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State Geologist and
Director of Research

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Division of Ground Water

V. C. FISHEL, B. S.,
Engineer in Charge

BULLETIN 61

GEOLOGY AND GROUND-WATER RESOURCES OF GRANT, HASKELL, AND STEVENS COUNTIES, KANSAS

By THAD G. McLAUGHLIN

with analyses by

H. A. STOLTENBERG

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

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GEOLOGY AND GROUND-WATER RESOURCES OF GRANT, HASKELL, AND STEVENS COUNTIES, KANSAS

By THAD G. McLAUGHLIN

ABSTRACT

The report describes the geography, geology, and ground-water resources of Grant, Haskell, and Stevens Counties in southwestern Kansas. These counties have an area of about 1,881 square miles and had a population of 7,227 in 1940. The area consists predominantly of flat upland plains which are disrupted only by the valleys of the Cimarron River and its tributaries and by sand hills. The climate is semiarid, the average annual precipitation being about 18 inches. Farming and raising of livestock are the principal occupations in this area. Irrigation has been practiced in several parts of the area and has increased greatly since 1940.

Almost all the exposed rocks in the Grant-Haskell-Stevens area are Pleistocene or Recent. A map showing the areas of outcrop of the rock formations is included in the report. The Meade formation (Pleistocene) and the Kingsdown formation (Pleistocene and Recent) crop out in most of Grant and Haskell Counties and in the northern part of Stevens County, and dune sand is at the surface in much of the remainder of the area. The Tertiary and Quaternary formations contain thick beds of coarse sand and gravel which yield large quantities of water to wells. The report also contains a diagrammatic cross section of the area showing the distribution of the rock formations above the Permian redbeds, as determined by extensive test drilling.

The report contains a map of the area showing by means of shading the depth to water level. The water table ranges in depth from less than 10 feet in parts of the valleys of the Cimarron River and its tributaries to almost 250 feet in the upland area in western Haskell County. A map showing by means of contours the shape and slope of the water table is also included in this report. This map shows that ground water moves eastward through Grant, Haskell, and Stevens Counties, and that the gradient of the water tables ranges from about 5 feet to the mile in eastern Haskell County to about 50 feet to the mile in southeastern Grant County.

The ground-water reservoir is recharged principally from rain and snow that fall within the area, by percolation from intermittent streams and depressions, and by underground movement from adjacent areas. Ground water is discharged from the ground-water reservoir by movement into adjacent areas to the south and east, by evaporation and transpiration in areas of shallow water table, by seepage into perennial streams, and by wells. All of the domestic, stock, public, industrial, and irrigation supplies are obtained from wells.

Most of the wells in this area are drilled, but a few are dug, driven, or bored. Of the 356 wells listed in the report, 20 were used for irrigation when visited. In 1942, they supplied about 3,500 acre-feet of water to irrigate 2,277 acres of land. The areas most favorable for the development of irrigation are in western Grant County, northern Stevens County, and northeastern Haskell County.

The ground water in Grant, Haskell, and Stevens Counties is hard but is suitable for most ordinary uses. Waters from the Pliocene and Pleistocene

formations are similar in composition and hardness. Waters from the Recent alluvium generally are very hard.

The principal water-bearing beds in this area are the Pliocene and Pleistocene deposits, including the Laverne, Rexroad (?), and Meade formations. The character and water supply of each formation are discussed in the report.

The field data upon which most of this report is based are given in tables; they include records of 356 wells and chemical analyses of the water from 76 representative wells and from one gravel pit. Logs of 60 test holes, water wells, and oil and gas wells in the area are given, including 46 test holes put down by the State and Federal Geological Surveys.

INTRODUCTION

Purpose and Scope of the Investigation

An investigation of the geology and ground-water resources of Grant, Haskell, and Stevens Counties was begun in May 1941, by the United States Geological Survey and the State Geological Survey of Kansas, with the coöperation of the Division of Sanitation of the Kansas State Board of Health and the Division of Water Resources of the Kansas State Board of Agriculture. The work was done under the general administration of R. C. Moore, state geologist, J. C. Frye, acting state geologist, and O. E. Meinzer, geologist in charge of the Division of Ground Water of the Federal Geological Survey, and under the direct supervision of S. W. Lohman, federal geologist in charge of ground-water investigations in Kansas.

Ground water is one of the principal natural resources of Kansas. This is particularly true in western Kansas where surface-water supplies are limited. The entire population of Grant, Haskell, and Stevens Counties obtains its water supply from wells. In addition, wells supply water for livestock and for the irrigation of more than 2,000 acres of land. Ground water acquires its great value as a natural resource because relatively large supplies are in storage and available for use at any time, and these supplies are replenished continuously or at intervals by precipitation, stream flow, or both. If withdrawals of ground water are kept within safe limits, the supply should last indefinitely.

The investigation in Grant, Haskell, and Stevens Counties was made to determine the quality, quantity, movement, and availability of ground water and the feasibility of further development of irrigation from wells. It is hoped that the data given herein will facilitate the safe development of the ground-water resources of these counties.

Location and Extent of the Area

Grant, Haskell, and Stevens Counties are in southwestern Kansas (Fig. 1). They are bordered on the west by Stanton and Morton Counties, on the north by Kearny and Finney Counties, on the east and southeast by Gray, Meade, and Seward Counties, and on the south by Texas County, Oklahoma. The area lies between parallels 37° and 37° 45′ north latitude and meridians 100° 39′ and 101° 34′ west longitude. It comprises about 52 townships and has an area of 1,881 square miles.

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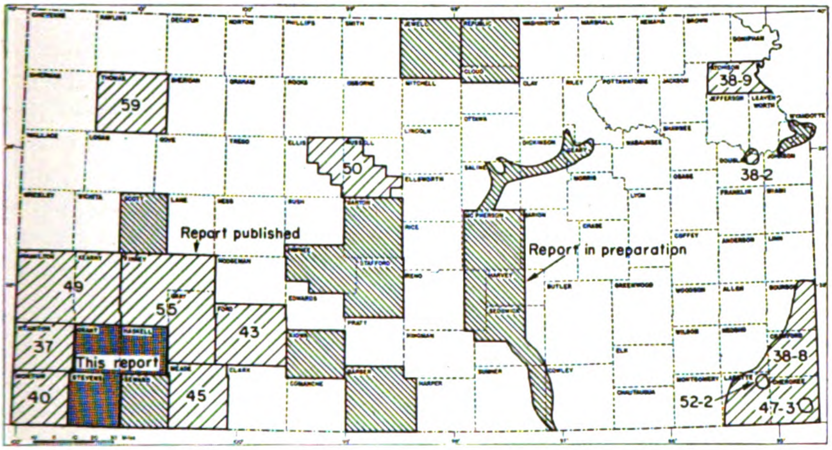


Fig. 1. Index map of Kansas showing area covered by this report and areas for which coöperative ground-water reports have been published or are in preparation.

Previous Investigations

Geologic and hydrologic studies in southwestern Kansas were made in 1885 by Hay (1890) who briefly discussed the geology and depths to water in this area. A similar but less detailed study was made in the same area in 1886 by St. John (1887). A more detailed study with particular reference to ground water in the Dakota and younger formations was made in 1895 and 1896 by Haworth (1897; 1897a). Johnson (1901; 1902), in his reports on the ulitization of the southern High Plains, made special reference to the source, availability, and use of ground water in western Kansas. Parker (1911) described briefly the ground-water conditions in Grant, Haskell, and Stevens Counties in his report on the chemical character of the water supplies of Kansas. Haworth (1913) made additional studies of ground-water conditions in this area in 1913.

The first detailed study of the geology and ground-water resources of this area was made by Darton (1920) in his description of the Syracuse and Lakin quadrangles, which include the northern part of Grant County. His report includes maps showing geology, topography, and depths to water level. More recently this area was described briefly by Theis, Burleigh, and Waite (1935) who made a reconnaissance of the ground-water resources of the High Plains; and by Smith (1940) who made a reconnaissance of the Tertiary and Quaternary geology of southwestern Kansas. Schoff (1939) made a detailed geologic and hydrologic study of Texas County, Oklahoma, which borders Stevens County on the south.

Since 1938 the State and Federal Geological Surveys in coöperation with the Division of Sanitation of the Kansas State Board of Health and the Division of Water Resources of the Kansas State Board of Agriculture have made detailed studies of the geology and ground-water resources of most of the counties in southwestern Kansas (Fig. 1). These include Stanton County (Latta, 1941), Morton County (McLaughlin, 1942), Ford County (Waite, 1942), Meade County (Frye, 1942), Hamilton and Kearny Counties (McLaughlin, 1943), Finney and Gray Counties (Latta, 1944), Seward County (Byrne and McLaughlin, in press), and Scott County (Waite, in press.)

Methods of Investigation

An observation-well program was begun in Grant and Haskell Counties by Woodrow W. Wilson in May and June 1941. About 30 representative wells were selected for periodic water-level measurements. Most of these wells have been measured monthly since that time in order to obtain information concerning the fluctuations of the ground-water table.

Field work in Grant and Haskell Counties was begun by the writer in July 1941 and continued through October 1941. In October 1941, an observation-well program was begun in Stevens County by Woodrow W. Wilson and the writer. Field work in Stevens County was done during July, August, and September 1942, and additional work was done in Grant and Haskell Counties in October 1942. Several days were spent in field investigations in this area in 1943 and 1944 by Claude W. Hibbard and the writer.

Data were obtained on 356 wells in Grant, Haskell, and Stevens Counties during this investigation. About 277 wells were measured

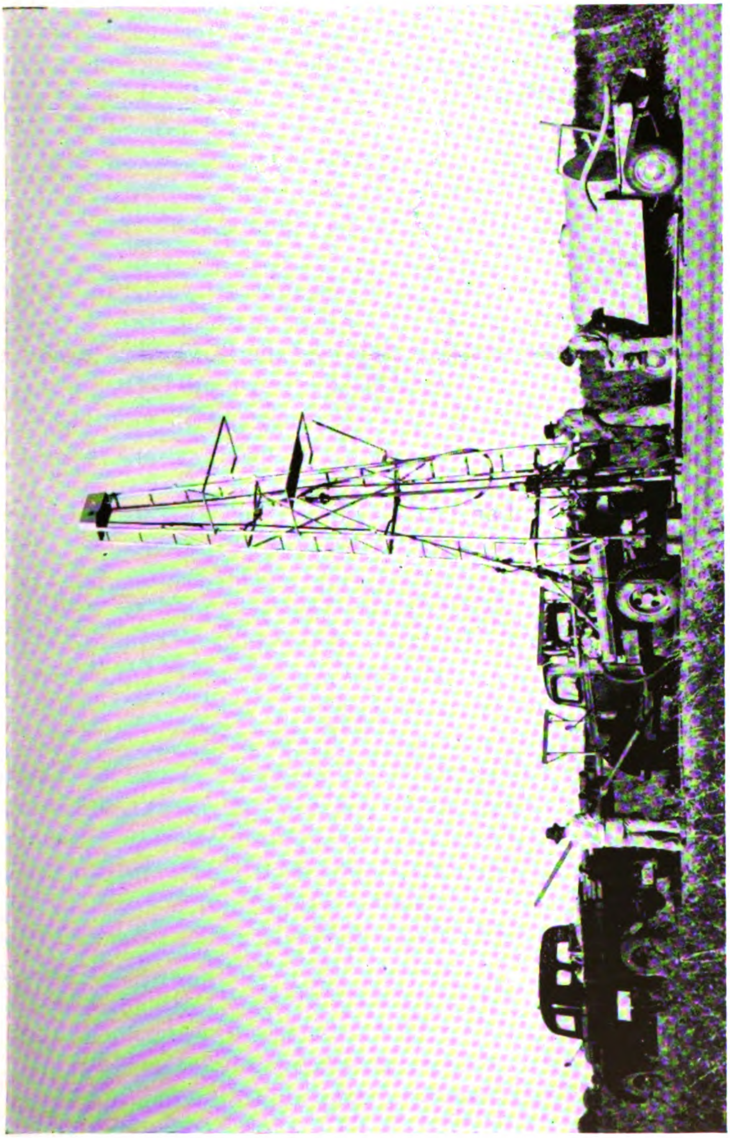


PLATE 4. Portable drilling machine owned by the State and Federal Geological Surveys and used in drilling test holes in Grant, Haskell, and Stevens Counties. (*Oren Bingham.*)

with a steel tape to determine the depth of the well and the depth to the water level below some fixed measuring point (generally the top of the casing). Additional data concerning the yield and drawdown of irrigation wells were obtained by measurement or from well owners. Only reported data were obtained for those wells that could not be measured, including the depth of the well, the depth to water level, the yield and drawdown of the well, and the character of the water-bearing materials. Seventy-two samples of water were collected from representative wells and were analyzed by Howard A. Stoltenberg, chemist, in the Water and Sewage Laboratory of the Kansas State Board of Health.

Thirty-nine test holes were drilled at strategic points in the area by the portable hydraulic-rotary drilling machine (Pl. 4) of the State and Federal Surveys, operated by Ellis D. Gordon, James B. Cooper, and Oscar S. Fent. The locations of these holes are shown on Plate 3. Test holes 1, 2, 3, 4, 5, 23, 35, and 38 were drilled in connection with investigations of the geology and ground-water resources of adjacent counties.

The drill cuttings were collected and studied in the field and later were examined microscopically in the office. The altitudes of the measuring points of the measured wells and of the test-hole locations were determined with a plane table and alidade. Those in Grant and Haskell Counties were determined by a level party headed by John B. LaDuex and those in Stevens County were determined in part by a level party headed by Richard N. Tripp and in part by a level party headed by Charles K. Bayne.

The field data were recorded on maps prepared for the Kansas Highway Planning Board by the Kansas Highway Department (Pls. 1 and 2). The roads and drainage on these maps were corrected by field observations and from aerial photographs obtained from the United States Department of Agriculture.

Wells shown on Plate 2 were located within the sections by use of the odometer, and the locations are believed to be accurate to 0.1 mile. The wells in each county are numbered by townships from north to south and by ranges from east to west, and within a township the wells are numbered in the same order as the sections. The Grant County wells are numbered from 1 to 129, the Haskell County wells from 130 to 227, and the Stevens County wells from 228 to 356. For each well shown on Plate 2 the number above the line corresponds to the number of the well in the well tables and the number below the line is the depth to the ground-water table below the land surface.

ACKNOWLEDGMENTS

Residents of the three counties were very coöperative in permitting the measurement of their wells and in supplying information about their wells and about the rock formations penetrated by the wells. In addition they permitted test drilling on their land and allowed pumping tests to be made on their wells. Data on the municipal water supplies were furnished by the city water departments. R. J. Phillippi of the Kansas State Corporation Commission supplied much information about the Hugoton gas field. Claude W. Hibbard spent several days in the field with the writer and made available much information about the stratigraphy and paleontology of the Tertiary and Quaternary deposits in Meade County and adjacent areas.

The manuscript for this report has been reviewed critically by S. W. Lohman, O. E. Meinzer, and W. D. Collins, of the Federal Geological Survey; J. C. Frye, acting state geologist; Paul D. Haney, director, and Ogden S. Jones, geologist, of the Division of Sanitation of the Kansas State Board of Health; and George S. Knapp, chief engineer of the Division of Water Resources of the Kansas State Board of Agriculture. Plates 1 and 2 and all figures were prepared under the supervision of Eileen Martin of the State Geological Survey. Plate 3 was prepared by Robert White.

GEOGRAPHY

HISTORY[1]

Grant County was created in 1887 by an act of the Kansas legislature by taking eight townships each from Hamilton and Kearny Counties. A census was taken in August 1887, indicating a population of 2,716. The county was organized in 1886 and the governor named Ulysses the temporary county seat. After the election of October 1888 Ulysses became the permanent county seat, having received more votes than the cities of Cincinnati and Surprise. The election was contested by Cincinnati but in 1890 the Supreme Court ruled in favor of Ulysses.

Because of the extended drought during the 1890's, which culminated in the panic of 1898, the population of Ulysses decreased from 1,500 to 40 and the bonded indebtedness grew to $84,000. In order to avoid financial chaos, the entire city (with the exception of the schoolhouse and courthouse) was moved 2 miles northwest and the city of New Ulysses was organized.

1. History of the organization of these counties is taken primarily from Blackmar (1912).

The unorganized county of Arapahoe was created by the legislature in 1873 and later (1883) became a part of Finney County. It was separated from Finney County in 1887 and named Haskell County for Dudley C. Haskell, congressman from Kansas. As a result of a census taken in March 1887 (population 2,841), the governor declared the county organized and named Santa Fe the temporary county seat. Santa Fe was chosen the permanent county seat by popular vote in preference to Ivanhoe and Lockport. In 1912, the Atchison, Topeka and Santa Fe Railway Company completed a branch line through Haskell County to Elkhart in Morton County. The city of Santa Fe was left without railroad facilities and the county seat was moved to Sublette.

The unorganized county of Stevens was created in 1873 and named for Thaddeus Stevens. The area became a part of Seward County in 1883 when the western boundary of Seward was extended to the Kansas-Colorado line. Stevens county was re-created in 1886, a census was taken (population 2,662), and Hugoton was designated the county seat.

Topography and Drainage

Grant, Haskell, and Stevens Counties are in the High Plains section of the Great Plains physiographic province. The area comprises parts of eight physiographic divisions (Fig. 2), most of which were defined by Smith (1940, pp. 140-146). These areas are described briefly in the following pages.

Syracuse upland.—This is the name given by Smith to the long tableland that extends from western Hamilton County to northwestern Grant County. The area is relatively flat but has fairly steep slopes on all sides. It was formed primarily by the folding of the rock strata on the north and by faulting and subsidence of the strata on the south. The surface of the area slopes east-southeastward at the rate of 10 to 30 feet to the mile.

Bear Creek depression.—Bear Creek crosses the northwestern corner of Grant County where it becomes a series of sinkholes and short intermittent streams rather than one continuous stream. It is bordered on the north and northwest by the Syracuse upland and on the east by the Haskell area. The southern boundary is not distinct because it grades imperceptibly into the Stanton area.

Finney sand plain.—The Finney sand plain (Smith, 1940) is an area intermediate in level between the Arkansas Valley and the uplands of the Haskell area. It extends from the Arkansas Valley southward into Grant and Haskell Counties (Fig. 2) and is covered by dune sand in all but its southern part. The southern boundary is a low bluff which generally is less than 50 feet high.

Stanton area.—Most of the western half of Grant County and the northwestern corner of Stevens County lie within the Stanton area, which is a broad, relatively flat plain that slopes east-northeastward. The lowest part of the area is near Bear Creek in the

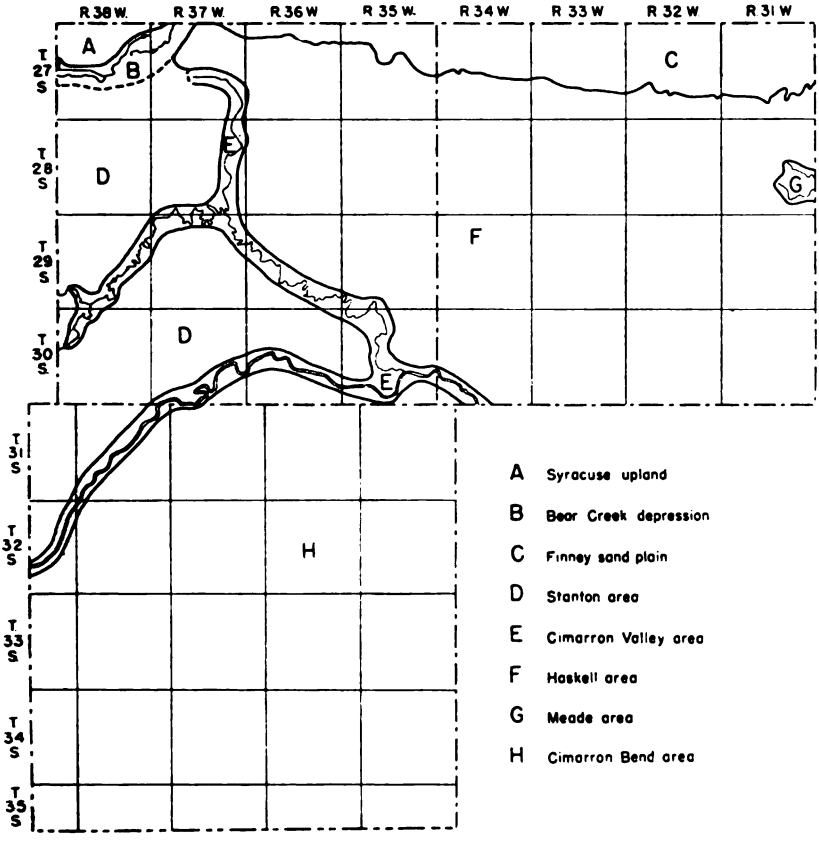


FIG. 2. Map of Grant, Haskell, and Stevens Counties showing physiographic divisions.

northwestern part of Grant County. The area is bordered on the south by the Cimarron River and on the east by Lakin Draw and North Fork Cimarron River.

Cimarron Valley area.—The valleys of the Cimarron River, North Fork Cimarron River, Sand Arroyo, and Lakin Draw constitute the Cimarron Valley area (Pls. 5 and 6). These valleys have a rela-

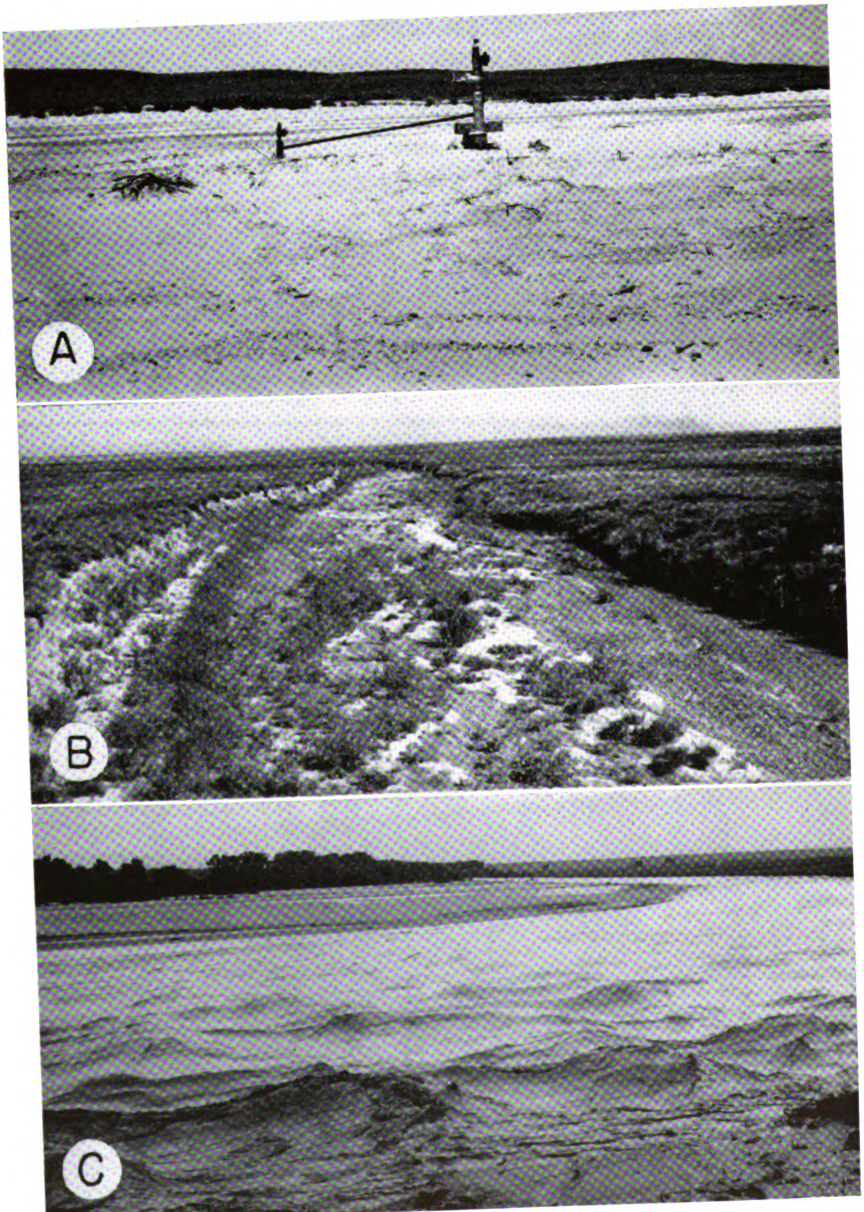


PLATE 5. Views of the Cimarron River channel: *A*, about 2 miles east of the Morton-Stevens County line; *B*, at the Satanta bridge; *C*, at the Ulysses bridge during a flood in 1942.

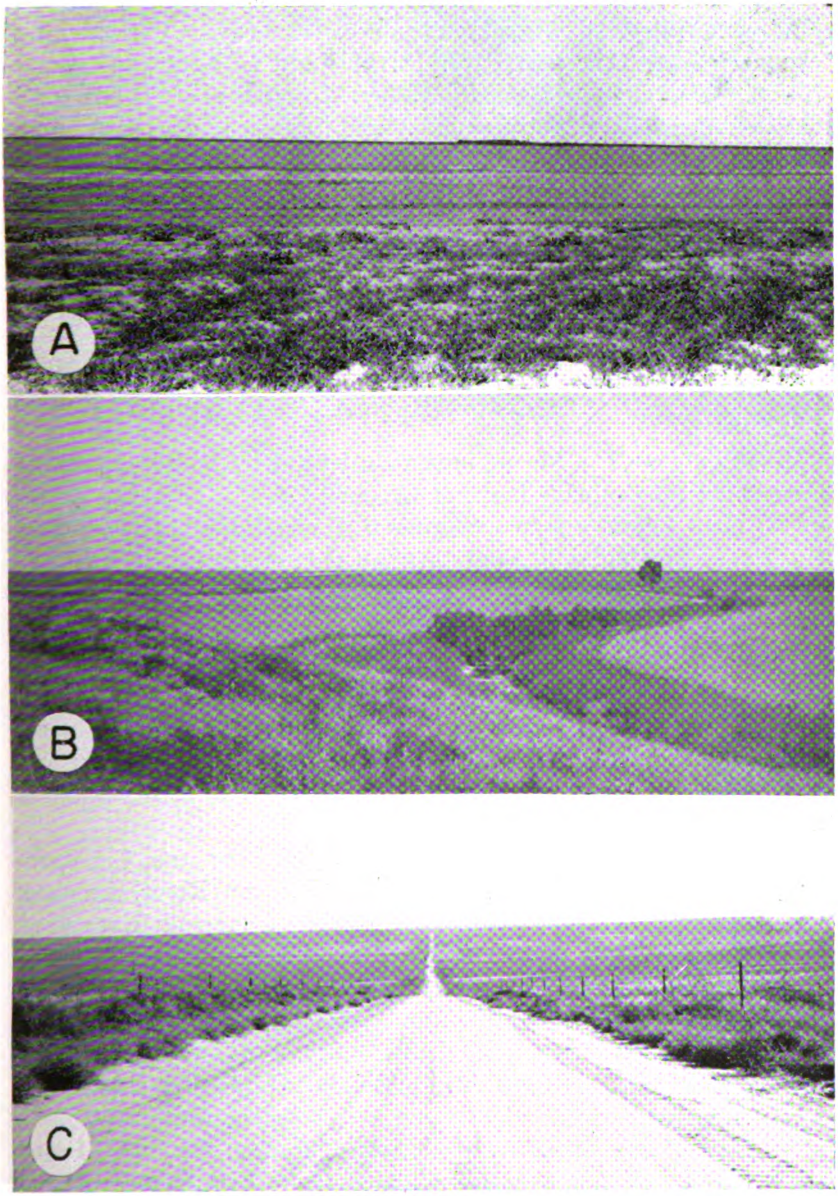


PLATE 6. *A,* Water-filled depression in Stanton area. *B,* Meandering channel of North Fork Cimarron River. C, Valley of North Fork Cimarron River near its confluence with the Cimarron River.

tively small amount of flat bottomland. In many places along the Cimarron Valley the bottomland has been cut away by the widening channel of the Cimarron River leaving only moderate pediment-like slopes along the sides of the valley. In other places, dune sand has been deposited within the valley and forms a typical sand-dune topography.

Haskell area.—The Haskell area, which was named by Smith (1940), is a broad, relatively flat upland extending across most of Haskell County and the eastern half of Grant County. In contrast to the Stanton area which slopes east-northeastward, the Haskell area slopes gently toward the east-southeast. The area is bordered on the east by Crooked Creek, on the north by the Finney sand plain, and on the south and west by the Cimarron River and its tributaries.

Meade area.—The Meade area was defined by Smith (1940) as comprising the drainage basin of Crooked Creek. The headwaters of Crooked Creek are in easternmost Haskell County; therefore the Meade area comprises only a small part of the Grant-Haskell-Stevens area. The Meade area is lower than the Haskell upland and slopes toward the east.

Cimarron Bend area.—The large upland area south of the Cimarron River was called the Cimarron Bend area by Smith (1940). It is a broad upland almost devoid of surface drainage and almost completely covered by sand dunes in various stages of development. The average slope is east-northeastward, as in the Stanton area.

The Grant-Haskell-Stevens area is drained by the Cimarron River and its tributaries (North Fork Cimarron River, Crooked Creek, Bear Creek, and Lakin Draw). The Cimarron River rises in New Mexico and enters Stevens County northwest of Feterita. It flows northeastward through northwestern Stevens County, eastward through southern Grant County, and southeastward through the southwestern corner of Haskell County.

Bear Creek rises in southeastern Colorado and enters Kansas a few miles north of Saunders whence it flows northeastward and joins Little Bear Creek in northeastern Stanton County. From there the stream flows eastward and enters Grant County about 3.3 miles south of the northwest corner of the county. In Grant and Kearny Counties, Bear Creek is not a single stream but is a series of short intermittent streams whose courses are determined largely by depressions or sinkholes. The streams have no valley and have only small, shallow channels bordered by low natural levees. Many years ago flood waters flowed from one depression to another and terminated in the sand hills south of Lakin. Several dikes have been built in an attempt to control the flood waters of Bear Creek, and little water can now reach the sand hills in Kearny County. Much of the flood water spreads over the fields and some enters the Cimarron drainage system by way of Lakin Draw.

Crooked Creek rises in northeastern Haskell County (Fig. 2) and drains parts of Haskell, Gray, Ford, and Meade Counties. It enters the Cimarron River in northeastern Beaver County, Oklahoma.

North Fork Cimarron River flows across the northwestern corner of Stevens County and the southeastern corner of Stanton County and enters Grant County near its southwest corner. The stream flows northeastward to Ulysses where it turns abruptly toward the southeast and joins the Cimarron River near the southeast corner of the county.

Sand Arroyo flows across southern Stanton County and enters Grant County about 7 miles north of the southwest corner of the county. It enters North Fork Cimarron River a short distance east of the Grant County line.

Lakin Draw is a short intermittent stream which flows southward from northern Grant County to North Fork Cimarron River near Ulysses. Part of the flood waters of Bear Creek flow southward through Lakin Draw to North Fork Cimarron River, but because of the low gradient of Lakin Draw part of the flood waters of North Fork Cimarron River extend northward in the channel of Lakin Draw for about 2 miles above their confluence.[2]

Climate

The climate of Grant, Haskell, and Stevens Counties is much like that of other parts of the High Plains section, and is characterized by low precipitation, rapid evaporation, and a wide range of temperature. The summer days generally are hot but, due to the movement of wind and the low humidity, the nights are relatively cool. The winters are moderately cold, but generally are free from excessive snowfall and damp cloudy days.

The mean annual precipitation in Grant, Haskell, and Stevens Counties is 17.71 inches. (All climatic data are from records of the

2. Mr. Joseph Jungferman, personal communication.

U. S. Weather Bureau stations at Ulysses, Sublette, and Hugoton.) The precipitation in this area usually is sporadic and somewhat local, the amount of rainfall in one storm at times varying greatly from one part of the area to another. The highest annual precipitation on record in this area was 28.34 inches at Hugoton in 1941. The next to the highest annual precipitation was 27.36 inches at Ulysses, also in 1941. The highest annual precipitation at Sublette was 27.24 inches in 1923. The mean annual precipitation is 17.24 inches at Ulysses (Fig. 3), 18.02 inches at Sublette (Fig. 4), and 17.87 inches

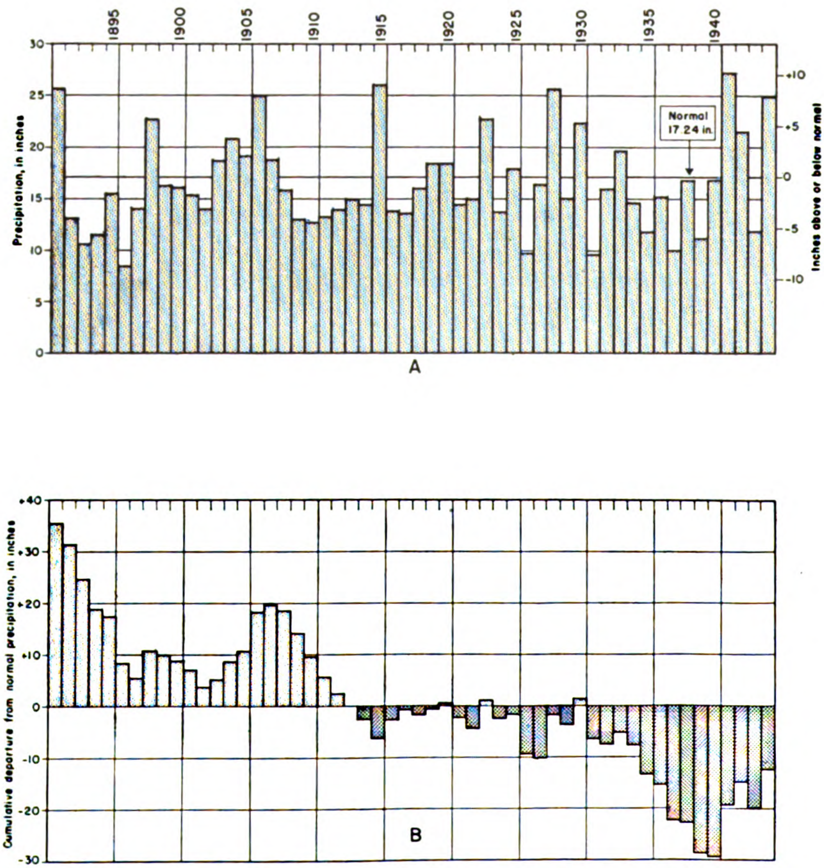


FIG. 3. Graphs showing (*A*) annual precipitation at Ulysses, and (*B*) cumulative departure from normal precipitation at Ulysses.

