestone pebbles	4	18

14-20-31aa.—Sample log of jetted well in NE NE sec. 31, T. 14 S., R. 20 W., Ellis County. Surface altitude, 2,083.0 feet; dry, August 9, 1950.

	Thickness, feet	Depth, feet
NEOGENE—Pleistocene		
Loveland Formation		
Silt, calcareous, dark gray	2	2
Clay, silty, calcareous, gray	2	4
Silt, clayey, calcareous, dark brown	12	16
Crete Formation		
Sand, medium to coarse; contains some fine gravel	12.5	28.5

14-20-31cc.—Sample log of jetted well in SW SW sec. 31, T. 14 S., R. 20 W., Ellis County. Surface altitude, 2,018.1 feet; water level, 8.20 feet, September 16, 1950.

	Thickness, feet	Depth, feet
NEOGENE—Pleistocene		
Terrace deposits		
Silt, calcareous, dark gray	1	1
Clay, silty, soft, calcareous, light gray	7	8
Sand, medium to coarse; contains some gravel	6	14
Gravel and sand	4	18

14-20-32aa3.—Sample log of drilled test hole in NE NE sec. 32, T. 14 S., R. 20 W., 400 feet south and 390 feet west of NE corner along fence line, 90 feet east of corner post, Ellis County. Surface altitude, 2,089.4 feet.

	Thickness, feet	Depth, feet
Silt, sandy, brown (road fill)	2	2
NEOGENE—Pleistocene		
Loveland Formation		
Silt, compact, sandy, gray to brown; contains some clay particles	1.5	3.5
Silt, sandy, gray to brown	2	5.5
Silt, sandy, rusty brown; contains some gravel	4.5	10
Silt, clayey, sandy, brown to buff	5	15
Silt, clayey, sandy, brown	3	18
Crete Formation		
Gravel (limestone and quartz pebbles), fine to coarse; contains clayey sandy silt	7	25
Gravel, fine to coarse, quartz and feldspar pebbles; contains silty clay 1 foot thick at 26 to 27 feet and some ¼-inch limestone pebbles and shell fragments	5	30
Gravel and sand, fine to medium	3	33
Gravel, fine to coarse, and gray clay	5	38
Gravel, coarse, predominantly limestone pebbles; contains some quartz and feldspar pebbles and some clay	6	44
CRETACEOUS		
Carlile Shale—Blue Hill Shale member		
Shale, noncalcareous, blue gray to black; contains fragments of limestone and satin spar	4	48

14-20-32ad.—Sample log of jetted well in SE NE sec. 32, T. 14 S., R. 20 W., Ellis County. Surface altitude, 2,079.2 feet; dry, August 16, 1950.

	Thickness, feet	Depth, feet
NEOGENE—Pleistocene		
Loveland Formation		
Silt, calcareous, dark gray	1	1
Silt, blocky, clayey, calcareous, dark brown	10.5	11.5
Crete Formation		
Sand, medium to coarse; contains some limestone pebbles and some clay	11.5	23

14-20-32bb.—Sample log of jetted well in NW NW sec. 32, T. 14 S., R. 20 W., Ellis County. Surface altitude, 2,089.7 feet; dry, August 19, 1950.

	Thickness, feet	Depth, feet
NEOGENE—Pleistocene		
Loveland Formation		
Silt, calcareous, dark gray	1	1
Clay, silty, calcareous, dark brown	1	2
Silt, clayey, calcareous, brown	3.5	5.5
Sand, very fine, silty	2.5	8
Silt, sandy, calcareous, dark gray	5	13

	Thickness, feet	Depth, feet
Crete Formation		
Gravel, medium; contains limestone fragments	4	17
Gravel, fine; contains limestone fragments and fine sand	3	20

14-20-32dd1.—Sample log of jetted observation well in SE SE sec. 32, T. 14 S., R. 20 W., Ellis County. Surface altitude, 2,056.4 feet; water level, 22.30 feet, September 15, 1950.

	Thickness, feet	Depth, feet
NEOGENE—Pleistocene		
Loveland Formation		
Silt, sandy, calcareous, dark gray	1	1
Clay, sandy, calcareous, dark gray	4	5
Crete Formation		
Sand, coarse	1	6
Sand, fine	2	8
Sand, very coarse; contains some gravel	7	15
Sand and gravel	10	25

14-20-34bb.—Sample log of jetted well in NW NW sec. 34, T. 14 S., R. 20 W., Ellis County. Surface altitude, 2,089.9 feet; water level, 15.66 feet, September 27, 1950.

	Thickness, feet	Depth, feet
NEOGENE—Pleistocene		
Colluvium(?)		
Silt, gray	0.5	0.5
Silt, clayey, calcareous, tan	1.5	2
Silt, loose, calcareous, brown	4	6
Silt, loose, sandy, tan	6	12
Sand, fine to very fine, silty, well sorted	5	17
Caliche, hard, white	.1	17.1
Sand, fine, very silty, tan	5.4	22.5

14-20-34bc.—Sample log of jetted well in SW NW sec. 34, T. 14 S., R. 20 W., Ellis County. Surface altitude, 2,079.7 feet; water level, 13.94 feet, September 27, 1950.

	Thickness, feet	Depth, feet
NEOGENE—Pleistocene		
Loveland Formation		
Silt, gray	0.5	0.5
Silt, loose, calcareous, brown	2.5	3
Silt, powdery, calcareous, tan	2	5
Silt, loose, clayey, noncalcareous, brown	7	12
Silt, clayey, calcareous, light brown	4	16
Silt, sandy, calcareous, dark brown; contains medium sand	5	21
Crete Formation		
Sand, fine to medium, silty, contains grains of igneous rock	6	27

14-20-35bb.—Sample log of jetted well in NW NW sec. 35, T. 14 S., R. 20 W., Ellis County. Surface altitude, 2,084.1 feet; dry, September 22, 1950.

	Thickness, feet	Depth, feet
NEOGENE—Pleistocene		
Colluvium		
Soil, silty, gray	1	1
Silt, very hard, tight, slightly sandy, gray	1	2
Silt, clayey, slightly sandy, tan	1	3
Clay, noncalcareous, white to gray	1	4
Sand, coarse, containing grains of igneous rock, and calcareous light-brown clay	2.5	6.5
Silt, clayey, noncalcareous, rust color	1	7.5
CRETACEOUS		
Carlile Shale—Blue Hill Shale member		
Shale, clayey, noncalcareous, olive green		7.5

14-20-35bc.—Sample log of jetted well in SW NW sec. 35, T. 14 S., R. 20 W., Ellis County. Surface altitude, 2,071.9 feet; water level, 9.05 feet, September 27, 1950.

	Thickness, feet	Depth, feet
NEOGENE—Pleistocene		
Loveland Formation		
Silt, dark gray	1	1
Silt, compact, clayey, gray	1	2
Silt, powdery, calcareous, tan	12	14
Silt, clayey; contains caliche nodules	1.5	15.5
Sand, medium, very silty	1.5	17
Crete(?) Formation		
Gravel, fine, silty, pebbles of limestone and igneous rock	1.8	18.8

14-20-35cc.—Sample log of jetted well in SW SW sec. 35, T. 14 S., R. 20 W., Ellis County. Surface altitude, 2,054.0 feet; water level, 11.39 feet, September 22, 1950.

	Thickness, feet	Depth, feet
NEOGENE—Pleistocene		
Loveland Formation		
Soil, silty, black	1	1
Silt, very compact, very calcareous, tan	2	3
Silt, clayey, loose, gray	1	4
Silt, blocky, clayey in zones, brown; contains some sand	14	18
Crete Formation		
Sand, coarse, well sorted; contains some fine gravel	7.4	25.4

14-20-36dd.—Sample log of jetted well in SE SE sec. 36, T. 14 S., R. 20 W., Ellis County. Surface altitude, 2,072.9 feet; water level, 16.26 feet, September 16, 1950.

	Thickness, feet	Depth, feet
NEOGENE—Pleistocene		
Loveland Formation		
Soil, silty, dark brown	2	2
Silt, blocky, sandy, gray	6	8
Silt, clayey, slightly sandy, hard, light tan	7	15
Silt, clayey, soft, light tan	2	17
Silt, hard, tan; contains some clay	7.5	24.5
CRETACEOUS		
Carlile Shale—Blue Hill Shale member		
Shale, clayey, noncalcareous, gray green	..	24.5

14-21-25cc.—Sample log of jetted well in SW SW sec. 25, T. 14 S., R. 21 W., Trego County. Surface altitude, 2,073.4 feet; water level, 12.90 feet, September 15, 1950.

	Thickness, feet	Depth, feet
NEOGENE—Pleistocene		
Loveland Formation		
Silt, clayey to sandy, calcareous, dark brown	6	6
Crete Formation		
Sand, medium	5	11
Sand and gravel	5	16

14-21-25dd.—Sample log of jetted well in SE SE sec. 25, T. 14 S., R. 21 W., Trego County. Surface altitude, 2,106.2 feet; water level, 12.20 feet, September 15, 1950.

	Thickness, feet	Depth, feet
NEOGENE—Pleistocene		
Loveland Formation		
Silt, calcareous, tan	1	1
Silt, calcareous, dark gray	8	9
Silt, clayey, blocky, calcareous, dark brown	18	27

14-21-26da.—Sample log of jetted well in NE SE sec. 26, T. 14 S., R. 21 W., Trego County. Surface altitude, 2,100.6 feet; dry, September 7, 1950.

	Thickness, feet	Depth, feet
NEOGENE—Pleistocene		
Loveland Formation		
Soil, silty, black	2	2
Silt, loose, dark gray	3	5
Silt, hard, blocky, dark brown	2	7
Silt, loose, clayey and sandy, tan	12	19

14-21-27ad.—Sample log of drilled test hole in SE NE sec. 27, T. 14 S., R. 21 W., 0.48 mile south of corner and eight feet west of center of road, Trego County. Surface altitude, 2,108.4 feet; water level, 76.70 feet, October 19, 1949.