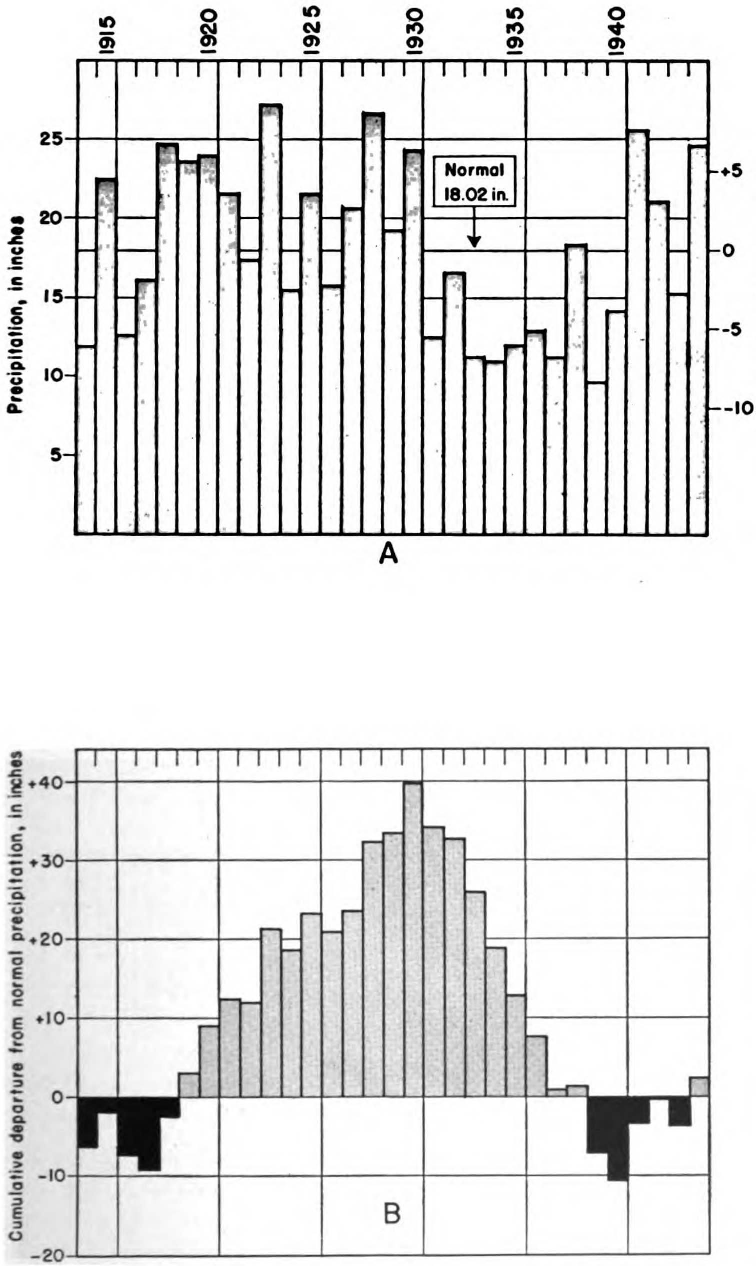


FIG. 4. Graphs showing (*A*) annual precipitation at Sublette, and (*B*) cumulative departure from normal precipitation at Sublette.

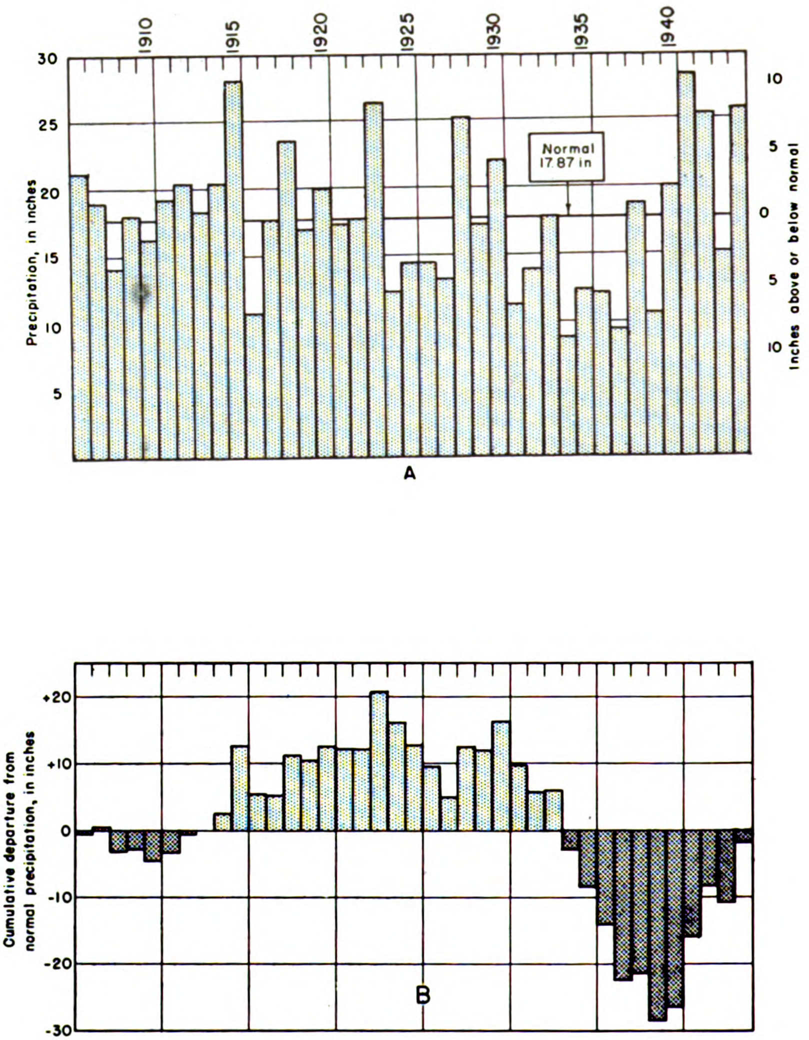


FIG. 5. Graphs showing (*A*) annual precipitation at Hugoton, and (*B*) cumulative departure from normal precipitation at Hugoton.

at Hugoton (Fig. 5). The greatest precipitation is during the summer, particularly in June, and the least is in December and January (Fig. 6). The mean annual temperature in this area is 54.6° F. The temperature in this area has been as high as 111° F. and as low as -28° F.

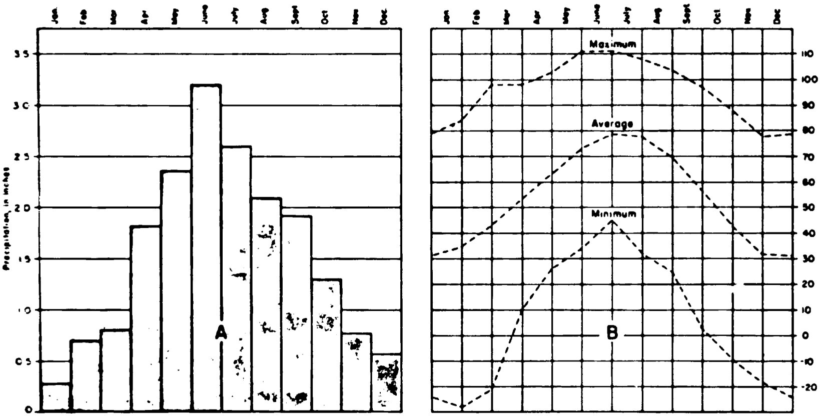


FIG. 6. Graphs showing (*A*) average monthly distribution of precipitation at Ulysses, Sublette, and Hugoton, and (*B*) monthly temperature ranges at Ulysses.

MINERAL RESOURCES

An important mineral resource of the Grant-Haskell-Stevens area is ground water, with which much of this report is concerned. Natural gas is another important mineral resource. A large part of the Hugoton gas field, the most important natural gas-producing area in Kansas, is located within these three counties. The first gas well in the Hugoton field was the Defenders Petroleum Company No. 1 Boles in sec. 3, T. 35 S., R. 34 W., in southwestern Seward County. It was completed in December 1922 and had an initial daily potential of 5 million cubic feet. The first gas well in the Grant-Haskell-Stevens area was the Independent Oil and Gas Company No. 1 Crawford which was drilled in sec. 31, T. 33 S., R. 37 W., in May 1927 to a depth of 3,502 feet. In January 1928, it was plugged back to the gas-producing zone at 2,620 feet and had an initial daily potential of 8 million cubic feet. There was little drilling in the field until 1930 and 1931 after the Argus Pipe Line Company had completed a pipe line from the gas field to Dodge City. There was additional drilling in 1936 and 1937 after the Northern Natural Gas Company and the Panhandle Eastern Pipe Line Company had completed pipe lines that connected the field with their major lines at Mullinville and Arkalon.

Drilling activities in the Hugoton area are described in the annual oil and gas development reports published by the State Geological Survey. Bulletin 54 (Ver Wiebe, 1944) and Bulletin 56 (Ver Wiebe,

1945) contain large maps that show all wells drilled in this field to the end of 1943 and 1944, respectively. On January 1, 1945, there were 328 gas wells in the Grant-Haskell-Stevens area, including 70 wells in Grant County, 41 in Haskell County, and 217 in Stevens County (Fig. 7). These wells had an average deliver-

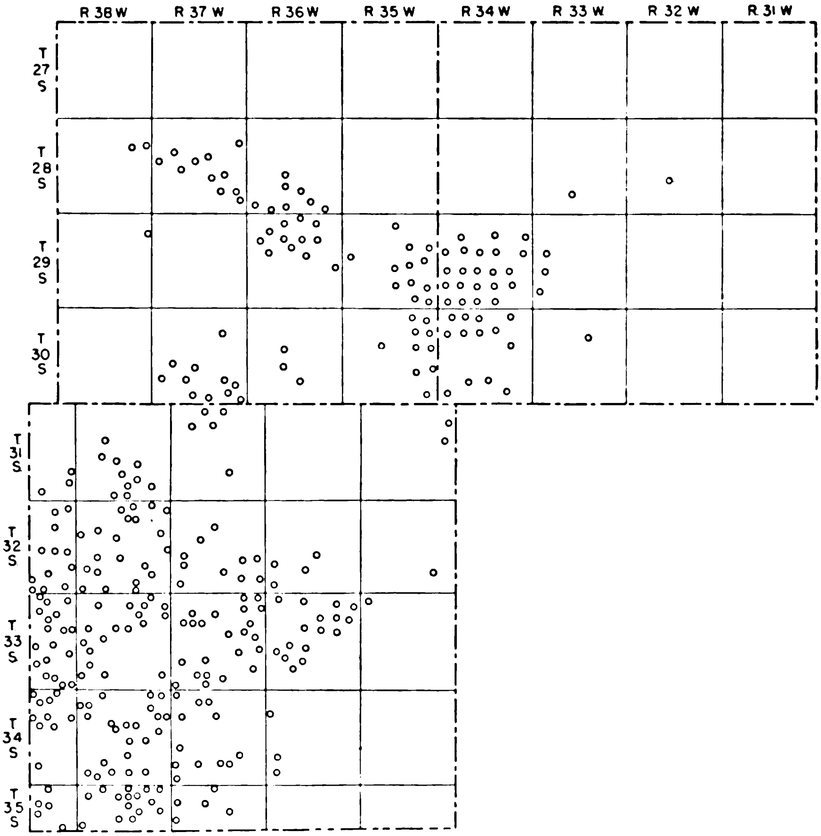


FIG. 7. Map of Grant, Haskell, and Stevens Counties showing the Hugoton gas field (modified from Ver Wiebe, 1944).

ability[3] of 1,788,623 cubic feet of gas a day. The aggregate potential open flow of 265 of these wells was more than 3 billion cubic feet of gas a day in 1943. In 1944 the entire Hugoton field produced 83,007,568,000 cubic feet of gas and by the end of that year the total production from the field was more than 433 billion cubic feet.

3. Deliverability standard pressure is 311.6 pounds per square inch. Data supplied by R. J. Phillippi of the Kansas State Corporation Commission.

According to Hemsell (1939, pp. 1054-1067), gas occurs in at least two zones and as many as six zones in the Permian rocks in the Hugoton field. The first gas is encountered about 10 feet below the top of the Herington limestone member of the Nolans limestone which is the uppermost formation in the Wolfcampian series. Much larger quantities of gas are obtained from the Krider limestone member which is at the base of the Nolans limestone. Additional quantities of gas are obtained from the Winfield limestone, from two zones in the Fort Riley limestone member of the Barneston limestone, and in a few places from the Florence limestone member of the Barneston limestone. Hemsell states that the gas-bearing beds dip 12 to 14 feet a mile east-southeastward toward the Anadarko Basin. Along the west side of the Hugoton field these beds grade laterally into red and brown clastics which serve as a trap for the gas that is migrating up the monoclinal structure.

By estimating that the average porosity of the gas-producing beds is 12 percent and that their average thickness is 45 feet, Hemsell computed that the Hugoton gas field originally had a reserve of 7.4 million cubic feet of gas to the acre. The proved area in Kansas, therefore, had a total reserve of nearly 12 trillion cubic feet of gas (Hemsell, 1939, p. 1061).

Deposits of volcanic ash occur in several places in Grant County (Pl. 12) and at one place in Haskell County, but only one deposit has been worked commercially (Landes, 1928, pp. 22, 23, 26-28). This deposit (owned by Western Spar Products Company) is in the NW¼ sec. 24, T. 30 S., R. 35 W., and formerly was connected to the Atchison, Topeka and Santa Fe railroad by a narrow gauge spur line. According to Landes (1928), the ash has an average thickness of 9 feet and is of good quality, ranking third among the 37 samples analyzed by him. The screen analysis of the ash from Grant County is given in Table 1. Several thousand tons of ash have been taken from this deposit and it has been estimated that 15,000 tons of ash remain.

TABLE 1.—*Screen analysis of volcanic ash from NW¼ sec. 24, T. 30 S., R. 35 W., Grant County (Landes, 1928, p. 23)*

(Percent by weight)

More than 0.833 mm.	0.833–0.147 mm.	0.147–0.074 mm.	0.074–0.046 mm.	Less than 0.046 mm.
0.2	5	18	25	52

Another deposit of volcanic ash, in NE¼ sec. 24, T. 30 S., R. 35 W., is reported to belong to the Pumicite Company and to contain about 60,000 tons of ash. Volcanic ash also is found in the following places in the Grant-Haskell-Stevens area: (1) NW¼ sec. 17, T. 30 S., R. 35 W., owned by C. D. Hickok estate, Ulysses, Kansas; (2) SW¼ sec. 6, T. 30 S., R. 35 W., owned by Charles P. Metcalf, Lawrence, Kansas; (3) SW¼ sec. 7, T. 29 S., R. 37 W., owned by Dan Sullivan, Ulysses, Kansas; (4) SE¼ sec. 19, T. 30 S., R. 34 W., owned by F. E. Murphy, Sublette, Kansas.

Sand and gravel is another mineral resource of this area, and is used primarily for road metal. It is found mainly along the Cimarron River and North Fork Cimarron River in the lower part of the Meade formation of Pleistocene age.

Agriculture

The soils of Grant, Haskell, and Stevens Counties are derived primarily from loess and dune sand. A relatively thin deposit of loess covers most of the Haskell and Stanton areas and the northern part of the Cimarron Bend area. The soils derived from loess are dark compact clay-loams and silty clay-loams which are especially suited for growing wheat and other small grains. Dune sand covers most of the Finney sand plain and most of the Cimarron Bend area (Pl. 1). Soils derived from dune sand are very sandy and are susceptible to wind erosion. Where the sand dunes are relatively old, however, the soils are developed more fully and are less susceptible to wind erosion. The older dune-sand soils are especially suited for growing row crops.

A total of 918,632 acres of land was under cultivation in Grant, Haskell, and Stevens Counties in 1940. (All agricultural data, unless otherwise stated, are from records of the U. S. Census Bureau). There were 1,128 farms in the three counties and the average farm comprised 842 acres. The following list of crops grown in Grant, Haskell, and Stevens Counties was compiled by the 1940 census (Table 2).

As indicated by Table 2, the total acreage of crops grown in the three counties decreased greatly between 1929 and 1939. This was caused primarily by abnormally low precipitation during that period. The precipitation since 1940 has been above normal and the total acreage of crops has increased greatly.

TABLE 2.—*Acreage of principal crops grown in Grant, Haskell, and Stevens Counties*

CROP	1929	1939
Wheat	478,194	158,005
Sorghums	76,495	62,416
Corn	62,597	359
Broomcorn	14,799	4,716
Root and grain crops (other than annual legumes)	a	3,454
Mixed grains	a	2,722
Barley	9,019	1,036
Hay (exclusive of sorghums)	703	728

a. No record available.

POPULATION

The population of Grant, Haskell, and Stevens Counties has fluctuated nearly in accordance with climatic conditions. The population probably was greatest during the land boom between 1885 and 1890, although no official census was taken at that time. Many towns were organized at that time, including 11 towns in Grant County and at least five in Haskell and Stevens Counties.

The population of the counties is shown in Table 3. (All population data, unless otherwise stated, are from records of the U. S. Census Bureau.)

TABLE 3.—*Population of Grant, Haskell, and Stevens Counties from 1889 to 1939*

	1889	1899	1909	1919	1929	1939
Grant County	1,308	422	1,087	1,087	3,092	1,946
Haskell County	1,077	457	993	1,455	2,805	2,088
Stevens County	1,418	620	2,453	3,943	4,655	3,193
Total	3,802	1,499	4,533	6,485	10,552	7,227

There are five cities in Grant, Haskell, and Stevens Counties. They are Ulysses, county seat of Grant County (population 824); Sublette, county seat of Haskell County (population 582); Satanta, (population 345) also in Haskell County; Hugoton, county seat of Stevens County (population 1,349); and Moscow (population 177), also in Stevens County.

Transportation

Branch lines of the Atchison, Topeka and Santa Fe Railway Company cross Grant, Haskell, and Stevens Counties and serve the principal communities. All state and federal highways in the three counties are hard surfaced. U. S. highway 160 enters Grant County from the west and extends east through Ulysses and Hickok to the site of the old town of Santa Fe in Haskell County and thence south into Seward County. U. S. highway 270 enters Grant County from the west and serves the communities of Ulysses, Hugoton, and Woods. U. S. highway 83 crosses the middle of Haskell County from north to south. Kansas highway 25 crosses Grant County from north to south and terminates at Hugoton. Kansas highway 45 parallels the Atchison, Topeka and Santa Fe railroad through Haskell and Stevens Counties and Kansas highway 51 crosses Stevens County as a part of U. S. Highway 270 and Kansas highway 45.

In addition to the highways, there are many graveled county and township roads in the area. Most of the roads are not surfaced, but because of slight precipitation and rapid evaporation the earth roads are passable during most of the year.

GENERAL GEOLOGY

Summary of Stratigraphy

Rocks that crop out in Grant, Haskell, and Stevens Counties are of sedimentary origin and their areal extent is shown on the geologic map (Pl. 1.) The rocks that supply water to wells are the Rexroad formation of Tertiary age, the Meade formation of Pleistocene age, and the Recent alluvium of the Cimarron River and its tributaries. The character and ground-water supply of the geologic formations in this area are described briefly in the generalized section (Table 4) and in more detail in the section on geologic formations and their water-bearing properties.

Geologic History

Grant, Haskell, and Stevens Counties are underlain by thick deposits of limestone, shale, sandstone, clay, sand, and gravel and smaller amounts of salt, gypsum, and anhydrite. The thickness of these sedimentary deposits is not known, but probably exceeds 5,000 feet. A well in northwestern Kearny County (Stanolind Oil and Gas Company No. 1 J. M. Judd) penetrated 6,005 feet of sedimentary rocks before entering the underlying igneous rocks. The character, appearance, and relationships of these rocks as studied in well cuttings and at outcrops reveal much of the geologic history of the region.

PALEOZOIC ERA

Only a few wells in southwestern Kansas have been drilled through all the sedimentary rocks; hence very little is known of the early Paleozoic sediments in this area. Those wells that were drilled to the underlying granite penetrated Cambrian, Ordovician, Mississippian, Pennsylvanian, and Permian marine limestone and shale. This indicates that southwestern Kansas was covered by seas during much of the Paleozoic era. The apparent absence of Silurian and Devonian deposits indicates that southwestern Kansas probably was a land area during that time. If deposits were laid down in this area during Silurian and Devonian time, however, they were removed by subsequent erosion, probably during Mississippian time. After Devonian time this area was again submerged and marine limestone and shale were deposited in Mississippian, Pennsylvanian, and early Permian time. In late Permian time there was general withdrawal of the sea and deposition of thick deposits of redbeds. The presence of salt and gypsum in these deposits implies an arid climate in late Permian time.

MESOZOIC ERA

Triassic period.—Conditions during Triassic time probably were similar to those in late Permian time inasmuch as the Triassic deposits in this region are very similar lithologically to the upper Permian deposits. Redbeds that probably are Triassic in age crop out in the Cimarron Valley in Morton County, but these seemingly do not extend into the Grant-Haskell-Stevens area. If Triassic beds were deposited in this area, they subsequently were removed by erosion.

Jurassic period.—Rocks of Jurassic age (Morrison formation) crop out at Two Buttes in southern Prowers County, Colorado, and have been encountered in test holes in Hamilton, Stanton, and Morton Counties, Kansas. Similar deposits were encountered in test hole 9 in northwestern Grant County. Fossil remains of dinosaurs and other land animals have been collected from beds of the Mor-

TABLE 4.—*Generalized section of the geologic formations in Grant, Haskell, and Stevens Counties, Kansas*

System	Series	Subdivision	Thickness (feet)	Physical character	Water supply
Quaternary	Recent	Alluvium	0–75 (?)	Coarse sand and gravel containing silt and clay.	Yields adequate supplies of relatively hard water to domestic and stock wells.
		unconformable on older formations			
		Dune sand	0–60±	Medium-grained sand containing fine-grained sand and silt.	Does not yield water to wells in this area, but assists in recharge of underlying formations.
		unconformable on older formations			
	Recent and Pleistocene	Terrace deposits	0–10 (?)	Coarse sand and gravel.	Do not yield water to wells in this area.
		unconformable on older formations			
		Kingsdown silt	0–40±	Silt and fine sand containing nodules of caliche.	
		disconformity			
	Pleistocene	Meade formation	50–150 (?)	Sand and gravel at base; sand, silt, clay, and caliche in upper part. Locally contains volcanic ash.	Yield abundant supplies of moderately hard water to domestic, stock, irrigation, and public-supply wells.
		unconformable on older formations			
Tertiary	Pliocene	Rexroad (?) formation*	100–200 (?)	Sand and gravel at base; sand, silt, clay, and caliche in upper part. Sand and gravel in part cemented with calcium carbonate.	
		unconformable on older formations			
		Laverne formation	0–300 (?)	Sand and gravel in lower part; micaceous sand, calcareous sandstone, silt, clay, caliche, and limestone in upper part.	Yields water to very few wells in this area because of its relatively great depth below land surface. An important potential source of ground water.
		unconformable on older formations			
Cretaceous	Gulfian†	Graneros shale	0–30±	Dark-gray to black fissile shale.	Yields little or no water to wells in this area.
		Dakota formation	0–150	Brown, yellowish-brown, reddish-brown, buff, and tan fine-grained sandstone and varicolored clay.	Locally is a potential source of ground water, but is practically unexploited in this area because of its great depth.

Cretaceous	Comanchean	Kiowa shale *local disconformity*	0–135	Dark-gray to black shale. Locally contains lenses of sandstone.	Yields little or no water to wells in this area.
		Cheyenne sandstone *disconformity*	0–100±	Gray and white fine-grained to coarse-grained sandstone.	Locally is a potential source of ground water, but is practically unexploited in this area because of its great depth.
Permian	Leonardian and Guadalupian†	Undifferentiated redbeds	1,500±	Brick-red sandstone and siltstone containing salt, gypsum, anhydrite, and dolomite.	Locally is a potential source of ground water, but is practically unexploited in this area because of its great depth and its generally high mineral content.

* NOTE BY R. C. MOORE.—The deposits designated as Rexroad (?) formation in this publication were called Rexroad formation [without query] in McLaughlin's manuscript of the report, and with acquiescence of supervisory officials of the Federal and State Geological Surveys this manuscript usage was set in print prior to my return from military service. Inasmuch as employment of Rexroad formation in the area here treated involves both a change in stratigraphic classification previously adopted by the Kansas Geological Survey (Frye and Hibbard, 1941; Frye, 1942; Moore, Frye, and Jewett, 1944, Kansas Geol. Survey, Bull. 52, p. 149) and extension in recognition of these deposits beyond Meade County, Kansas, it was desirable to review published and unpublished available data bearing on these changes. All pertinent publications were examined and an unpublished manuscript by Byrne and McLaughlin on Seward County was read. Conferences were held with Dr. J. C. Frye, who has studied Cenozoic deposits in southwestern Kansas extensively, with Dr. C. W. Hibbard, who has collected and studied vertebrate remains from virtually all known southwestern Kansas fossil-bearing localities, and with Dr. A. B. Leonard, who for some years has been investigating fossil molluscan faunas from Cenozoic deposits in western Kansas.

Classification of the Rexroad deposits as a member of the Ogallala formation previously has been judged appropriate on the grounds that (1) known occurrence of these fossil-bearing beds is geographically restricted to parts of Meade County, Kansas, (2) the lower boundary of the Rexroad deposits is poorly defined, (3) lithologic distinction between Rexroad and pre-Rexroad Ogallala deposits is slight or lacking, and (4) there is great difficulty generally in mapping Rexroad as a separate stratigraphic unit. Although a disconformity indicating break in sedimentation is inferred to exist in parts of Meade County at the base of the Rexroad, elsewhere in this region sedimentation of Rexroad on Ogallala was presumed to be conformable (Frye and Hibbard, 1941). Definition of the stratigraphic span of the Ogallala formation in southwestern Kansas properly is not based solely or even primarily on time concepts, in such fashion that it is presumed to exclude deposits interpreted to be younger than the so-called "Algal limestone" of northern Kansas—despite the fact that this limestone marks the top of the Ogallala in the north. Thus, it has seemed proper to apply the name Ogallala in a broadly inclusive manner to Tertiary terrestrial deposits of the western Kansas region in which neither lithologic nor structural grounds for significant subdivision in mapping is afforded. Inasmuch as the Rexroad (?) deposits of Seward County and areas farther west, which are reported to rest unconformably on Laverne deposits, are not established as true Rexroad, evidence is not yet available to show that an important break in sedimentation occurs at the base of the Rexroad; also, satisfactory grounds for recognizing Rexroad deposits outside of Meade County, Kansas, seem not yet to have been brought forward. Nevertheless, paleontological evidence emphasizes the lesser age of the Rexroad beds (very late Pliocene or early Pleistocene) as compared with pre-Rexroad Ogallala deposits elsewhere (early to late Pliocene). All things considered, it is judged desirable to revert to the original usage of Smith (1940) in which Rexroad deposits are treated as a distinct formation.

The question of recognizing Rexroad formation in Seward, Grant, Haskell, Stevens, and Morton counties is quite distinct from that of classifying these deposits as a formation or as a member. Evidence that Cenozoic deposits older than the Meade formation of this region belong to the Rexroad rather than the Ogallala seems not yet to have been obtained. Vertebrate remains from southeastern Seward County studied by Hibbard (1944, 1944a, and personal communication, June 14, 1946) indicate middle Pliocene age or at least a distinctly greater antiquity than the type Rexroad fauna; this refers to Hibbard's Saw Rock Canyon locality and vicinity. Leonard reports that fossil mollusk assemblages associated with the Saw Rock Canyon vertebrates are clearly differentiated from those of the type Rexroad. Rhinoceros remains found by Smith (1940, p. 74) near Arkalon in Seward County assuredly denote pre-Rexroad Ogallala, though mapped as Rexroad (Byrne, F. S., and McLaughlin, T. G., unpublished report). Accordingly, I judge that no secure grounds have yet been adduced for recognition of Rexroad outside of areas in Meade County, and it seems probable that all of the Rexroad (?) formation of this report comprises Ogallala deposits of pre-Rexroad age. Changes have been made in proof to indicate the questionable identification of Rexroad in Grant, Haskell, Stevens, Morton, and Seward Counties.

The outcrop areas of Rexroad (?) formation (probably Ogallala) have been omitted from the geologic map (Pl. 1); although small (see p. 118), these areas are not differentiated from the Meade formation.

† The classification is that in use by the State Geological Survey of Kansas but not by the U. S. Geological Survey.

rison formation in other areas. During the Jurassic period the fluviatile Morrison deposits were laid down on a large land mass which probably extended into the Grant-Haskell-Stevens area, but most of these beds subsequently were removed from this area by erosion.

Cretaceous period.—Sand now forming the Cheyenne sandstone was deposited in the northern part of Grant and Haskell Counties in early Cretaceous time (Pl. 3 and Fig. 8), probably by streams

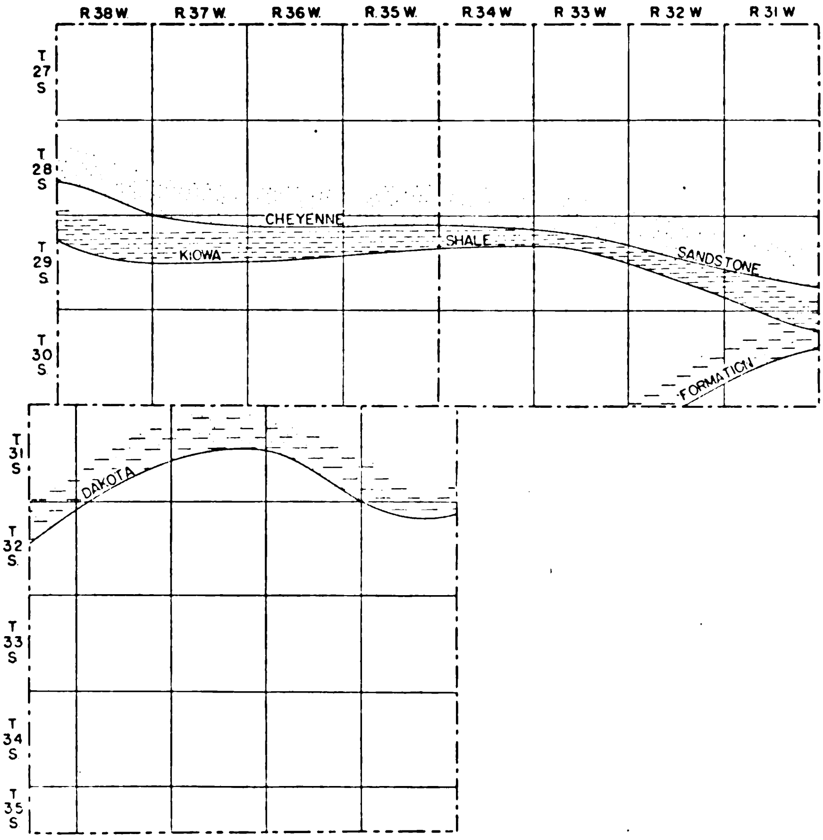


FIG. 8. Map of Grant, Haskell, and Stevens Counties showing the southern limits of the Dakota, Kiowa, and Cheyenne formations.

(Twenhofel, 1924, p. 19). Then an invasion of the sea brought about the deposition of the dark fossiliferous muds that formed the Kiowa shale. At the beginning of late Cretaceous time the sand and clay of the Dakota formation were laid down, probably in broad low lagoonal areas resembling the lower Mississippi Delta

(Plummer and Romary, 1942, pp. 341-2). Although the Dakota sediments are nonmarine, Plummer and Romary believe they were deposited near sea level under conditions similar to those prevailing during the formation of the Mississippi Delta.

Marine deposits of limestone, chalk, and shale were laid down in southwestern Kansas in late Cretaceous time. The late Cretaceous sea probably covered much if not all of the Grant-Haskell-Stevens area, but subsequent erosion has removed most of the sediments that were deposited in it except a thin deposit of Graneros shale in northeastern Haskell County (Pl. 3). At the end of the Cretaceous period occurred the mountain-making movements that produced the Rocky Mountains and affected at least part of the High Plains section. At this time the Cretaceous and older beds probably were tilted to the slightly inclined position they now have.

CENOZOIC ERA

Tertiary period.—A long period of erosion probably took place after the tilting of the Cretaceous and older beds in early Tertiary time. During this time the Cretaceous deposits lying above the Dakota formation were removed from the Grant-Haskell-Stevens area by erosion, leaving only the remnant of Graneros shale in northeastern Haskell County. Later, but still in early Tertiary time, the Syracuse anticline was being formed, causing a tilting of the rocks in northwestern Grant County (Pl. 3). At the beginning of the Pliocene epoch the deposits that comprise the Laverne formation (Gould and Lonsdale, 1926a; Frye and Hibbard, 1941) were laid down in parts of southwestern Kansas (Meade and Seward Counties) and northwestern Oklahoma (Beaver and Harper Counties). These deposits probably underlie much of the Grant-Haskell-Stevens area but they do not crop out in this area and seemingly cannot be distinguished from the overlying deposits by examination of well cuttings. Frye (1942, p. 23) suggested that these deposits were laid down in part in small lakes and on the flood plains of streams. The beds of coarse sand and gravel in the lower part were deposited by streams. Toward the end of Tertiary time, aggrading and laterally shifting streams deposited the silt, sand, and gravel comprising the Ogallala formation. The Ogallala formation in most, if not all, of the Grant-Haskell-Stevens area was then removed by erosion and deposits of the Rexroad (?) formation were laid down by streams (according to views of the author).

Quaternary period.—Near the end of the Tertiary period or in the early part of the Quaternary period there probably was renewed folding of the Syracuse anticline accompanied by faulting. This period of deformation probably was the same as that which produced the major faulting in the Meade Basin in Meade County, Kansas (Frye and Hibbard, 1941). Subsequent to the period of deformation, extensive deposits of sand, gravel, silt, clay, and volcanic ash were laid down in the Grant-Haskell-Stevens area, and comprise the Pleistocene Meade formation.

During late Pleistocene time, aggrading streams flowing at the upland level spread fine sand and silt over their flood plains. These sediments, which comprise a part of the Kingsdown silt, probably were laid down over most of Grant, Haskell, and Stevens Counties. Erosion subsequently removed much of the water-laid part of the Kingsdown silt from the Grant-Haskell-Stevens area. In late Pleistocene and/or Recent time a thin deposit of loess was laid down over most of Grant and Haskell Counties and over the northern part of Stevens County. The loess deposits are considered the uppermost part of the Kingsdown silt.

During late Pleistocene and/or Recent time the high terrace deposits of the Cimarron River were laid down, the valley was deepened nearly to its present level, and the alluvium was deposited. More recently (primarily since the flood of May 1914) the channel of the Cimarron River has widened throughout most of its course in Grant, Haskell, and Stevens Counties. When this area was surveyed in 1874 the width of the channel of the Cimarron River was measured at each section line that the river crossed. The greatest measured width of the channel in this area in 1874 was 132 feet, at the west line of sec. 35, T. 30 S., R. 37 W., and the smallest width was 17 feet, at the west line of sec. 23, T. 30 S., R. 35 W. The average width at that time (average of more than 40 measurements) was about 47 feet. In 1939, however, the greatest width was more than 0.5 mile, the smallest width was about 125 feet, and the average width (based on measurements from aerial mosaics) was approximately 1,000 feet.

Other events in late Pleistocene and Recent time included the deposition of dune sand over most of Stevens County and parts of Grant and Haskell Counties and the formation of sinkholes, most of which are in the Stanton area in the vicinity of Bear Creek. This area probably subsided at the time of the folding and faulting of the Syracuse anticline. The sinkholes and depressions, which probably began to form after the major subsidence, continued to form through Recent time. The most recent sinkhole adjacent to the Syracuse anticline began to develop in western Hamilton County on December 18, 1929 (Bass, 1931).

GROUND WATER

PRINCIPLES OF OCCURRENCE

The discussion of principles governing the occurrence of ground water that is given here takes account of conditions in Grant, Haskell, and Stevens Counties. Preparation of the discussion has been based chiefly on the authoritative and detailed treatment of the occurrence of ground water by Meinzer (1923), to which the reader is referred for more extended consideration. A general discussion of the principles of the occurrence of ground water with special reference to Kansas has been published by Moore (1940).

The rocks that make up the outer crust of the earth generally are not entirely solid, but contain numerous openings, called voids or interstices, which may contain air, natural gas, oil, or water. The number, size, shape, and arrangement of the interstices in rocks depend upon the character of the rocks. The occurrence of water in any region, therefore, is determined by the geology.

The interstices or voids in rocks range in size from microscopic openings to the huge caverns found in some limestones. The open spaces generally are connected so that water may percolate from one to another, but in some rocks these open spaces are isolated and the water has little chance to percolate. In Grant, Haskell, and Stevens Counties the rocks from which ground water is obtained are poorly consolidated silt, sand, and gravel. Generally the sand and gravel of the Rexroad (?) and Meade formations contain many interstices and water percolates freely through them, but locally these interstices may be filled with calcium carbonate or other material, such as clay, that makes the rock almost impermeable. Some of the silt, sand, and gravel of the Rexroad and Meade formations is poorly sorted and the finer particles fill much of the space between the larger particles, thereby decreasing space available to ground water.

The porosity of a rock is the percentage of the volume of the rock that is occupied by the interstices. A rock is said to be saturated when all its interstices are filled with water or other liquid, and the porosity is then practically the percentage of the volume of rock that is occupied by water. The porosity of a rock determines only the amount of water a rock can hold, not the amount it may yield to wells. Some rocks may be moderately porous and yet will not yield an appreciable amount of water to a well. The permeability of a rock is defined as its capacity for transmitting water under pressure and is measured by the rate at which it will transmit water through a given cross section under a given difference of pressure per unit of distance. A rock containing very small interstices may be very porous but it would be difficult to force water through it, whereas a coarser-grained rock, although it may have less porosity, generally is much more permeable. Water may be held in rocks by the force of molecular attraction, which, in some fine-grained rocks, is sufficiently great to make the rock relatively impermeable.

Below a certain level in the earth's crust the permeable rocks generally are saturated with water and are said to be in the zone of saturation. The upper surface of the zone of saturation is called the ground-water table or simply the water table. All the rocks above the water table are in the zone of aeration, which ordinarily consists of three parts: the belt of soil water, the intermediate or vadose zone, and the capillary fringe.

The belt of soil water lies just below the land surface and contains a small amount of water held by molecular attraction. The soil zone must be saturated with water before any water can percolate downward to the water table. The thickness of the zone is dependent upon the character and thickness of the soil and upon the precipitation.

The intermediate or vadose zone lies between the belt of soil water and the capillary fringe. The interstices in the rocks in this zone generaly are filled with air but may contain water for a short time while it is moving downward from the belt of soil water to the ground-water table. The vadose zone may be absent in places, such as some river valleys where the water table is near the surface, or it may be more than 200 feet thick, as in parts of Grant, Haskell, and Stevens Counties.

The capillary fringe lies directly above the water table and is formed by water rising from the zone of saturation by capillary action. The water in the capillary fringe is not available to wells, which must be deepened to the zone of saturation before water will enter them. The capillary fringe may be absent in coarse sediments, where the capillary attraction is negligible, but may be as much as 8 feet thick in very fine-grained sediments.

WATER IN SAND AND GRAVEL

Grant, Haskell, and Stevens Counties are underlain by thick deposits of unconsolidated materials that were laid down by streams in Tertiary and Quaternary time. The sorting action of streams on these sediments caused the deposition of many distinct beds of gravel, sand, silt, and clay. Deposits of such uniform texture may have a relatively high porosity. Coarse, well-sorted gravel of this type has a relatively high specific yield and permeability, and properly constructed wells in this material yield large quantities of water. Some of the stream-laid material is poorly sorted and finer material occupies much of the pore space between the larger grains, reducing the porosity and specific yield.

In Grant, Haskell, and Stevens Counties, water is found in unconsolidated beds of sand and gravel in the Rexroad (?) and Meade formations and in the alluvium in the Cimarron River Valley. The Rexroad (?) and Meade formations are most important sources of ground water in the Grant-Haskell-Stevens area. Most of the domestic, stock, irrigation, industrial, and public-supply wells in this area obtain water from these deposits. The yields of wells ending in the Rexroad (?) and Meade strata range from a few gallons a minute to more than 1,400 gallons a minute. The alluvium of the Cimarron River Valley probably would yield relatively large quantities of water to wells. The Cimarron River, however, has widened its channel and destroyed most of the bottom land, and as a result no irrigation has been developed in the valley area. The Laverne formation is an important potential source of ground water in this area but it is practically unexploited because of its great depth

WATER IN SANDSTONE

The particles comprising a sandstone generally are more even-grained and better sorted than those in unconsolidated sand and gravel. These particles are held together by cementing material which in some places may fill the interstices and prevent water from percolating through them. In this area, sandstone occurs in the Cheyenne and Dakota formations and locally in the Kiowa shale, but very few wells penetrate these beds because an adequate supply of potable water can be obtained in the overlying unconsolidated Tertiary and Quaternary deposits.

WATER IN SHALE

Shale is formed by the induration of clay or clayey mixtures; it generally has a relatively low specific yield and therefore yields little or no water to wells. In some areas the shale may have many open joints and bedding planes and consequently a higher permeability; in other areas it may contain sand grains in sufficient quantity to make it somewhat permeable. In this area shale occurs in the Kiowa and Dakota formations and does not yield water to wells.

Permeability of Water-Bearing Materials

The rate of movement of ground water is determined by the size, shape, quantity, and degree of interconnection of the interstices and by the hydraulic gradient. The capacity of a water-bearing material for transmitting water under hydraulic head is its permeability. The coefficient of permeability may be expressed as the rate of flow of water, in gallons a day, through a cross-sectional area of 1 square foot under hydraulic gradient of 100 percent at a temperature of 60° F. (Meinzer's coefficient; see Stearns, 1927, p. 148.) The coefficient of transmissibility is a similar measure and may be defined as the number of gallons of water a day transmitted through each 1-foot strip extending the height of the aquifer under a unit-gradient (Theis, 1935, p. 520). The coefficient of transmissibility may also be expressed as the number of gallons of water a day transmitted through each section 1 mile wide extending the height of the aquifer, under a hydraulic gradient of 1 foot to the mile.

The coefficient of transmissibility is equivalent to the coefficient of permeability (corrected for temperature) multiplied by the thickness of the aquifer.

The coefficient of permeability of water-bearing materials can be determined in the laboratory (methods summarized by V. C. Fishel in Wenzel, 1942, pp. 56-58) or in the field. Pumping tests were made in Grant and Stevens Counties between June 1, 1941, and October 1, 1942, by Melvin S. Scanlan of the Division of Water Resources of the Kansas State Board of Agriculture and Woodrow W. Wilson of the Federal Geological Survey. Discharge measurements were made using a Collins flow meter (Pl. 8) and measurements of drawdown and recovery were made using a steel tape or an electrical measuring device, or both.

Theis (1935) has shown that to the extent that Darcy's law governs the motion of ground water under natural conditions and under the artificial conditions caused by pumping, an analogy exists between hydrologic conditions in an aquifer and thermal conditions in a similar thermal system. Darcy's law is analogous to the law of the flow of heat by conduction, hydraulic pressure being analogous to temperature. hydraulic gradient to thermal gradient, permeability to thermal conductivity, and specific yield to specific heat. From his equation expressing the relation between the drawdown and the rate and duration of discharge of a well, Theis developed the following recovery formula for determining the transmissibility of an aquifer (as defined above):

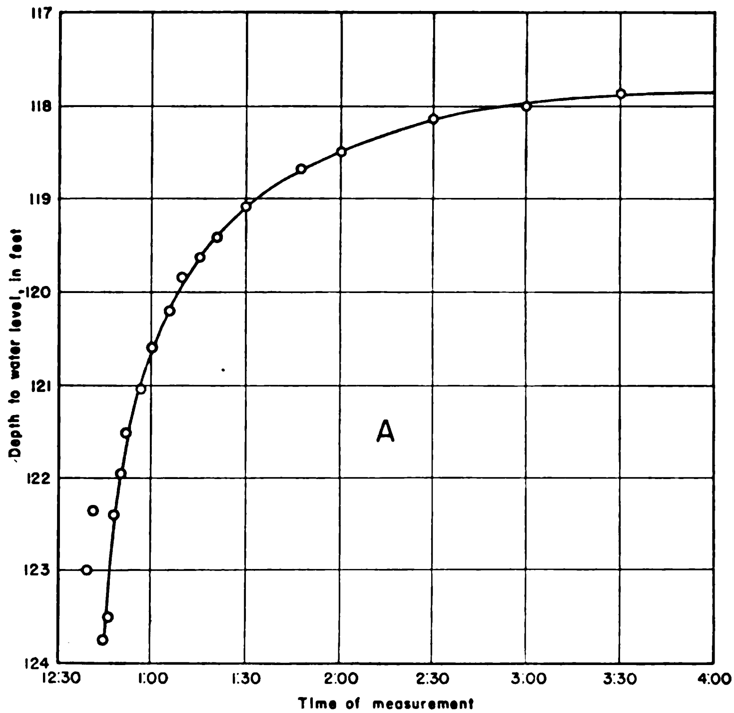
$$T = \frac{264q}{s} \log_{10} \frac{t}{t_1}$$

in which T = coefficient of transmissibility
q = pumping rate, in gallons a minute
t = time since pumping began, in minutes
t_1 = time since pumping stopped, in minutes
s = residual drawdown at the pumped well, in feet at time t_1

The residual drawdown (s) is computed by subtracting the static water-level measurement (Table 5) from water-level measurements made after pumping stops (Fig. 9). The proper ratio $\frac{\log_{10} t/t_1}{s}$ is determined graphically by plotting $\log_{10} t/t_1$ against corresponding values of s (Fig. 9). This procedure is simplified by plotting t/t_1 on the logarithmic coördinate of semi-logarithmic paper. For any convenient value of $\log_{10} t/t_1$, the corresponding value of s may be found by inspection, provided the curve passes through the origin. If the curve does not pass through the origin, it can be made to do so approximately by applying an empirical correction to the formula as follows: $T = \frac{264q}{s} \log_{10} \frac{t \pm c}{t_1}$ in which c is a correction factor (Wenzel, 1942, p. 127). Only one (well 115) of the curves for tests in Grant and Stevens Counties passed through the origin. The correction factors needed to make the other curves pass through the origin ranged from —185 to + 147.

The weighted average discharge (q) of well 115 was 680 gallons a minute (Table 5). When values for s, t/t_1, and q are substituted in the Theis recovery formula, the coefficient of transmissibility of the water-bearing material at the pumped well is found to be 43,573. Dividing the coefficient of transmissibility by the average thickness of the saturated water-bearing material in the vicinity of the well, 295 feet, the average coefficient of permeability is found to be about 148. (The temperature of the water was 60° F., hence no temperature correction is needed.) Data on seven pumping tests in Grant and Stevens Counties are listed in Table 6.

The irrigation wells listed in Table 6 obtain water primarily from the Rexroad (?) formation but also from the lower part of the Meade formation. As indicated by the pumping tests, these



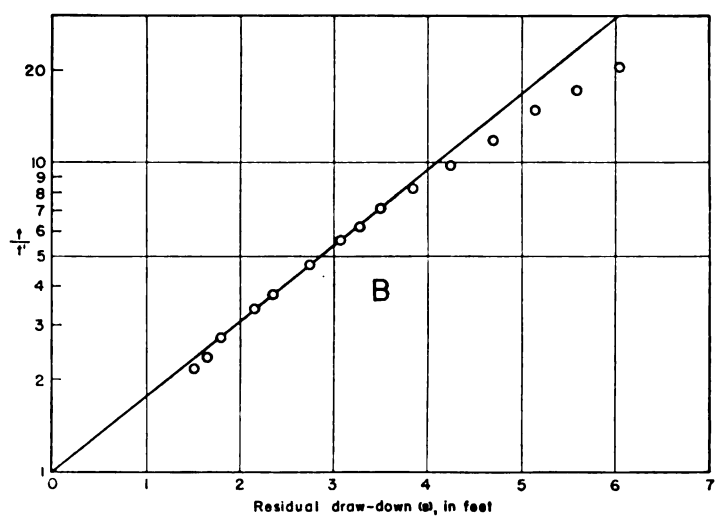


FIG. 9. *A,* Recovery curve for well 115. *B,* Curve for pumping test on well 115 obtained by plotting s against t/t_1.

deposits have low to moderate permeabilities, but because of the great thickness of saturated material the coefficient of transmissibility generally is large. Some wells, such as 299, penetrated deposits consisting primarily of silt, whereas wells 244 and 247 encountered thick deposits of sand and gravel. Two of the wells listed in Table 6 (30 and 56) penetrated the entire thickness of saturated material above the Cretaceous deposits.

TABLE 5.—*Data on pumping test of well 115, Grant County, made on September 25, 1942, by Melvin Scanlan, Woodrow W. Wilson, and Thad G. McLaughlin*

Time since pumping started (minutes) t	Time since pumping stopped (minutes) t_1	t/t_1	Yields (gallons a minute)	Depth to water level (feet)	Draw-down (feet)	Remarks
....	....	....	....	116.36	....	Static water level. Pump started.
6	....	....	652	139.59	23.23	
36	....	....	557	139.47	23.11	
66	....	....	536	140.10	23.74	
96	....	....	768	140.06	23.70	
126	....	....	746	140.00	23.64	
156	....	....	756	139.65	23.29	
186	....	....	750	139.59	23.23	
194	....	....	....	....	....	Pump stopped.
195.5	1.5	130.30	....	123.00	6.64	
197	3	65.67	....	122.35	5.99	
200	6	33.33	....	123.76	7.40	
202	8	25.25	....	123.50	7.14	
204	10	20.40	....	122.40	6.04	
206	12	17.17	....	121.96	5.60	
208	14	14.86	....	121.51	5.15	
212	18	11.78	....	121.04	4.68	
216	22	9.82	....	120.59	4.23	
221	27	8.19	....	120.20	3.84	
226	32	7.06	....	119.85	3.49	
231	37	6.24	....	119.63	3.27	
236	42	5.62	....	119.43	3.07	
246	52	4.73	....	119.10	2.74	
263	69	3.81	....	118.70	2.34	
276	82	3.37	....	118.51	2.15	
306	112	2.73	....	118.15	1.79	
336	142	2.37	....	118.01	1.65	
366	172	2.13	....	117.87	1.51	

TABLE 6.—*Results of pumping tests in Grant and Stevens Counties*

Well No.	Water-bearing formations	Discharge (gallons a minute)	Drawdown (feet)	Duration of pumping (minutes)	Specific capacity (*a*)	Coefficient of trans-missibility	Approximate thickness of water-bearing material (feet)	Coefficient of permeability (*b*)
30	Rexroad (?) and Meade..	1,122	23.03	199	48.7	53,954	247	218
56	do..................	871	34.24	199	25.4	23,600	245	96
92	do..................	456	22.80	183	20.0	4,485	350	13
115	Rexroad (?) and/or Meade	680	23.43	194	29.0	43,573	295	148
244	Rexroad (?) and Meade..	1,086	12.54	218	86.6	147,028	295	498
247	do..................	1,324	14.31	207	92.5	88,412	290	305
299	do..................	551	82.80	319	6.7	3,853	480	8

(*a*) The specific capacity of a well is its rate of yield per unit of drawdown and is determined by dividing the tested capacity in gallons a minute by the drawdown in feet.

(*b*) Coefficient of transmissibility divided by thickness of saturated water-bearing material; temperature of water 60° F., hence no correction for temperature is needed.

Artesian Conditions

The head of water has been defined as the height that a column of water will rise in a tightly cased well which has no discharge. Ground water that rises in wells to a level above that at which the water is encountered is said to be artesian or "piestic" (Meinzer and Wenzel, 1942, p. 451).

The Rexroad (?) formation in places contains beds of saturated sand and gravel in which the ground water is confined by overlying beds of clay which are relatively impermeable. Wells drilled to these water-bearing beds encounter water under artesian head, and in Lakin Draw and North Fork Cimarron Valley the head is sufficient to cause a few of them to flow. Artesian water has been encountered in many wells in Grant, Haskell, and Stevens Counties, but the water generally is not under sufficient head to flow at the surface.

The only flowing wells in this area are near Ulysses. Well 47 encountered artesian water at a depth of about 160 feet, and in 1943 it had a measured yield of 1.25 gallons a minute. A feebly flowing well about 2 miles southeast of Ulysses in North Fork Cimarron Valley was reported to be 220 feet deep.

The Water Table

The upper surface of the zone of saturation in ordinary permeable soil or rock has been defined as the ground-water table, or simply the water table. Where the upper surface is in impermeable material the water table is absent. The water table is not a plane surface in all parts of the area, but in places has irregularities comparable with and related to those of the land surface, although it is less rugged. It does not remain stationary but fluctuates up and down. The irregularities are caused chiefly by local differences in gain and loss of water, and the fluctuations are caused by variations from time to time in gain or loss of water. The water-table contours shown on Plate 2 were based on water-level measurements made during the summers of 1941 (Grant and Haskell Counties) and 1942 (Stevens County) and represent the approximate shape and slope of the water table at the time the measurements were made. Fluctuations in water level, particularly in the areas of shallow water, might cause considerable change in the shape and slope.

SHAPE AND SLOPE

The shape and slope of the water table in Grant, Haskell, and Stevens Counties are shown on the map (Pl. 1) by contours drawn on the water table. Each point on the water table along a contour has the same altitude. The water-table contours show the configuration of the water surface just as topographic contours show the shape of the land surface. The direction of movement of the ground water is at right angles to the contours in the direction of the downward slope.

The map (Pl. 1) shows that the general movement of the ground water in Grant, Haskell, and Stevens Counties is toward the east, but that the slope and the direction of movement range considerably from one part of the area to another. The maximum slope is about 50 feet to the mile and is near Ryus in southeastern Grant County. The minimum slope is about 5 feet to the mile and is in eastern Haskell County. The average slope in the northern part of the area is 7.5 feet to the mile whereas the average slope in the southern part of the area is 10 feet to the mile.

The shape and slope of the water table determine the rate and direction of movement of ground water and are controlled by several factors. Irregularities in the shape and slope of the water table may be caused by: (1) configuration of the bedrock floor; (2) discharge of ground water into streams; (3) recharge of the ground-water reservoir by ephemeral streams; (4) unequal additions of water to the ground-water reservoir; (5) local differences in the permeability and thickness of the deposits; and (6) pumping of water from wells.

The shape of the underlying bedrock floor of Cretaceous and Permian rocks in Grant, Haskell, and Stevens Counties has no apparent effect upon the shape or slope of the water table. As indicated by Figure 10, the surface of the bedrock floor in Stevens County slopes toward the southeast whereas the water table slopes eastward and east-northeastward. Figure 10 also shows a trough in southeastern Haskell County and a ridge in northeastern Haskell County, neither of which is indicated by the shape of the water table. Figure 10 shows a high ridge in northwestern Grant County which also is not indicated by the shape or slope of the water table.

The discharge of ground water into the Cimarron and North Fork Cimarron Rivers has modified the shape and slope of the water table in this area, as indicated by the upstream flexure of the water table contours along the Cimarron River in the western part of its course through southern Grant County. Along North Fork Cimarron River the effect is noticeable both southeast and southwest of Ulysses.

Streams that flow only after rains are termed ephemeral or intermittent streams. Their channels lie above the water table and are dry much of the time. During periods of stream flow, part of the water in an ephemeral stream may seep into the stream bed and

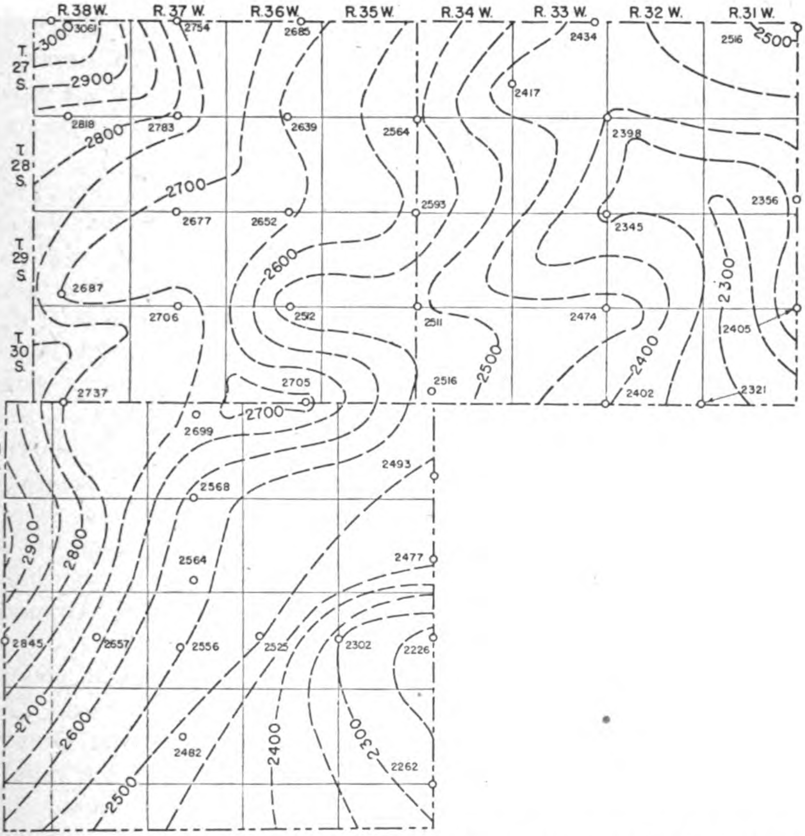


Fig. 10. Map of Grant, Haskell, and Stevens Counties showing the topography of the rocks beneath the Tertiary and Quaternary deposits.

move downward to the ground-water reservoir; hence streams of this type are called losing or influent streams. Bear Creek in northwestern Grant County is an example of this type of stream. Water seeps into the stream bed and moves downward to the ground-water reservoir creating a ridge on the water table, as indicated by the downstream flexure of the water-table contours in the vicinity of Bear Creek (Pl. 1). The water-table ridge probably was caused in part by seepage of water from sinkholes in the vicinity of Bear Creek.

The Cimarron River is a losing stream in a part of its course in northwestern Stevens County, in southeastern Grant County, and in southwestern Haskell County (Pl. 5). As shown by Plate 1, there is a ridge on the water table beneath the Cimarron River from a point about 7 miles west of the Grant-Haskell line to about 3 miles below the point where the river crosses the Haskell-Seward line. North Fork Cimarron River is a losing stream in western and southeastern Grant County, but its effect on the shape of the water table could not be indicated on the water-table contour map because of insufficient data.

Unequal additions of water to the ground-water reservoir have caused some of the irregularities in the shape of the water table in the Grant-Haskell-Stevens area. In the northwestern part of Grant County, Bear Creek is a series of intermittent streams terminating in sinkholes. In addition, there are many other sinkholes or depressions in that area. After heavy rains, the water stands in the depressions until it evaporates or percolates downward to the water table (Pl. 6), and this is in part the cause of the ridge on the water table in the vicinity of Bear Creek. Similar though less pronounced depressions in many parts of the Grant-Haskell-Stevens area also contribute water to the ground-water reservoir. Conditions favorable for the addition of water to the ground-water reservoir are to be found in the sand-hills areas where there are many undrained basins underlain by moderately permeable rocks. (See Ground-water recharge.)

Local differences in permeability are among the principal factors affecting the shape and slope of the water table in this area. The area of steeply sloping water table in southeastern Grant County and southwestern Haskell County that is indicated by the closely spaced contours (Pl. 1), and which extends southeastward through southwestern Seward County and into Oklahoma, probably is caused by a relatively low permeability of the rocks through which the ground water moves. In western Grant and Stevens Counties the upper part of the zone of saturation is in the lower part of the Meade formation, which is primarily sand and gravel; hence water moves relatively freely through it and the slope of the water table is slight. In southeastern Grant and southwestern Haskell Counties, where the water table is in the clay and silt of the Rexroad formation, however, the water cannot move freely through the fine

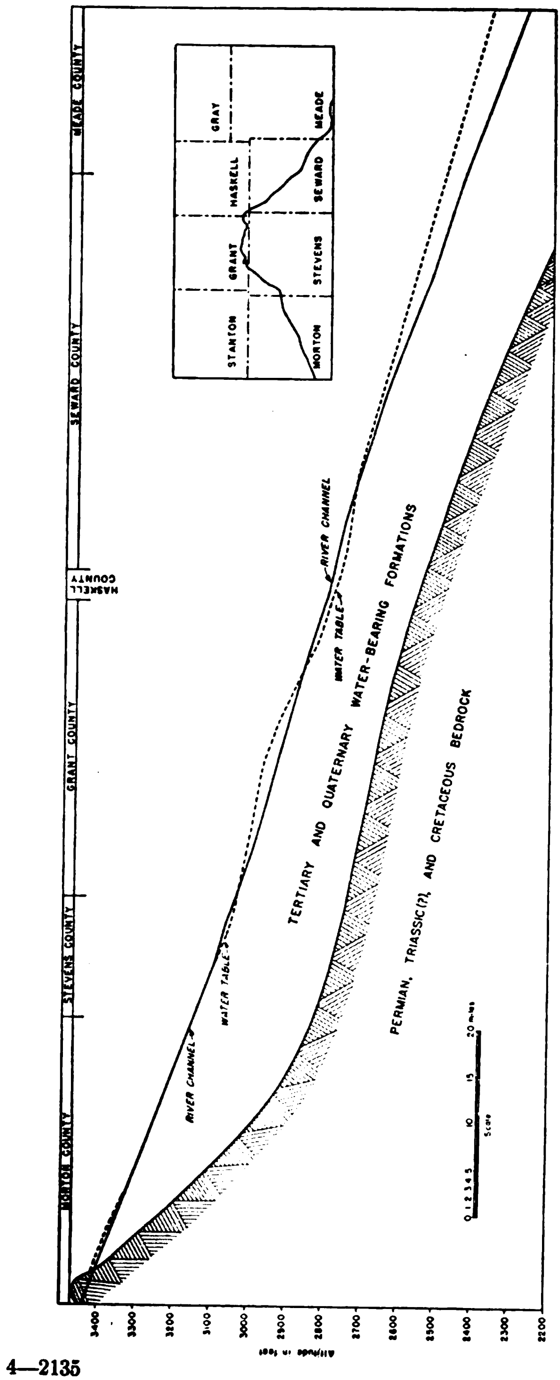


FIG. 11. Cross section along Cimarron River between Point of Rocks in Morton County and the Kansas-Oklahoma line showing the relation of the river channel to the altitude of the water table in adjacent upland areas.

material and therefore the water table has a steep slope. The gradient of the river channel in this area is less than it is in areas upstream and downstream. Therefore, the water table gradient exceeds the stream gradient and the Cimarron becomes a losing stream (Fig. 11).

Figure 11 illustrates the relation of the channel of the Cimarron River to the level of the water table in adjacent upland areas. Where the water table is above the channel, the Cimarron River generally flows; and where the water table is below the channel, the Cimarron generally is dry. Throughout much of its course in eastern Morton County and northwestern Stevens County the channel of the Cimarron River is nearly level with or is below the level of the water table in adjacent areas. Figure 11 is based on water-level measurements made during the summers of 1941 and 1942 and may not represent accurately the conditions during other seasons or years.

Some variations in stream flow in the Cimarron River are shown in Figure 12 which was compiled from data obtained by joint studies of the states of Kansas and Oklahoma and the Water Resources Branch of the U. S. Geological Survey. Measurements of stream flow along the Cimarron River show that the river valley between the Elkhart bridge and the Satanta station absorbs a large quantity

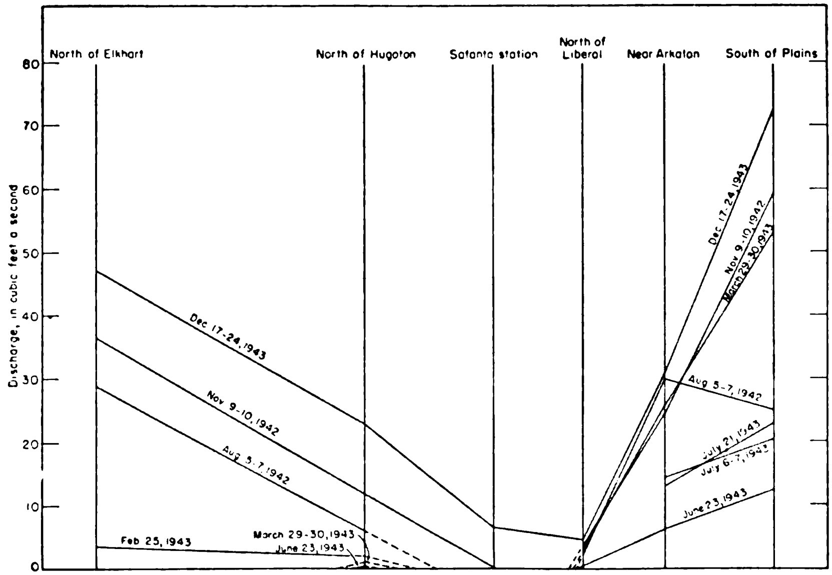


FIG. 12. Variations in stream flow in the Cimarron River.

of water. They also indicate that discharges of more than 40 cubic feet a second at the Elkhart bridge are required to produce a surface flow at Satanta. Small discharges have been observed in this losing section of the Cimarron River. When the stream is dry at the Elkhart bridge, discharges of as much as 1.13 cubic feet a second have been measured at the bridge north of Hugoton. Although the Cimarron River is a losing stream through Morton, Stevens, Grant, and Haskell Counties, there is a very rapid recovery of stream flow in Seward and Meade Counties.

Most of the water that is lost between Point of Rocks and the Satanta station is added to the ground-water reservoir although some is then lost by transpiration from vegetation on the valley floor. The relatively rapid addition of water to the ground-water reservoir in the losing sections of the stream generally forms a mound or ridge on the water table. The ground water moves from the ridge at approximately right angles to the stream. Water on the north or northwest side of the stream probably reënters the stream in a relatively short distance because the general movement of ground water is toward the east (Pl. 1). This may account for the small local areas where the Cimarron is a gaining stream. Ground water that moves south and southeastward from the ridge then flows eastward across the Cimarron Bend area. At least a part of this water reënters the Cimarron River between the Liberal bridge and the Forgan bridge. What effect the loss in stream flow between Point of Rocks and Satanta station has upon the gain in stream flow between the Liberal and Forgan bridges and upon the level of the water table in the Cimarron Bend area is not known. This could not be determined until the loss of water by transpiration and evaporation in the Cimarron Valley and the addition of water by ground-water recharge in the Cimarron Bend area are known.

Local depressions are formed on the water table when large quantities of water are pumped from wells. These generally are short-lived, however, because water moves in from adjacent areas to replenish the water that is withdrawn by pumping. There seems to have been no permanent lowering of the water table in this area by pumping from wells.

RELATION TO TOPOGRAPHY

The depth to water level below the land surface in Grant, Haskell, and Stevens Counties is controlled largely by the configuration of the land surface. A map (Pl. 2) has been prepared showing by isobath lines the depths to water level in wells in the three counties. Isobath lines connect points of equal depth to water level. As shown on the map, the depths to water level in the Grant-Haskell-Stevens area range from less than 10 feet in the Cimarron Valley area to nearly 250 feet in the Haskell area. For the purpose of detailed description, Grant, Haskell, and Stevens Counties may be divided into eight areas based upon the depths to water level: (1) Syracuse upland, (2) Bear Creek depression, (3) Finney sand plain, (4) Stanton area, (5) Cimarron Valley area, (6) Haskell area, (7) Meade area, and (8) Cimarron Bend area. These areas are the same as the topographic divisions, and their locations and areal extent are described in the section on Topography and drainage on pages 16 to 21 (note Fig. 2).

Syracuse upland.—On the Syracuse upland, which extends into northwestern Grant County, depths to water level range from about 50 feet near Bear Creek to about 120 feet at the northwest corner of the county, and the depths of wells range from about 60 feet to more than 130 feet. The Rexroad (?) and Meade formations are the principal water-bearing beds in this area.

Bear Creek depression.—The area of sinkholes and depressions in the vicinity of Bear Creek is called the Bear Creek depression. As stated in the section on Topography and drainage, it is difficult to distinguish the southern limit of the Bear Creek depression because it merges gradually into the Stanton area. In this discussion the limits shown in Figure 2 will be used. Wells in this area range in depth from about 50 feet to more than 110 feet and the water levels are 35 to 50 feet below land surface. The wells obtain water from are the Meade or Rexroad (?) formations or both.

Finney sand plain.—Northeastern Grant County and northern Haskell County are a part of the Finney sand plain which extends northward to the Arkansas Valley in Kearny and Finney Counties. The depths to water level in wells range from a little more than 50 feet in the westernmost part of the area in Grant County and the northeastern corner of Haskell County to about 145 feet near the Grant-Haskell line. The wells in this area range in depth from about 70 feet to almost 200 feet. The principal water-bearing beds are the Meade or Rexroad (?) formations or both.

Stanton area.—Most of western Grant County and the northwestern part of Stevens County are in the Stanton area which extends westward into Stanton, Hamilton, and Morton Counties. In

Grant and Stevens Counties this is an area of shallow to intermediate depth to water, the water level in most of the area being less than 100 feet below land surface. The depth to water level in the area between Bear Creek and North Fork Cimarron River is in most places less than 50 feet, whereas in southwestern Grant County and northwestern Stevens County the depth to water level in most places is between 100 and 150 feet. Wells in the Stanton area obtain water from the Rexroad (?) or Meade formations or both; their depths range from 50 to more than 300 feet.

Cimarron Valley area.—The valleys of the Cimarron River and its principal tributaries constitute the Cimarron Valley area (Fig. 2). Depths to water level are less than 10 feet in the lowlands along the Cimarron River, in the lower part of Lakin Draw, and in the lowlands in the central part of North Fork Cimarron Valley. Depths to water level are as much as 150 feet at the edges of the Cimarron and North Fork Cimarron Valleys near their confluence. The greatest depth to water in the Cimarron Valley is about 50 feet in southwestern Haskell County. The principal water-bearing formation in the Cimarron Valley is the alluvium. In the valleys of Lakin Draw, Sand Arroyo, and North Fork Cimarron River the Meade formation supplies most of the water to wells. In southeastern Grant County the slope of the water table exceeds the slope of the Cimarron River so that in southeastern Grant and southwestern Haskell Counties the water table is near the base of the alluvium (Pl. 3). Wells in this area obtain water from the Rexroad (?) formation and perhaps also from the Meade formation and from the alluvium, and range in depth from 15 to 61 feet.

Haskell area.—Most of Haskell County and a large part of eastern Grant County lie within the Haskell area (Fig. 2) in which the depth to water level ranges from about 80 feet in the vicinity of Hickok to nearly 250 feet in northwestern Haskell County. The depth to water level is more than 150 feet in about 90 percent of the area, and is more than 200 feet in about 30 to 40 percent of the area. Wells in this area range in depth from slightly less than 100 feet to more than 300 feet, and most of them obtain water from the Rexroad (?) formation. A few get all or part of their water from the lower part of the Meade formation, and a few may obtain part of their water from the upper part of the Laverne formation.

Meade area.—The headwaters of Crooked Creek in eastern Haskell County lie within the Meade area (Fig. 2). The depths to water level in this small area range from about 140 feet to 170 feet, and the depths of the wells range from about 150 to 200 feet. Most of the wells obtain water from the Rexroad formation.

Cimarron Bend area.—Almost all of Stevens County and a small part of Grant County lie within the Cimarron Bend area, which also includes southern Morton and southwestern Seward Counties. The depths to water level range from about 75 feet in the area northwest of Feterita to about 215 feet in the area east of Moscow. The depths to water level in most of the area, however, are between 100 and 150 feet. The depths of wells in the Cimarron Bend area range from about 80 feet to more than 300 feet. The principal water-bearing formation is the Rexroad (?), but many wells get part of their water from the Meade formation and some of the deep wells may penetrate beds of the Laverne formation.