	Thickness, feet	Depth, feet
Silt, black, dark brown (road fill)	2	2
NEOGENE—Pleistocene		
Loveland Formation		
Silt, brown, and angular limestone gravel	2	4
Silt, plastic, tan to brown	6	10
Silt, sandy, rusty brown	3	13
Silt, plastic, buff	8	21
Gravel (limestone pebbles), and brown silt	4	25
Silt, plastic, clayey, gray	3	28
Crete Formation		
Gravel, medium to fine; contains some coarse arkosic sand	7	35
Gravel, medium to coarse	2	37
Gravel, medium to coarse, arkosic	2	39
Sappa Formation		
Silt, calcareous, gray white	6	45
Silt, calcareous, gray white to buff	5	50
Silt, calcareous, gray white to cream color	5	55
Silt, calcareous, white	8	63
Grand Island Formation		
Gravel (limestone pebbles); contains some gray silt	4	67
Clay, gray, and silt; contains limestone gravel	3	70
Gravel, fine to medium, pebbles of limestone and quartz	4	74
Gravel, medium to coarse, pebbles of limestone and quartz, and gray silt	4	78
Gravel, fine to coarse, pebbles of limestone and quartz,	6	84
Gravel, coarse, pebbles of limestone and quartz	5	89
Gravel, medium to fine, pebbles of igneous rock	2	91
Gravel, coarse to fine, pebbles of igneous rock and limestone	2	93
CRETACEOUS		
Carlile Shale		
Shale, pliable, plastic, calcareous, blue	2	95

14-21-27dd.—Sample log of jetted well in SE SE sec. 27, T. 14 S., R. 21 W., Trego County. Surface altitude, 2,099.5 feet; water level, 27.30 feet, September 15, 1950.

	Thickness, feet	Depth, feet
NEOGENE—Pleistocene		
Loveland Formation		
Silt, calcareous, light gray	3	3
Clay, calcareous, light tan; contains coarse sand	14	17
Crete Formation		
Sand, coarse to very coarse, poorly sorted; contains some gravel	13	30

14-21-28cb.—Sample log of jetted well in NW SW sec. 28, T. 14 S., R. 21 W., Trego County. Surface altitude, 2,118.4 feet; dry, August 3, 1950.

	Thickness, feet	Depth, feet
NEOGENE—Pleistocene		
Loveland Formation		
Silt, calcareous, light gray	1	1
Clay, sandy, calcareous, brown	8	9
Crete(?) Formation		
Sand, poorly sorted; contains limestone pebbles	13	22
No sample	5.1	27.1

14-21-28cc.—Sample log of jetted well in SW SW sec. 28, T. 14 S., R. 21 W., Trego County. Surface altitude, 2,096.7 feet; water level, 12.50 feet, August 3, 1950.

	Thickness, feet	Depth, feet
NEOGENE—Pleistocene		
Loveland Formation		
Silt, calcareous, tan	1	1
Clay, calcareous, tan to gray; contains some sand	6	7
Crete Formation		
Sand, very coarse; contains gravel	12	19
Driven from 19 to 25 feet	6	25

14-21-30cd.—Sample log of jetted well in SE SW sec. 30, T. 14 S., R. 21 W., Trego County. Surface altitude, 2,065.4 feet; water level, 13.08 feet, July 14, 1950.

	Thickness, feet	Depth, feet
NEOGENE—Pleistocene		
Terrace deposits		
Silt, dark brown	1	1
Sand, silty, tan	15	16
CRETACEOUS		
Carlile Shale		
Shale, blue	.8	16.8

14-21-30da.—Sample log of jetted well in NE SE sec. 30, T. 14 S., R. 21 W., Trego County. Surface altitude, 2,122.7 feet; dry, September 15, 1950.

	Thickness, feet	Depth, feet
NEOGENE—Pleistocene		
Loveland Formation		
Silt, black	3	3
Silt, sandy, tan	5	8
Crete Formation		
Sand, coarse to very coarse; contains a few pebbles	13	21

14-21-30dd.—Sample log of jetted well in SE SE sec. 30, T. 14 S., R. 21 W., Trego County. Surface altitude, 2,112.9 feet; dry, July 19, 1950.

	Thickness, feet	Depth, feet
NEOGENE—Pleistocene		
Crete Formation		
Silt, black; contains some very coarse sand	3	3
Sand, very coarse; contains some gravel	7	10
Gravel	0.5	10.5
Sand, medium	1.5	12
Sand, very coarse; contains some gravel	2	14

14-21-32ad.—Sample log of jetted well in SE NE sec. 32, T. 14 S., R. 21 W., Trego County. Surface altitude, 2,049.1 feet; water level, 6.50 feet, August 3, 1950.

	Thickness, feet	Depth, feet
NEOGENE—Pleistocene		
Alluvium		
Silt, calcareous, light tan	2	2
Sand, very coarse, clayey	0.5	2.5
Clay, calcareous, dark gray; contains some sand	4.5	7
Sand, very coarse; contains some fine gravel	9	16
Clay, sandy, soft, calcareous, blue gray	5	21
CRETACEOUS		
Carlile Shale		
Shale, weathered, calcareous, black to dark gray		21

14-21-33bb.—Sample log of jetted observation well in NW NW sec. 33, T. 14 S., R. 21 W., Trego County. Surface altitude, 2,057.7 feet; water level, 7.90 feet, August 3, 1950.

	Thickness, feet	Depth, feet
NEOGENE—Pleistocene		
Alluvium		
Silt, calcareous, tan	1	1
Clay, calcareous, dark gray; contains some sand	4	5
Clay, sandy, calcareous, tan	18	23
Sand, very coarse	5	28
CRETACEOUS		
Carlile Shale		
Shale, weathered, clayey, calcareous, dark gray to black,		28

14-21-34aa.—Sample log of drilled well in NE NE sec. 34, T. 14 S., R. 21 W., 25 feet south and 35 feet west of center of crossroads, Trego County. Surface altitude, 2,095.4 feet; dry, October 22, 1949.

	Thickness, feet	Depth, feet
NEOGENE—Pleistocene		
Loveland Formation		
Silt, friable, slightly sandy, brown	1	1
Silt, clayey, slightly sandy, brown to gray buff	1.5	2.5
Silt, clayey, sandy, buff	2.5	5
Silt, sandy, rusty brown; contains buff silt	2	7
Crete Formation		
Sand, coarse, and fine quartz and feldspar gravel; contains some clay	3	10
Sand, fine to coarse; contains some fine gravel	5	15
Sand, medium to coarse; contains some fine to medium gravel	2	17
Gravel, fine to coarse, quartz and feldspar pebbles	8	25
Gravel, medium to coarse, limestone pebbles	7	32
CRETACEOUS		
Carlile Shale		
Shale, plastic, weathered, yellow to gray	2	34
Shale, noncalcareous, blue black	3	37

14-21-34ad.—Sample log of drilled test hole in SE NE sec. 34, T. 14 S., R. 21 W., 0.35 mile south of corner and 6 feet west of center of road, Trego County. Surface altitude, 2,087.3 feet.

	Thickness, feet	Depth, feet
Silt, gray to brown (road fill)	1	1
NEOGENE—Pleistocene		
Loveland Formation		
Silt, plastic, clayey, calcareous, buff	1	2
Silt, sandy, calcareous, tan	3	5
Crete Formation		
Gravel, fine to coarse, pebbles of igneous rock and limestone; contains silt	4	9
Gravel, fine to medium, quartzose, and coarse sand	5	14
Gravel, coarse to fine, pebbles of quartz, claystone, and ironstone	2	16
Sand, coarse to medium, quartz and feldspar grains	2	18
Sand, coarse, and fine to medium quartz gravel	3	21
Gravel, fine to medium	2	23
CRETACEOUS		
Carlile Shale		
Shale, pliable, plastic, noncalcareous, blue gray to black	3	26

14-21-34da.—Sample log of drilled test hole in NE SE sec. 34, T. 14 S., R. 21 W., 0.3 mile north of corner and 12 feet west of center of road, Trego County. Surface altitude, 2,041.4 feet; water level, 16.90 feet, October 13, 1949.

	Thickness, feet	Depth, feet
NEOGENE—Pleistocene		
Terrace deposits		
Sand, fine to coarse; contains silt	3	3
Silt, fine, sandy, buff	6	9
Silt, buff to gray buff; contains fine to coarse gravel	6	15
Silt, buff to brown; contains medium to coarse sand	3	18
Clay, plastic, gray; contains fine to coarse sand and gravel	7	25
Clay, plastic, gray; contains some gravel and sand	5	30
Clay, plastic, gray; contains fine and coarse sand	5	35
Clay, gray; contains fine to coarse gravel	5	40
Clay, sandy, gray; contains some coarse sand	4	44
Clay, pliable, plastic, slightly sandy, gray	6	50
Gravel, fine to medium, and coarse sand	6	56
Gravel, fine to coarse, pebbles of igneous rock, limestone, and shale	7	63
CRETACEOUS		
Carlile Shale—Fairport Shale member		
Shale, calcareous, gray black	5	68

14-21-34dd.—Sample log of drilled test hole in SE SE sec. 34, T. 14 S., R. 21 W., 300 feet north of corner and 20 feet west of center of road, Trego County. Surface altitude, 2,028.4 feet.

	Thickness, feet	Depth, feet
NEOGENE—Pleistocene		
Alluvium		
Sand, fine to coarse quartz and feldspar grains; contains some silt	3	3
Sand, fine to coarse; contains some silt	2	5
Sand, medium to coarse, and fine gravel	5	10
Gravel, medium to coarse	2	12
Gravel, medium to coarse; contains some shale fragments	1	13
CRETACEOUS		
Carlile Shale—Fairport Shale member		
Shale, fissile, calcareous, black	5	18

14-21-35cb.—Sample log of jetted well in NW SW sec. 35, T. 14 S., R. 21 W., Trego County. Surface altitude, 2,047.4 feet; dry, August 4, 1950.