FLUCTUATIONS IN WATER LEVEL

The water table does not remain stationary but fluctuates much like the water surface of any surface reservoir. Whether the water table rises or declines depends upon the amount of recharge into the ground-water reservoir and the amount of discharge. If the inflow exceeds the draft, the water table will rise; conversely, if the draft exceeds the inflow into the ground-water reservoir, the water table will decline. The water table fluctuates more by the addition or depletion of a certain quantity of water than does the level of a surface reservoir, because ground water occupies only part of the volume of a ground-water reservoir. If the sand and gravel of a water-bearing formation has an average specific yield of 25 percent, the addition of 1 foot of water to the sand and gravel will raise the water table in that material about 4 feet. Changes of water levels record the fluctuations of the water table and hence the recharge and discharge of the ground-water reservoir.

The principal factors that control the rise of the water table (ground-water recharge) in the Grant-Haskell-Stevens area are: (1) the amount of rainfall that penetrates the soil and descends to the zone of saturation, (2) seepage from streams and depressions, and (3) the quantity of water added to the ground-water reservoir by underground movement from the west and northwest. The factors that cause a decline in the water table in this area (ground-water discharge) are: (1) movement into areas to the east and to the south, (2) evaporation and transpiration, (3) seeps and springs, and (4) pumpage from wells. If the quantity of ground water discharged from a ground-water reservoir during a year is greater than the recharge during that year, the water table will decline. During a period of dry years, however, the water table may decline, even though there has been little or no pumping from wells, but in a subsequent period of wet years the water table may rise. The decline of the water table during a dry year, therefore, does not necessarily mean that there has been an excessive withdrawal of water from the ground-water reservoir, for during dry years there is less recharge of the ground-water reservoir because of the decreased precipitation. At the same time the discharge of ground water is increased by greater evaporation and transpiration and by increased pumpage for irrigation. Conversely, during wet years the recharge from precipitation is increased and the loss of water by evaporation, transpiration, and pumpage is reduced.

The fluctuations of the water table in Grant, Haskell, and Stevens Counties were determined by observing the water levels in wells. Periodic water-level measurements were begun on 28 wells in Grant and Haskell Counties in May and June 1941, and on nine wells in Stevens County in October 1942. Water-level measurements in these wells were made monthly by Woodrow W. Wilson of the Federal Geological Survey and later by Allen Graffham and Howard Palmer of the Division of Water Resources of the Kansas State Board of Agriculture.

Water-level measurements in 1941, 1942, and 1943 have been published in annual water-level reports of the U. S. Geological Survey (Water-Supply Papers 938, 946, and 988), and future measurements will be published in ensuing reports of this series. The well numbers used in this report and the Water-Supply Papers are given in Table 7.

Ground-Water Recharge

Recharge is the addition of water to the underground reservoir and may be accomplished in several ways. All ground water within a practical drilling depth beneath Grant, Haskell, and Stevens Counties is derived from water that falls as rain or snow either within the area or within nearby areas to the west and north. Once the water becomes a part of the ground-water body it moves down the slope of the water table, later to be discharged at some point farther downstream.

The underground reservoir beneath this area is recharged primarily by local precipitation. Other important factors affecting recharge in this area are seepage from streams and depressions and subsurface inflow from areas to the west and north.

RECHARGE FROM PRECIPITATION

The average annual precipitation in Grant, Haskell, and Stevens Counties is about 18 inches, but probably only a small part of this water reaches the zone of saturation owing to several factors. Of the precipitation in this area, part is lost by evaporation and transpiration, part is lost by runoff, and the remainder may percolate downward to the zone of saturation.

TABLE 7.—*Observation wells in Grant, Haskell, and Stevens Counties*

Grant County		Haskell County		Stevens County	
Well number in this report	Well number in Water-Supply Papers 938, 946, and 988	Well number in this report	Well number in Water-Supply Papers 938, 946, and 988	Well number in this report	Well number in Water-Supply Papers 938, 946, and 988
4	6	136	13	242	28
18	5	141	1	245	21
22	1	143	3	265	29
24	4	144	14	266	27
28	2	153	4	288	30
42	14	157	8	294	15
43	7	165	15	299	10
51	9	170	6	309	26
61	3	171	5	311	12
64	11	204	7	....	....
71	8	206	12	....	....
73	13	209	11	....	....
82	15	217	9	....	....
120	10	227	10	....	....

The quantity of water lost by evaporation depends on several factors, including temperature, humidity, vegetative covering, depth to water level below land surface, and the length of time the processes of evaporation have access to the moisture. The topography of Grant, Haskell, and Stevens Counties is characterized by flat uplands containing numerous sinks and depressions and by large areas of dune sand having little or no surface drainage. Much of the moisture that falls in this area is held in the sinks, depressions, and other undrained areas until it evaporates or moves downward to the zone of saturation. Large lakes caused by heavy precipitation in the Bear Creek depression (Pl. 6) may exist for many months before being dried by evaporation and seepage. A large part of the precipitation in Grant, Haskell, and Stevens Counties probably is lost by evaporation, but also some of the precipitation is lost by transpiration from plants, particularly from May through August when precipitation is highest and plant growth is most abundant.

Because the drainage in this area is poorly developed, only a small percentage of the precipitation is carried away by the Cimarron River and its tributaries; hence the loss by runoff is relatively small. Most of the floods in the Cimarron River are caused by heavy precipitation in New Mexico, Colorado, and Oklahoma and local precipitation seems to have comparatively little effect on the stream flow.

Water that is not lost by evaporation, transpiration, and runoff percolates downward into the soil zone. The soil will absorb moisture until the amount of water it contains is greater than can be held against the pull of gravity, at which time part of the water moves downward to the zone of saturation. This downward movement may be prevented by plant transpiration which, during the growing season, may deplete the soil moisture as rapidly as it can be replenished by the precipitation. At the end of the growing season the moisture in the soil may be depleted. Water that enters the soil zone during the fall and winter tends to replenish the soil moisture because there is less transpiration and evaporation during these seasons. From this time until transpiration and evaporation again become important factors, much of the precipitation moves downward through the soil and to the water table. Because of the high rate of transpiration and evaporation, there probably is little recharge during the summer except where the water table is relatively near the land surface.

Hydrographs showing the fluctuations of water levels in 21 wells in Grant, Haskell, and Stevens Counties are shown in Figures 13, 14, and 15 together with the precipitation at the nearest station of the U. S. Weather Bureau. These graphs show a relatively close correlation between the water levels in wells and the precipitation. The correlation is particularly close in areas where the depths to

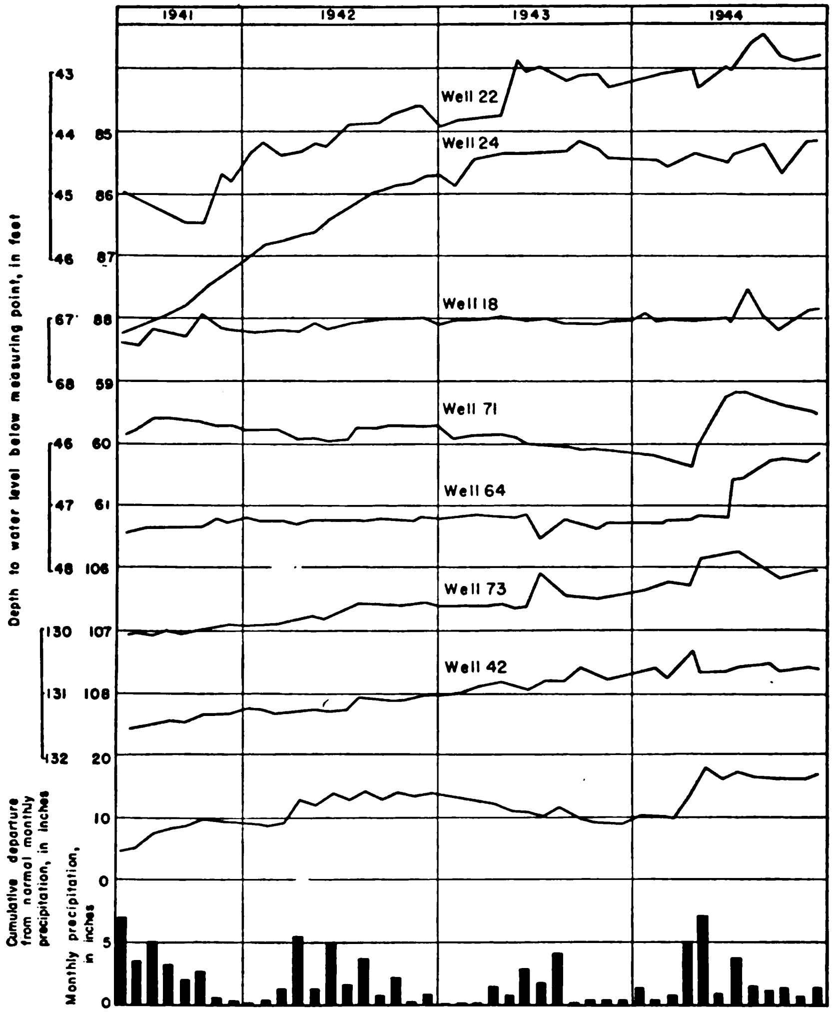


FIG. 13. Hydrographs showing fluctuations of the water levels in seven wells in Grant County, cumulative departure from normal monthly precipitation at Ulysses, and monthly precipitation at Ulysses.

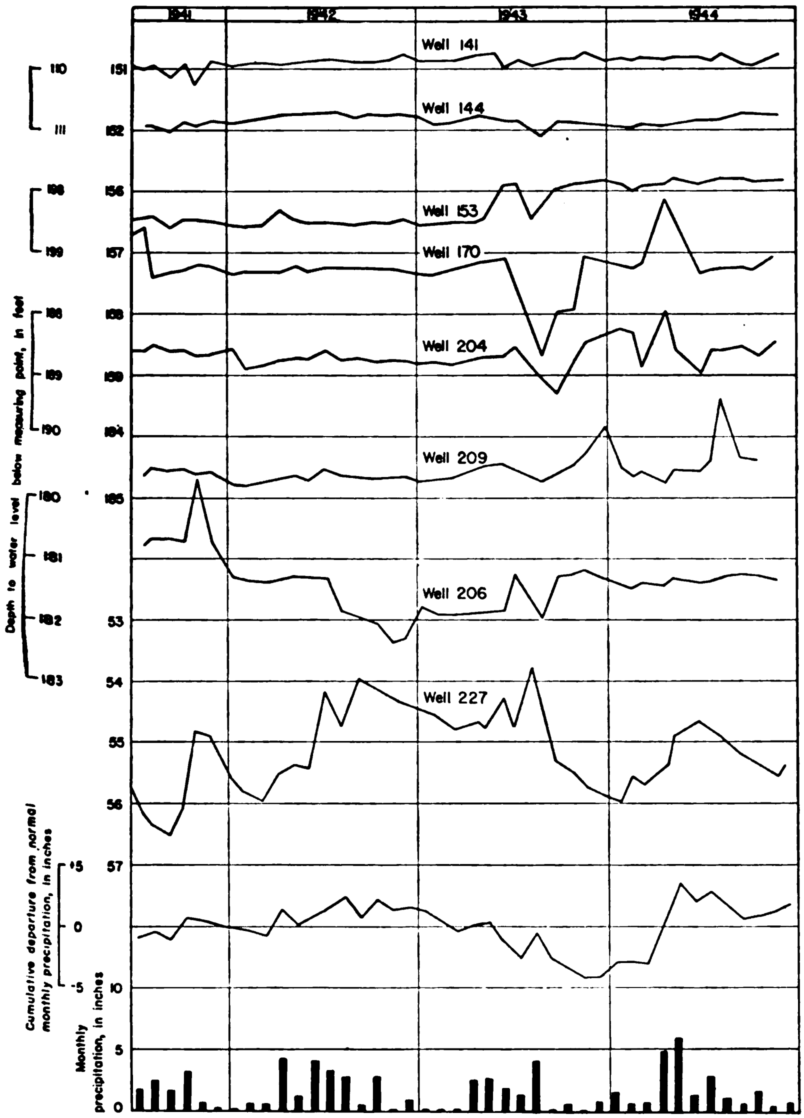


FIG. 14. Hydrographs showing fluctuations of the water levels in eight wells in Haskell County, cumulative departure from normal monthly precipitation at Sublette, and monthly precipitation at Sublette.

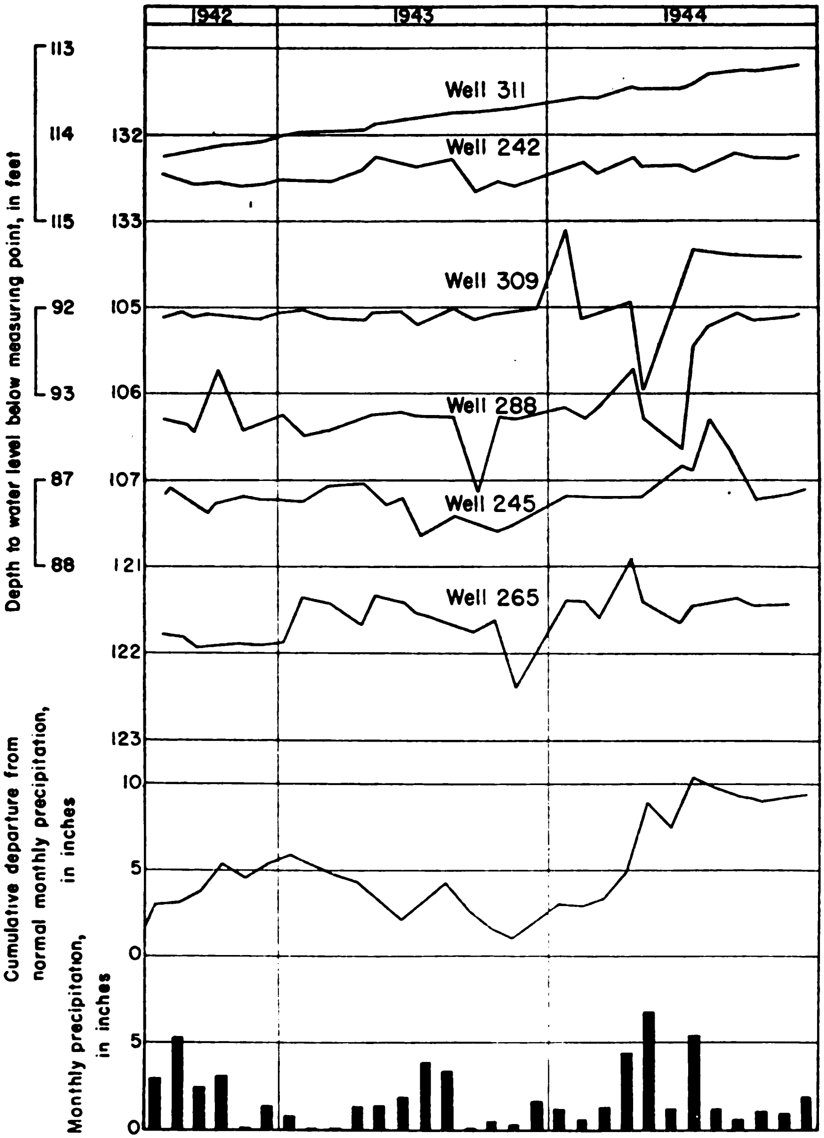


FIG. 15. Hydrographs showing fluctuations of the water levels in six wells in Stevens County, cumulative departure from average monthly precipitation at Hugoton, and monthly precipitation at Hugoton.

water level are not great, but the influence of precipitation upon water levels is noticeable even in areas of great depth to water level.

Water levels in wells 22 and 24 in Grant County are approximately 3 feet higher than they were when periodic water-level measurements were begun in 1941 (Fig. 13); hence the recharge of the ground-water reservoir in the vicinity of these wells has been relatively large. Water levels in other wells, such as 73, 42, 141, 144, 153, 242, and 311 (Figs. 13, 14, 15), in which the depth to water level is more than 100 feet, have risen much more slowly but just as steadily and with smaller fluctuations. The water levels in wells 18, 64, 71, 73, 245, and 288 remained approximately the same or rose slowly from 1941 until 1944 when they rose abruptly, even though the precipitation was not as great in 1944 as it was in 1941. In 1941 the soil moisture had been nearly depleted after 10 years of drought and most of the precipitation that seeped below land surface was used to replenish the soil moisture; therefore, very little water moved downward to the zone of saturation. In 1944, however, there was adequate soil moisture and much of the rainfall percolated downward to the zone of saturation, causing an abrupt rise in water levels.

The trend of the water level in well 227 correlates closely with the cumulative departure from normal monthly precipitation. The well is in the Cimarron Valley near the Satanta bridge where the Cimarron is a losing stream. At least part of the sharp peaks on the hydrograph show the effect of flood waters in the nearby channel.

The water levels in 67 percent of the observation wells in these counties were higher at the end of 1943 than they were at the beginning of record, probably as a result of the above-normal precipitation during 1941 and 1942. Owing to the below-normal precipitation in 1943 the water levels in several wells declined, but because of heavy precipitation during the first half of 1944 the levels again rose. At the end of 1944, the water levels in 92 percent of the observation wells were higher than at the beginning of record.

Only fragmentary records of the water levels in wells in Grant, Haskell, and Stevens Counties for the years preceding 1941 are available; hence the effect of the drought between 1931 and 1940 on the water table is not known. The first water-level measurements in the Grant-Haskell-Stevens area were made in Haskell County in 1891 by members of the Nettleton survey (Nettleton, 1892). During the present investigation an attempt was made to locate and measure some of the old wells that were measured in

1891, but the last one had been destroyed during the preceding year. Several wells were found near the sites of the old wells, however, and measurements of water level in these wells indicate that the depths to water level in the deep-water areas in Haskell County were approximately the same in 1891 as they were in 1942. The static water level in an old dug well in the NE¼ sec. 25, T. 29 S., R. 33 W. was 200 feet in 1891. The static water level in a well in the same quarter section, but probably a few hundred feet south, was 201.7 in 1942. The land surface in that vicinity is nearly level; therefore the difference in altitude of the measuring points of the two wells probably did not exceed 2 or 3 feet.

Recharge from precipitation in the Finney sand plain in northern Grant and Haskell Counties and in the dune-sand area south of the Cimarron River probably is relatively rapid. The many undrained basins in these areas serve as catchment areas for the rainfall, and the porous sandy soil permits the downward percolation of water to the zone of saturation. Most of the precipitation in these areas percolates downward or evaporates.

There probably is much recharge in the Cimarron Bend area, even though the depth to water level in most places is more than 100 feet and in many places is more than 200 feet. The water-table contour maps of Morton (McLaughlin, 1942, Pl. 1), Stevens (Pl. 1), and Seward (Byrne and McLaughlin, 1946, Pl. 1) Counties show that in general the ground water is moving east-southeastward from the Cimarron River, which forms the northwestern boundary of the area. The water table along most of the Cimarron Valley in this area is either lower or higher than it is in adjacent upland areas. Ground water adjacent to the Cimarron Valley moves toward the river but does not cross the depression or ridge on the water table. For this reason, little or no ground water can move into the Cimarron Bend area from adjacent areas north and west of the river; therefore most of the ground water in this area is derived from local precipitation.

Recharge from precipitation in the upland areas which are not covered by dune sand probably is much less than in the Finney sand plain and the Cimarron Bend area. These uplands, such as the Stanton and Haskell areas, contain numerous undrained basins but the soil is less porous and the depth to water level generally is great; hence only a small part of the precipitation reaches the ground-water reservoir. In the northern part of the Stanton area and in the Bear Creek depression the recharge probably is relatively large because there are numerous sinkholes and depressions and because the depth to water level in most places is less than 50 feet.

Recharge from precipitation in the valleys probably is very large. The sandy soil is very porous and the water table is near the land surface; hence water can readily percolate downward to the zone of saturation. In addition, some of the runoff from adjacent uplands may percolate downward in the valley areas to recharge the ground-water reservoir.

RECHARGE FROM SEEPAGE

Some water is contributed to the ground-water reservoir by seepage from streams. Bear Creek, Lakin Draw, and Sand Arroyo are losing streams; that is, the stream channels are above the water table and water moves downward to recharge the ground-water reservoir. The Cimarron and North Fork Cimarron Rivers are losing streams along parts of their courses, and in such places some of the flood water moves downward to the zone of saturation. The Cimarron River is a losing stream in northwestern Stevens, eastern Grant, and southwestern Haskell Counties, whereas in western Grant County it is a gaining stream (Fig. 11). Water that is discharged into the river in western Grant County generally evaporates or percolates downward before it reaches the Grant-Haskell line.

RECHARGE BY SUBSURFACE INFLOW

Ground water in Grant, Haskell, and Stevens Counties is derived in part by subsurface inflow from Stanton and Morton Counties on the west and from Kearny and Finney Counties on the north. This movement of water into the area is indicated by the slope of the water table (Pl. 1) and by the quantity of fluoride in the water (Fig. 17). Along the fault at the southern and eastern edges of the Syracuse anticline, the Dakota formation is level with the Tertiary and Quaternary silt, sand, and gravel, and the high-fluoride water from the Dakota formation moves southeastward into the Tertiary and Quaternary deposits of Grant County.

DISCHARGE OF SUBSURFACE WATER

The discharge of subsurface water has been divided by Meinzer (1923a, pp. 48-56) into vadose-water discharge (discharge of soil water not derived from the zone of saturation) and ground-water discharge (discharge of water from the zone of saturation).

VADOSE-WATER DISCHARGE

The discharge of soil water not derived from the zone of saturation is called vadose-water discharge and includes the discharge of water directly from the soil by evaporation and through growing plants by transpiration. The consumption of soil water by crops is large and is of vital importance to agriculture. This consumption of soil water generally reduces the recharge, for the deficiency of soil moisture must be replenished before recharge can take place.

GROUND-WATER DISCHARGE

Ground-water discharge is the discharge of water directly from the zone of saturation or from the capillary fringe and may take place through evaporation and transpiration or as hydraulic discharge through springs, seeps, wells, or infiltration galleries.

Discharge by transpiration and evaporation.—Water may be taken into the roots of plants directly from the zone of saturation or from the capillary fringe, and be discharged from the plants by the process known as transpiration. The depth from which plants will lift the ground water varies with species of plants and types of soil. The limit of lift by ordinary grasses and field crops is not more than a few feet; however, alfalfa and certain types of desert plants have been known to send their roots to depths of 60 feet or more to reach the water table (Meinzer, 1923, p. 82).

Discharge of ground water by evaporation and transpiration in Grant, Haskell, and Stevens Counties probably is limited to areas where the depth to water level is small, such as the Cimarron Valley area, Bear Creek depression, and parts of the Stanton area. In these areas such discharge probably is very slight except in the lowlands along the Cimarron River and North Fork Cimarron River. In North Fork Cimarron Valley some ground water is transpired by alfalfa, and much water is evaporated from the small ponds in the stream channel that are fed by ground-water discharge. Water is also discharged by evaporation from the broad sandy channel of the Cimarron River, particularly in parts of Stevens and Grant Counties where the water table is at or near the level of the channel. The discharge by transpiration along the Cimarron River probably is not great because of the scanty vegetative covering.

Discharge by springs and seeps.—Some ground water in this area is discharged by springs and seeps, although the amount is relatively small. Most important of these is Wagon Bed Spring, in the north half of sec. 33, T. 30 S., R. 37 W. near the Ulysses bridge, at a well-known camp site on the old Santa Fe trail. There are a few other springs and many seeps along the Cimarron River and North Fork Cimarron River but they are small.

Discharge by wells.—Another method of discharge of water from the ground-water reservoir is by pumping from wells. There were 20 irrigation wells in operation in this area in 1943 and there were municipal wells at Ulysses, Sublette, Satanta, Moscow, and Hugoton. Most of the rural residents of the area derive their domestic and stock supplies of water from wells, but the amount of water discharged for this purpose is relatively small. The recovery of ground water from wells is discussed in the next section.

Recovery

PRINCIPLES OF RECOVERY

Water is discharged from a well by a pump or some other lifting device or by natural artesian flow (for a more detailed discussion of principles of recovery see Meinzer, 1923a, pp. 60-68). When water is standing in a well, there is equilibrium between the head of the water inside the well and the head of the water outside the well. Whenever the head inside a well is reduced, a resultant differential head is established and water moves into the well. The head of the water inside a well may be reduced in two ways: (1) by lowering the water level by a pump or other lifting device, and (2) by reducing the head at the mouth of a well that discharges by artesian pressure. Whenever water is removed from a well there is a resulting drawdown or lowering of the water level, or, in a flowing artesian well, an equivalent reduction in artesian head.

When water is discharged from a well the water table is lowered in an area around the well to form a depression somewhat resembling an inverted cone, which is known as the cone of depression, and the distance that the water level is lowered is the drawdown. The drawdown in a well increases as the rate of pumping is increased.

The capacity of a well is the rate at which it will yield water after the water stored in the well has been removed; it depends upon the quantity of water available, the thickness and permeability of the water-bearing bed, and the construction and condition of the well. The capacity of a well generally is expressed in gallons a minute. The known or tested capacity of a strong well generally is less than its total capacity, but some weak wells are pumped at their total capacity.

The specific capacity of a well is its rate of yield per unit of drawdown, and is determined by dividing the tested capacity in gallons a minute by the drawdown in feet. Well 247 in northern Stevens County yields 1,326 gallons a minute and has an average drawdown of 14.3 feet; hence its specific capacity is 92.7.

When water is withdrawn from a well the water level drops rapidly at first and then more slowly until it finally becomes nearly stationary. Conversely, when the withdrawal ceases the water level rises rapidly at first and then more slowly until it eventually resumes its original position or approximately its original position (Fig. 9).

DUG WELLS

Dug wells are excavated with picks, shovels, spades, or by power machinery and generally are between 2 and 10 feet in diameter. Most of the wells constructed in Grant, Haskell, and Stevens Counties prior to 1900 were dug wells, many of which were quite deep. Nettleton (1892) lists five dug wells in Haskell County in the vicinities of Lockport (sec. 13, T. 27 S., R. 33 W.), Santa Fe (sec. 36, T. 28 S., R. 33 W.), and Loco City (sec. 36, T. 30 S., R. 33 W.). The wells were 3 feet in diameter and ranged in depth from 107 feet to 240 feet. The Pugh well in western Haskell County, which served the residents of western Haskell and eastern Grant County prior to 1900, was 236 feet deep. Almost all the dug wells have been replaced by drilled wells, but there are still a few shallow dug wells in the Cimarron and North Fork Cimarron Valleys, most of which are curbed with stone or timber. Most of them are poorly sealed and may be contaminated by the entrance of surface waters. Because of the difficulties of digging by hand below the water table, dug wells generally are excavated only a few feet below the water table and, therefore, are more likely to fail during a drought than are drilled wells which generally extend many feet below the water table.

DRILLED WELLS

Most of the domestic, stock, irrigation, and public-supply wells in Grant, Haskell, and Stevens Counties are drilled wells that have been excavated by means of percussion (cable-tool) or rotary drills. Most of the drilled wells were constructed by means of portable cable-tool drilling rigs and are cased with galvanized-iron or wrought-iron casing. The drilled domestic and stock wells generally are 4 to 6 inches in diameter and those used for irrigation and public-supply purposes generally are 15 to 25 inches in diameter.

Drilled wells in consolidated deposits.—Few if any water wells in Grant, Haskell, and Stevens Counties penetrate the consolidated sediments of Cretaceous age, although most of the irrigation wells in the area of shallow water northwest of Ulysses have been drilled nearly to the top of the Dakota formation. Many wells penetrate consolidated sand and gravel ("mortar beds") in the Tertiary and Quaternary deposits, but these generaly are well-cemented and probably yield very little water to wells. Inasmuch as the consolidated beds in the Tertiary and Quaternary deposits are thin, most wells are cased through both the unconsolidated and consolidated materials.

Drilled wells in unconsolidated deposits.—Almost all the wells in Grant, Haskell, and Stevens Counties obtain all or part of their water from unconsolidated materials of Tertiary or Quaternary age or both. The principal unconsolidated water-bearing deposits are the Rexroad (?), Meade, and Laverne formations, but water is also obtained from unconsolidated alluvium in the larger stream valleys. Wells in unconsolidated deposits generally are cased nearly to the bottom of the hole with galvanized-iron or wrought-iron casing. In some wells the water may enter only through the open end of the casing, but in many wells—particularly those used for irrigation—the casing is perforated below the water table to increase the facilities for intake. The size of the perforations is an important factor in the construction of such a well, and the capacity or even the life of the well may be determined by it. If the perforations are too large, the fine material may filter through and fill the well; if the perforations are too small, they may become clogged so that water will not enter the well freely.

Wells in unconsolidated sediments may be equipped with well screens or strainers. It is common practice to select a slot size that will pass 30 to 60 percent of the water-bearing material, depending upon the texture and degree of assortment. Retention of the coarser particles around the screen forms a natural gravel packing that greatly increases the effective diameter of the well, and hence increases its capacity.

Gravel-wall wells generally are effective for obtaining large supplies of water from relatively fine-grained unconsolidated deposits, and they are used widely for irrigation. In constructing a well of this type, a hole 30 to 60 inches in diameter is first drilled by the rotary method or by means of an orange-peel bucket and is cased temporarily with iron or steel pipe. A well screen or perforated casing of smaller diameter than the hole is then lowered into place and centered in the larger pipe opposite the water-bearing beds. Unperforated casing extends from the screen to the surface. The annular space between the inner and outer casings is then filled with sorted gravel, preferably of a grain size just a little larger than the openings in the screen or perforated casing, and also slightly larger than that of the water-bearing material. In most wells of this type a medium or coarse-grained gravel is used, but in very fine-grained deposits a fine-grained gravel or coarse-grained sand should be used. The outer casing is then withdrawn part way to uncover the screen and allow the gravel packing to come in contact with the water-bearing material. Some wells in the Grant-Haskell-Stevens area have been gravel-packed with gravel that is less satisfactory than the water-bearing material it replaced. During the field investigation it was noted that several irrigation wells were gravel-packed with poorly sorted gravel containing pebbles ranging in diameter from less than 1 inch to more than 3 inches. It was stated by several drillers that smaller pebbles could not be used because the perforations in the casing were too large.

In deciding whether or not to use gravel-wall construction it is important to know the character of the water-bearing material. If the material is a coarse gravel, as it is in parts of Grant, Haskell, and Stevens Counties, it generally is unnecessary to use gravel packing. Some wells have been walled with a gravel packing that is finer and less permeable than the water-bearing material it replaced, thus reducing the yield.

According to McCall and Davison (1939, p. 29) drawdown can be kept to a minimum in several ways:

> First, the well should be put down through all valuable water-bearing material. Secondly, the casing should be properly perforated so as to admit water to the well as rapidly as the surrounding gravel will yield the water. Third, the well should be completely developed so that the water will flow freely into the well. . . . Increasing the depth of a well will have a greater effect on reducing the drawdown than will increasing the diameter, so long as additional water-bearing formations are encountered.

A report (Davison, 1939) containing descriptions of pumping plants, the conditions for which each is best suited, construction methods, and a discussion of cost of construction is available from the Division of Water Resources, Kansas State Board of Agriculture, Topeka, Kansas, and the reader is referred to this publication for additional details of well construction.

METHODS OF LIFT AND TYPES OF PUMPS

Most wells in Grant, Haskell, and Stevens Counties, particularly those used for domestic and stock supplies, are equipped with lift or force pumps. The cylinders or working-barrels in lift pumps and force pumps are similar and are placed at a level below that of the water table. A lift pump generally discharges water only at the pump head, whereas a force pump can force water above this point—for example, to an elevated tank. Most of the pumps are operated by windmills, but a few are operated by hand. Two wells in the vicinity of Ulysses flow at the surface (p. 45) and therefore do not have to be pumped.

The discharge pipe in drilled domestic and stock wells (1.5 inches to 3 inches in diameter) generally is clamped between two 4- by 4-inch wooden blocks that rest on the top of the casing. A circular piece of galvanized iron or steel is placed between the clamp and the casing on some wells to prevent small objects from falling into the well. If a well is cased with galvanized-iron casing, the clamp may be supported by railroad ties in order to avoid crushing the casing. The irrigation wells in this area are equipped with deep-well turbine pumps, which consist of a series of connected turbines, called bowls or stages, that are placed near or just below the water level and are connected by a vertical shaft to a pulley at the top. Turbines equipped with pulleys generally are belt-driven by gasoline or natural-gas engines, but some turbine pumps have gear heads which are directly connected to the source of power. One irrigation well (46) in Lakin Draw formerly was equipped with a centrifugal pump installed in a pit so that the pumping water level would not exceed the working suction limit, but this well is no longer in use.

UTILIZATION OF WATER

Most of the wells in Grant, Haskell, and Stevens Counties supply or have supplied water for domestic and stock use. Much of the water pumped from wells in this area is used for irrigation, although only a small percentage of the wells are used for this purpose. Many wells have been drilled to supply water for use in drilling gas wells, but these generally are abandoned as soon as the gas well has been completed. A few wells are used for public-water supplies and for railroads.

DOMESTIC AND STOCK SUPPLIES

Domestic wells supply water in homes for drinking, cooking, and washing, and in schools other than those supplied by municipal wells. Stock wells supply water for livestock, principally cattle and sheep that are pastured on winter wheat. Most of the domestic and stock wells are small-diameter drilled wells equipped with lift or force pumps operated by windmills or by hand. In the valleys where the water table is shallow, a few domestic and stock wells are dug or driven. The water used for domestic and stock supplies is moderately hard but generally is satisfactory. Much of the ground water in northern Stevens County and in western Grant County contains sufficient fluoride to be injurious to children's teeth during the period of their formation (see Quality of Water).

PUBLIC SUPPLIES

The cities of Ulysses, Sublette, Satanta, Hugoton, and Moscow have municipal water supplies derived from wells.

Ulysses.—Ulysses (population, 824, according to 1940 census) is supplied by two wells (52 and 53) which obtain water from the Rexroad (?) and Meade formations. The wells are said to be 290 feet deep and are cased with 12-inch wrought-iron casing. Each well is equipped with a turbine pump powered by a natural-gas engine. Well 52 is reported to yield 200 gallons a minute with a drawdown of 28 feet; well 53 is reported to yield 150 gallons a minute, but there is no record of the drawdown. Water is pumped from the wells directly into the mains, the excess water going into the 75,000-gallon elevated steel storage tank in the city park. No data on the consumption of water were available. The water is moderately hard and contains 1.7 parts per million of fluoride which is considered sufficient to cause very slight mottling of children's teeth. (See analysis 52, Table 11.)

Sublette.—The water supply of Sublette (population, 582) is obtained from two wells (183 and 184) within the city limits. Well 183, which is near the depot of the Atchison, Topeka and Santa Fe Railway Company, is 290 feet deep and is reported to have a static water level 201 feet below land surface. The well is cased with 6-inch wrought-iron casing and is equipped with a turbine pump powered by an electric motor. The yield of the well is reported to be 100 gallons a minute. Well 184, which is near the elevated reservoir, is 275 feet deep and has a static water level of about 202 feet.

It is a 24-inch gravel-walled well cased with wrought-iron casing and is equipped with a turbine pump powered by an electric motor. The reported yield of this well is 175 gallons a minute on open flow at land surface and 150 gallons when the water is pumped into the mains.

Water is pumped from the wells directly into the 4-inch mains, the excess water going into an elevated steel storage tank having a capacity of 20,000 gallons. The water is moderately hard but is suitable for most domestic uses. (See analysis 183, Table 12.)

Satanta.—Satanta (population, 345) is supplied by two wells (218, 219) which obtain water from the Rexroad (?) formation and perhaps in part from the Laverne formation. The wells are near the municipal swimming pool in the northern part of town; they are reported to be 280 feet deep and to have a static water level of 200 feet. Each well is cased with 8-inch wrought-iron casing and is equipped with a turbine pump powered by an electric motor. Well 218 is reported to yield 150 gallons a minute. Well 219 is reported to yield 325 gallons a minute when the water is discharged at land surface and 250 gallons a minute when the water is discharged into the mains. The drawdown of this well is reported to be 40 feet when it is being pumped at the rate of 325 gallons a minute.

Water is pumped from the wells directly into the 4- and 6-inch mains, the excess water going into an elevated steel storage tank having a capacity of 50,000 gallons. The water is moderately hard, but otherwise is of good quality. (See analysis 218, Table 12.)

Hugoton.—The water supply of Hugoton (population, 1,349) is obtained from two wells (296 and 297) which penetrate Tertiary and Quaternary deposits. Well 296 is a gravel-walled well drilled to a depth of 308 feet (log 52) and has a static water level of 80 feet. It is cased with 12-inch wrought-iron casing and has 40 feet of screen set opposite the coarser water-bearing materials. The coarsest water-bearing materials were found between the depths of 248 and 267 feet. The well is equipped with a turbine pump powered by an electric motor, and is reported to yield 130 gallons a minute with a drawdown of 80 feet after 30 hours of pumping.

Well 297 (log 53), which is in the city park, is a gravel-walled well drilled to a depth of 300 feet and has a static water level of 85 feet. It is cased with 18-inch wrought-iron casing and has 80 feet of slotted screen set at various intervals between the depths of 88 and 300 feet. The well is equipped with a turbine pump powered by an electric motor, and it yields 230 gallons a minute with a draw-down of 160 feet after 28 hours of pumping.

Water is pumped from the wells directly into the mains, which range in diameter from 4 to 6 inches. The excess water is stored in two reservoirs, one underground and the other elevated, the aggregate capacity of which is 285,000 gallons. The average daily consumption of water in Hugoton in 1941 was 126,847 gallons. The water is moderately hard but otherwise is of good quality. The fluoride content is within the safe limit discussed under Quality of Water. (See analysis 296, Table 13.)

Moscow.—Moscow (population, 177) is supplied by a well (239) which penetrates Tertiary and Quaternary deposits. The well is reported to be 290 feet deep and to have a static water level of 140 feet. It is cased with 6-inch oil-well casing and is equipped with a 3-inch lift pump powered by a 5-horsepower electric motor. The reported yield of the well is 10 gallons a minute.

Water is pumped from the well directly into the 2-inch mains, the excess water going into a steel storage tank having a capacity of 27,500 gallons. The water contains 1.2 parts per million of fluoride which is considered sufficient to cause very slight mottling of some children's teeth. (See analysis 239, Table 13.)

RAILROAD SUPPLIES

The Atchison, Topeka and Santa Fe Railway Company has four wells in Grant, Haskell, and Stevens Counties that are used for railroad supplies (54, 182, 216, and 295). In addition, they have one well at Moscow (238) which was formerly used for railroad supply. (See logs 47, 48, 49, 50, and 51.) The wells range in depth from 182 to 334 feet and the depths to water level range from 50 feet at Ulysses to 220 feet at Satanta. The wells are cased with wrought-iron casing and most of them are equipped with lift pumps. The well at Hugoton is equipped with a deep-well turbine pump.

INDUSTRIAL SUPPLIES

Many wells have been drilled in Grant, Haskell, and Stevens Counties to supply water for use in drilling gas wells. Most of these wells are abandoned after completion of the gas well, but a few have been sold to farmers who now use them for watering stock. These wells generally penetrated much of the Tertiary and Quaternary water-bearing materials and ranged in depth from about 200 feet to more than 400 feet. They were cased with 8- or 10-inch wrought-iron casing and generally were equipped with cylinder or with air-lift pumps. Data concerning their yields and drawdowns were not available, but it was reported that a few of these wells yielded as much as 500 gallons a minute.

POSSIBILITIES OF FURTHER DEVELOPMENT OF INDUSTRIAL SUPPLIES FROM WELLS

Abundant supplies of natural gas and ground water are available in Grant, Haskell, and Stevens Counties for the development of industries. This area is underlain by thick deposits of saturated material that would yield moderate to large quantities of water to wells (Pl. 3). Industrial wells could be developed in almost any part of the area provided preliminary test holes penetrated an adequate thickness of coarse water-bearing material. The area in which industrial supplies could be developed is much larger than the area in which irrigation supplies could be developed, because industry would not be as limited as irrigation by the type of soil and by pumping lift (Fig. 16). There are large areas in Stevens County, for example, where sandy soil and irregular topography prevent the development of irrigation but where industrial wells could be constructed. This is also true in the dune-sand area in northern Grant and Haskell Counties.

IRRIGATION SUPPLIES

Prior to the extended drought between 1931 and 1940 there was little or no irrigation with water from wells in this area except from one shallow well (46) in Lakin Draw northeast of Ulysses. The repeated crop failures after 1931 stimulated interest in irrigation in this area so that in 1943 there were 20 irrigation wells, 14 of which were in Grant County. Although the precipitation has been above normal since 1940, the interest in irrigation has continued, particularly in the area of shallow water northwest of Ulysses where experiments have been made in the irrigation of potatoes, onions, and melons.

The records of all the irrigation wells in this area visited during the field investigation are given in Tables 18, 19, and 20 and the locations of the wells are shown on Plate 2. The area that was reported to have been irrigated in 1942 comprised 1,744 acres from 13 wells in Grant County, 61 acres from two wells in Haskell County, and 472 acres from four wells in Stevens County. This survey of irrigated acreage was made by Woodrow W. Wilson in April 1943. Data on the quantity of water pumped for irrigation in 1942 are not available; however, six of the wells were reported

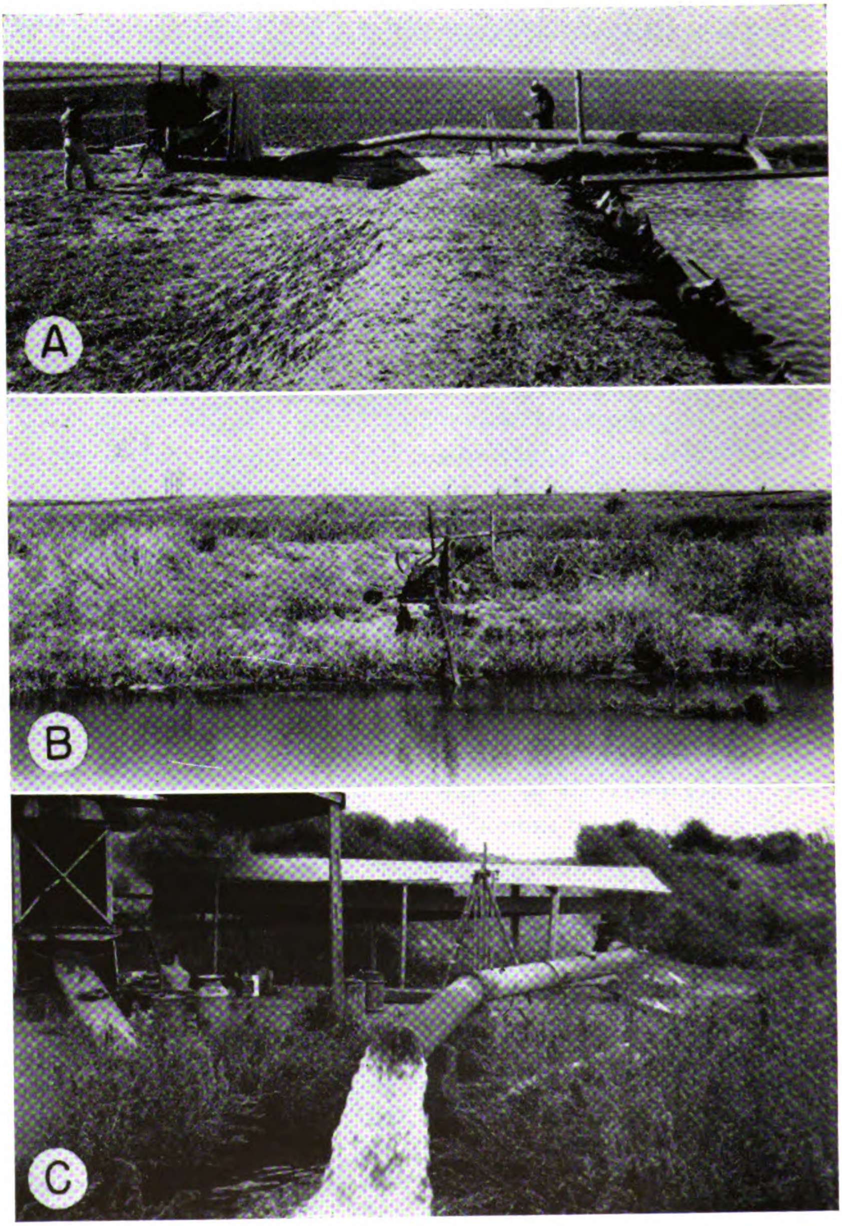


PLATE 7. Irrigation pumping plants in Grant and Stevens Counties: *A*, Well 299 near Hugoton; *B*, Stream pumping plant in North Fork Cimarron River at the south edge of Ulysses; *C*, Well 247 in northern Stevens County.

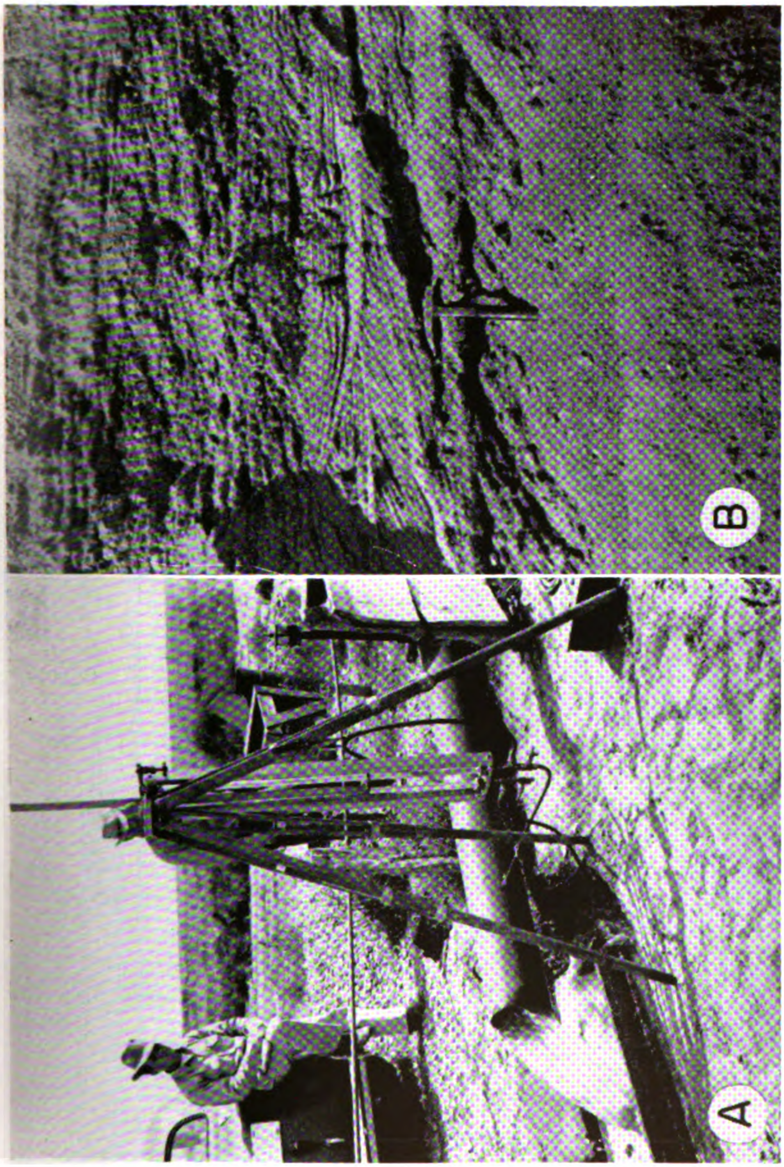


PLATE 8. *A*, Irrigation well 115 in Grant County. *B*, Outcrop of sand and gravel of the Meade formation in Haskell County (sec. 29, T. 30 S., R. 34 W.).

to have pumped 1,030 acre-feet of water to irrigate 668 acres of land. This is equivalent to about 1.5 acre-feet of water for each acre of land. Similarly, according to the U. S. Census, the average quantity of water used in western Kansas in 1939 to irrigate one acre of land was 1.5 acre-feet. If it is assumed that 1.5 acre-feet of water was used for each irrigated acre of land in Grant, Haskell, and Stevens Counties in 1942, then the quantity of water pumped for irrigation during that year would be about 3,500 acre-feet.

TABLE 8.—*Pumping tests of irrigation plants in Grant, Haskell, and Stevens Counties*[1]

Well No.	Draw-down (feet)	Discharge (gallons a minute)		Well No.	Draw-down (feet)	Discharge (gallons a minute)	
		Total	Per foot of draw-down			Total	Per foot of draw-down
29	23.2	1,184	51.03		23.64	746	31.56
30	19.85	1,098	55.31		23.29	756	32.46
	21.85	1,117	51.12		23.23	750	32.29
	22.82	1,120	49.08	244	12.72	1,100	86.48
	23.40	1,130	48.29		11.73	1,060	90.37
	23.95	1,132	47.27		12.09	1,070	88.50
	24.21	1,124	46.43		12.38	1,080	87.24
	24.57	1,118	45.50		12.66	1,020	80.57
31	(2)	967	....		13.10	1,100	83.97
	(2)	994	....		13.17	1,160	88.08
56	(2)	995	....		13.36	1,148	85.93
	(2)	932	....	247	12.74	1,297	101.81
	(2)	909	....		13.58	1,312	96.61
	30.2	878	29.07		14.15	1,318	93.14
	35.8	869	24.27		14.34	1,324	92.33
	36.8	848	23.04		14.48	1,324	91.44
	37.3	836	22.47		15.64	1,355	86.64
	(2)	825	....		15.22	1,350	88.70
60	31.17	1,435	46.04	299	15.35	614	11.96
92	17.91	452	25.24		66.71	600	8.99
	21.25	459	21.60		75.12	570	7.59
	23.05	455	19.74		79.97	561	7.02
	24.17	458	18.95		83.59	547	6.54
	24.98	459	18.37		86.79	544	6.27
	25.45	453	17.80		88.83	536	6.03
115	23.23	652	28.07		90.48	526	5.81
	23.11	557	24.10		91.45	526	5.75
	23.74	536	22.58		93.67	520	5.55
	23.70	768	32.40		94.64	524	5.54

1. Pumping tests made by the Division of Water Resources of the Kansas State Board of Agriculture in coöperation with the State and Federal Geological Surveys. Wells 30, 92, 115, 244, 247, and 299 were tested by Melvin Scanlan and W. W. Wilson; wells 29, 31, 56, and 60 were tested by K. D. McCall, Melvin Scanlan, and W. W. Wilson.

2. No drawdown measurement available.

The annual pumpage for irrigation in this area varies with the precipitation, but prior to the end of 1943 the pumpage increased each year because of the increase in number of pumping plants and in irrigated acreage. In 1944, however, the pumpage decreased because of abundant precipitation and the scarcity of farm labor.

Yields of irrigation wells.—The yields of 10 irrigation wells in Grant, Haskell, and Stevens Counties were determined by pumping tests, the results of which are given in Table 8.

The wells that were tested were deep wells equipped with turbine pumps powered by gasoline, diesel, or natural-gas engines. Measurements of yield were made using a Collins flow gage (Pl. 8). An electrical contact device and a steel tape or both were used for measuring the drawdowns in the wells while pumping, and a steel tape was used for all water-level measurements after pumping stopped. The yields of the wells ranged from 452 to 1,435 gallons a minute; the drawdowns in nine of the wells ranged from 11.73 to 94.64 feet, and the specific capacities ranged from 5.5 to 101.8. Well 145, for which no discharge measurements are available, was reported to yield 800 gallons a minute with a measured drawdown of 6.26 feet. If the reported yield is correct, the specific capacity of the well is 128, which is the highest that has been reported or measured in this area.

Construction of irrigation wells.—The irrigation wells in Grant, Haskell, and Stevens Counties are of one type. They are deep wells that penetrate all or most of the water-bearing materials above the Dakota formation. Most of the wells are gravel-walled wells cased with 16-inch wrought-iron casing and equipped with deep-well turbine pumps powered by natural-gas engines. Some of the wells penetrate water-bearing formations so fine-grained that the wells should be gravel-packed in order to keep out the sand and obtain larger yields (see p. 68). In order to obtain an efficient well, it is essential to use proper size gravel and proper size screens or perforations. Gravel-packing adds to the cost of construction and should be used only where water in satisfactory quantities can be obtained in no other way and then only after a thorough study of the water-bearing material to determine the proper size of gravel to be used and, therefore, the proper slot size of screen or perforation of casing. For detailed descriptions of gravel-packing, the reader is referred to Rohwer (1940), Bennison (1943), and Davison (1939).

Depth and diameter of irrigation wells.—The irrigation wells in

Grant, Haskell, and Stevens Counties, except well 46 which is abandoned, range in depth from 112 feet to 375 feet, and the diameters range from 12 to 18 inches (Table 9).

TABLE 9.—*Depths and diameters of irrigation wells in Grant, Haskell, and Stevens Counties*

Depth (feet)	Number of wells	Diameter (inches)	Number of wells
100–200	2	12	2
201–300	12	16	15
301–400	6	18	3
Total,	20	Total,	20

Types of irrigation pumps.—All the irrigation wells in Grant, Haskell, and Stevens Counties are equipped with deep-well turbine pumps, most of which have 6-inch or 8-inch discharge pipes. Well 46 in Lakin Draw is equipped with a centrifugal pump, but this well has been abandoned.

Irrigation pump power.—Engines using natural gas for fuel operate about half of the pumps on irrigation wells in this area. The remainder are operated by gasoline or diesel engines (Table 10). There are very few electric power lines near irrigation wells

TABLE 10.—*Type of power used for operating irrigation pumps in Grant, Haskell, and Stevens Counties*

TYPE OF POWER	Number of wells
Diesel engine	2
Gasoline engine	8
Natural-gas engine	10
Total	20

in this area, but all the wells except 134 and 145 are within the limits of the Hugoton gas field; hence there is an abundance of low-priced fuel available to irrigation plants. Data on the consumption of natural gas (determined by pumping tests conducted by Kenneth D. McCall, Melvin Scanlan, and Woodrow W. Wilson) by four pumping plants in Grant and Stevens Counties (30, 56, 244, and 247) indicate a cost of fuel of 0.28 cent per acre-foot of water per foot of lift. The average lift in the four wells was 95 feet, the average discharge was 1,100 gallons a minute, and the average cost of fuel per acre-foot of water was $0.27. Most of the power units on irrigation wells in this area are belted to the pump pulleys, but a few are direct-connected to the shafts.

POSSIBILITIES OF FURTHER DEVELOPMENT OF IRRIGATION SUPPLIES FROM WELLS

The feasibility of further development of irrigation supplies from wells is dependent upon the safe yield of the ground-water reservoir (the amount of water that can be withdrawn annually over a long period of years without depletion), the cost of drilling and pumping, the types of soil, the quality of water, the kinds of crops raised, the market and price conditions, and perhaps other factors. The ability of an underground reservoir to yield water over a long period of years is limited, as is that of a surface reservoir. If water is withdrawn from an underground reservoir by pumping and by other means (seeps, springs, evaporation, and transpiration) faster than water enters it, the supply will be depleted and the water levels in wells will decline. The amount of water that can be withdrawn annually over a long period of years without depletion of the ground-water reservoir is dependent upon the capacity of the underground reservoir and upon the amount of water that is added annually to the reservoir by recharge.

The cost of drilling and pumping is determined in part by the depth to water level. In areas where the water level is relatively deep the wells must be deep and the pumping lift is great. The cost of a well is also determined in part by the permeability and the thickness of the water-bearing materials. Wells may encounter relatively fine-grained materials that cause the yield of the well to be relatively small. Gravel-packing may increase the yield, but it also adds to the cost. The character of the soil and the contour of the land surface also are important factors. The soil may be too sandy, as it is in many parts of Stevens County, or the land may be poorly drained, as it is in parts of northwestern Grant County and in much of the dune-sand area in Stevens County.

Grant, Haskell, and Stevens Counties are underlain by thick deposits of water-bearing silt, clay, sand, and gravel. An irrigation well could be developed in almost any part of the area provided preliminary test drilling indicated an adequate thickness of water-bearing sand and gravel. Among the chief factors limiting the development of irrigation in this area are depth to water, condition of soil, and surface slope. The depth to water level in much of Grant, Haskell, and Stevens Counties is so great that irrigation from wells is not economically feasible. The depth to water level beyond which pumping from wells for irrigation is too costly is difficult to determine and is variable. The limit may be influenced by type of crop grown, quality of the soil, price of crops, climate, cost of fuel, and drawdown of the well. Well 299, for example, has a pumping lift of more than 177 feet, although the static water level is only 82.8 feet. Well 145, however, has a static water level of 161.4 feet but the pumping lift is only 167.7 feet. (For a discussion of cost of pumping, the reader is referred to McCall and Davison, 1939, and McCall, 1944.) In the discussion of the possibilities of further development of irrigation, only those areas are considered where the depth to water level is less than 100 feet. This is an arbitrary limit and may be altered by various conditions as stated above. In addition, as pumping equipment is improved the economic limit of pumping lifts may increase. In 1943, there were six irrigation wells in this area having a static water level greater than 100 feet and seven irrigation wells having a pumping lift greater than 100 feet.

The shallow-water areas in Grant, Haskell, and Stevens Counties are very similar to the irrigation area near Plainview and Hereford in the panhandle of Texas. Both areas are a part of the High Plains, are underlain by thick deposits of Tertiary or Quaternary sediments or both, have a similar climate, and have almost equal depths to water level. According to White, Broadhurst, and Lang (1940) there were approximately 1,700 irrigation wells in the High Plains of Texas in 1939 which were used to irrigate about 230,000 acres of land. In 1940, there were about 2,100 irrigation wells in the area. It is believed that irrigation could be developed profitably in the areas of shallow water in Grant, Haskell, and Stevens Counties. Many irrigation wells in the High Plains of Texas have static water levels greater than 100 feet; hence it is believed that water could be pumped economically in the areas in Grant, Haskell, and Stevens Counties where the depth to water is less than 100 feet. Inasmuch as all the potential irrigation areas in Grant and Stevens Counties are within the limits of the Hugoton gas field where there is an abundance of low-priced fuel, it is believed that water could be pumped more economically here than in the High Plains of Texas.

The Grant-Haskell-Stevens area also is very similar to the large irrigation area in Scott County, Kansas. The areas have similar climate and geology except that the water-bearing materials generally are much thicker in the Grant-Haskell-Stevens area. The cost of fuel per acre-foot of water per foot of lift in Grant, Haskell, and Stevens Counties is much less than it is in Scott County because of the low cost of natural gas in the Hugoton gas field. The average cost of natural gas per acre-foot of water per foot of lift in four irrigation plants tested in Grant and Stevens Counties was 0.28 cent. The average cost of fuel per acre-foot of water per foot of lift in 27 plants tested in Scott County was 0.96 cent for 12 plants using natural gas and 2.7 cents for 15 plants using electricity (McCall, 1944, pp. 25-30). The average lift in the four wells in Grant and Stevens Counties was 95 feet, whereas the average lift in the 27 plants in Scott County was 83 feet.

The cost of fuel for pumping water for irrigation also seems to be less in the vicinity of the Hugoton gas field than in any other upland area in southwestern Kansas. The Division of Water Resources of the Kansas State Board of Agriculture tested 22 deep-well pumping plants in southwestern Kansas in 1938 (Anon., 1938) and found that the average cost of fuel per acre-foot of water per foot of lift was 1.07 cents in plants using natural gas, 2.90 cents in plants using gasoline, 2.18 cents in plants using distillate, and 2.69 cents in plants using electricity. The average lift in these wells was 98.7 feet. As stated above, the average cost of fuel per acre-foot of water per foot of lift in four plants that were tested in Grant and Stevens Counties was 0.28 cent. It must be remembered, however, that this represents only the cost of fuel and does not include the initial cost of the plant or the cost of lubrication and maintenance.

For the purpose of more detailed description, Grant, Haskell, and Stevens Counties may be divided into five areas based upon possibilities of further development of irrigation from wells: (1) Stanton-Grant area, (2) Moscow area, (3) Feterita area, (4) Woods area, and (5) northeastern Haskell area (Fig. 16).

Stanton-Grant area.—The shallow-water area in western Grant, eastern Stanton, and northwestern Stevens Counties is one of the largest potential areas of irrigation in western Kansas (Fig. 16). The area in which the depth to water level is less than 100 feet is more than 500 square miles, of which about 280 square miles are in Grant County and 15 square miles are in Stevens County. (See Plate 2 of a report by Latta, 1941, and Plate 2 of this report.) Much of this land is not suitable for irrigation, but no attempt was

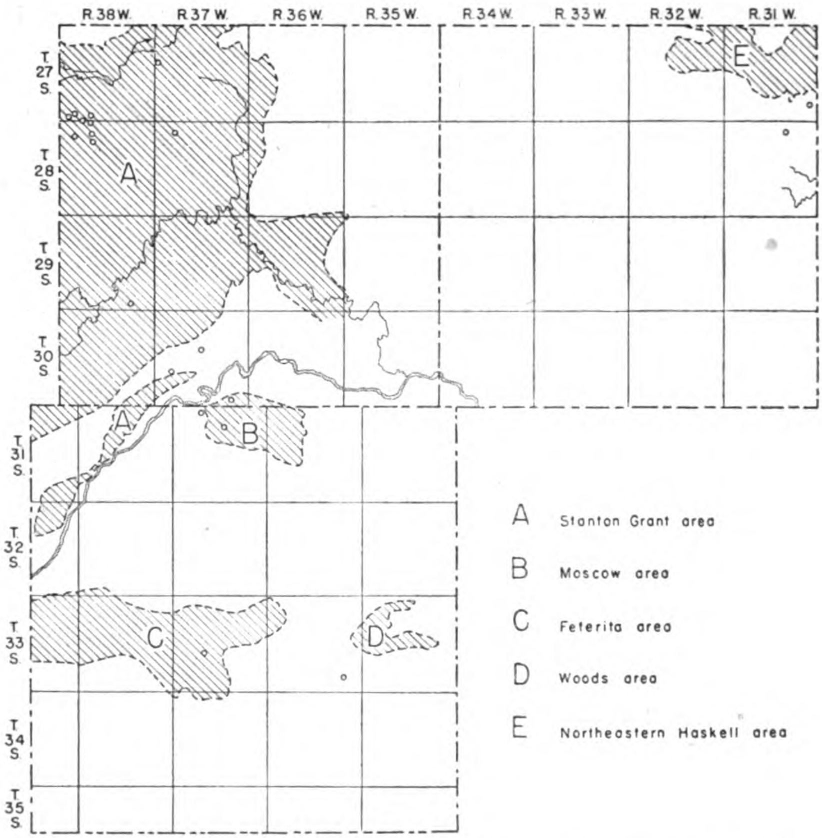


FIG. 16. Map of Grant, Haskell, and Stevens Counties showing areas most favorable for development of irrigation.

made during this investigation to classify land according to its suitability for irrigation. Part of the land is underlain by dune sand, part is poorly drained, and part is unsuitable for other reasons. Nevertheless, there are many thousand acres of land in this area that could be irrigated with water from wells. The thickness of the saturated material is between 250 and 350 feet in most of the area but is only 200 feet in northwestern Grant County on the southeastern flank of the Syracuse anticline (Pl. 3).

It is not possible at present to estimate the quantity of water that could be pumped annually from wells in this area without depleting the supply of ground water. The water levels in all of the observation wells in this area fluctuate somewhat in accordance with precipitation, indicating that there is recharge from precipitation in this area. Theis, Burleigh, and Waite (1935, pp. 2, 3) believe that the average annual recharge from precipitation in the High Plains is about one-half inch of water. The recharge in the Stanton-Grant area probably exceeds the average recharge in the High Plains, inasmuch as the depth to water level probably is less than the average depth to water level in the High Plains. One-half inch of recharge annually would amount to more than 8.5 million gallons or 26.7 acre-feet for each square mile.

The heaviest pumping in this area is in northwestern Grant County, where there are several wells in a relatively small area. The pumpage of water in that area has not as yet caused appreciable lowering of the water table. In August 1944, the Division of Water Resources of the Kansas State Board of Agriculture installed an automatic water-level recorder on a well in the SE cor. NE¼ sec. 6, T. 28 S., R. 38 W., in the most heavily pumped area, so that a continuous record of the water level in this well will be available. If further development of irrigation in this area causes the water table to decline, steps can be taken to prevent overdevelopment. If the wells are properly spaced, several thousand acres could be irrigated without depleting the supply of ground water. Properly constructed wells in this area probably would yield 500 to 1,500 gallons of water a minute. In the valleys, where the water table generally is shallow, a battery of several wells connected to a centrifugal pump could be constructed. The yield of these wells generally is greater than the yield of single deep wells.

Moscow area.—Additional land could be irrigated in the small area northwest of Moscow in northern Stevens and southern Grant Counties (Fig. 16). The land is relatively flat and the depth to water level is between 80 and 100 feet. The thickness of the saturated material ranges from about 150 feet in the eastern part of the area to about 280 feet in the northwestern part of the area. Test hole 33, in the NE cor. sec. 9, T. 31 S., R. 37 W., penetrated 280 feet of saturated material above the Dakota formation, and this test hole and the irrigation wells in this area encountered much coarse sand and gravel. The specific capacities of the irrigation wells in this area are relatively large. (Table 7, wells 244 and 247.)

Periodic measurements of water level have been made in one well (245) in this area, and were begun during the summer of 1942 which was a year of above-normal precipitation. Because of the below-normal precipitation in 1943 the water level declined, but because of above-normal precipitation in 1944 the water level reached its highest stage since periodic measurements were begun. This indicates that the pumpage has had little or no effect on the water table and that there is recharge from precipitation. If there were excessive pumping in this area and the water table declined, the Cimarron River in this area would become a losing stream instead of a gaining stream; and instead of ground water being lost by discharge into the river, the ground-water reservoir would be recharged by the downward movement of runoff water of the Cimarron River through the broad sandy stream channel.

Feterita area.—The Feterita area extends from Hugoton through Feterita to Rolla in Morton County (Fig. 16). This area consists of all the land in which the depth to water level is less than 100 feet, except those areas covered by relatively young sand dunes which cause the land to be very sandy and irregular (Pl. 1). All this area is covered by mature and old-age sand dunes, but there are many parts of the area in which a good soil has developed and in which the land is relatively flat.

There is one irrigation well (299) in this area in Stevens County, but several have been drilled in the Morton County part of the area. The thickness of saturated material ranges from about 300 feet at the Morton-Stevens line to more than 400 feet in the eastern part of the area. There is little danger of overdevelopment of irrigation in this area because irrigation will necessarily be restricted to small areas where the soil and surface slopes are favorable.

This area is underlain by dune sand and the drainage is poorly developed; hence practically all the precipitation in this area moves downward toward the zone of saturation or evaporates, and little or no water is lost by runoff. Because the soil and topography of the area limit the development of irrigation, the recharge from precipitation in this area probably will be adequate to supply all the irrigation wells that may be constructed.

Woods area.—The area of shallow water in the vicinity of Woods in eastern Stevens County is underlain by dune sand, much of which has an irregular surface slope and a very sandy soil (Fig. 16). The area most favorable for the development of irrigation is that in which the depth to water level is less than 100 feet and in which the dune sand has reached the mature or old-age stage of the dune-sand cycle (note pages 134, 135).

The depth to water level in this area ranges from about 75 feet to 100 feet and the thickness of saturated material is greater than in any other part of the Grant-Haskell-Stevens area. Test holes 38 and 39 encountered approximately 600 feet of saturated material above the Permian redbeds. This area is similar to the Feterita area in that irrigation can be developed only where the land is relatively flat and where the soil is not too sandy. This area and adjacent areas are underlain by dune sand containing many undrained basins. The recharge here is relatively large and probably would supply all the irrigation wells that will be constructed in the limited areas where both the soil and topography are suitable for the development of irrigation.

Northeastern Haskell area.—The area of shallow water in northeastern Haskell County comprises about 25 square miles bounded on the north and west by sand dunes and on the south by the 100-foot isobath line (Fig. 16). The area extends into southeastern Finney County and west-central Gray County (Latta, 1944, pp. 122, 123). There are no irrigation wells in this area in Haskell County but there are two irrigation wells (134 and 145) south of the area where the depth to water exceeds 100 feet (Pl. 2). These wells penetrate thick deposits of sand and gravel and have relatively high specific capacities. There were six irrigation wells in the Gray County part of the shallow-water area in 1940. These wells are 110 to 165 feet deep and the depth to water level in them ranges from about 64 feet to about 110 feet. The yields of the wells range from about 800 to 1,100 gallons a minute (Latta, 1944, p. 122).

The depth to water in the Haskell County part of the area ranges from about 65 feet to 100 feet. The thickness of saturated material ranges from about 200 feet at the northeast corner of Haskell County to more than 300 feet in the southern and western parts of the area. Test hole 6 at the northeast corner of the area penetrated 207 feet of saturated material, of which 118 feet consisted primarily of sand or gravel or both (Pl. 3). A test hole (log 5) drilled at the NE corner sec. 31, T. 27 S., R. 30 W., Gray County, penetrated almost 300 feet of saturated material above the Dakota formation, nearly 200 feet of which was sand and gravel.

Inasmuch as the northeastern Haskell area is isolated and almost completely surrounded by large areas of sand dunes or areas in which the depth to water level exceeds 100 feet, it is believed that almost every suitable acre in the area could be irrigated with water from wells. Ground water moves into the area from the sand hills northwest of the area in southern Finney County. The large area of sand dunes serves as a catchment area for precipitation so that recharge of the ground-water reservoir probably greatly exceeds the average recharge in the High Plains. Because of this movement of water from the northwest and because very little irrigation can be developed in adjacent areas it is believed that many irrigation wells can be constructed in this area. A reasonable lowering of the water table in this area by pumping would increase the gradient of the water table and, therefore, would increase the movement of water from the sand-dune area.

Summary.—The irrigation areas discussed in the preceding pages are limited to places in which the depth to water level is less than 100 feet, but, as stated above, there are six irrigation wells in Grant, Haskell, and Stevens Counties having a static water level of more than 100 feet. In addition, there are many irrigation wells in southwestern Kansas and the panhandle of Texas in which the static water level is more than 100 feet. Whether or not irrigation wells having a pumping lift of more than 100 feet can be operated economically is questionable. Because of the abundance of low-priced fuel in the Hugoton gas field the economic limit of pumping lift probably is as great or greater in this area than in any other part of the High Plains.