	Thickness, feet	Depth, feet
NEOGENE—Pleistocene		
Terrace deposits		
Silt; contains very coarse sand	1	1
Sand, very coarse, poorly sorted	5	6
CRETACEOUS		
Carlile Shale		
Shale, clayey, calcareous, dark gray; weathers tan	5	11

14-21-35cc.—Sample log of jetted well in SW SW sec. 35, T. 14 S., R. 21 W., Trego County. Surface altitude, 2,033.7 feet; water level, 12.20 feet, September 15, 1950.

	Thickness, feet	Depth, feet
NEOGENE—Pleistocene		
Terrace deposits		
Silt, very sandy, calcareous	3	3
Clay, very sandy, calcareous, tan	7	10
Sand, medium to coarse, well sorted	2	12
Sand, very coarse; contains limestone pebbles	8	20

14-21-36bc.—Sample log of jetted well in SW NW sec. 36, T. 14 S., R. 21 W., Trego County. Surface altitude, 2,073.8 feet; dry, September 7, 1950.

	Thickness, feet	Depth, feet
NEOGENE—Pleistocene		
Loveland Formation		
Soil, silty, black	1	1
Silt, clayey, calcareous, gray	2	3
Silt, very sandy, gray	2	5
Crete Formation		
Sand, coarse to very coarse, poorly sorted; contains much gravel	5	10
Sand and gravel	10	20

14-22-25da1.—Sample log of jetted well in NE SE sec. 25, T. 14 S., R. 22 W., Trego County. Surface altitude, 2,103.3 feet; water level, 6.90 feet, September 15, 1950.

	Thickness, feet	Depth, feet
NEOGENE—Pleistocene		
Alluvium		
Silt, dark brown; contains coarse sand	0.5	0.5
Sand, very coarse; contains some gravel	7.6	8.1

14-22-25da2.—Sample log of jetted well in NE SE sec. 25, T. 14 S., R. 22 W., Trego County. Surface altitude, 2,098.9 feet; water level, 5.25 feet, September 15, 1950.

	Thickness, feet	Depth, feet
NEOGENE—Pleistocene		
Alluvium		
Silt; contains some very coarse sand	1	1
Sand, very coarse; contains some gravel	6.1	7.1

14-22-36aa.—Sample log of drilled observation well in NE NE sec. 36, T. 14 S., R. 22 W., 0.2 mile west of corner and 20 feet south of center of road, Trego County. Surface altitude, 2,114.7 feet; water level, 42.65 feet, October 19, 1949.

	Thickness, feet	Depth, feet
NEOGENE—Pleistocene		
Crete Formation		
Silt, dark brown; contains fine to coarse gravel and some coarse sand	1	1
Gravel, fine to coarse, quartzose, rusty brown	1	2
Gravel, fine quartz and feldspar pebbles	3	5
Gravel, fine to coarse, pebbles of quartz, feldspar, and limestone	2	7
Gravel, fine to medium, quartzose; contains some coarse sand	3	10
Gravel, fine to coarse, quartzose	4.5	14.5
Sappa Formation		
Silt, soft, plastic, gray white	5.5	20
Silt, clayey, calcareous, gray white	6	26
Silt, sandy, tan to cream color	6	32
Gravel, fine to medium, and medium to coarse sand; contains some limestone fragments	6	38
Silt, clayey, calcareous, gray white	7	45
Silt, calcareous, gray to gray white	5	50
Silt, gray to gray white	8	58
Grand Island Formation		
Gravel, fine to medium, pebbles of igneous rock	7	65
Gravel, fine, and coarse quartz sand	3	68
CRETACEOUS		
Carlile Shale—Fairport Shale Member		
Shale, calcareous, blue black; contains limy material at 68 feet	6.5	74.5

14-22-36ad.—Sample log of jetted well in SE NE sec. 36, T. 14 S., R. 22 W., Trego County. Surface altitude, 2,069.2 feet; water level, 6.95 feet, September 15, 1950.

	Thickness, feet	Depth, feet
NEOGENE—Pleistocene		
Alluvium		
Silt, dark brown	1	1
Silt, very sandy; contains some gravel	4	5
Clay, calcareous, light brown; contains some very coarse sand	7	12
Sand, coarse; contains some pebbles of quartz and limestone	4	16
Sand, very coarse; contains some fine gravel	8.4	24.4

14-22-36da.—Sample log of jetted well in NE SE sec. 36, T. 14 S., R. 22 W., Trego County. Surface altitude, 2,068.3 feet; water level, 6.50 feet, September 15, 1950.

	Thickness, feet	Depth, feet
NEOGENE—Pleistocene		
Alluvium		
Sand, fine; contains some silt	3	3
Sand, very coarse	9	12
Gravel; contains some sand and limestone pebbles	2	14
Sand, very coarse; contains some gravel	3.4	17.4

14-22-36dd.—Sample log of jetted well in SE SE sec. 36, T. 14 S., R. 22 W., Trego County. Surface altitude, 2,063.4 feet; water level, 3.85 feet, September 15, 1950.

	Thickness, feet	Depth, feet
NEOGENE—Pleistocene		
Alluvium		
Silt, sandy, brown	0.5	0.5
Sand, very coarse	4.5	5
Gravel, very coarse; contains pebbles of quartz and limestone	5	10
Sand and gravel	1.6	11.6

15-16-30cc.—Sample log of drilled test hole in SW SW sec. 30, T. 15 S., R. 16 W., Ellis County. Surface altitude, 1,843.2 feet.

	Thickness, feet	Depth, feet
NEOGENE—Pleistocene		
Alluvium		
Silt, gray buff; contains medium to fine gravel and sand	7	7
Gravel, coarse to fine, and sand; contains gray silt	13	20
Gravel, very coarse to fine; contains sand	12	32
CRETACEOUS		
Graneros Shale		
Shale, dark gray	8	40
Shale, dark greenish gray; contains fine greenish-gray sandstone	10	50

15-16-31bb.—Sample log of drilled test hole in NW NW sec. 31, T. 15 S., R. 16 W., Ellis County. Surface altitude, 1,860.6 feet; water level, 22.30 feet, January 14, 1944.

	Thickness, feet	Depth, feet
Road fill	3	3
NEOGENE—Pleistocene		
Terrace deposits		
Sand, coarse to fine, and silt, buff; contains coarse to fine gravel	7	10
Silt, slightly clayey, yellow gray; contains medium to fine gravel and sand	15	25
Sand, coarse to fine, and medium to fine gravel; contains buff and green silt	5	30
Sand, coarse to fine; contains medium to fine gravel	10	40
Gravel, very coarse to fine, and sand	10	50
Gravel, medium to fine; contains sand	4	54
CRETACEOUS		
Graneros Shale		
Shale, greenish gray; contains very fine silty gray-green sandstone	6	60

15-17-1dd.—Sample log of drilled test hole in SE SE sec. 1, T. 15 S., R. 17 W., 0.2 mile north of corner and 10 feet west of center of road, Ellis County. Surface altitude, 1,881.1 feet.

	Thickness, feet	Depth, feet
Silt, dark brown; contains sand and gravel (road fill),	3	3
NEOGENE—Pleistocene		
Terrace deposits		
Silt, compact, sandy, brown to tan	3	6
Silt, compact, sandy, brown	2	8
Silt, medium compact, gray brown	2	10
Silt, compact, dark brown	5	15
Silt, compact, calcareous, sandy, gray	2	17
Silt, very sandy, gray	1	18
Gravel, medium to coarse; contains some sand	5	23
Gravel, coarse to medium	4	27
CRETACEOUS		
Greenhorn Limestone		
Shale and limestone, interbedded, gray	2	29

15-17-12aa.—Sample log of drilled test hole in NE NE sec. 12, T. 15 S., R. 17 W., 0.2 mile south of corner and 10 feet west of center of road, Ellis County. Surface altitude, 1,884.6 feet; water level, 22.67 feet, November 4, 1949.

	Thickness, feet	Depth, feet
Silt, friable, sandy, brown (road fill)	3	3
NEOGENE—Pleistocene		
Terrace deposits		
Silt, sandy, calcareous, tan	3	6
Silt, clayey, slightly calcareous, tan	4	10
Silt, sandy, brown; contains gravel	7	17

	Thickness, feet	Depth, feet
Clay, sandy, gray	3	20
Gravel, fine to coarse, pebbles of quartz, feldspar, and limestone	5	25
CRETACEOUS		
Greenhorn Limestone		
Shale, brittle, calcareous, blue gray	2	27

15-18-7bb.—Sample log of jetted well in NW NW sec. 7, T. 15 S., R. 18 W., Ellis County. Surface altitude, 2,065.7 feet; water level, 6.80 feet, July 14, 1950.

	Thickness, feet	Depth, feet
NEOGENE—Pleistocene		
Nebraskan(?) deposits		
Silt, dark brown	1	1
Clay, sandy, gray	4	5
Clay, very sandy, coarse to medium, tan	5	10
CRETACEOUS		
Carlile Shale		
Shale, buff and blue, weathered	2	12

15-18-7cc.—Sample log of jetted well in SW SW sec. 7, T. 15 S., R. 18 W., Ellis County. Surface altitude, 2,069.9 feet; water level, 7.55 feet, July 14, 1950.

	Thickness, feet	Depth, feet
NEOGENE—Pleistocene		
Nebraskan(?) deposits		
Silt, brown	1	1
Silt, sandy, tan; contains some quartz gravel	5	6
Gravel; contains some quartz and black chert fragments	0.5	6.5
Clay, sandy, buff	2	8.5
CRETACEOUS		
Carlile Shale		
Shale, clayey, light gray and tan	0.5	9

15-18-17ba.—Drillers log of upper part of Palmer Oil Corporation No. 1 Carl Ruder well in NE NW sec. 17, T. 15 S., R. 18 W., Ellis County. Drilled August and September 1935. Surface altitude, 1,982.0 feet.