There are large areas in Grant, Haskell, and Stevens Counties where the depth to water level is slightly more than 100 feet and where irrigation could be developed if the cost of pumping is not too great. The Stanton-Grant area has been divided into two parts in Figure 15, the two parts being separated by an area in which the depth to water level ranges from 100 to 115 feet (Pl. 2). Similarly, in most of the area east of U. S. highway 270 between the Cimarron River and North Fork Cimarron River the depth to water level does not exceed 120 feet. Also there are many areas in Stevens County where the depth to water level is a little more than 100 feet and where the soil and topography are suitable for irrigation. Finally, the depth to water in most of that part of northeastern Haskell County lying between the 100-foot and 150-foot isobath lines is less than 110 feet (Pl. 2). The static water level in the areas mentioned above are more than 100 feet, but if a well penetrates an adequate thickness of coarse sand and gravel the drawdown will not be great and hence the pumping lift may be less than the lift in some wells having a static water level less than 100 feet. As irrigation with water from wells is increased in this area the economic limit of pumping lifts for various types of crops and for various climatic conditions probably will be determined.

Quality of Water

The chemical character of the ground waters in Grant, Haskell, and Stevens Counties is indicated by the analyses in Tables 11, 12, and 13. The analyses were made by H. A. Stoltenberg in the Water and Sewage Laboratory of the Kansas State Board of Health. Seventy-six samples of water were collected from representative wells distributed as uniformly as possible within the area and among the water-bearing formations, and one sample was collected from a gravel pit. The analyses of the water supplies at Ulysses (52), Sublette (183), Satanta (218), and Hugoton (296) are analyses of composite samples from two wells. The constituents listed were determined by methods used by the U. S. Geological Survey.

CHEMICAL CONSTITUENTS IN RELATION TO USE

The following discussion of the chemical constitutents of ground water in relation to use has been adapted from publications of the United States Geological Survey.

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

TABLE 11.—*Analyses of waters from wells in Grant County, Kansas*

Analyzed by H. A. Stoltenberg. Dissolved constituents given in parts per million [1], reacting values (in italics) given in equivalents per million

Well No. on Plate 2	LOCATION	Depth (feet)	Geologic source [a]	Date of collection, 1941	Temperature (°F)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na+K)	Bicarbonate (HCO_3)	Sulphate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	Hardness (calculated as $CaCO_3$)		
																Total	Carbonate	Noncarbonate
3	*T. 27 S., R. 35 W.* SW SW sec. 6	135	Rexroad and/or Meade	Oct. 28	60	0.31	49 *2.44*	7 *.58*	12 *.50*	182 *2.98*	14 *.29*	5.5 *.16*	0.3 *.02*	4.1 *.07*	183	151	149	2
5	SE SE sec. 16	170	do	do	58	.04	47 *2.34*	6.6 *.54*	9 *.39*	174[3] *2.85*	13 *.27*	2.5 *.07*	.3 *.02*	3.9 *.06*	169	144	142	2
17	*T. 27 S., R. 37 W.* SW SW sec. 1	160	do	Oct. 27	58	1.9	101 *5.04*	40 *3.29*	62 *2.71*	200 *3.28*	305 *6.34*	40 *1.13*	1.6 *.08*	13 *.21*	664	416	164	252
21	SE NE sec. 28	60	do	Oct. 28	58	1	63 *3.14*	43 *3.53*	123 *5.35*	295 *4.84*	317 *6.59*	16 *.45*	1.5 *.08*	3.5 *.06*	716	334	242	92
26	*T. 27 S., R. 38 W.* SE NE sec. 20	100	do	Oct. 20	59	.06	209 *10.43*	70 *5.75*	33 *1.43*	229 *3.76*	230 *4.78*	106 *2.99*	.6 *.03*	376 *6.05*	1,139	809	188	621
35	*T. 28 S., R. 35 W.* NW NW sec. 15	220	Rexroad	Oct. 28	62	.68	55 *2.74*	12 *.99*	45 *1.96*	190 *3.12*	104 *2.16*	11 *.31*	.5 *.03*	4.1 *.07*	327	186	156	30
38	*T. 28 S., R. 36 W.* SE SE sec. 3	200	do	do	61	1.4	60 *2.99*	36 *2.96*	56 *2.43*	310 *5.08*	137 *2.85*	13 *.37*	1.3 *.07*	0 *.00*	460	298	254	44
43	SE SW sec. 36	91	do	Oct. 27	59	12	67 *3.34*	20 *1.64*	34 *1.47*	254 *4.16*	68 *1.41*	30 *.85*	.6 *.03*	0 *.00*	359	249	203	41
52	*T. 28 S., R. 37 W.* SW SW sec. 27	290	Rexroad and Meade			.02	64 *3.19*	33 *2.71*	43 *1.87*	198 *3.25*	188 *3.91*	15 *.42*	1.7 *.09*	6.2 *.10*	507	295	162	133
55	NE NE sec. 35	165	do	do	61	.38	98 *4.89*	82 *6.74*	138 *6.02*	240 *3.94*	486 *10.11*	121 *3.41*	2.8 *.15*	2.4 *.04*	1,051	582	197	385
57	*T. 28 S., R. 38 W.* NW SE sec. 4	55	do	do	59	1.4	66 *3.29*	45 *3.70*	72 *3.13*	202 *3.31*	258 *5.37*	39 *1.10*	3 *1.6*	11 *.18*	596	350	166	184

	T. 29 S., R. 35 W.																
68	SE SW sec. 12	234	Rexroad	do	59	1.3	72 *3.59*	25 *2.06*	41 *1.77*	241 *3.95*	140 *2.91*	14 *.39*	.8 *.04*	8 *.13*	423	282	198	84
	T. 29 S., R. 36 W.																
72	NW NE sec. 4	113	Rexroad and/or Meade	do	59	.75	62 *3.09*	24 *1.97*	22 *.96*	199[4] *3.26*	79 *1.64*	36 *1.02*	.7 *.04*	4 *.06*	328	253	163	90
76	NE NW sec. 25	119	do	do	59	.22	47 *2.34*	30 *2.47*	40 *1.74*	234 *3.84*	45 *.94*	57 *1.61*	2.2 *.12*	2.3 *.04*	341	240	192	48
	T. 29 S., R. 37 W.																
A[5]	SW SW sec. 7	.....	Meade	Oct. 21	63	.30	78 *3.89*	75 *6.16*	214 *9.29*	276 *4.53*	616 *12.81*	66 *1.86*	2.3 *.12*	1 *.02*	1,191	502	226	276
84	SW SW sec. 22	80	Rexroad and/or Meade	do	62	1.7	66 *3.29*	32 *2.63*	40 *1.76*	195 *3.20*	165 *3.43*	31 *.87*	1.4 *.07*	7.1 *.11*	442	296	160	136
	T. 29 S., R. 38 W.																
86	NE NE sec. 16	150	do	do	60	1.3	58 *2.89*	27 *2.22*	29 *1.26*	190 *3.12*	132 *2.74*	13 *.37*	1.2 *.06*	6.2 *.10*	363	256	156	100
89	NE NE sec. 27	25	do	do	63	.92	139 *6.94*	101 *8.30*	195 *8.49*	310 *5.08*	725 *15.08*	76 *2.14*	2.6 *.14*	80 *1.29*	1,474	762	254	508
	T. 30 S., R. 35 W.																
93	SW SE sec. 2	240	Rexroad	Oct. 27	60	2.1	43 *2.14*	20 *1.64*	16 *.71*	210[6] *3.44*	34 *.71*	7 *.20*	1.1 *.06*	5.3 *.08*	234	189	172	17
	T. 30 S., R. 36 W.																
102	SW SE sec. 1	140	Rexroad and/or Meade	do	59	.66	57 *2.84*	28 *2.30*	32 *1.37*	206 *3.38*	95 *1.98*	31 *.87*	1.8 *.09*	12 *.19*	360	257	169	88
104	NW NW sec. 5	125	do	do	59	13	53 *2.64*	39 *3.20*	32 *1.39*	219 *3.59*	128 *2.66*	26 *.73*	2.6 *.14*	7.1 *.11*	410	292	180	112
106	SE SE sec. 23	25	Alluvium	do	59	.25	87 *4.34*	45 *3.70*	106 *4.59*	368[7] *6.04*	278 *5.78*	25 *.70*	1.8 *.09*	1.6 *.02*	729	402	302	100
	T. 30 S., R. 37 W.																
114	NE NE sec. 16	120	Rexroad and/or Meade	do	59	.54	63 *3.14*	20 *1.64*	30 *1.32*	202 *3.31*	103 *2.14*	16 *.45*	2.4 *.13*	4.4 *.07*	340	239	166	73
119	SW NW sec. 27	25	Alluvium	do	60	1.2	49 *2.44*	24 *1.97*	39 *1.68*	218 *3.58*	97 *2.02*	12 *.34*	1.6 *.08*	4.1 *.07*	337	220	179	41
	T. 30 S., R. 38 W.																
126	SE SE sec. 10	140	Rexroad and/or Meade	Oct. 21	60	16	57 *2.84*	25 *2.06*	35 *1.53*	234 *3.84*	94 *1.96*	14 *.39*	1.6 *.08*	10 *.16*	370	245	192	53

a. For Rexroad read Rexroad (?).
1. One part per million is equivalent to one pound of substance per million pounds of water and is equivalent to 8.33 pounds per million gallons.
2. Calculated.
3. Includes the equivalent of 2.4 parts per million carbonate.
4. Includes the equivalent of 4.8 parts per million carbonate.
5. Sample collected from gravel pit in the Meade formation.
6. Includes the equivalent of 3.6 parts per million carbonate.
7. Includes the equivalent of 9.6 parts per million carbonate.

Table 12.—*Analyses of waters from wells in Haskell County, Kansas*

Analyzed by H. A. Stoltenberg. Dissolved constituents given in parts per million [1], reacting values (in italics) given in equivalents per million

Well No. on Plate 2	Location	Depth (feet)	Geologic source [a]	Date of collection, 1942	Temperature (°F)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na+K)	Bicarbonate (HCO_3)	Sulphate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	Hardness (calculated as $CaCO_3$)		
																Total	Carbonate	Noncarbonate
133	*T. 27 S., R. 31 W.* NE NE sec. 22	100	Rexroad and/or Meade	Sept. 12	60	0.20	51 *2.54*	8 *.66*	12 *.54*	196 *3.21*	12 *.25*	1.8 *.05*	0.3 *.02*	13 *.21*	196	160	160	0
135	*T. 27 S., R. 32 W.* NW SW sec. 6	119	do	do	60	5.1	52 *2.59*	7.2 *.59*	8 *.35*	182[3] *2.98*	14 *.29*	3.5 *.10*	.3 *.02*	8.4 *.14*	190	159	149	10
138	SW NW sec. 19	120	do	do	61	1.4	53 *2.64*	8.4 *.69*	19 *.81*	241 *3.95*	5.1 *.11*	1.8 *.05*	.3 *.02*	.75 *.01*	210	166	166	0
139	SW NW sec. 24	127	do	do	60	.22	51 *2.54*	7.7 *.63*	12 *.51*	190 *3.12*	13 *.27*	3.2 *.09*	.3 *.02*	11 *.18*	193	158	156	2
142	*T. 27 S., R. 33 W.* SE SW sec. 18	160	do	do	62	.10	51 *2.54*	7.7 *.63*	12 *.52*	188 *3.08*	16 *.33*	3 *.08*	.2 *.01*	12 *.19*	196	158	154	4
148	*T. 28 S., R. 31 W.* NW NW sec. 15	180	Rexroad	do	62	.34	47 *2.34*	7.4 *.61*	5.3 *.23*	176 *2.89*	6.4 *.13*	1.8 *.05*	.3 *.02*	5.8 *.09*	162	148	144	4
150	*T. 28 S., R. 32 W.* SW SE sec. 6	185	do	do	61	.79	50 *2.50*	8.5 *.70*	8.5 *.37*	186[3] *3.05*	16 *.33*	1.2 *.03*	.3 *.02*	8.8 *.14*	187	160	152	8
151	SW SE sec. 13	220	do	do	63	.24	50 *2.50*	6.7 *.55*	7.4 *.32*	184 *3.02*	7.4 *.15*	2.2 *.06*	.3 *.02*	7.5 *.12*	174	152	151	1
158	*T. 28 S., R. 33 W.* SE SW sec. 22	232	do	do	59	2.3	44 *2.20*	10 *.82*	17 *.75*	189 *3.10*	24 *.50*	4.8 *.14*	.6 *.03*	0 *.00*	197	151	151	0
160	*T. 28 S., R. 34 W.* NW NW sec. 9	262	do	do	62	8.8	44 *2.20*	11 *.90*	19 *.82*	187 *3.07*	28 *.58*	5.5 *.16*	.8 *.04*	4.2 *.07*	215	155	154	1
163	SE SE sec. 30	210	do	do	62	.75	45 *2.24*	14 *1.15*	17 *.73*	202 *3.31*	25 *.52*	3.2 *.09*	.7 *.04*	10 *.16*	217	170	166	4

	T. 29 S., R. 31 W.																	
167	NE SE sec. 3	180	do	Sept. 11	60	.60	46 *2.30*	10 *.82*	9 *.39*	187 *3.07*	10 *.21*	3.2 *.09*	.3 *.02*	7.5 *.12*	180	156	154	2
172	SE NE sec. 20	172	do	do	61	1.2	47 *2.34*	10 *.82*	13 *.57*	187 *3.07*	19 *.40*	3.5 *.10*	.4 *.02*	8.4 *.14*	196	158	154	4
	T. 29 S., R. 32 W.																	
179	SW SW sec. 15	213	do	do	61	.16	46 *2.30*	10 *.82*	14 *.62*	182 *2.98*	22 *.46*	4 *.11*	.6 *.03*	9.7 *.16*	197	156	149	7
183	NE SW sec. 32	299	do	....	....	.13	47 *2.34*	11 *.90*	3.8 *.16*	185 *3.03*	47 *.98*	7 *.20*	.7 *.04*	3.7 *.06*	265	162	152	10
	T. 29 S., R. 33 W.																	
186	SW SE sec. 12	202	do	Sept. 12	60	.54	47 *2.34*	12 *.99*	17 *.73*	189[4] *3.10*	34 *.71*	5 *.14*	.7 *.04*	4.1 *.07*	215	166	155	11
189	SW SW sec. 30	222	do	Sept. 11	62	13	50 *2.50*	16 *1.32*	30 *1.31*	210 *3.44*	61 *1.27*	8.8 *.25*	1 *.05*	7.5 *.12*	279	191	172	19
	T. 29 S., R. 34 W.																	
191	NE NE sec. 16	210	do	do	64	1.9	53 *2.64*	20 *1.64*	25 *1.10*	221[5] *3.62*	65 *1.35*	8 *.22*	.9 *.05*	8.8 *.14*	293	214	181	33
195	NE SE sec. 31	230	do	do	63	2.6	70 *3.49*	31 *2.55*	47 *2.06*	232[5] *3.80*	175 *3.64*	17 *.48*	1 *.05*	8 *.13*	468	302	190	112
	T. 30 S., R. 31 W.																	
198	NE NE sec. 3	180	do	do	60	.28	46 *2.30*	11 *.90*	14 *.63*	188 *3.08*	20 *.42*	4.8 *.14*	.5 *.03*	9.7 *.16*	290	160	154	6
202	SW SE sec. 22	180	do	do	60	.21	47 *2.34*	12 *.99*	18 *.79*	192 *3.15*	33 *.69*	7.2 *.20*	.7 *.04*	2.4 *.04*	216	166	158	8
203	SE SW sec. 36	160	do	do	60	1.8	47 *2.34*	13 *1.07*	22 *.94*	200[4] *3.28*	40 *.83*	5.2 *.15*	.7 *.04*	2.9 *.05*	233	170	164	6
	T. 30 S., R. 32 W.																	
207	NE NE sec. 12	186	do	do	62	.94	45 *2.24*	12 *.99*	17 *.73*	184 *3.02*	33 *.69*	6 *.17*	.6 *.03*	2.9 *.05*	210	162	151	11
212	NW NW sec. 31	195	do	do	64	2.3	53 *2.64*	20 *1.64*	30 *1.31*	210 *3.44*	81 *1.68*	11 *.31*	1 *.05*	7.1 *.11*	310	214	172	42
	T. 30 S., R. 34 W.																	
218	NE SW sec. 13	280	do	do	....	.14	73 *3.64*	27 *2.22*	43 *1.87*	222 *3.64*	169 *3.52*	15 *.42*	1.1 *.06*	5.3 *.09*	502	293	182	111
223	NE NW sec. 20	210	do	do	62	.69	64 *3.19*	31 *2.55*	35 *1.53*	218 *3.58*	149 *3.10*	16 *.45*	1 *.05*	5.8 *.09*	412	287	179	108

a. For Rexroad read Rexroad (?).
1. One part per million is equivalent to one pound of substance per million pounds of water and is equivalent to 8.33 pounds per million gallons.
2. Calculated.
3. Includes the equivalent of 2.4 parts per million carbonate.
4. Includes the equivalent of 6 parts per million carbonate.
5. Includes the equivalent of 4.8 parts per million carbonate.

Table 13.—*Analyses of waters from wells in Stevens County, Kansas*

Analyzed by H. A. Stoltenberg. Dissolved constituents given in parts per million [1], reacting values (in italics) given in equivalents per million

Well No. on Plate 2	Location	Depth (feet)	Geologic source [a]	Date of collection, 1942	Temperature (°F)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na+K)	Bicarbonate (HCO_3)	Sulphate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	Hardness (calculated as $CaCO_3$) Total	Carbonate	Noncarbonate
	T. 31 S., R. 35 W.																	
229	NE NE sec. 17	200	Rexroad	Oct. 21	60	7.6	57 *2.84*	28 *2.30*	38 *1.66*	233 *3.82*	114 *2.37*	18 *.51*	1.2 *.06*	2.5 *.04*	383	257	191	66
232	SW SW sec. 35	225	do	do	61	.69	56 *2.79*	34 *2.79*	31 *1.36*	209 *3.43*	133 *2.77*	16 *.45*	.9 *.05*	15 *.24*	391	279	172	107
	T. 31 S., R. 36 W.																	
234	NW NW sec. 7	107	Rexroad and/or Meade	do	60	2.6	49 *2.44*	31 *2.55*	43 *1.87*	232 *3.80*	113 *2.35*	14 *.39*	1.2 *.06*	16 *.26*	386	250	190	60
239	SE NW sec. 26	200	do			.36	45 *2.25*	30 *2.47*	40 *1.74*	222 *3.64*	107 *2.23*	12 *.34*	1.2 *.06*	9.7 *.16*	383	236	182	54
	T. 31 S., R. 37 W.																	
249	SW SE sec. 29	165	do	do	61	.04	75 *3.74*	32 *2.63*	47 *2.04*	239 *3.92*	181 *3.76*	16 *.45*	.7 *.04*	15 *.24*	486	318	196	122
	T. 31 S., R. 38 W.																	
252	SW SW sec. 27	114	do	do	64	3.8	46 *2.30*	32 *2.63*	49 *2.13*	271 *4.44*	86 *1.79*	18 *.51*	1 *.05*	17 *.27*	388	246	222	24
253	NE NE sec. 29	21	Alluvium	do	61	.34	78 *3.89*	38 *3.12*	71 *3.10*	260 *4.26*	240 *4.99*	24 *.68*	1.1 *.06*	7.5 *.12*	500	350	213	137
	T. 32 S., R. 35 W.																	
260	NW NW sec. 16	143	Rexroad and/or Meade	do	61	.33	53 *2.64*	30 *2.47*	39 *1.69*	217 *3.56*	123 *2.56*	14 *.39*	.9 *.05*	15 *.24*	384	256	178	78
	T. 32 S., R. 37 W.																	
273	NE SE sec. 18	145	do	do	61	.72	61 *3.04*	17 *1.40*	13 *.57*	224 *3.67*	34 *.71*	16 *.45*	.3 *.02*	9.7 *.16*	264	222	184	38
	T. 33 S., R. 35 W.																	
284	SW SE sec. 16	111	do	Oct. 15	62	8.8	61 *3.04*	21 *1.73*	22 *.96*	217 *3.56*	71 *1.48*	22 *.62*	.6 *.03*	2.1 *.03*	317	238	178	60
	T. 33 S., R. 36 W.																	
287	SW SW sec. 14	115	do	do	61	.51	70 *3.49*	22 *1.81*	23 *1.02*	194 *3.18*	69 *1.44*	29 *.82*	.5 *.03*	53 *.85*	364	265	159	106

296	*T. 33 S., R. 37 W.* SW NE sec. 16	308	Rexroad and Meade	....	......	.07	72 *3.59*	33 *2.71*	40 *1.74*	215 *3.53*	176 *3.66*	20 *.56*	.4 *.02*	16 *.26*	509	315	176	139
301	SW SW sec. 28	107	Rexroad and/or Meade	Oct. 20	61	.46	63 *3.14*	15 *1.23*	18 *.80*	179 *2.94*	65 *1.35*	20 *.56*	.5 *.03*	18 *.29*	290	218	147	71
303	*T. 33 S., R. 38 W.* NW SW sec. 2	120	do	do	62	.06	64 *3.19*	28 *2.30*	42 *1.81*	240 *3.94*	133 *2.77*	16 *.45*	.6 *.03*	7.1 *.11*	411	274	197	77
305	SE NE sec. 6	180	Rexroad and Meade	do	62	18	54 *2.69*	22 *1.81*	32 *1.38*	233 *3.82*	67 *1.39*	16 *.45*	.6 *.03*	12 *.19*	338	225	191	34
308	NW NW sec. 21	120	Rexroad and/or Meade	do	61	.11	45 *2.24*	16 *1.32*	18 *.78*	199 *3.26*	26 *.54*	11 *.31*	.3 *.02*	13 *.21*	239	178	163	15
318	*T. 33 S., R. 39 W.* SE SE sec. 24	111	do	do	61	.03	51 *2.54*	14 *1.15*	8.7 *.38*	192 *3.15*	20 *.42*	4 *.11*	.4 *.02*	23 *.37*	217	184	158	26
324	*T. 34 S., R. 35 W.* SE SE sec. 34	140	do	Oct. 21	60	2.5	56 *2.79*	26 *2.14*	9.7 *.42*	235 *3.85*	34 *.71*	16 *.45*	.9 *.05*	18 *.29*	281	246	192	54
327	*T. 34 S., R. 36 W.* NW NE sec. 15	172	do	do	62	.37	79 *3.94*	17 *1.40*	10 *.45*	200 *3.28*	80 *1.66*	21 *.59*	.3 *.02*	15 *.24*	323	267	164	103
328	SW NW sec. 19	165	do	do	61	.30	80 *3.99*	16 *1.32*	17 *.75*	179 *2.94*	88 *1.83*	30 *.85*	.3 *.02*	26 *.42*	347	266	147	119
339	*T. 34 S., R. 38 W.* NE NE sec. 1	120	do	Oct. 20	60	.38	60 *2.99*	12 *.99*	14 *.63*	180 *2.95*	33 *.69*	28 *.79*	.4 *.02*	9.7 *.16*	248	199	148	51
340	NE NE sec. 4	167	do	do	63	2	66 *3.29*	18 *1.48*	15 *.65*	205 *3.36*	66 *1.37*	16 *.45*	.3 *.02*	14 *.22*	300	238	168	70
342	SE SE sec. 22	168	do	do	63	.56	71 *3.54*	11 *.90*	10 *.45*	217 *3.56*	29 *.60*	21 *.59*	.3 *.02*	7.5 *.12*	259	222	178	44
345	SW SW sec. 31	210	Rexroad	do	62	.76	64 *3.19*	12 *.99*	15 *.64*	204 *3.34*	46 *.96*	13 *.37*	.3 *.02*	8 *.13*	261	209	167	42
351	*T. 35 S., R. 36 W.* NE NE sec. 3	160	Rexroad and/or Meade	Oct. 21	60	1.5	59 *2.94*	19 *1.56*	6.7 *.29*	183 *3.00*	52 *1.08*	14 *.39*	.6 *.03*	18 *.29*	262	225	150	75
355	*T. 35 S., R. 38 W.* SW SE sec. 4	152	do	Oct. 20	61	.90	75 *3.74*	14 *1.15*	8.7 *.38*	199 *3.26*	45 *.94*	27 *.76*	.3 *.02*	18 *.29*	288	244	163	81

a. For Rexroad read Rexroad (?).
1. One part per million is equivalent to one pound of substance per million pounds of water or 8.33 pounds per million gallons of water.
2. Calculated.

The dissolved solids in samples of water collected in Grant, Haskell, and Stevens Counties ranged from 162 to 1,474 parts per million, and 57 of the samples contained between 160 and 400 parts per million of dissolved solids (Table 14). More than 84 percent

TABLE 14.—*Dissolved solids in samples of water from wells in Grant, Haskell, and Stevens Counties*

Dissolved solids (parts per million)	Number of samples			
	Grant County	Haskell County	Stevens County	Total
101–200	2	13	0	15
201–300	1	10	11	22
301–400	9	0	11	20
401–500	4	2	2	8
501–600	2	1	2	5
601–700	1	0	0	1
701–800	2	0	0	2
801–900	0	0	0	0
901–1,000	0	0	0	0
More than 1,000	4	0	0	4
Total	25	26	26	77

of the samples of water contained less than 500 parts per million and, therefore, are suitable for most ordinary uses.

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

In addition to the total hardness, the tables of analyses show the carbonate hardness and the noncarbonate hardness. The carbonate hardness is that caused by calcium and magnesium bicarbonates, and can be almost entirely removed by boiling. In some reports this type of hardness is called temporary hardness. The noncarbonate hardness is caused by sulphates or chlorides of calcium and magnesium, but it cannot be removed by boiling and has been called permanent hardness. With reference to use with soaps, there is no difference between the carbonate and noncarbonate hardness. In general the noncarbonate hardness forms harder scale in steam boilers.

Water having a hardness of less than 50 parts per million generally is rated as soft, and its treatment for the removal of hardness under ordinary circumstances is not necessary. Hardness between 50 and 150 parts per million does not seriously interfere with the use of water for most purposes; however, it does slightly increase the consumption of soap, and its removal by a process of softening is profitable for laundries or other industries using large quantities of soap. Waters in the upper part of this range of hardness will cause scale on steam boilers. Hardness above 150 parts per million can be noticed by anyone, and if the hardness is 200 or 300 parts per million it is common practice in some parts of the country to soften water for household use or to install cisterns to collect soft rain water. Where municipal water supplies are softened, an attempt generally is made to reduce the hardness to 60 or 80 parts

TABLE 15.—*Hardness of samples of water from wells in Grant, Haskell, and Stevens Counties*

Hardness (parts per million)	Number of samples			
	Grant County	Haskell County	Stevens County	Total
101–200	4	21	3	28
201–300	13	4	20	37
301–400	2	1	3	6
401–500	2	0	0	2
501–600	2	0	0	2
601–700	0	0	0	0
701–800	1	0	0	1
801–900	1	0	0	1
Total	25	26	26	77

per million. The additional improvement from further softening of a whole public supply is not deemed worth the increase in cost.

Water samples collected in Grant, Haskell, and Stevens Counties ranged in hardness from 144 to 809 parts per million. The hardness of 65 of the 77 samples of water ranged between 100 and 300 parts per million and the hardness of two samples of water exceeded 600 parts (Table 15).

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

The iron content of samples of water from Grant, Haskell, and Stevens Counties ranged from 0.02 to 18 parts per million. Most of the samples of water (55), however, contained between 0.1 and 2 parts per million of iron and only six samples contained more than 8 parts (Table 16).

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

Twenty-eight of the 77 samples collected in Grant, Haskell, and Stevens Counties contained one or more parts per million of fluoride (Table 17). Of these, 18 samples were from wells in Grant County,

TABLE 16.—*Iron content of samples of water from wells in Grant, Haskell, and Stevens Counties*

Iron (parts per million)	Number of samples			
	Grant County	Haskell County	Stevens County	Total
Less than 0.1	3	0	4	7
0.1–1.0	11	17	14	42
1.1–2.0	7	4	2	13
2.1–3.0	1	3	2	6
3.1–4.0	0	0	1	1
4.1–5.0	0	0	0	0
5.1–6.0	0	1	0	1
6.1–7.0	0	0	0	0
7.1–8.0	0	0	1	1
More than 8.0	3	1	2	6
Total	25	26	26	77

TABLE 17.—*Fluoride content of samples of water from wells in Grant, Haskell, and Stevens Counties*

Fluoride (parts per million)	Number of samples			
	Grant County	Haskell County	Stevens County	Total
Less than 0.5	2	10	11	23
0.5–0.9	5	11	10	26
1.0–1.4	4	5	5	14
1.5–1.9	7	0	0	7
2.0–2.9	6	0	0	6
More than 2.9	1	0	0	1
Total	25	26	26	77

five were from Haskell County, and five were from Stevens County. The fluoride content of the water samples ranged from 0.2 to 3 parts per million.

The fluoride content of water from wells in this area is illustrated in Figure 17. Most of the high-fluoride waters in southwestern

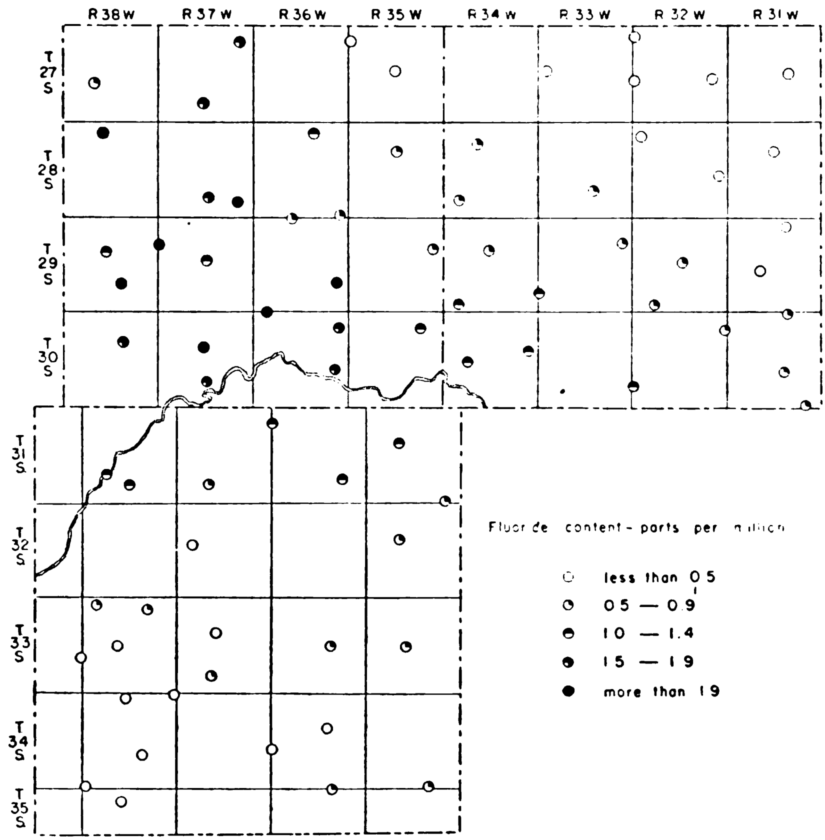


FIG. 17. Map showing the fluoride content of water from wells in Grant, Haskell, and Stevens Counties.

Kansas are believed to be derived from the Dakota formation. High-fluoride waters in other formations generally seem to be the result of contamination by waters from the Dakota formation. In Stanton and Morton counties (Latta, 1941, and McLaughlin, 1942) high-fluoride waters from the Dakota formation move eastward into the Tertiary sediments, causing the waters in them to have a relatively high fluoride content. The Tertiary sediments in Grant, Haskell, Stanton, and parts of Morton and Stevens Counties overlie the Dakota formation; hence water in the Tertiary and overlying sediments probably is contaminated by high-fluoride waters from the underlying Dakota formation. The fluoride content of the ground water south of the Cimarron River in Morton and Stevens Counties is much lower than it is north of the river. This probably is caused by (1) the absence of the Dakota formation south of Cimarron River (except in northern Stevens County), (2) the slope of the water table in the vicinity of the Cimarron River, which prevents ground water moving from areas north and west of the river to areas south and east of the river (see explanation, page 62), and (3) the dilution of the ground water by the relatively rapid recharge of the ground-water reservoir in the dune-sand areas south of the river. In northern Stevens County, where the Tertiary and Quaternary sediments are underlain by the Dakota formation and where there is no dune sand to facilitate recharge, the fluoride content of ground water is higher than in any other part of the county (Fig. 17).

The fluoride content of water from wells in northeastern Grant County and the northeastern half of Haskell County is very low. This seems to have been caused by the movement of low-fluoride water into this area from the Finney sand plain where the recharge of the ground-water reservoir is so rapid that the ground water has a low-fluoride content even though the water-bearing material is underlain by the Dakota formation. (Compare the fluoride content of ground water as shown in Figure 17 with the direction of movement of ground water as shown on Plate 1.)

Water for irrigation.—The suitability of water for irrigation is commonly believed to depend mainly on the quantity of soluble salts and on the ratio of the quantity of sodium to the quantity of sodium, calcium, and magnesium. The quantity of chloride may be large enough to affect the use of the water, and in some areas there may be other constituents, such as boron, in sufficient quantity to cause difficulty. In a discussion of the interpretation of analyses with reference to irrigation in southern California, Scofield (1933) states that if the concentration of dissolved salts is less than 700 parts per million there is not much probability of harmful effects in irrigation, but that if it exceeds 2,100 parts per million there is a strong probability of damage either to the crops, to the land, or to both. Water containing less than 50 percent sodium (the percentage being calculated as 100 times the ratio of the sodium to all the bases, in equivalents) is not likely to be injurious, but if it contains more than 60 percent sodium its use is inadvisable. Similarly, less than 142 parts per million of chloride is not objectionable, but more than 355 parts per million of chloride is undesirable. It is recognized that the harmfulness of irrigation water is so dependent on the types of land and crops, on the manner of use, and on the drainage that no definite limits can be adopted.

All but six of the samples of water collected in Grant, Haskell, and Stevens Counties were within the limits suggested by Scofield for waters safe for use in irrigation. Six of the water samples contained more than 700 parts per million of dissolved solids but none contained more than 2,100 parts of dissolved solids—the upper limit set by Scofield.

SANITARY CONSIDERATIONS

The analyses of water that are given in Tables 11, 12, and 13 show only the amounts of dissolved mineral matter in the water and do not indicate the sanitary quality of the water. An abnormal amount of certain mineral matter, such as nitrate, however, may indicate pollution of the water.

Much of the population of Grant, Haskell, and Stevens Counties is dependent upon private water supplies from wells, and every precaution should be taken to protect these supplies from pollution. A well should not be constructed where there are possible sources of pollution, such as barnyards, privies, and cesspools, and every well should be tightly sealed to a level somewhat below that of the water table. Dug wells are more likely to be contaminated from surface water than are drilled wells, chiefly because dug wells generally are not effectively cased or sealed at the surface. Drilled wells generally are well protected by the casing, although many are poorly sealed at the top.

QUALITY IN RELATION TO WATER-BEARING FORMATIONS

The quality of water from the principal water-bearing formations in Grant, Haskell, and Stevens Counties is shown in Figure 18 and is discussed below.