	Thickness, feet	Depth, feet
NEOGENE—Pleistocene		
Alluvium		
Silt and sand	10	10
CRETACEOUS		
Carlile Shale and Greenhorn Limestone		
Shale, gray, calcareous	41	51
Limestone, chalky, and calcareous shale	17	68
Shale, gray, calcareous	27	95
Limestone, white, chalky, and calcareous shale	10	105
Shale, gray, calcareous; contains thin crystalline limestone layers	35	140

	Thickness, feet	Depth, feet
Graneros Shale		
Shale, dark gray, noncalcareous	22	162
Shale, brown, contains yellow ochre	13	175
Dakota Formation and Kiowa Shale		
Clay, white and light gray; contains quartz grains	35	210
Clay, gray; contains pyrite, iron pellets, and lignite fragments	25	235
Sand, fine and medium, small amount of coarse to very coarse brown iron-stained sand	10	245
Clay, buff, sandy; contains iron pellets	30	275
Clay, light gray and maroon; contains iron throughout,	40	315
Clay, white, and sandy limonite	15	330
Clay and shale, gray; contains limonite, sandy at base,	35	365
Sand, fine to medium, gray, glauconitic, subangular	5	370
Shale, gray and maroon, silty, limonitic; contains glauconitic sand at base	48	418
Shale, gray, silty and limonitic	7	425
Shale, medium gray, buff, and maroon, silty at 475 to 480 feet	55	480
Sand, gray, very fine to medium, round to subround; contains pyrite, chalcopyrite, and glauconite	20	500
Shale, gray and reddish brown, silty, limonitic	15	515
Sand, silty, very fine to fine, some medium, reddish brown; contains white sand, pyrite, and glauconite,	35	550
Sand, red, silty, glauconitic	15	565
Silt, red, sandy, and gray shale; contains pyrite	10	575
Cheyenne Sandstone		
Sand, fine, whitish buff; contains some medium sand	10	585
Sand, rounded, well sorted, fine to medium, buff; contains small amount of pyrite and glauconite	135	720
Sand, rounded, well sorted, fine, stained reddish buff; contains redbed fragments at 760 to 765 feet	85	805
PERMIAN SYSTEM		
Nippewalla Group		
Siltstone and shale, red, sandy		

15-18-18cc.—Sample log of jetted well in SW SW sec. 18, T. 15 S., R. 18 W., Ellis County. Surface altitude, 2,014.8 feet; water level, 11.50 feet, September 15, 1950.

	Thickness, feet	Depth, feet
NEOGENE—Pleistocene		
Colluvium		
Silt, dark brown, calcareous	2	2
Sand and gravel, clayey	2.5	4.5
Clay and coarse sand, calcareous, light tan	4.5	9
Sand, very coarse; contains some gravel	1	10
Sand, very coarse, clayey; contains some weathered limestone fragments	2.6	12.6

15-18-21aa.—Sample log of drilled test hole in NE NE sec. 21, T. 15 S., R. 18 W., 45 feet west and 30 feet south of center of crossroads and 4 feet east of stone corner post, Ellis County. Surface altitude, 2,036.5 feet; water level, 10.50 feet, November 2, 1949.

	Thickness, feet	Depth, feet
Soil, medium compact, sandy, brown	1	1
NEOGENE—Pleistocene		
Nebraskan(?) deposits		
Silt, medium compact, sandy, rusty brown	0.5	1.5
Silt, calcium carbonate cemented, compact, sandy, buff; contains sand and gravel	2	3.5
Gravel, fine to medium; contains caliche and silt	2.5	6
Clay, calcareous, gray to yellow; contains gravel and satin spar	4	10
CRETACEOUS		
Carlile Shale—Fairport Shale member		
Clay and shale, gray and yellow; contains weathered bentonite	2	12
Shale and clay, compact, calcareous, gray and yellow,	8	20
Shale and clay, gray, yellow; contains chalky limestone	3	23
Shale, gray yellow; contains streaks of bentonite	3	26

15-18-27cb3.—Sample log of drilled observation well in NW SW sec. 27, T. 15 S., R. 18 W., 0.3 mile north of corner, 150 feet north of north end of bridge, and 35 feet east of center of road, Ellis County. Surface altitude, 1,907.9 feet; water level, 9.32 feet, November 2, 1949.

	Thickness, feet	Depth, feet
NEOGENE—Pleistocene		
Terrace deposits		
Silt, sandy, tan; contains medium sand	3	3
Sand, medium to coarse; contains coarse gravel	7	10
Sand, coarse, quartzose, and medium to coarse gravel,	5	15
Gravel, fine to coarse, quartzose; contains blue-gray silt at 18 feet and a few limestone pebbles	5	20
Sand, coarse, quartzose, and fine gravel	5	25
Gravel, medium to fine, quartzose, and coarse sand; contains limestone pebbles	5	30
Sand, medium to coarse, quartzose; contains blue-gray clay	5	35
Sand, coarse, and fine to medium quartz and limestone gravel	5	40
Sand, medium to coarse, quartzose	9	49
CRETACEOUS		
Graneros Shale		
Shale, calcareous, blue gray to black	1	50

15-18-27cb4.—Sample log of drilled test hole in NW SW sec. 27, T. 15 S., R. 18 W., 0.4 mile north of corner and 35 feet east of center of road, Ellis County. Surface altitude, 1,919.4 feet; water level, 22.40 feet, November 5, 1949.

	Thickness, feet	Depth, feet
NEOGENE—Pleistocene		
Terrace deposits		
Silt, tan, and fine to medium sand	2	2
Silt, medium compact, sandy, buff	8	10
Silt, calcareous, gray buff	7	17
Silt, plastic, calcareous, gray buff; contains some gravel at 17 feet	5	22
Silt, sandy, gray, and coarse limestone and quartz gravel	8	30
Gravel, coarse, quartzose, and gray compact silt	10	40
Gravel, coarse; contains blue-gray silt to 44 feet	10	50
Gravel, coarse; contains some layers of gray silt	9	59
CRETACEOUS		
Graneros Shale		
Shale, blue to blue gray, and limestone	4	63

15-18-27cc.—Sample log of drilled test hole in SW SW sec. 27, T. 15 S., R. 18 W., 45 feet north and 30 feet east of center of crossroads, Ellis County. Surface altitude, 1,911.3 feet; water level, 15.00 feet, November 2, 1949.

	Thickness, feet	Depth, feet
Silt, sandy, brown (road fill)	3	3
NEOGENE—Pleistocene		
Terrace deposits		
Silt, compact, sandy, tan	4	7
Sand, medium to coarse, quartzose	3	10
Sand, medium to coarse, quartzose, and medium to coarse gravel	5	15
Sand, coarse, grains of quartz, limestone, and shale, and medium to coarse gravel	5	20
Gravel, fine to coarse, pebbles of quartz, feldspar, and limestone; contains shell fragments	6.5	26.5
CRETACEOUS		
Graneros Shale		
Shale, very solid, calcareous, gray; contains much lag	3.5	30

15-18-33ad.—Sample log of drilled test hole in SE NE sec. 33, T. 15 S., R. 18 W., 0.3 mile south of corner and 30 feet west of center of road, Ellis County. Surface altitude, 1,954.4 feet; water level, 32.40 feet, November 2, 1949.

	Thickness, feet	Depth, feet
NEOGENE—Pleistocene		
Loveland Formation		
Silt, friable, brown	4	4
Silt, slightly sandy, buff	4	8
Silt, rusty brown; contains coarse sand in upper part	2	10

	Thickness, feet	Depth, feet
Crete Formation		
Gravel, fine to medium; contains coarse sand	5	15
Gravel, fine to medium, and coarse sand; contains very little silt	5	20
Sand, coarse, quartzose, and fine gravel	6	26
Gravel, fine to medium; contains very little yellow silt	4	30
Gravel, fine to medium, quartzose	6	36
CRETACEOUS		
Greenhorn Limestone		
Shale, calcareous, gray to gray black	3	39

15-18-34cb.—Sample log of drilled test hole in NW SW sec. 34, T. 15 S., R. 18 W., 0.3 mile north of corner and 35 feet east of center of road, Ellis County. Surface altitude, 1,955.5 feet.

	Thickness, feet	Depth, feet
Silt, brown	3	3
NEOGENE—Pleistocene		
Loveland Formation		
Silt, medium compact, tan	4	7
Silt, brown; contains fine to medium sand and medium gravel	5	12
Crete Formation		
Sand, medium to coarse; contains silt and medium to coarse gravel	8	20
Gravel, medium to coarse, quartzose	5	25
Gravel, coarse, quartzose; contains shale and limestone fragments	4	29
Gravel, coarse; contains some yellow clay	5	34
CRETACEOUS		
Greenhorn Limestone		
Shale, calcareous, gray to black	3	37

15-19-2cc.—Sample log of jetted well in SW SW sec. 2, T. 15 S., R. 19 W., Ellis County. Surface altitude, 2,041.2 feet; dry, August 1, 1950.

	Thickness, feet	Depth, feet
NEOGENE—Pleistocene		
Alluvium		
Silt, calcareous, dark gray	1.5	1.5
Clay, calcareous, tan; contains some sand	7.5	9
Clay, calcareous; contains some very coarse sand	3	12
Sand, very coarse; contains some fine gravel	2	14
Clay, sandy to very sandy in zones, calcareous, yellow tan	7	21

15-19-4cb.—Sample log of jetted well in NW SW sec. 4, T. 15 S., R. 19 W., Ellis County. Surface altitude, 2,054.3 feet; water level, 6.90 feet, September 16, 1950.

	Thickness, feet	Depth, feet
NEOGENE—Pleistocene		
Loveland Formation		
Soil, silty, dark gray	1	1
Silt, soft, tan; contains some clay	5	6
Silt, blocky, dark brown; contains much coarse sand	5	11
Silt, clayey, sandy, soft, tan	1	12
Silt, very sandy, hard, blocky, brown	4	16
Crete Formation		
Sand, very coarse, well sorted; contains yellow opal-cemented layer at base	5	21

15-19-4da.—Sample log of jetted well in NE SE sec. 4, T. 15 S., R. 19 W., Ellis County. Surface altitude, 2,064.1 feet; water level, 7.94 feet, September 16, 1950.