Pliocene and Pleistocene deposits.—The Pliocene deposits comprising the Laverne and Rexroad (?) formations and Pleistocene deposits comprising the Meade formation yield water to most of the wells in the Grant-Haskell-Stevens area, and many of the wells obtain water from two or more of these formations. The ground water in the sediments above the Dakota formation may be con-

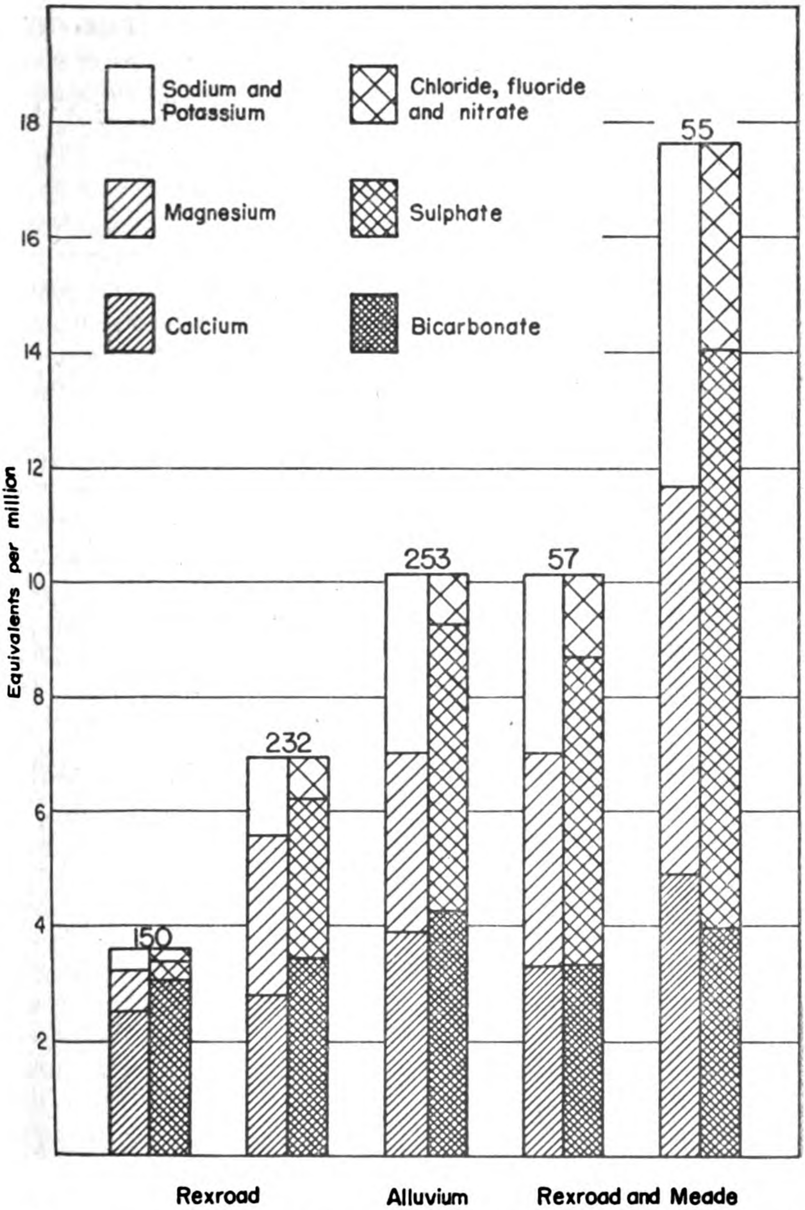


FIG. 18. Analyses of waters from the principal water-bearing formations in Grant, Haskell, and Stevens Counties.

sidered a single body of water because the water-bearing formations above the Dakota are lithologically similar and because there are no impermeable beds that separate entirely the water of one formation from that of another. For these reasons, the quality of water in all the Pliocene and Pleistocene formations will be discussed in one section. All but three wells listed in Tables 11, 12, and 13 get water from the Rexroad (?), Meade, or Laverne formations; hence the discussion of quality of water in the preceding pages applies almost entirely to water from these formations.

The quality of water in the Pliocene and Pleistocene formations is not uniform throughout the area but has been modified in different areas by different conditions. As explained above, the fluoride content (Fig. 17) of water from these formations has been modified by recharge and by lateral movement of ground water. In general, the ground water in Haskell County is softer than that in Grant and Stevens Counties (Table 15), and the ground water in Grant County is of poorer quality than in the remainder of the area.

Alluvium.—Samples of water were collected from three wells in the alluvium of the Cimarron River (wells 106, 119, and 253, Tables 11 and 13). The total dissolved solids in these waters ranged from 337 to 729 parts per million and the hardness ranged from 220 to 402 parts per million. The fluoride content of waters from these wells was relatively high (1.1, 1.6, and 1.8 parts per million).

GEOLOGIC FORMATIONS AND THEIR WATER-BEARING PROPERTIES

PERMIAN SYSTEM

UNDIFFERENTIATED REDBEDS

Character.—The undifferentiated redbeds of Permian age are not exposed in Grant, Haskell, and Stevens Counties, and the only available data concerning these beds are the logs of the many gas wells that have been drilled in this area. Therefore, no detailed lithologic description of them can be given. The redbeds encountered in these wells consist principally of red shale, siltstone, and sandstone containing interbedded salt, gypsum, anhydrite, and dolomite.

Distribution and thickness.—The Permian redbeds underlie all of Grant, Haskell, and Stevens Counties but they do not crop out in this area. The nearest outcrop is in southeastern Meade County about 20 miles from the southeast corner of Haskell County. The total thickness of redbeds exposed in Meade County is more than 100 feet (Frye, 1942, p. 93). There is an erosional unconformity between the Permian redbeds and the overlying Cretaceous or younger sediments, and the thickness of the redbeds in this area, therefore, is variable. Most of the oil and gas tests in this and adjacent areas penetrate between 1,200 and 1,600 feet of redbeds.

Age and correlation.—Norton (1939) and others have determined by the study of well cuttings that the Permian redbeds underlying Grant, Haskell, and Stevens Counties and adjacent areas include representatives of all the formations recognized by the State Geological Survey of Kansas from the lower Ninnescah shale to the Taloga formation.

Water supply.—No water is obtained from the redbeds in Grant, Haskell, and Stevens Counties. These beds yield some water to artesian wells in Morton County, but the water has a relatively high mineral content and is not suitable for most uses. Potable water is reported to have been encountered in a few gas-test wells in the redbeds in Grant and Stevens Counties, but no chemical analyses of the waters are available.

JURASSIC (?) SYSTEM

MORRISON (?) FORMATION

Several test holes drilled by the State and Federal Geological Surveys in Stanton, Morton, and Hamilton Counties (Latta, 1941, and McLaughlin, 1942 and 1943) encountered deposits of green, rusty-brown, and maroon clays that probably are a part of the Morrison formation. A test hole in Hamilton County penetrated nearly 100 feet of these deposits. The formation also crops out at Two Buttes in eastern Colorado and has been encountered in test holes in Norton County near the Kansas-Nebraska line.

Test hole 9 in northwestern Grant County encountered 6.5 feet of greenish-gray clayey shale before entering the Permian redbeds. This material is believed to be a part of the Morrison formation and probably represents the easternmost extension of this formation in southwestern Kansas. It has not been encountered in test holes in Kearny, Finney, or eastern Morton Counties nor in any other part of the Grant-Haskell-Stevens area. No wells in this area obtain water from these beds.

Cretaceous System

For a review of the history of the naming of the early Cretaceous units in Kansas the reader is referred to a report by Waite (1942, pp. 135-137.) Plummer and Romary (1942, p. 319) have redefined and subdivided the Dakota formation according to the present usage of the State Geological Survey of Kansas. The usage of the terms Cheyenne sandstone, Kiowa shale, and Dakota formation is followed in this report.

The Cheyenne and Kiowa formations crop out in Kiowa and Comanche Counties and the Dakota crops out in many isolated areas in the southwestern part of the state. All pre-Graneros Cretaceous sediments containing marine fossils are considered by the State Geological Survey of Kansas to be the Kiowa shale. The nonmarine sediments below the Kiowa shale are called Cheyenne sandstone and the nonmarine sediments above are called the Dakota formation. Inasmuch as the dividing line between these formations is based on paleontological evidence, it is in many places difficult to determine the contact between the Kiowa shale and the Cheyenne or Dakota formations. It is even more difficult, if not impossible, to determine accurately the contacts from test-hole cuttings; nevertheless, an attempt has been made in this report (Pl. 3) to differentiate the three formations by the lithology of well cuttings. It is realized that the exact contacts cannot be determined because of the absence of remains of fossils in the well cuttings, but it is believed that the contacts shown in Plate 3 are approximately correct. Test holes in this area penetrated approximately 100 feet of brown to buff sandstone and varicolored clay which were referred to the Dakota formation, but in some places a few feet of sandstone at the base may represent a sandstone lens in the Kiowa shale. Beneath the Dakota formation the test drill penetrated a thick section of gray to black shale which was called the Kiowa shale. Below this, a few test holes penetrated fine to coarse white quartz sand which was called Cheyenne sandstone (Pl. 3).

CHEYENNE SANDSTONE

Character.—The Cheyenne sandstone does not crop out in Grant, Haskell, or Stevens Counties, but it was encountered in several test holes in Grant and Haskell Counties (Pl. 3). The nearest areas of outcrop of the Cheyenne are in southeastern Colorado and southern Kansas where it is principally white to yellow quartz sandstone of medium to coarse grain. The formation also contains subordinate amounts of shale, and in Kiowa County it is conglomeratic near the base (Latta, in press). The material encountered in the test holes drilled by the State and Federal Geological Surveys was principally white very fine- to coarse-grained quartz sandstone. The sandstone was friable to tightly cemented and contained a small amount of gray-green clay.

Distribution and thickness.—The Cheyenne sandstone underlies most of the north half of Grant and Haskell Counties (Pl. 3 and Fig. 8), but it has not been encountered in test holes in Stevens County. The Cheyenne also has been encountered in test holes in northwestern Morton County, northern Stanton County, and in Hamilton County, and crops out in Cimarron County, Oklahoma, Baca County, Colorado, and in Kiowa and Comanche Counties, Kansas. The Cheyenne sandstone ranges in thickness from a featheredge to more than 100 feet in the northwestern part of the area. The maximum thickness penetrated by test holes in this area was 77 feet. The Cheyenne attains a thickness of 70 feet in Cimarron County, Oklahoma (Schoff and Stovall, 1943); 50 feet at Two Buttes, in southeastern Colorado; and 95 feet in southern Kiowa County, Kansas (Latta, in press).

Age and correlation.—The Cheyenne sandstone does not crop out in the Grant-Haskell-Stevens area, and no fossils were encountered in the test holes that penetrated the formation; hence the age of these beds must be determined by correlation with lithologically similar beds in adjacent areas. These beds are very similar in lithology to the lower member (Cheyenne sandstone member) of the Purgatoire formation of southeastern Colorado, northeastern New Mexico, and the panhandle of Oklahoma, and they resemble closely the Cheyenne sandstone of Kiowa and Comanche Counties, Kansas. The stratigraphic position of the sandstone below a dark shale that is believed to be correlative with the Kiowa shale and with the Kiowa shale member of the Purgatoire formation also aids in its correlation.

Marine fossils collected from the Cheyenne sandstone member of the Purgatoire formation in Texas and Cimarron Counties, Oklahoma, are believed by Stanton (Schoff, 1939, p. 55) and Bullard (1928, p. 116) to be of Washita (Lower Cretaceous) age.

Origin.—A marine origin of the Cheyenne sandstone member of the Purgatoire formation in Texas and Cimarron Counties, Oklahoma, is implied by the presence of marine fossils in those beds. In Comanche and Kiowa Counties, Kansas, however, a nonmarine origin of the Cheyenne sandstone is indicated by discontinuous bedding, cross-lamination, the absence of marine fossils, and the presence of land plants. The Cheyenne sandstone in Kansas is believed to be of continental origin, and all Lower Cretaceous sediments containing marine fossils are referred to the Kiowa shale by the State Geological Survey of Kansas.

Water supply.—No wells in the Grant-Haskell-Stevens area obtain water from the Cheyenne sandstone, but a few wells obtain water from these beds in southwestern Stanton County (Latta, 1941, p. 72) and in northwestern Morton County (McLaughlin, 1942, p. 76). The Cheyenne sandstone also yields water to several flowing wells in the vicinity of Coolidge in Hamilton County. The Cheyenne is overlain in all of Grant and Haskell Counties by thick deposits of more permeable water-bearing material, and wells can obtain adequate quantities of water without being drilled into the underlying Cheyenne (Pl. 3).

KIOWA SHALE

Character.—The Kiowa shale does not crop out in the Grant-Haskell-Stevens area but it has been encountered in several test holes and is known to underlie the northern part of Grant and Haskell Counties (Pl. 3). The Kiowa shale encountered in test holes in Grant and Haskell Counties consists almost entirely of dark-gray to black laminated shale which is in part calcareous. A few test holes encountered thin beds of fine-grained sandstone. At the type locality in Kiowa County the Kiowa shale contains several thin beds of fossiliferous limestone, but none of these were noted in the well cuttings from test holes in Grant and Haskell Counties. The Kiowa shale, where exposed, generally is conformable on the Cheyenne sandstone, but there are a few seemingly local disconformities.

Distribution and thickness.—The Kiowa shale underlies the northern part of Grant and Haskell Counties (Fig. 8 and Pl. 3). Test holes drilled by the State and Federal Geological Surveys indicate that it also underlies the northern part of Meade County, most of Gray, Finney, Kearny, and Hamilton Counties, northern and western Stanton County, and northwestern Morton County. The nearest outcrops of the Kiowa shale are in Clark, Kiowa, and Comanche Counties.

The Kiowa shale in Grant and Haskell Counties ranges in thickness from a featheredge to 133 feet in test hole 18 (log 18). The shale ranges in thickness from 67 to 115 feet in Stanton County (Latta, 1941), 35 to 85 feet in Morton County, 49 to 131 feet in Hamilton County, and has a maximum reported thickness of 308 feet in Kiowa County (Latta, in press).

Age and correlation.—No fossils were obtained from cuttings from the test holes in this area; hence, the shale must be correlated by lithology and stratigraphic position. The predominance of black shale in this formation, together with its position above a white sandstone (Cheyenne) and below brown sandstone and varicolored clay (Dakota), indicates that the bed of shale is equivalent to the Kiowa shale in Kiowa County.

Water supply.—The Kiowa shale yields no water to wells in Grant, Haskell, and Stevens Counties. The formation is relatively impermeable and is overlain by thick deposits of water-bearing materials that yield adequate quantities of water to wells.

DAKOTA FORMATION

Character.—The character of the Dakota formation in this area was determined by the study of cuttings from 28 test holes that penetrated these beds. The formation consists principally of buff, yellow-brown, and brown sandstone and varicolored clay. The sandstone generally consists of very fine-grained to medium-grained quartz sand which has been coated primarily by iron oxide. Concretions of ironstone and fragments of charcoal are common. The clay ranges in color from gray to various shades of brown, red, and purple and generally is sandy. Where the Dakota formation crops out in adjacent areas the sandstone usually is poorly bedded, and in places it is strongly ripple-marked and cross-bedded. The cementing material in the sandstones generally is iron oxide, although in parts of Kearny and Morton Counties silica is the principal cement.

The Dakota formation in this and adjacent areas is about one-half sandstone and one-half clay. Test holes in the Dakota formation in Hamilton County encountered 55 to 60 percent sandstone, and outcrops of the Dakota formation in Cimarron County, Oklahoma, consist of about three-fourths sandstone and one-fourth clay (Schoff and Stovall, 1943). In north-central Kansas the dominant rock constituents of the Dakota formation are clay, shale, and siltstone instead of sandstone (Plummer and Romary, 1942).

Distribution and thickness.—The Dakota formation underlies all of Grant County, all but the southeastern corner of Haskell County, and a part of northern Stevens County (Pl. 3 and Fig. 8). The formation also underlies northwestern Seward County, much of Gray, Finney, Kearny, Hamilton, and Stanton Counties, and the northern half of Morton County. It is absent in southern Morton County and in much of Stevens, Seward, and Meade Counties.

The thickness of the Dakota formation in the Grant-Haskell-Stevens area ranges from a featheredge at its southern limit to more than 100 feet. Test hole 30 (log 30) encountered 152 feet of Dakota. After deposition of the Dakota formation, the area was eroded so that probably there is not a complete section of the Dakota formation in this area except in northeastern Haskell County where the Dakota is overlain by the Graneros shale. Test hole 6 (log 6) which was drilled in that area (Pl. 3) did not penetrate the entire formation. The Dakota is thin near its southern limit and where it has been eroded in Pliocene drainageways (Fig. 10). In test hole 7 (log 7) in northwestern Haskell County, which was drilled in one of these drainageways, the Dakota was absent and the drill encountered Kiowa shale below the undifferentiated Pliocene and Pleistocene deposits.

The exposed thickness of the Dakota formation is about 30 feet in Hamilton County, 49 feet in Kiowa County (Latta, in press) and 185 feet in Cimarron County, Oklahoma (Schoff and Stovall, 1943). These beds seem to thicken toward the northeast, inasmuch as Plummer and Romary (1942, p. 330) report more than 300 feet of Dakota in Lincoln County in north-central Kansas.

Age and correlation.—The age and correlation of the Dakota formation are discussed briefly under the introduction to the section on the Cretaceous system on page 104.

Water supply.—The Dakota formation yields little or no water to wells in Grant, Haskell, and Stevens Counties. It is overlain in this area by thick deposits of saturated materials of Pliocene and Pleistocene age which yield adequate supplies of water to most wells. A few of the irrigation wells in northwestern Grant County may have been drilled a few feet into the Dakota formation and they may obtain a small part of their water from it, but the quantity of water derived from this formation probably is small.

The Dakota is an important water-bearing formation in some areas adjacent to Grant, Haskell, and Stevens Counties. The beds of sandstone in the Dakota formation yield water to many domestic and stock wells in southern Hamilton County, in western and southwestern Stanton County (Latta, 1941, p. 79), and in northwestern Morton County. Water encountered in the Dakota generally is under artesian pressure because the water-bearing sandstones are overlain by relatively impermeable clay within the Dakota formation or by shale of the overlying Graneros shale. In the Arkansas Valley in western Hamilton County there is one flowing artesian well that obtains water from the Dakota.

GRANEROS SHALE

Test hole 6 at the northeast corner of Haskell County encountered 31.5 feet of dark-gray to black fissile shale which probably is a part of the Graneros shale. Cretaceous beds younger than the Dakota formation have been encountered in many test holes in Gray and Finney Counties. Latta (1944, p. 40) reports a buried ridge of Upper Cretaceous rocks in southern Gray County which trends northwest-southeast, and a north-south ridge extending from near Pierceville to the northeastern corner of Haskell County. The Graneros shale encountered in test hole 6 is a part of this ridge and forms its southern edge. The Graneros shale probably pinches out in a relatively short distance south and west, for it was not encountered in any other test hole in the Grant-Haskell-Stevens area. The shale is relatively impermeable and probably yields no water to wells in this area.

TERTIARY SYSTEM

PLIOCENE SERIES

Laverne formation

The Laverne formation was named and described from a locality in Harper County, Oklahoma, by V. V. Waite in an unpublished manuscript which was quoted by Gould and Lonsdale (1926a). These beds were studied in 1889 by Cragin (1891) who correlated them with the "Loup Fork beds." Case (1894, pp. 143-147) visited the area in 1893 and made a collection of the flora. In 1902, Adams (1902, pp. 301-303) described similar rocks in the Cimarron Valley in southeastern Seward County and suggested that they were of Tertiary age and were equivalent to the beds described by Cragin. More recently the flora and fauna of the Laverne deposits in Beaver County, Oklahoma, were described by Chaney and Elias and by Hesse (Chaney and Elias, 1936, pp. 16-23 and 47-72). Smith (1940, pp. 37-39) measured a section of the Laverne formation in Seward County and tentatively assigned these beds to early Pliocene. More detailed studies of these beds have been made recently by Frye and Hibbard (1941), Frye (1942), and Byrne and McLaughlin (in press).

Character.—Where the Laverne formation crops out in the Cimarron Valley in Meade and Seward Counties it consists primarily of shale, sand, and chalky sandstone containing caliche and thin-bedded limestone. Test holes drilled in that area, however, indicate that only a small part of the formation is exposed and that sand and gravel are the dominant constituents of the formation. The proportion of clay and shale seems to increase toward the west.

The sand and gravel are made up of materials derived from igneous rocks. The gravel consists principally of fragments of quartz and feldspar; the sand is primarily quartz but is in part feldspar. A few beds of sand contain abundant flakes of mica. The beds of sand generally are moderately well-sorted and are in places cross-bedded.

The clay and shale range from dark blue gray to light green, pink, and maroon but generally are gray. The clay is massive, blocky, and poorly bedded, whereas the shale is thinly bedded.

The calcareous sandstone is soft, friable, poorly bedded, very porous, and is fine-grained to very fine-grained. It can be cut easily with a saw and has been quarried locally for building stone. These beds generally are cream-colored to buff but weather to brown, dark gray, and nearly black. They contain abundant ostracodes and some remains of fish. Sections of the Laverne formation measured by Claude W. Hibbard and the writer are given below and on page 116.

Section of Laverne formation, sec. 25, T. 34 S., R. 31 W., Seward County

Laverne formation	Thickness, feet
15. Sandstone, fine to coarse, light tan to buff	2
14. Shale, gray, poorly bedded	5
13. Caliche, sandy, very hard, white. Weathers to smooth round boulders	.5
12. Shale, thin-bedded, varicolored. Predominantly yellowish near base, gray in middle, and pink to maroon near top	6.1
11. Sandstone, fine-grained, compact, hard. Forms prominent ledge. Weathers to large disc-shaped blocks having pitted surface. Top 4 inches contains caliche	3
10. Alternating thin beds of gray, tan, and green shale and buff friable sandstone. Beds contain a few white limy zones. Abundant crystals of gypsum in upper part	19.2
9. Shale, dark gray, containing lenses of thin buff sandstone.	1.3
8. Sandstone, medium-grained, white, containing thin partings of dark-gray shale	.6

7.	Caliche, dense, hard, white	.3
6.	Shale, massive, light gray to blue gray	3.6
5.	Sand, fine to coarse, yellowish buff to rusty brown, and gravel, fine; unconsolidated to moderately well consolidated. Forms massive ledge where consolidated	12
4.	Silt, sandy, and clay	12
3.	Sandstone, fine-grained and very fine-grained, very porous, highly calcareous, even-bedded, cream-colored to light tan, containing silt and lesser amounts of medium sand and clay. In places it is case-hardened. Locally known as "saw rock." Contains abundant ostracodes	21
2.	Shale, silty, calcarous, diatomaceous, light buff to yellow tan, containing sand	20–30
1.	Clay, blue gray	20
	Thickness of Laverne formation exposed	126.6–136.6

The lithology of the Laverne formation in Grant, Haskell, and Stevens Counties is known only from test-hole cuttings, and because of the lithologic similarity of the Laverne and overlying Tertiary and Quaternary formations it is not possible to recognize the upper limit of the Laverne with certainty. All the Tertiary and Quaternary deposits (except dune sand and alluvium), therefore, are shown as undifferentiated Pliocene and Pleistocene deposits on Plate 3. Inasmuch as the thickness of the Kingsdown, Meade, and Rexroad (?) formations probably is not over 350 or 400 feet, all Tertiary sediments more than 400 feet below land surface probably are a part of the Laverne formation. In Grant, Haskell, and Stevens Counties the Tertiary sediments that are more than 400 feet below land surface consist mainly of sand and gravel, although a few test holes (34, 37, 39, 40, and 45) encountered much silt and clay below that depth.

Distribution and thickness.—The only known outcrops of the Laverne formation are in Meade and Seward Counties, Kansas, and in Beaver and Harper Counties, Oklahoma, but the subsurface extent of this formation probably is much greater than is implied by the limited areas of outcrop. The Laverne probably does not extend beyond Crooked Creek in Meade County where Permian rocks are at or near the surface and are overlain by the Ogallala formation. Similarly, these beds probably pinch out in Morton, Stanton, and Hamilton Counties where Cretaceous and older rocks are at or near the surface and are in many places overlain by the Ogallala formation. The Laverne probably underlies all of the Grant-Haskell-Stevens area except western Grant County, northwestern Stevens County, and northeastern Haskell County.

If it is assumed that the thickness of the overlying formations does not exceed 400 feet, then the greatest thickness of the Laverne formation encountered in test holes in this area would be approximately 300 feet in test hole 38 on the Stevens-Seward line. The Laverne probably thins westward and may be absent in the western part of the area. Test holes drilled in the area of outcrop of the Laverne indicate that the maximum thickness of the Laverne formation in that area may be as much as 485 feet. The thinnest section of Laverne encountered was about 350 feet.

Age and correlation.—Many years ago, remains of fish, turtle, and plants were taken from a quarry in the Laverne formation on the Nieland ranch in sec. 24, T. 34 S., R. 31 W., in Seward County, but the specimens were not identified. Since that time no identifiable remains of vertebrates have been reported from these beds in Kansas. Many ostracodes have been found in the Laverne in the same locality (Frye and Hibbard, 1941, pp. 401, 402), but they were not sufficiently diagnostic to date the beds.

In 1940, S. W. Lohman collected material containing diatoms from the Laverne formation on the Nieland ranch. The diatoms were studied by K. E. Lohman of the U. S. Geological Survey, who recognized 34 species and varieties (listed in Frye and Hibbard, 1941, pp. 402, 403). The diatom flora contained many species that now live in saline lake waters, indicating that the diatomaceous marl was deposited under similar conditions. A molluscan fauna taken from beds above the diatomaceous marl, however, is believed by Leonard and Franzen (1944, p. 31) to have lived in fresh-water lakes. The best age determination that could be made from the flora was upper Miocene to lower Pleistocene. In a letter dated April 1, 1941 (Frye and Hibbard, 1941, p. 403), K. E. Lohman stated:

> This flora cannot be correlated with the diatom-bearing beds in Beaver County, Oklahoma . . . as only 12 percent of the present flora occurs in the Beaver County material. Eighteen percent of the present flora occurs in the Ogalalla formation of Wallace County, Kansas . . . but this again is too small a percentage for a comparison, particularly as it does not include the most significant species.

In the area of outcrop of the Laverne formation in Kansas, these beds are overlain by the post-Ogallala (?) Rexroad (?) formation. Inasmuch as the Laverne underlies Rexroad (?) and is lithologically dissimilar to the nearby middle Pliocene Ogallala formation, the Laverne formation probably is pre-Ogallala or lower Pliocene.

There is not sufficient fossil evidence at present to correlate the beds in Kansas with the Laverne formation in Oklahoma, but the similarity in lithology and structure of the beds in both areas indicate that they are equivalent. According to Hesse (Chaney and Elias, 1936, p. 68) the fauna from the beds in Oklahoma is most closely related to the Clarendon fauna of Texas and more distantly to the Esmeralda, Big Springs Canyon, Burge, and other faunas of lower Pliocene age.

Water supply.—Few wells in Grant, Haskell, and Stevens Counties obtain water from the Laverne formation, because adequate quantities of water generally can be obtained from the overlying beds. A few of the deeper irrigation wells may obtain some water from the Laverne, but most of the irrigation wells are in western Grant County where the Laverne is very thin or absent. Some of the deep wells that were used to supply water for drilling gas wells probably obtained part of their water from beds in the Laverne formation.

The Laverne formation contains thick beds of sand and gravel in its lower part in much of the Grant-Haskell-Stevens area and therefore is a potential source of large quantities of ground water.

*Ogallala formation**

The Ogallala formation of middle Pliocene age does not crop out in Grant, Haskell, or Stevens Counties, but it may be present in the subsurface. The nearest known outcrops of the Ogallala formation are in southern Hamilton County, in the vicinity of Point of Rocks in the Cimarron Valley in Morton County, along Crooked Creek in Meade County, and along the Beaver River in Texas County, Oklahoma. It is doubtful if the Ogallala in any of these areas extends into the Grant-Haskell-Stevens area except perhaps in southern Stevens County. The Ogallala does not crop out in Stevens County and cannot be identified from drill cuttings.

*Rexroad (?) formation**

The Rexroad formation was named by Smith (1940, pp. 95-99) from exposures along tributaries of Crooked Creek on the Rexroad ranch in sec. 22, T. 33 S., R. 29 W., Meade County, Kansas. In 1941, these beds were designated the Rexroad member (upper Pliocene) of the Ogallala formation by Frye and Hibbard (1941, p. 407) for the following reasons:

(1) . . . on the basis of both surface and subsurface data, it seems evident that in parts of the basin there was continuous sedimentation from

* See note by R. C. Moore on page 33.

middle Pliocene through upper Pliocene time, and in these localities no break is distinguishable; (2) the deposits were trapped in a local basin, and, although there are deposits of equivalent age outside this general area, they are not stratigraphically continuous with the deposits of the Rexroad type locality, and are not genetically related to them; and (3), as Smith (1940, pp. 95-97) has pointed out, the lithology of the Rexroad beds for the most part is indistinguishable from the middle Pliocene part of the Ogallala formation. For these reasons the Rexroad beds do not constitute a mappable unit, except partially in the vicinity of the type locality, where the upper contact, but not the lower, can be mapped.

Various studies indicate that the Rexroad deposits occur stratigraphically above the "Algal limestone" which represents the top of the Ogallala formation. In a recent paper (Elias, 1945) by members of the geological surveys and the museums of vertebrate paleontology at the Universities of Kansas and Nebraska it was proposed—

that Blancan be used to serve as a provincial time zone for beds and faunas in the Great Plains region younger than the "Algal limestone" and older than beds of undoubted Pleistocene age.

The Rexroad deposits, therefore, appropriately may be considered as a distinct stratigraphic unit.

Much additional work was done on the beds of the Rexroad in the summers of 1943 and 1944 by Claude W. Hibbard and the writer who measured sections of these beds in Meade County and on Rexroad (?) in areas farther west. We concluded from these studies that sedimentation seemingly was discontinuous from middle Pliocene through upper Pliocene time inasmuch as the Rexroad or Rexroad (?) is nowhere known to lie on Ogallala. Where the base of the Rexroad (?) appears, it is underlain by the Laverne formation. The lower part of the Rexroad (?) formation comprises sand and gravel channeled deeply into the underlying beds. We also concluded that the deposits are widespread, inasmuch as typical Rexroad beds crop out in the Cimarron Valley of Meade County, Rexroad (?) beds occur westward to Morton County, and all these have distinctive lithology.

For these reasons, the Rexroad—plus Rexroad (?)—is judged to be a mappable unit and in this report and a forthcoming one on Seward County (Byrne and McLaughlin, 1946) it will be classed as a formation.

Character.—The Rexroad (?) formation comprises sand and gravel in the lower part, sand and silt containing nodules and thin stringers of caliche in the middle, and silt and clay in the upper part.

The sand and gravel are mostly grains and pebbles of igneous rocks which probably were derived from the Rocky Mountains. They range from fine to coarse but generally are not as coarse as the sand and gravel in the overlying Meade formation. In most places the sand and gravel are in part cemented by calcium carbonate to form "mortar beds" which crop out as prominent ledges in parts of the Cimarron Valley. "Mortar beds" of the Rexroad (?) differ in general from similar beds of the Ogallala formation in that they contain less calcium carbonate, are coarser grained, consist mainly of materials derived from igneous rocks, and, in addition, their weathered surface is smoother. The "mortar beds" of the Rexroad (?) resemble more closely those in the sand and gravel of the Meade formation, although the "mortar beds" of the Meade generally are much coarser grained.

Sand and gravel of the Rexroad (?) formation grade upward into fine sand and silt containing a small amount of clay. In the zone of transition the clay and silt bind the pebbles of sand and gravel to form a moderately well-consolidated bed which weathers to a nearly vertical ledge. The material in this zone is poorly sorted and "dirty," whereas the underlying beds are more uniform, well sorted, and "clean."

The middle part of the formation generally consists of reddish silt and sand which in many places contain clay. These beds are poorly sorted, moderately well consolidated, and contain many nodules and thin stringers of caliche which give them a red and white mottled appearance. The caliche nodules usually are relatively soft but in places they are hard and are more resistant to erosion than the surrounding rock material, causing the accumulation of caliche rubble on eroded surfaces.

The upper part of the formation consists of better sorted and finer grained material, and generally contains one or more beds of brown to gray-green clay and one or more beds of caliche ranging in thickness from a few inches to about 2 feet. One 2-foot bed of caliche near the top of the formation is cherty and is extremely hard, and weathers to characteristically irregular, rough, pitted boulders. In many places this bed has been removed by the deep channeling of the overlying Meade formation (Pl. 9).

Except for the two small outcrops in Grant and Stevens Counties, lithology of the Rexroad (?) formation in the Grant-Haskell-Stevens area is known only from well cuttings. Where these beds crop out in this area they underlie the basal sand and gravel of the Meade formation and consist of brown blocky clay and buff-red silty sand containing nodules and stringers of caliche. The lithology of these deposits is characteristic of part of the middle and upper parts of the Rexroad (?) formation. Well cuttings indicate that the lower part of the formation in this area consists primarily of sand and gravel.

Several sections of the Rexroad (?) formation as measured by Claude W. Hibbard and the writer are listed below. The first was measured in one of the very few places where both the top and bottom of the Rexroad (?) formation are exposed, although in this section some upper beds seem to have been removed by channeling of the overlying Meade formation (Pls. 9 and 11).