	Thickness, feet	Depth, feet
NEOGENE—Pleistocene		
Alluvium		
Soil, silty, dark brown	2	2
Clay, silty, calcareous, tan; contains fine sand	7	9
Silt, hard, blocky, sandy, brown	1	10
Silt, clayey, hard, calcareous, buff	2	12
CRETACEOUS		
Carlile Shale		
Shale, plastic, noncalcareous, blue green	1	13

15-19-5cb.—Sample log of jetted well in NW SW sec. 5, T. 15 S., R. 19 W., Ellis County. Surface altitude, 2,041.5 feet; water level, 31.10 feet, September 16, 1950.

	Thickness, feet	Depth, feet
NEOGENE—Pleistocene		
Loveland Formation		
Soil, silty, dark gray	1	1
Silt, loose, clayey, dark gray	2	3
Silt, very clayey, sandy, soft, plastic, tan	3	6
Clay, silty, tan; contains some coarse sand and limestone pebbles	1	7
Crete Formation		
Silt, blocky, sandy, extremely clayey, dark brown to tan; contains limestone fragments	26	33
Sand, fine to medium, very silty	1.8	34.8

15-19-7ad.—Sample log of jetted well in SE NE sec. 7, T. 15 S., R. 19 W., Ellis County. Surface altitude, 2,003.8 feet; water level, 10.80 feet, September 27, 1950.

	Thickness, feet	Depth, feet
NEOGENE—Pleistocene		
Alluvium		
Silt, sandy	1	1
Sand, medium to fine, arkosic	2	3
Sand, very coarse, and fine gravel	14.5	17.5

15-19-7bc1.—Sample log of drilled test hole in SW NW sec. 7, T. 15 S., R. 19 W., 0.45 mile south of corner and 7 feet east of center of road, Ellis County. Surface altitude, 2,030.1 feet.

	Thickness, feet	Depth, feet
Silt, sandy, dark brown (road fill)	1	1
NEOGENE—Pleistocene		
Loveland Formation		
Silt, loose, sandy, buff	2	3
Sand, coarse, quartzose, and brown silt	4	7
Crete Formation		
Sand, coarse; contains fine quartz gravel and shell fragments	8	15
Sand, medium to coarse, quartzose; contains some fine gravel	5	20
Sand, coarse, grains of limestone and granite	5	25
Gravel, fine to coarse, pebbles of granite and limestone; contains clay at 28.5 feet	4	29
Gravel, fine to coarse, pebbles of granite and limestone	3	32
CRETACEOUS		
Carlile Shale		
Shale, calcareous, sandy, dark gray	4	36

15-19-7bc2.—Sample log of jetted well in SW NW sec. 7, T. 15 S., R. 19 W., Ellis County. Surface altitude, 2,029.1 feet; water level, 9.65 feet, September 16, 1950.

	Thickness, feet	Depth, feet
NEOGENE—Pleistocene		
Loveland Formation		
Silt, hard, sandy, tan	1	1
Silt, loose, sandy, buff	2	3
Silt, sandy, dark brown	4	7
Crete Formation		
Sand, poorly sorted, fine to very coarse; contains some gravel	15.2	22.2

15-19-7dd.—Sample log of jetted well in SE SE sec. 7, T. 15 S., R. 19 W., Ellis County. Surface altitude, 2,018.8 feet; dry, September 27, 1950.

	Thickness, feet	Depth, feet
NEOGENE—Pleistocene		
Loveland Formation		
Silt, sandy	1	1
Sand, medium to fine, silty, grains of igneous rock	3	4
Crete Formation		
Sand, medium to very coarse, grains of igneous rock; contains fine gravel	18.9	22.9

15-19-8bb.—Sample log of jetted well in NW NW sec. 8, T. 15 S., R. 19 W., Ellis County. Surface altitude, 2,020.7 feet; water level, 21.80 feet, September 16, 1950.

	Thickness, feet	Depth, feet
NEOGENE—Pleistocene		
Loveland Formation		
Soil, silty, black	1	1
Silt, very clayey, calcareous, tan	4	5
Silt, clayey, sandy, tan	1	6
Crete Formation		
Sand, medium to very coarse, poorly sorted; contains some fine gravel	9	15
Sand	7	22

15-19-9bb.—Sample log of jetted well in NW NW sec. 9, T. 15 S., R. 19 W., Ellis County. Surface altitude, 2,045.1 feet; water level, 26.30 feet, September 16, 1950.

	Thickness, feet	Depth, feet
NEOGENE—Pleistocene		
Loveland Formation		
Soil, silty, dark gray	1	1
Silt, soft, clayey, calcareous, light tan	5	6
Silt, hard, sandy, dark brown	3	9
Sand, fine to very fine, very silty	9	18
Crete Formation		
Silt, very sandy, loose, calcareous, tan	16.8	34.8

15-19-9cb.—Sample log of jetted well in NW SW sec. 9, T. 15 S., R. 19 W., Ellis County. Surface altitude, 2,027.2 feet; dry, September 6, 1950.

	Thickness, feet	Depth, feet
NEOGENE—Pleistocene		
Loveland Formation		
Soil, silty, black	2	2
Silt, soft, clayey, light tan	2	4
Silt, hard, very calcareous, brown	5	9
Silt, very sandy, loose, tan	9	18
Sand, fine, silty	2	20
Crete Formation		
Sand	12	32

15-19-9cc.—Sample log of drilled observation well in SW SW sec. 9, T. 15 S., R. 19 W., 30 feet east and 25 feet north of center of crossroads, Ellis County. Surface altitude, 2,017.5 feet; water level, 33.01 feet, October 24, 1949.

	Thickness, feet	Depth, feet
NEOGENE—Pleistocene		
Loveland Formation		
Silt, medium compact, dark brown	2.5	2.5
Silt, fairly compact, sandy, calcareous, buff	2.5	5
Silt, medium compact, sandy, buff	2	7
Silt, calcareous, rusty brown to brown	4	11
Silt, buff, and medium to coarse sand	5	16
Crete, Sappa(?), and Grand Island(?) Formations		
Sand, medium to coarse, arkosic	4	20
Sand, coarse, arkosic	5	25
Gravel, medium coarse, arkosic, and coarse sand	5	30
Gravel, fine, arkosic, and coarse sand	5	35
Gravel, medium to coarse, arkosic	2	37
Clay, gray tan to buff, and coarse quartz gravel	6	43
Gravel, coarse to medium, interbedded with gray, buff, and white clay	7	50
Gravel, fine to medium, arkosic	4	54
Clay and limestone, weathered, white and gray; contains medium to fine gravel	3.5	57.5
CRETACEOUS		
Carlile Shale		
Shale, sandy, calcareous, dark gray to gray	2.5	60

15-19-10ab.—Sample log of jetted well in NW NE sec. 10, T. 15 S., R. 19 W., Ellis County. Surface altitude, 2,044.3 feet; water level, 7.40 feet, September 15, 1950.

	Thickness, feet	Depth, feet
NEOGENE—Pleistocene		
Colluvium		
Silt, calcareous, dark gray	1	1
Clay, sandy, slightly calcareous, dark gray	3	4
Clay, calcareous, tan	8	12
Clay, very hard, sandy, calcareous, tan; contains limestone fragments	3	15

15-19-10ad2.—Sample log of jetted well in SE NE sec. 10, T. 15 S., R. 19 W., Ellis County. Surface altitude, 2,021.1 feet; water level, 13.85 feet, September 15, 1950.

	Thickness, feet	Depth, feet
NEOGENE—Pleistocene		
Alluvium		
Silt, calcareous	2	2
Clay, calcareous, dark gray	2	4
Silt, sandy, noncalcareous, black	4	8
Clay, calcareous, brown; contains small limestone fragments	6	14
Sand, fine to medium, clayey	2	16

15-19-10bb.—Sample log of jetted well in NW NW sec. 10, T. 15 S., R. 19 W., Ellis County. Surface altitude, 2,043.1 feet; water level, 5.80 feet, September 15, 1950.

	Thickness, feet	Depth, feet
NEOGENE—Pleistocene		
Alluvium		
Soil, silty, dark gray	1	1
Silt, slightly sandy, hard, calcareous, brown	10	11
Sand, very coarse, very silty	6	17
Silt, clayey, very sandy, brown	3	20
Sand, medium to coarse; contains fine gravel	3	23

15-19-10cb.—Sample log of jetted well in NW SW sec. 10, T. 15 S., R. 19 W., Ellis County. Surface altitude, 2,032.4 feet; water level, 21.95 feet, September 15, 1950.

	Thickness, feet	Depth, feet
NEOGENE—Pleistocene		
Loveland Formation		
Soil, silty, black	3	3
Silt, blocky, gray, black stains on joints; contains some sand	3	6
Silt, sandy, gray	21	27
Crete Formation		
Sand, fine to medium, well sorted, yellow	6	33

15-19-13cb.—Sample log of jetted well in NW SW sec. 13, T. 15 S., R. 19 W., Ellis County. Surface altitude, 2,004.0 feet; dry, July 25, 1950.

	Thickness, feet	Depth, feet
NEOGENE—Pleistocene		
Loveland Formation		
Silt, calcareous, dark gray	4	4
Clay, light tan; contains some coarse sand	10	14
Crete Formation		
Sand, medium to coarse, well sorted	16.5	30.5

15-19-14aa.—Sample log of jetted well in NE NE sec. 14, T. 15 S., R. 19 W., Ellis County. Surface altitude, 2,017.8 feet; water level, 4.35 feet, September 15, 1950.

	Thickness, feet	Depth, feet
NEOGENE—Pleistocene		
Alluvium		
Silt, calcareous, gray to black	1	1
Clay, calcareous, light gray	6	7
Sand, fine, clayey	1	8
Clay, calcareous, yellow	1	9
CRETACEOUS		
Carlile Shale		
Shale, weathered, clayey	..	9

15-19-15aa.—Sample log of jetted well in NE NE sec. 15, T. 15 S., R. 19 W., Ellis County. Surface altitude, 2,007.5 feet; dry, July 28, 1950.

	Thickness, feet	Depth, feet
NEOGENE—Pleistocene		
Loveland Formation		
Silt, calcareous, dark brown	1	1
Clay, silty, calcareous, light gray to tan	3	4
Clay, sandy, calcareous	1.5	5.5
Crete Formation		
Sand, coarse to very coarse, clayey; contains abundant limestone pebbles	4.5	10
Clay, sandy, calcareous, tan	11	21
Clay; contains some coarse to very coarse sand	4.8	25.8

15-19-15ad.—Sample log of jetted well in SE NE sec. 15, T. 15 S., R. 19 W., Ellis County. Surface altitude, 2,002.1 feet; water level, 12.61 feet, July 28, 1950.

	Thickness, feet	Depth, feet
NEOGENE—Pleistocene		
Alluvium		
Silt, calcareous, dark gray	1	1
Clay, calcareous, light gray; contains some fine sand	5	6
Sand, medium, clayey	1	7
Clay, calcareous, light gray; contains some medium to coarse sand	7	14
Sand, coarse to very coarse, well sorted; contains some clay	11	25

15-19-15bc.—Sample log of jetted well in SW NW sec. 15, T. 15 S., R. 19 W., Ellis County. Surface altitude, 2,001.2 feet; water level, 23.40 feet, September 15, 1950.

	Thickness, feet	Depth, feet
NEOGENE—Pleistocene		
Loveland Formation		
Silt, calcareous, dark gray	1.5	1.5
Clay, soft, calcareous, light gray	5	6.5
Clay, sandy, calcareous, gray	0.5	7
Crete Formation		
Sand, medium, arkosic, well sorted	3	10
Sand	15.6	25.6

15-19-15dd.—Sample log of drilled observation well in SE SE sec. 15, T. 15 S., R. 19 W., 4 feet west of telephone pole 101, 24 feet north and 20 feet west of center of road intersection, Ellis County. Surface altitude, 1,993.0 feet; water level, 26.07 feet, October 29, 1949.

	Thickness, feet	Depth, feet
Soil, friable, brown	1	1
NEOGENE—Pleistocene		
Crete Formation		
Silt, tan; contains gravel	5	6
Sand and fine gravel	4	10
Gravel, fine to coarse, arkosic; contains sand and thin clay layers at 18 feet	10	20

	Thickness, feet	Depth, feet
Gravel and sand	6.5	26.5
Clay, iron stained, yellow to light gray	0.5	27
Sand, coarse, and fine gravel	3.5	30.5
Sappa(?) Formation		
Clay, plastic, sandy, yellow to light gray	4.5	35
Clay, plastic, calcareous, gray	2	37
Sand, coarse to medium; contains a small amount of gravel	1	38
Clay, fine, plastic, sandy, blue gray and light gray	2	40
Grand Island(?) Formation		
Sand, coarse; contains thin clay layers	4	44
Sand, coarse, and fine to very coarse gravel	7	51
CRETACEOUS		
Greenhorn Limestone		
Limestone, hard, and blue-gray shale	0.5	51.5

15-19-16aa.—Sample log of jetted well in NE NE sec. 16, T. 15 S., R. 19 W., Ellis County. Surface altitude, 2,023.1 feet; dry, August 18, 1950.

	Thickness, feet	Depth, feet
NEOGENE—Pleistocene		
Loveland Formation		
Clay, loose, silty, calcareous, black	2	2
Clay, loose, calcareous, light gray	5.5	7.5
Silt, clayey, calcareous, dark brown	16.5	24
Silt, sandy, calcareous, light brown	2	26
Crete Formation		
Sand, medium, well sorted; contains many clay particles	6	32

15-19-16cb.—Sample log of jetted well in NW SW sec. 16, T. 15 S., R. 19 W., Ellis County. Surface altitude, 2,008.8 feet; water level, 27.70 feet, September 16, 1950.

	Thickness, feet	Depth, feet
NEOGENE—Pleistocene		
Loveland Formation		
Silt, calcareous, dark gray	1	1
Clay, silty, calcareous, dark gray	3	4
Silt, calcareous, tan; contains some clay	6	10
Crete Formation		
Sand, medium to coarse	8	18
Sand and gravel	13	31

15-19-16dd.—Sample log of jetted well in SE SE sec. 16, T. 15 S., R. 19 W., Ellis County. Surface altitude, 1,997.4 feet; dry, August 7, 1950.

	Thickness, feet	Depth, feet
NEOGENE—Pleistocene		
Loveland Formation		
Silt, clayey and sandy, calcareous, dark brown	7	7
Crete Formation		
Sand, no sample collected	11.8	18.8

15-19-18bb.—Sample log of drilled test hole in NW NW sec. 18, T. 15 S., R. 19 W., 0.2 mile south and 0.15 mile east of corner, top of low terrace, Ellis County. Surface altitude, 1,980.9 feet; water level, 20.10 feet, October 24, 1949.

	Thickness, feet	Depth, feet
NEOGENE—Pleistocene		
Terrace deposits		
Sand, medium to coarse, arkosic	2	2
Gravel, fine to medium, quartzose, and coarse sand	3	5
Silt, sandy, gray brown, and coarse sand	7	12
Silt, loose, clayey, sandy, brown	3	15
Gravel, pebbles of quartz and limestone, and brown silt	8	23
Gravel, medium to coarse, pebbles of quartz and limestone	7	30
Gravel, fine to coarse, pebbles of quartz and limestone; contains gray silt	7	37
Gravel, fine to coarse, pebbles of quartz and limestone, gray, and interbedded silt	5	42
Gravel, coarse, pebbles of igneous rock and limestone; contains blue-gray silt layers	8	50
Gravel, coarse to medium, pebbles of quartz and limestone; contains some silt	10	60
Gravel, coarse, pebbles of igneous rock and limestone,	6.5	66.5
CRETACEOUS		
Greenhorn Limestone		
Limestone and shale, interbedded, gray to white	2	68.5

15-19-18da.—Sample log of jetted well in NE SE sec. 18, T. 15 S., R. 19 W., Ellis County. Surface altitude, 1,975.8 feet; water level, 8.68 feet, September 19, 1950.

	Thickness, feet	Depth, feet
NEOGENE—Pleistocene		
Terrace deposits		
Sand, very fine, silty, well sorted	8	8
Sand, medium	7	15
Sand, coarse to very coarse; contains some fine gravel and small amount of clay	6	21

15-19-21ad.—Sample log of jetted well in SE NE sec. 21, T. 15 S., R. 19 W., Ellis County. Surface altitude, 1,978.2 feet; dry, August 7, 1950.

	Thickness, feet	Depth, feet
NEOGENE—Pleistocene		
Loveland Formation		
Silt, very sandy in lower zone, calcareous, black to dark gray	5	5
Crete Formation		
Sand, coarse	0.5	5.5
CRETACEOUS		
Greenhorn Limestone		
Limestone, light tan	0.2	5.7
Clay, calcareous, white	0.4	6.1
Limestone, white to buff	0.1	6.2

15-19-22ad.—Sample log of jetted well in SE NE sec. 22, T. 15 S., R. 19 W., Ellis County. Surface altitude, 1,982.4 feet; water level, 16.10 feet, September 15, 1950.

	Thickness, feet	Depth, feet
NEOGENE—Pleistocene		
Loveland Formation		
Silt, calcareous, dark gray	3	3
Clay, calcareous, light gray	7	10
Clay, calcareous, blue gray; contains very fine sand	4	14
Crete Formation		
Sand, medium to coarse, well sorted	4.7	18.7

15-19-22dd.—Sample log of jetted well in SE SE sec. 22, T. 15 S., R. 19 W., Ellis County. Surface altitude, 1,965.5 feet; water level, 16.25 feet, September 15, 1950.

	Thickness, feet	Depth, feet
NEOGENE—Pleistocene		
Terrace deposits		
Silt, calcareous, dark gray	4	4
Clay, sandy to very sandy, calcareous, light gray	14	18
Sand, medium to fine	3	21
CRETACEOUS		
Greenhorn Limestone		
Limestone	0.3	21.3

15-19-24bc.—Sample log of jetted well in SW NW sec. 24, T. 15 S., R. 19 W., Ellis County. Surface altitude, 1,969.1 feet; water level, 9.05 feet, September 15, 1950.

	Thickness, feet	Depth, feet
NEOGENE—Pleistocene		
Alluvium		
Silt, calcareous, dark gray	3	3
Clay, calcareous, gray; contains some coarse sand	9	12
Gravel, fine, well sorted; contains some coarse sand	3.2	15.2

15-19-24cd.—Sample log of jetted well in SE SW sec. 24, T. 15 S., R. 19 W., Ellis County. Surface altitude, 1,975.8 feet; water level, 22.40 feet, July 24, 1950.

	Thickness, feet	Depth, feet
NEOGENE—Pleistocene		
Loveland Formation		
Silt, calcareous, dark brown	1	1
Clay, sandy, calcareous, dark gray	4	5
Crete Formation		
Sand, fine	2	7
Sand, medium to fine	7	14
Gravel, coarse	1	15
Sand, coarse	1	16
Sand, coarse; contains some gravel	3	19
Gravel, coarse	2	21

	Thickness, feet	Depth, feet
Sand and gravel, clayey, coarse; contains some limestone fragments	6	27
Sand, very coarse; contains limestone fragments	1.4	28.4
CRETACEOUS		
Greenhorn Limestone		
Limestone, hard, chalky white to gray		28.4

15-19-25aa.—Sample log of jetted well in NE NE sec. 25, T. 15 S., R. 19 W., Ellis County. Surface altitude, 1,967.7 feet; water level, 16.20 feet, July 24, 1950.

	Thickness, feet	Depth, feet
NEOGENE—Pleistocene		
Loveland Formation		
Silt, calcareous, dark brown	1.5	1.5
Crete Formation		
Sand and gravel, clayey, calcareous, light tan	3.5	5
Sand and gravel, medium; contains limestone fragments	1	6
Sand, very coarse	1	7
Sand, fine, calcareous	11.5	18.5

15-19-25bb.—Sample log of jetted well in NW NW sec. 25, T. 15 S., R. 19 W., Ellis County. Surface altitude, 1,975.8 feet; dry, September 15, 1950.

	Thickness, feet	Depth, feet
NEOGENE—Pleistocene		
Loveland Formation		
Silt, calcareous, light gray	3	3
Crete Formation		
Sand, medium to coarse, well sorted, silty	10.5	13.5
CRETACEOUS		
Carlile Shale		
Shale, gray to buff		13.5

15-20-1bb.—Sample log of jetted well in NW NW sec. 1, T. 15 S., R. 20 W., Ellis County. Surface altitude, 2,034.4 feet; water level, 22.10 feet, September 16, 1950.

	Thickness, feet	Depth, feet
NEOGENE—Pleistocene		
Terrace deposits		
Silt, calcareous, dark brown	2	2
Silt, clayey, calcareous, light brown	3	5
Silt, calcareous; contains sand and much limestone gravel	14	19
Sand, medium to coarse, well sorted	5	24

15-20-1da1.—Sample log of drilled test hole in NE SE sec. 1, T. 15 S., R. 20 W., 12 feet south of half-mile line and 6 feet west of center of road, Ellis County. Surface altitude, 2,043.0 feet; water level, 36.05 feet, October 22, 1949.

	Thickness, feet	Depth, feet
Silt, compact, dark brown (road fill)	2	2
NEOGENE—Pleistocene		
Loveland Formation		
Silt, compact, brown	3	5
Silt, slightly sandy, tan; contains caliche fragments	2	7
Silt, medium compact, buff	8	15
Silt, fairly loose, sandy, gray brown	4	19
Silt, sticky, clayey, dark gray	4	23
Silt, very sandy; contains gravel	3	26
Crete Formation		
Gravel, fine to medium, quartzose; contains some coarse gravel	4	30
Gravel, fine to medium, quartzose; contains limestone fragments	5	35
Gravel, fine, pebbles of quartz and limestone; contains some light-brown clay at 37 feet	5	40
Gravel, medium to fine, pebbles of igneous rock and limestone	3.5	43.5
CRETACEOUS		
Carlile Shale		
Shale, very compact, calcareous, blue gray	2.5	46

15-20-1da2.—Sample log of jetted well in NE SE sec. 1, T. 15 S., R. 20 W., Ellis County. Surface altitude, 2,044.6 feet; dry, September 12, 1950.

	Thickness, feet	Depth, feet
NEOGENE—Pleistocene		
Loveland Formation		
Soil, silty, black	1	1
Silt, hard, sandy, brown	1	2
Silt, clayey, soft, calcareous, tan; contains some sand,	8	10
Silt, loose, clayey, calcareous, brown	10	20
Silt, noncalcareous, dark gray; contains some sand	4	24
Crete Formation		
Sand, medium, well sorted; contains some gravel	7.9	31.9

15-20-2bc.—Sample log of jetted well in SW NW sec. 2, T. 15 S., R. 20 W., Ellis County. Surface altitude, 2,057.9 feet; water level, 8.74 feet, September 21, 1950.

	Thickness, feet	Depth, feet
NEOGENE—Pleistocene		
Loveland Formation		
Soil, silty, black	1	1
Silt, sandy, dark brown	2	3
Silt, very clayey, plastic, gray	2	5
Silt, loose, sandy, light brown	10	15

Crete Formation	Thickness, feet	Depth, feet
Sand, fine to medium, well sorted, arkosic, silty	3	18
Sand, very coarse; contains fine gravel	7.2	25.2

15-20-2da.—Sample log of jetted well in NE SE sec. 2, T. 15 S., R. 20 W., Ellis County. Surface altitude, 2,015.7 feet; water level, 9.49 feet, September 20, 1950.

NEOGENE—Pleistocene

Alluvium	Thickness, feet	Depth, feet
Soil, silty to sandy, dark gray	1	1
Silt, sandy to very sandy, loose, gray	4	5
Sand, medium to very coarse, poorly sorted; contains some medium limestone gravel near top	7.5	12.5

15-20-4aa.—Sample log of jetted well in NE NE sec. 4, T. 15 S., R. 20 W., Ellis County. Surface altitude, 2,054.0 feet; water level, 7.12 feet, September 23, 1950.

NEOGENE—Pleistocene

Alluvium	Thickness, feet	Depth, feet
Soil, silty, sandy, black	1	1
Silt, clayey, soft, sandy, gray	2	3
Silt, soft, sandy, tan	2	5
Sand, medium to coarse, silty	1	6
Silt, loose, slightly sandy, tan	6	12
Sand, coarse to very coarse; contains some gravel	4.5	16.5
Silt, clayey, gray; contains much coarse gravel	11.5	28
Gravel, medium, pebbles of igneous rock; contains some silt	0.5	28.5

15-20-4cc1.—Sample log of jetted well in SW SW sec. 4, T. 15 S., R. 20 W., Ellis County. Surface altitude, 2,004.5 feet; water level, 8.30 feet, September 15, 1950.

NEOGENE—Pleistocene

Alluvium	Thickness, feet	Depth, feet
Silt, sandy to clayey, dark gray	3	3
Sand, medium to very coarse; contains some gravel zones	17	20

15-20-4cc2.—Sample log of jetted well in SW SW sec. 4, T. 15 S., R. 20 W., Ellis County. Surface altitude, 2,024.8 feet; water level, 23.90 feet, September 15, 1950.

NEOGENE—Pleistocene

Terrace deposits	Thickness, feet	Depth, feet
Silt, sandy, clayey, calcareous, dark gray	26	26
Sand, coarse to very coarse	4	30

15-20-4da.—Sample log of jetted well in NE SE sec. 4, T. 15 S., R. 20 W., Ellis County. Surface altitude, 2,040.7 feet; water level, 18.90 feet, September 20, 1950.

	Thickness, feet	Depth, feet
NEOGENE—Pleistocene		
Loveland Formation		
Soil, silty, black	1	1
Silt, dark gray; contains some sand	2	3
Silt, clayey, plastic, light gray; contains some sand	3	6
Silt, loose, blocky, brown	10	16
Crete Formation		
Sand, medium to coarse; contains some fine gravel	7	23

15-20-5ad.—Sample log of jetted well in SE NE sec. 5, T. 15 S., R. 20 W., Ellis County. Surface altitude, 2,053.5 feet; dry, August 15, 1950.

	Thickness, feet	Depth, feet
NEOGENE—Pleistocene		
Crete Formation		
Silt, sandy, calcareous, dark gray	1	1
Sand, very fine, silty	6.5	7.5
Sand, coarse to very coarse; contains fine gravel	7.5	15
Sand, fine	1	16
Sand, very coarse	2	18
Sand	12	30

15-20-9aa.—Sample log of jetted well in NE NE sec. 9, T. 15 S., R. 20 W., Ellis County. Surface altitude, 2,014.6 feet; water level, 5.30 feet, September 20, 1950.

	Thickness, feet	Depth, feet
NEOGENE—Pleistocene		
Alluvium		
Silt, calcareous, dark brown	2	2
Clay, soft, sandy, calcareous, light gray	2	4
Clay, brown; contains coarse sand and some gravel	1	5
Sand and gravel, very coarse, poorly sorted	4	9
Sand, medium, clayey	1	10
Sand, medium, very clayey	5	15
Sand, fine; contains gray silty clay	8	23

15-20-11ad.—Sample log of jetted well in SE NE sec. 11, T. 15 S., R. 20 W., Ellis County. Surface altitude, 2,001.5 feet; water level, 11.13 feet, September 16, 1950.

	Thickness, feet	Depth, feet
NEOGENE—Pleistocene		
Loveland Formation		
Silt, very sandy (fine sand), tan	1	1
Crete Formation		
Sand, silty, poorly sorted, very fine to coarse	6	7
Silt, clayey, sandy, plastic, tan	10	17

15-20-12aa.—Sample log of drilled observation well in NE NE sec. 12, T. 15 S., R. 20 W., 20 feet west and 18 feet south of center of crossroads, Ellis County. Surface altitude, 2,038.4 feet; water level, 39.23 feet, October 22, 1949.

	Thickness, feet	Depth, feet
NEOGENE—Pleistocene		
Loveland Formation		
Silt, slightly sandy, dark brown	2	2
Clay, sandy, dark gray to tan; contains caliche	3	5
Silt, loose, sandy, brown to tan	2	7
Silt, sandy, rusty brown	1	8
Silt, friable, sandy, tan	2	10
Crete Formation		
Sand, coarse, quartzose, and rusty-brown silt	5	15
Gravel, medium to coarse, quartzose, and fine to medium sand; contains a 0.5-foot clay layer at 18 feet,	5	20
Gravel, coarse to fine, quartzose	5	25
Gravel, fine to coarse, pebbles of quartz and limestone; contains some coarse sand	5	30
Gravel, medium to coarse, pebbles of quartz and limestone	5	35
Gravel, coarse, pebbles of quartz and limestone; contains clay layer at 37 feet	5	40
Sand, medium to coarse, quartzose; contains some limestone pebbles	5	45
Gravel, fine to medium, pebbles of quartz and limestone; contains 8-inch clay layer at 48 feet	6	51
Sappa(?) and Grand Island(?) Formations		
Clay, compact, plastic, gray; contains lag	4	55
Sand, medium to very coarse, quartzose; contains some medium gravel	3	58
CRETACEOUS		
Carlile Shale		
Shale, compact, calcareous, blue black to blue	2	60

15-20-12bb.—Sample log of jetted well in NW NW sec. 12, T. 15 S., R. 20 W., Ellis County. Surface altitude, 2,043.3 feet; dry, September 13, 1950.

	Thickness, feet	Depth, feet
NEOGENE—Pleistocene		
Loveland Formation		
Soil, compact, gray	1	1
Silt, loose, clayey, sandy, brown; contains some caliche particles	9	10
Crete Formation		
Sand, medium to coarse; contains some gravel	23.6	33.6

15-21-2bb.—Sample log of drilled test hole in NW NW sec. 2, T. 15 S., R. 21 W., 90 feet north and 30 feet east of center of road intersection, Trego County. Surface altitude, 2,031.4 feet.

	Thickness, feet	Depth, feet
NEOGENE—Pleistocene		
Alluvium		
Silt, brown	1	1
Sand, fine to coarse; contains some brown silt	4	5
Gravel and sand, fine to coarse	3	8
Gravel, fine to coarse, and medium sand	3	11
CRETACEOUS		
Carlile Shale		
Shale, black and blue black to dark gray	3	14

15-21-3ad.—Sample log of drilled test hole in SE NE sec. 3, T. 15 S., R. 21 W., 0.45 mile south of corner and 10 feet west of center of road, Trego County. Surface altitude, 2,100.7 feet.

	Thickness, feet	Depth, feet
Silt, brown to gray (road fill)	3	3
NEOGENE—Pleistocene		
Loveland Formation		
Silt, slightly sandy, reddish brown	9	12
Silt, sandy, tan, and medium sand	3	15
Crete Formation		
Sand, medium to coarse, and fine gravel	5	20
Sand, fine to coarse; contains silt at 25.5 feet	5.5	25.5
Gravel, fine, and coarse sand	2.5	28
Gravel, medium to coarse	2	30
CRETACEOUS		
Carlile Shale		
Shale, gray, blue black, and black	4	34

15-21-3dd.—Sample log of drilled test hole in SE SE sec. 3, T. 15 S., R. 21 W., 100 feet north and 7 feet west of center of road intersection, Trego County. Surface altitude, 2,148.8 feet.

	Thickness, feet	Depth, feet
Silt, brown (soil and road fill)	1	1
NEOGENE—Pleistocene		
Loveland(?) Formation		
Silt, clayey, tan	1	2
Silt, sandy, buff	2	4
Clay, pliable, plastic, tan to light gray	2.5	6.5
CRETACEOUS		
Carlile Shale		
Shale, plastic, gray to blue gray; contains bentonite	3.5	10

15-22-1ab.—Sample log of jetted well in NW NE sec. 1, T. 15 S., R. 22 W., Trego County. Surface altitude, 2,068.6 feet; water level, 8.30 feet, July 14, 1950.

	Thickness, feet	Depth, feet
NEOGENE—Pleistocene		
Alluvium		
Silt, clayey, dark brown	9	9
Sand, medium to coarse	6	15
CRETACEOUS		
Carlile Shale		
Shale, blue	0.5	15.5

16-17-1bb2.—Sample log of drilled test hole in NW NW sec. 1, T. 16 S., R. 17 W., 0.1 mile south of corner and 5 feet east of center of road, Rush County. Surface altitude, 1,887.7 feet; water level, 19.90 feet, November 3, 1949.

	Thickness, feet	Depth, feet
Soil, compact, brown (road fill)	3	3
NEOGENE—Pleistocene		
Crete Formation		
Silt, slightly sandy, calcareous, tan	4	7
Sand, medium to coarse, and fine to medium gravel	3	10
Gravel, fine to medium, arkosic, and coarse sand	5	15
Gravel, medium to fine, quartzose	5	20
Gravel, coarse to medium	5	25
CRETACEOUS		
Greenhorn Limestone		
Shale, calcareous, gray and blue gray, and yellow clay,	2	27

16-17-1bc.—Sample log of drilled test hole in SW NW sec. 1, T. 16 S., R. 17 W., 0.4 mile south of corner and 5 feet east of center of road, Rush County. Surface altitude, 1,896.9 feet; water level, 24.80 feet, November 3, 1949.

	Thickness, feet	Depth, feet
Silt, solid, brown (road fill)	3	3
NEOGENE—Pleistocene		
Loveland Formation		
Silt, compact, tan	5	8
Crete Formation		
Sand, medium to coarse, well sorted	5	13
Gravel, fine to medium, and medium to coarse sand; contains silt	7	20
Gravel, fine to medium, pebbles of igneous rock, limestone, and shale	6	26
CRETACEOUS		
Greenhorn Limestone		
Shale, clayey to compact, gray and blue gray	2	28

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28-6242

State Geological Survey of Kansas

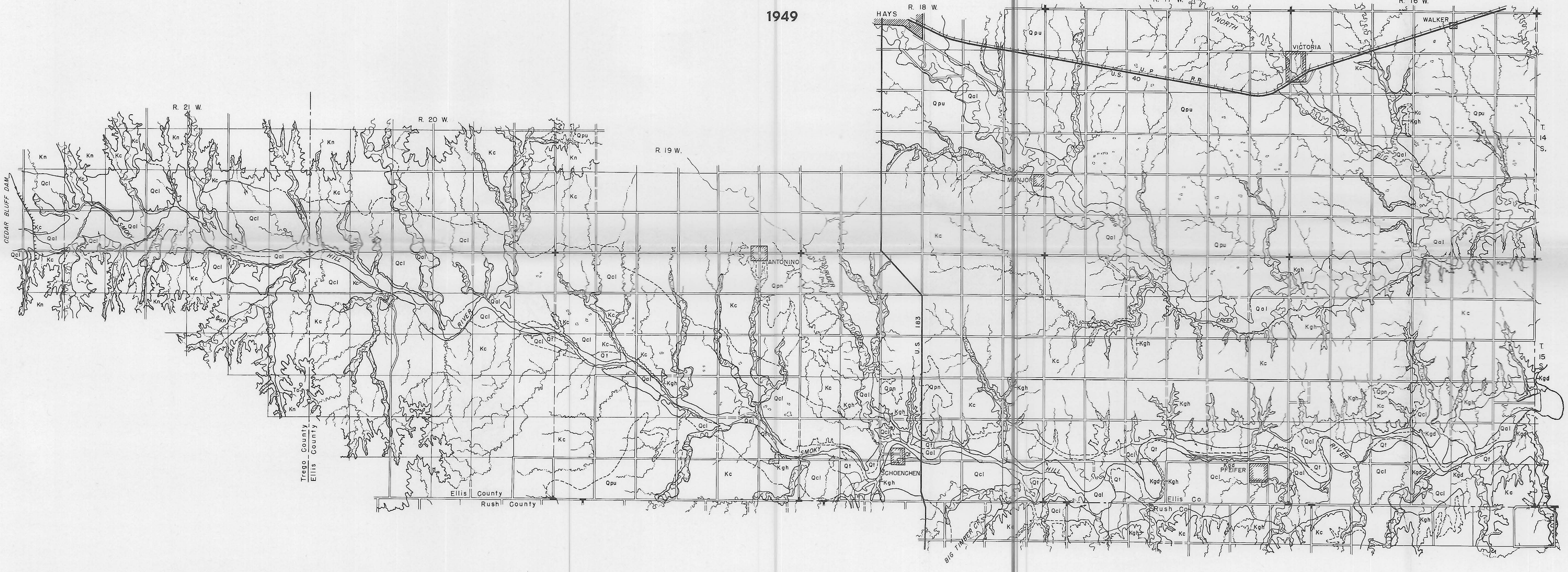
AREAL GEOLOGY OF SOUTHERN ELLIS COUNTY AND PARTS OF TREGO AND RUSH COUNTIES, KANSAS

Bulletin 149

Plate 1

By Alvin R. Leonard

1949



EXPLANATION

NEOGENE

PLEISTOCENE

Qal / Qt

Recent alluvium and Late Wisconsinan terrace deposits

Silt and sandy silt overlying sand and gravel capable of yielding large quantities of water to wells. Dashed line denotes terrace scarp where it can be recognized.

Qcl

Crete and Loveland Formations

Buff silt and sandy silt underlain by arkosic sand, gravel, and cobbles. Locally includes underlying gray silt, sand, and volcanic ash of the Sappa Formation and arkosic sand and gravel and fragments and pebbles of chalk of the Grand Island Formation. Forms prominent terrace along Smoky Hill River. Yields water to domestic and stock wells in most of the outcrop area.

Qpu

Undifferentiated Pleistocene deposits

Silt, silty clay, sand, and gravel. Includes Nebraskan and Kansan age gravels and Crete, Loveland, and Peoria Formations underlying prominent terrace along Big Creek. Also includes silt and gravel of unknown age in southwestern part of T. 15 S., R. 19 W., and in western part of T. 14 S., R. 19 W. Yields water to domestic and stock wells.

Qpn

Nebraskan (?) deposits

Silty sand and gravel composed of chalk pebbles, mortar-bed fragments, pebbles of "Algal limestone", and reworked crystalline material from the Ogallala Formation, loosely cemented with calcium carbonate. Locally, yields water to domestic and stock wells.

PLIOCENE

To

Ogallala Formation

Sand, gravel, silt, and clay, loosely cemented to form "mortar beds". Lies above the water table and does not yield water to wells in this area.

CRETACEOUS

GULFIAN

Kn

Niobrara Chalk (Fort Hays Limestone member)

Massive chalky limestone. Yields no water to wells in this area.

Kc

Carlile Shale

Upper part is clayey and sandy shale containing concretions. Lower part consists of chalky shale alternating with thin chalky limestones. Where weathered, lower chalky part yields water locally to domestic and stock wells.

Kgh

Greenhorn Limestone

Calcareous shale, limestone, chalky limestone, and thin bentonite beds. Locally, yields water where the upper part of the limestone is weathered.

Kgd

Graneros Shale and Dakota Formation

Clay, shale, and sandstone. Sandstone where present generally yields mineralized water to domestic and stock wells.

Federal or state highway
Graded road
Ungraded road
Section line (no road)
Township line (no road)
County line
Railroad
Perennial stream
Intermittent stream
Undrained depression

MAP OF SOUTHERN ELLIS COUNTY AND PARTS OF TREGO AND RUSH COUNTIES, KANSAS

Showing location of wells and test holes and water-table contours

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of Kansas

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Plate 2

By Alvin R. Leonard
1949

GEOLOGIC CROSS SECTIONS IN SOUTHERN ELLIS COUNTY AND PARTS OF TREGO AND RUSH COUNTIES, KANSAS

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1949

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Plate 3