Section of Rexroad (?) and Laverne formations in sec. 7, T. 35 S., R. 30 W., Meade County

	Thickness, feet
Rexroad (?) formation	
19. Sand and gravel; coarse; locally cemented with calcium carbonate to form "mortar beds"	11
Rexroad (?) formation	
18. Silt, fine sandy, buff red, containing caliche	13.5
17. Silt, sandy, light brown to red, containing caliche. The caliche near the top is nodular and cherty	14
16. Silt, fine sandy, buff red to red, containing caliche. Material near the middle cemented with calcium carbonate	14
15. Caliche, siliceous, massive, very hard, white	2
14. Sand, fine to coarse, tan to buff red, containing irregular nodules and bands of caliche and much silt. Becomes finer toward top. Most of the silt and caliche are in the upper part	20
13. Sand and gravel; coarse; moderately well sorted; cross-bedded. The pebbles are predominantly igneous rocks but some are abraded fragments of caliche. The upper two-thirds of the bed is cemented with calcium carbonate to form "mortar beds." The "mortar beds" form prominent ledges and cap several low mesas and have been eroded into long rectangular blocks	22.5
Laverne formation	
12. Clay, brown, containing lenses of rust-stained quartz sand. Weathers to gray green. Contains fragments of fossil camel	17
11. Sand, fine to medium, gray to yellow, cemented with calcium carbonate to form "mortar beds." Bed dips eastward	15
10. Sand and gravel; unconsolidated; yellow to rusty	5.5
9. Clay, silty, blocky, tan, sandy at top	2.5
8. "Mortar beds," thin, crinkly, containing fine to medium sand	0.2
7. Sand, fine, and silt; pinkish	1
6. Sand, fine to medium, yellowish tan, containing a few pebbles of coarse sand and gravel. Upper part cemented with calcium carbonate to form "mortar beds." Dips west-southwestward	5
5. Clay, gray	8

4. Sandstone, massive, soft, friable, highly calcareous, very porous, tan to buff, containing very fine sand, silt, and a few grains of medium sand. Contains abundant remains of ostracodes. Locally known as "saw rock"	21
3. Clay and silt; containing fine sand	2
2. Sand, fine to coarse, yellow to rusty	2
1. Sand, fine, tan	1
Thickness of Rexroad (?) formation	86
Thickness of Laverne formation	80.2

Section of Rexroad (?) formation in sec. 19, T. 34 S., R. 30 W., Meade County, and sec. 24, T. 34 S., R. 31 W., Seward County

	Thickness, feet
Rexroad (?) formation	
8. Caliche, cherty, very hard, white. Forms prominent bench	2
7. Unexposed. Covered by caliche rubble from above. Gentle slope indicates silt or clay	10
6. Clay, silty and fine sandy, gray brown to buff, containing thin impersistent layers of caliche	21
5. Clay and silt; fine sandy; buff to pink; containing nodules and thin stringers of caliche	16.5
4. Sand and gravel; containing abraded pebbles of caliche and small lenses of clay	7.5
3. Clay, light brown	2
2. Clay, blue gray, containing caliche. Weathers to rusty brown	2
1. Sand and gravel; coarse. Pebbles are predominantly igneous rocks but some are abraded caliche. Base not exposed	9-25
Thickness of Rexroad (?) formation exposed	70-86

Section of Rexroad (?) formation in SE¼ sec. 35 and SW¼ sec. 36, T. 32 S., R. 33 W., Seward County

	Thickness, feet
Terrace deposits	
8. Sand and gravel; coarse; containing cobbles as large as 5 inches in diameter	3
Meade formation	
7. Sand and gravel; coarse; cemented near base with calcium carbonate to form "mortar beds"	20
Rexroad (?) formation	
6. Clay, blocky, gray green and brown. Grades upward into fine-grained micaceous sand. The sand is cemented in some places to form a 4-inch "mortar bed"	3.8
5. Shale, calcareous, thin-bedded, white, containing fine sand and remains of ostracodes	0-0.5
4. Silt, fine sandy, tan at base to green at top. Varies from massive at base to blocky in middle to thin-bedded at top. Top part grades laterally into a varved diatomaceous marl	4
3. Clay, blocky, in part sandy, brown to gray	4

2. Sand, fine, and silt; poorly sorted; consolidated; tan to reddish brown; containing nodules of caliche. Lower 5 feet is mostly fine sand containing clay as a binder. Middle 4 feet mostly tan to brown silt containing irregular nodules of caliche which give the rock a mottled appearance. Upper 4 feet predominantly massive fine-grained poorly consolidated tan to red-brown sand.	13
1. Sand and gravel; coarse	15
Thickness of Rexroad (?) formation exposed	40.3

Section of Rexroad (?) formation near Ulysses bridge along south bluff of Cimarron River in NW¼ sec. 35, T. 30 S., R. 37 W., Grant County

	Thickness, feet
Meade formation	
5. "Mortar beds," gray, containing sand and fine gravel at base and coarse gravel in upper part	17
Rexroad (?) formation	
4. Clay, dark gray to brown, containing pebbles of caliche	1.5
3. Sand, fine, consolidated, gray, containing silt and clay	3
2. Clay, blocky, grayish brown, containing several thin bands of caliche	10.5
1. Sand, fine, reddish brown, containing silt, clay, and a small amount of caliche. Weathers to massive ledge	5
Thickness of Rexroad (?) formation exposed	20

Section of Rexroad (?) formation in road cut near Rolla bridge in SE¼ NW¼ sec. 35, T. 32 S., R. 40 W., Morton County

	Thickness, feet
Terrace deposits	
3. Gravel, coarse, consisting of pebbles of both igneous and sedimentary rocks. Contains a few pieces of scoriaceous basalt	3
Rexroad (?) formation	
2. Clay, brown, blocky, weathers to grayish brown. Contains a gray calcareous zone about 5 feet from base	8
1. Sand, fine, and silt; reddish tan; contains caliche at base	7
Thickness of Rexroad (?) formation exposed	15

Distribution and thickness.—Rexroad (?) deposits crop out in many places in the Cimarron Valley between central Seward County and southwestern Meade County and along tributaries of Crooked Creek in west-central Meade County. Outcrops occur also in the banks of the Cimarron River in secs. 35 and 36, T. 32 S., R. 33 W., Seward County, in NW¼ sec. 35, T. 30 S., R. 37 W., Grant County (Pl. 9), in secs. 20 and 29, T. 31 S., R. 38 W., Stevens County, and in sec. 35, T. 32 S., R. 40 W., Morton County (Pl. 9). The Rexroad (?) appears in nearly vertical bluffs in Grant and Stevens Counties but is not shown on Plate 1 because the outcrops are very small. The Rexroad (?) was unrecognized in Grant and Stevens Counties

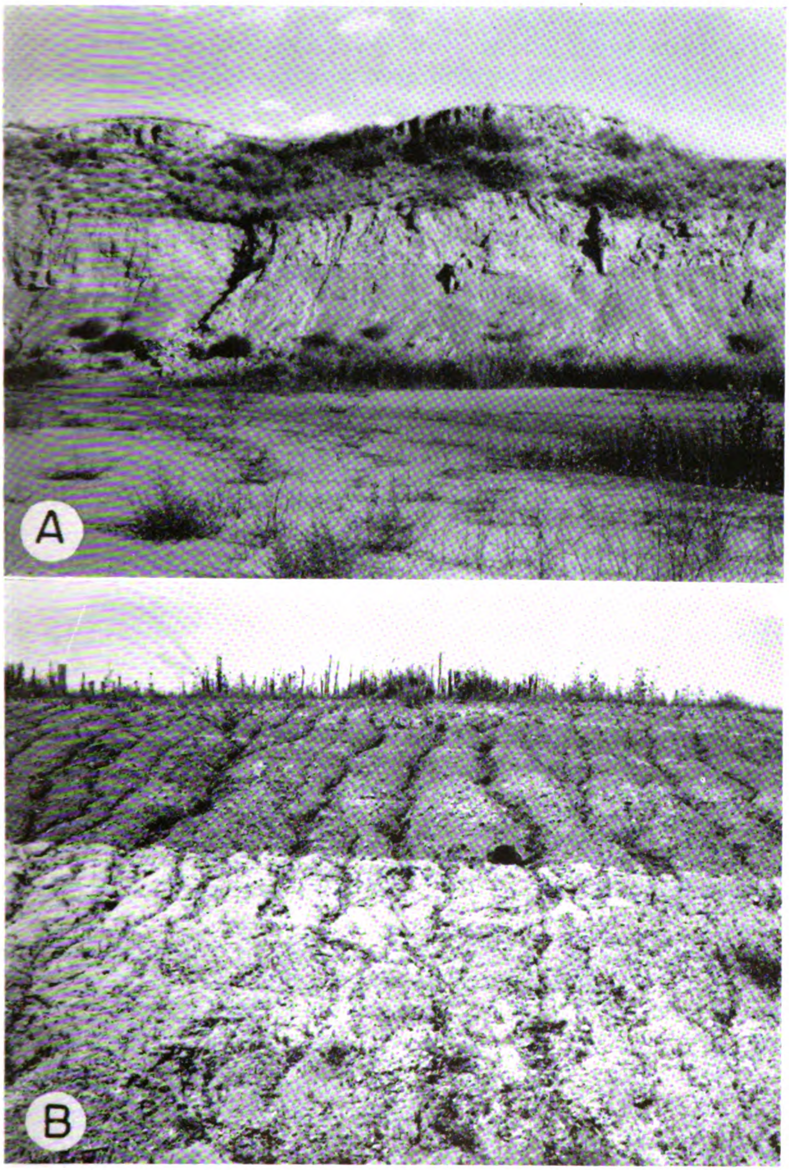


PLATE 9. Outcrops of Rexroad (?) formation: *A,* Along Cimarron River about a quarter of a mile downstream from the Ulysses bridge, Grant County. *B,* In road cut north of the Rolla bridge, Morton County.

and in Morton County (McLaughlin, 1942) until 1944 after field work for the Grant-Haskell-Stevens area had been completed.

The channel of the Cimarron River has been cut to approximately the level of contact between the Meade and Rexroad (?) formations from western Stevens County to central Seward County. Where the gravel and sand of the Meade are thin, a few feet of Rexroad (?) may be exposed; but where the Meade has channeled deeply into the Rexroad (?), only sand and gravel of the Meade are exposed along the channel. In addition, recent pediment-like deposits cover much of the valley floor and mask the bedrock except in a few places where the surficial deposits have been removed by widening of the channel of the Cimarron River. Additional widening of the channel may expose other beds of the Rexroad (?).

The Rexroad (?) formation probably underlies all or most of Grant, Haskell, and Stevens Counties. The outcrops of this formation in many places in the Cimarron Valley between Morton County and Meade County imply widespread distribution. The Rexroad (?) probably pinches out in northwestern Grant or southeastern Hamilton County on the flank of the Syracuse anticline. True Rexroad probably does not extend east of Crooked Creek in Meade County and Rexroad (?) beds end between the Rolla and Elkhart bridges in the Cimarron Valley in Morton County. On the south side of the Cimarron River, however, the Rexroad (?) may extend much farther to the south and west. In a gravel pit 5 miles north and 1 mile east of Elkhart in Morton County, terrace deposits overlie "mortar beds" of the Meade formation which are channeled into a brown clay that resembles closely upper beds of the Rexroad (?) formation. North of the Cimarron River in that vicinity, however, the Ogallala formation is at or near the surface.

The top and base of the Rexroad (?) formation could not be determined by study of cuttings from test holes in Grant, Haskell, and Stevens Counties; hence the thickness of the formation in this area is not known. Greatest measured thickness of the Rexroad (?) is 86 feet in Meade and Seward Counties (note the first two sections given above), but at only one place are the top and bottom of the formation exposed. The thickness of the upper part of the formation is moderately uniform, whereas the thickness of the basal sand and gravel is highly variable. Where the base of the Rexroad (?) is exposed there has been relatively little or no channeling into the underlying Laverne formation. Hence the basal sand and gravel and therefore the entire Rexroad (?) formation are relatively thin.

Test holes drilled near the areas of outcrop of the Rexroad in Meade County and of the Rexroad (?) in Seward County indicate that these deposits may be as much as 170 feet thick. Test holes that penetrated thick sections of Rexroad (?) encountered thick deposits (50 to 100 feet) of sand and gravel in the lower part.

The thinnest exposed section of the Rexroad (?) beds is in southeastern Seward County where there is less than 15 feet of the Rexroad (?) between basal sand and gravel of the Meade formation and the Laverne formation. This outcrop is less than 1 mile from one of the places where the measured thickness of the Rexroad (?) is 86 feet.

Age and correlation.—The age of the Rexroad (?) formation is not definitely known. The formation is younger than the Ogallala formation because much or all of the Ogallala between east-central Morton County and Crooked Creek in Meade County, in the view of the author, was removed by erosion before the Rexroad was laid down. The Rexroad is separated from the overlying Pleistocene Meade formation by a prominent disconformity.

Fossils from the Rexroad formation (type) in Meade County have been described by Hibbard (1938a, 1939, 1941, 1941a, 1941b), Baker (1938), Taylor (1941 and 1941), and Wetmore (1944). Hibbard's interpretation of the Rexroad fauna is as follows (Frye and Hibbard, 1941, p. 410):

On the basis of the fossil mammals the Rexroad, Blanco, Benson, and Hagerman faunas are believed to be of approximately the same age. The differences between the faunas are thought to be of only geographical significance. The Rexroad fauna shows a closer relationship to the Blanco and Benson faunas than to the Hagerman fauna. Although the fauna as a whole shows relationships with forms now found in Mexico and Central America rather than with the recent forms now found in southwestern Kansas, a few fossil forms possess boreal affinities.

The fauna indicates that meadow flats and timbered areas existed at least along parts of the late Pliocene stream valleys, and that the climatic conditions then were not drier nor colder than those at present. There is some indication, moreover, that the climate of late Pliocene time lacked extremely cold winters or severely hot summers, accordingly being more equable than the present climate, and that there was a somewhat greater degree of humidity than exists now in this region.

The environment during Rexroad time as interpreted by Wetmore (1944, p. 91) from his study of the remains of birds is as follows:

Of the identified specimens, more than one-half belong to aquatic species that live in and around marshes, streams, and ponds. Remains of turkeys represent birds of wooded areas, while parrots, pigeons, and quail are species of forests, or regions where thickets and groves grow amid plains, prairies, or savannas. The passeriform birds may have lived in prairie land, in thickets, or in forests.

McGrew (1944, pp. 33-42) has correlated the Rexroad and Blanco faunas with the Sand Draw and Broadwater faunas of Nebraska, which he considers to be Pleistocene (Aftonian). He states that:

Geologically, there seems to be little reason to assign the Rexroad to the late Pliocene. Some rather significant geologic changes—the faulting, the development of sink holes, and erosion—took place between the Pliocene beds beneath and the Rexroad proper.

Similarly, there was movement along the major faults (Frye, 1942, p. 26), continued solution and collapse, and widespread erosion after the deposition of the Rexroad formation and before the accumulation of the Meade formation. It does not seem to be possible at present, therefore, to date the Rexroad formation accurately on the basis of geologic history or stratigraphic position.

Vertebrate paleontologists of Kansas and Nebraska are in agreement that the Rexroad fauna of Kansas is equivalent in age to the Broadwater fauna of western Nebraska and the Blanco fauna of northwestern Texas and that the deposits from which these faunas were taken occur stratigraphically above the horizon of the "Algal limestone" (top of the Ogallala) and below the horizon of beds of undoubted Pleistocene age (such as the Meade formation).

In a recent paper by Elias (1945), the geologists and vertebrate paleontologists of the Nebraska and Kansas geological surveys proposed that:

the placement of the Blancan in either the late Pliocene or in the early Pleistocene of the standard time scale be held in abeyance until there is more general agreement among paleontologists as to age; and that Blancan be used to serve as a provincial time zone for beds and faunas in the Great Plains region younger than the "Algal limestone" and older than the beds of undoubted Pleistocene age.

Water supply.—The Rexroad (?) formation probably yields water to many deep wells in Grant, Haskell, and Stevens Counties. Deep irrigation wells in areas of shallow water probably obtain part of their water from the Rexroad (?). Where the depth to water is 150 to 200 feet or more below land surface (Pl. 2) almost all wells get all or part of their water from the Rexroad (?). Where the water table is at or below the top of the Rexroad (?) beds, as in east-central Grant County and in central and west-central Haskell County (note the water table near the top of a persistent zone of silt and clay, Pl. 3), wells generally must be drilled through the upper part of the Rexroad (?) into basal sand and gravel to obtain sufficient water. At the site of the former town of Santa Fe, near the center of Haskell County, the municipal wells failed to encounter an adequate supply of water in the silt and clay just below the water table, although nearby dug wells obtained water sufficient for most domestic and stock uses. The municipal wells, however, were deepened to the underlying sand and gravel in order to obtain an adequate supply of water. Where Rexroad (?) deposits are present in Grant, Haskell, and Stevens Counties, supplies of water adequate for most uses probably can be obtained from the basal sand and gravel. Water from the Rexroad (?) deposits generally is moderately hard but is suitable for most uses.

QUATERNARY SYSTEM

PLEISTOCENE SERIES

Meade formation

The Meade formation was recognized and described by Cragin (1896, p. 53) as the *Meade gravels*. The name was proposed for the lowest of three "terranes" in the vicinity of the old Vanhem post office in sec. 13, T. 30 S., R. 23 W., Clark County (Hibbard, 1944b, p. 709). In addition, he gave the name *Pearlette ash* to the deposits of volcanic ash in that region. Smith (1940, pp. 100-111) described the Pleistocene *Odee formation* and local Pleistocene deposits that he called *Equus niobrarensis beds* and *Jones Ranch beds*. Frye and Hibbard (1941, pp. 411-419) redefined the Meade formation to include Cragin's *Meade gravels* and *Pearlette ash;* Smith's *Odee formation, Equus niobrarensis beds,* and *Jones Ranch beds;* and all other beds of Pleistocene age above the Rexroad formation and below the Kingsdown silt. Additional fossils studied by Hibbard (personal communication) indicate that the *Jones Ranch beds* are equivalent to the Kingsdown silt. The term "Meade formation" is used in this report as defined by Frye and Hibbard except that the *Jones Ranch beds* are considered a part of the Kingsdown silt.

Character.—The Meade formation in Grant, Haskell, and Stevens Counties consists of thick deposits of coarse sand and gravel at the base (Pls. 8, 9, 10, and 11) overlain by red silt and sand which contain abundant nodules of caliche. In a few places in this area there are small outcrops of volcanic ash (Pl. 12). The uppermost beds of the Meade formation (*Odee formation* and *Equus niobrarensis beds*) are thin or absent in this area. The following measured section of the Meade formation at the type locality is taken from Frye (1942, p. 98):

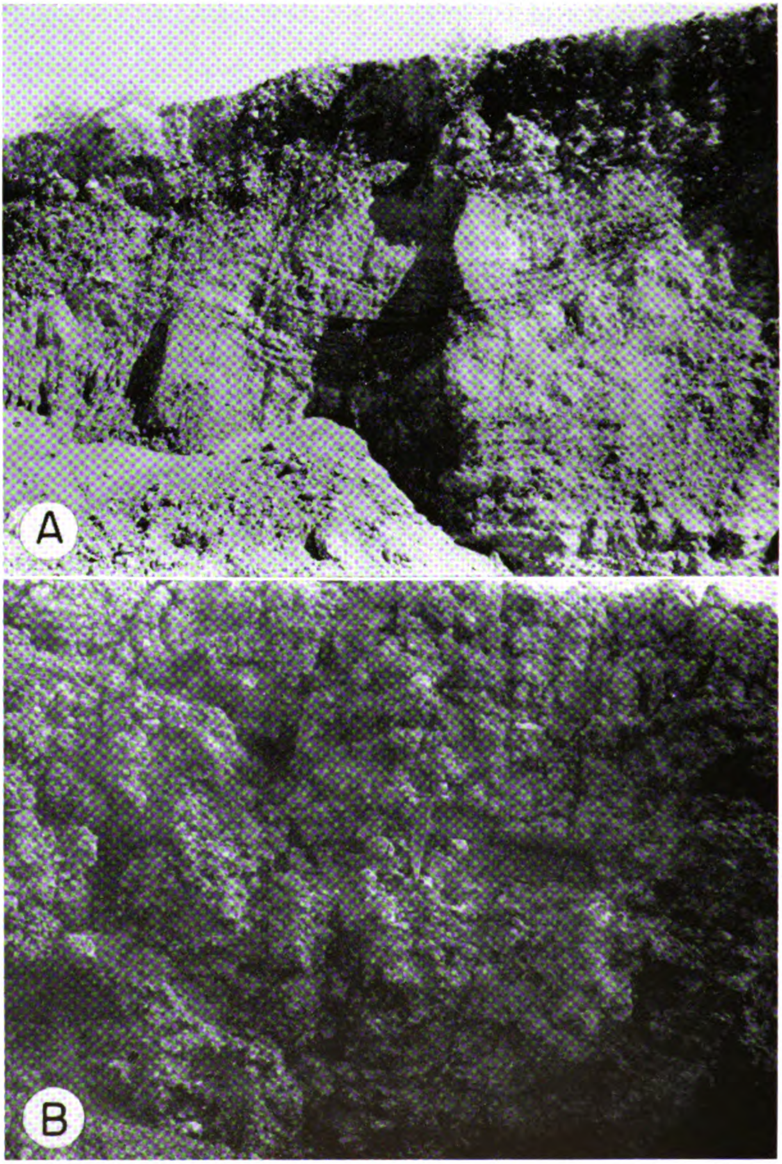


PLATE 10. Outcrops of the Meade formation: *A,* In gravel pit near Bear Creek in northern Stanton County; *B,* in south bluffs along Cimarron River about a quarter of a mile downstream from the Ulysses bridge.

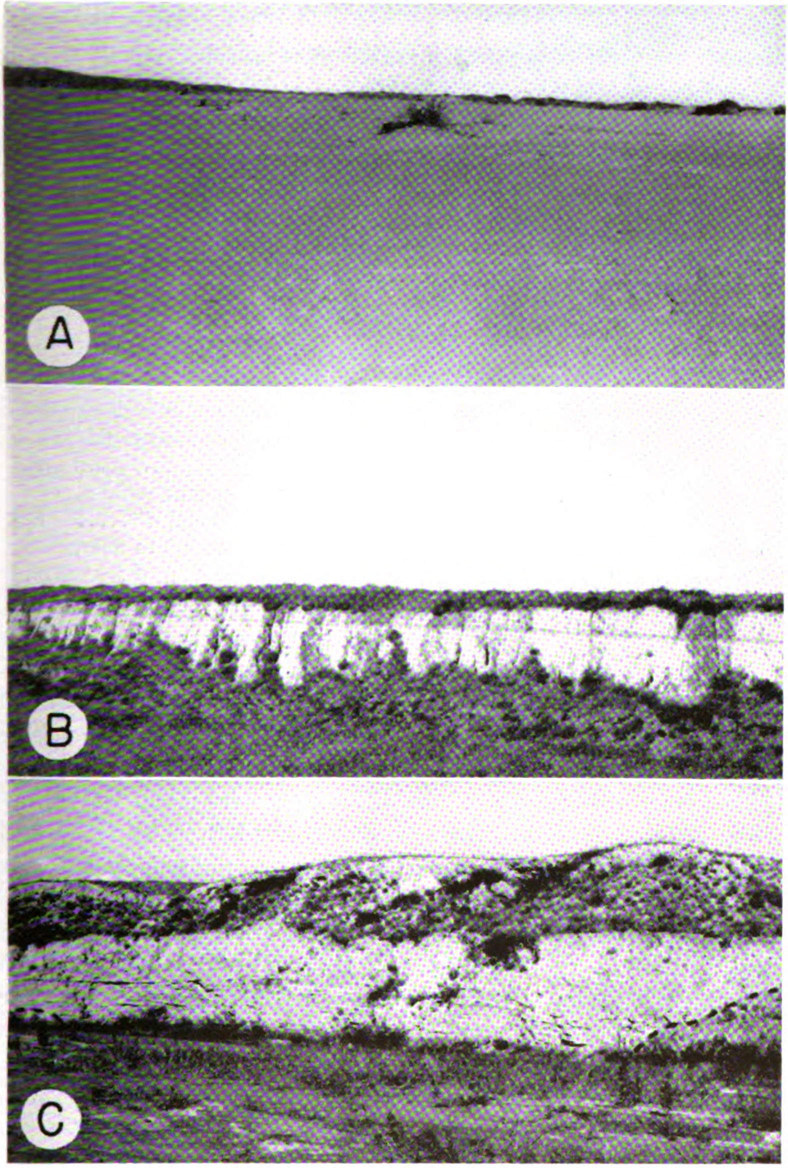


PLATE 11. *A,* Blowout in dune sand in western Stevens County. *B,* Outcrop of the Kingsdown silt in Haskell County (sec. 27, T. 30 S., R. 34 W.). *C,* Meade formation channeled into Rexroad (?) deposits in southern Grant County (a quarter of a mile below Ulysses bridge).

Section of Meade formation in sec. 21, T. 33 S., R. 28 W., Meade County

Meade formation	Thickness, feet
18. Silt, sand, and some clay; tan to buff brown; massive; contains sandy beds and caliche cobbles	14.8
17. Sand and silt; gray to gray tan	5.4
16. Clay, containing some silt and sand; light gray; massive. Breaks with a conchoidal fracture when dry	4.5
*15. Volcanic ash, pearl gray, lenticular, somewhat impure	1.6
14. Silt, clay, and some sand; gray; massive; contains a few calcareous nodules. (Borchers fauna, where present, occurs at top of this bed)	6.4
13. Volcanic ash (Cragin's *Pearlette ash*), pearl gray, thin-bedded and cross-bedded	7.1
12. Clay, silt, and some sand; tan gray and brown gray; massive. Grades upward into yellowish gray-green sand and contains some mottled yellow-brown silt. Contains a few thin beds of ash and calcareous nodules. (Cudahy fauna occurs at top of this bed, where present)	9.5
11. Sand, silt, and coarse gravel; brown; contains abundant nodules. Grades upward into red-brown to tan-maroon sand and silt	8.8
10. Sand, coarse, and well sorted at base, grading upward into finer, more poorly sorted sand. Calcareous nodules at top	10.1
Ogallala formation	
Thickness of Meade formation	68.2

The lower part of the Meade formation in Grant, Haskell, and Stevens Counties consists of thick deposits of coarse sand and gravel derived from the Rocky Mountains. The grains and pebbles are primarily granite, pink feldspar, quartz, and other material derived from igneous rocks; in addition, there are many water-worn pebbles of caliche and "mortar beds" derived from Tertiary sediments. Pebbles of light-green and brown chalcedony also are abundant.

The sand and gravel of the Meade formation generally is cross-bedded and well sorted. A part of the sand and gravel usually is cemented with calcium carbonate to form "mortar beds," which are more resistant to erosion than adjacent sediments and which erode to prominent ledges (Pl. 9). The ledges are most conspicuous along the south side of the Cimarron River a short distance below the Ulysses bridge (NW¼ sec. 35, T. 30 S., R. 37 W.). The "mortar beds" generally consist of coarse sand and fine to coarse gravel; in a few places, however, they consist primarily of very coarse gravel (Pl. 10). The "mortar beds" generally are cross-bedded.

* This section was examined later by Claude W. Hibbard (personal communication) who was unable to find bed 15.

The sand and gravel of the Meade formation generally is much coarser than basal sand and gravel of the Rexroad (?) formation. In addition it contains a greater abundance of water-worn pebbles of caliche and it seems to contain much more chalcedony, although no pebble counts of the two deposits of sand and gravel have been made. The basal sand and gravel of the Meade differs more markedly from the deposits of sand and gravel in the Ogallala formation. Smith (1940, p. 42) reports that the sand and gravel in the Ogallala formation in Meade and Clark Counties contains abundant pebbles of fine-grained sandstone, gray quartzite, and ironstone which he believes were derived primarily from the Dakota and other Cretaceous formations. Few, if any, pebbles, derived from these types of rocks have been found in the Meade formation. Water-worn pebbles of caliche, which are common in the Meade, are rare in the Ogallala.

The beds lying above the basal sand and gravel of the Meade formation consist of poorly sorted reddish silt and sand containing nodules and stringers of white caliche, and resemble closely the reddish beds above basal sand and gravel of the Rexroad (?) formation. In general, however, the nodules of caliche in the Meade are more resistant to erosion than those in the Rexroad (?), and outcrops of these beds generally are covered with caliche rubble. These beds are moderately well indurated and form relatively steep slopes in some places. They are well exposed in a road cut a short distance south of the Ulysses bridge in sec. 27, T. 30 S., R. 37 W.

The zone of transition between the sand and gravel and the overlying reddish beds consists of materials common to both deposits. The materials are poorly sorted, moderately well indurated silt, sand, and gravel, which form steep slopes in some places. A typical outcrop of the sand and gravel, the zone of transition, and the overlying reddish silt and sand is 0.8 mile east of the Stevens-Seward line in sec. 19, T. 31 S., R. 34 W. Volcanic ash crops out in the same draw.

The two beds of the Meade formation that are most widespread in Grant, Haskell, and Stevens Counties, and which are described above, are equivalent to beds 10 and 11 in the type section of the Meade formation (page 126). The uppermost deposits of the Meade formation are thin or absent in most of the Grant-Haskell-Stevens area, but an outcrop of silty clay in northeastern Haskell County (SE¼ NE¼ sec. 3, T. 27 S., R. 31 W.) may be equivalent to

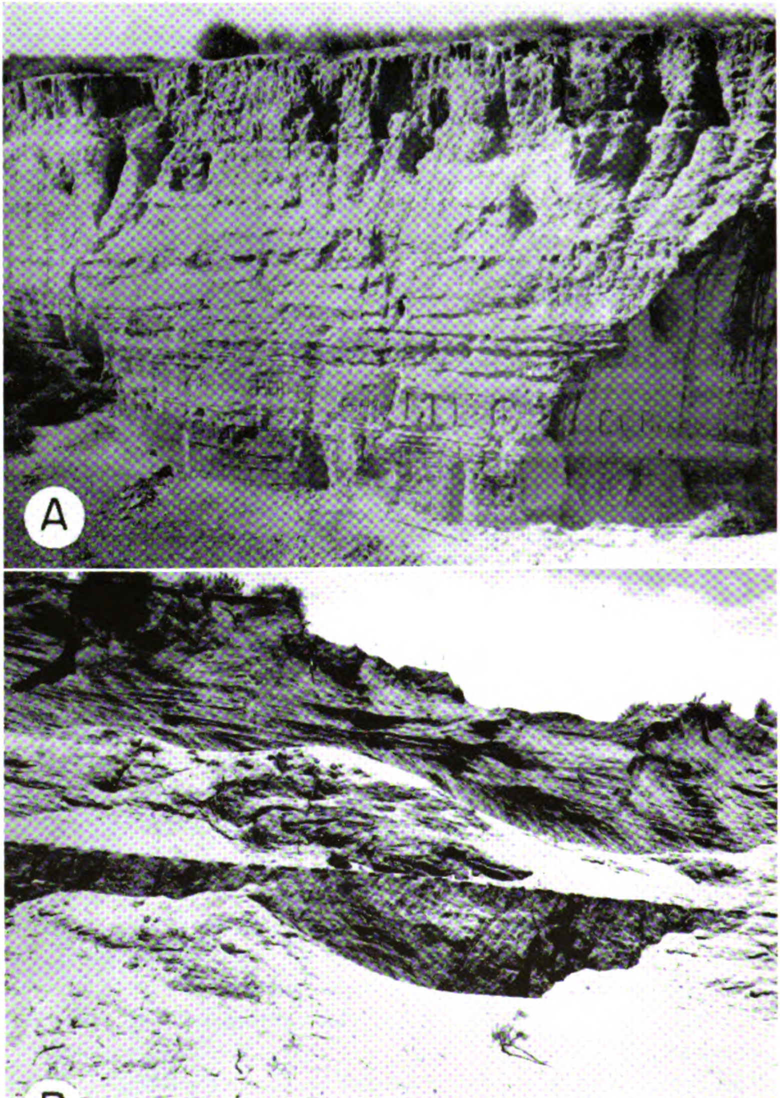


PLATE 12. *A,* Volcanic ash in southeastern Grant County (sec. 24, T. 30 S., R. 35 W.). *B,* Dune sand overlying alluvium in western Stevens County (sec. 23, T. 32 S., R. 39 W.).

Smith's *Jones Ranch beds* (note section on Age and correlation). Volcanic ash, which occurs in the upper part of the type section of the Meade formation, also is found in a few places in Grant County (Pl. 12), and the locations of these deposits are given on pages 27 and 28.

Distribution and thickness.—The Meade formation underlies almost all of Grant, Haskell, and Stevens Counties, and is absent only in places where the Cimarron River has cut through the Meade into the underlying Rexroad deposits: The Meade formation underlies most of or part of Hamilton, Stanton, Morton, Kearny, Grant, Stevens, Finney, Haskell, Seward, Gray, Ford, Meade, Clark, and Kiowa Counties, Kansas, and Texas and Beaver Counties, Oklahoma. In much of this area, however, it does not crop out but is overlain by the Kingsdown silt and by dune sand.

The thickness of the Meade formation in Grant, Haskell, and Stevens Counties is known only approximately inasmuch as the base of the formation cannot be determined accurately from drill cuttings. The measured thickness at the type locality is approximately 68 feet, but most of the beds in the upper part of the type section do not extend into this area. The lowermost beds, however, are much thicker in this area than at the type locality. The basal deposit of sand and gravel is 10 feet thick at the type locality but is nearly 50 feet thick in western Seward County and in parts of Grant, Haskell, and Stevens Counties and also is about 50 feet thick in Clark County (Hibbard, 1944b, p. 714). The deposit of reddish silt and sand above the basal sand and gravel of the Meade formation is also thicker in the Grant-Haskell-Stevens area than at the type locality, where it is only about 9 feet thick. This zone is 15 feet thick in southeastern Seward County and seems to be thicker along the Cimarron River in southern Grant County. The total thickness of the Meade may exceed 100 feet in some parts of the Grant-Haskell-Stevens area but it thins westward from this area and is absent in parts of Morton County that lie north of the Cimarron River.

Age and correlation.—Since 1936, Claude W. Hibbard of the University of Kansas Museum of Vertebrate Paleontology has been collecting fossils from the Meade formation of southwestern Kansas during which time he has collected the Cudahy, Borchers, and Cragin Quarry faunas (Hibbard, 1938, 1939a, 1940, 1940a, 1941c, 1943). The fossils that have been collected indicate that the Meade formation is Pleistocene. The Cudahy fauna (taken from bed 12

9—2135

of the type section) is believed by Hibbard (1944b, p. 741) to be in part a glacial fauna. The Borchers fauna (taken from bed 14 in the type section) is believed to be of an early interglacial stage and to represent the oldest known interglacial fauna in Kansas (Frye and Hibbard, 1941, p. 417). The Cragin Quarry fauna represents an interglacial fauna that is younger than the Borchers fauna. The Jones Ranch fauna was taken from beds that Hibbard (Frye and Hibbard, 1941, pp. 418, 419) believes were deposited in an isolated sinkhole at a time when the region was cooler than during the interglacial stages represented by the Cragin Quarry and Borchers faunas.

Few fossils have been taken from the Meade formation in Grant, Haskell, and Stevens Counties. The tooth of a Pleistocene horse (*Equus niobrarensis* Hay) and a tooth (Lm3) of a Pleistocene musk-ox (*Euceratherium* sp.) were collected from the Sullivan gravel pit in the SW¼ sec. 7, T. 29 S., R 37 W.

Water supply.—The Meade formation yields water to almost all wells in areas where the depth to water level is less than 100 feet below land surface (Pl. 2). It probably is the most important water-bearing formation in much of Grant and Stevens Counties, where it yields water to most of the irrigation wells, but it lies above the water table in much of Haskell County, southwestern Stevens County, and eastern Grant County.

The uppermost beds of the Meade formation in Grant, Haskell, and Stevens Counties are poorly sorted and probably yield only small quantities of water to wells. The deposits of sand and gravel at the base of the Meade, however, are relatively thick and are moderately well sorted in this area. Where these deposits are saturated, they yield moderate to large quantities of water to wells.

Analyses of water from wells in the Meade and other formations in this area are listed in Tables 11, 12, and 13.

PLEISTOCENE AND RECENT SERIES

Kingsdown silt

Cragin (1896, p. 54) named and described the *Kindsdown marl* from outcrops southwest of Kingsdown in Ford County and in the valley of Bluff Creek in northern Clark County, and believed that it might be late Pliocene. He did not designate a type locality for these beds, but they are typically exposed in the vicinity of the old Vanhem post office in sec. 13, T. 30 S., R. 23 W., Clark County. Smith (1940, pp. 111-116) redefined Cragin's *Kingsdown marl* as the *Kingsdown formation* and designated as the type locality an outcrop that he measured in sec. 13, T. 30 S., R. 23 W., Clark County. The *Kingsdown formation* of Smith included only beds of Pleistocene age. Frye and Hibbard (1941, pp. 419, 420) redefined these beds as the Kingsdown silt, inasmuch as they consist dominantly of silt, and included the overlying loess of uppermost Pleistocene and Recent age. More recently, Hibbard (1944b, pp. 745-752) recognized two phases of the Kingsdown in northern Clark County which he has called lower and upper Kingsdown silt. The Kingsdown silt exposed in Grant, Haskell, and Stevens Counties and in adjacent areas probably is equivalent to the upper Kingsdown silt as defined by Hibbard, but no attempt is made in this report to differentiate the two units.

Character.—The lower part of the Kingsdown silt in the Grant-Haskell-Stevens area is predominantly light tan to buff and consists of fine sand which grades upward into silt, sandy silt, and loess. The upper part of these beds contains small nodules and stringers of caliche. The fine sand at the base generally is thinly bedded but the overlying silt and loess are massive.

The Kingsdown silt is best exposed in this area in a road cut a short distance north of the Ulysses bridge in Grant County, at a road cut along Kansas highway 45 in sec. 27, T. 30 S., R. 34 W., Haskell County, and in a railroad cut in the SW¼ sec. 27 and NW¼ sec. 34, T. 30 S., R. 34 W., also in Haskell County (Pl. 11).

Distribution and thickness.—The Kingsdown silt underlies much of Grant and Haskell Counties but is relatively thin or absent in Stevens County where the dune sand generally is underlain by the Meade formation. Its thickness probably does not exceed 40 feet in Grant, Haskell, and Stevens Counties. The Kingsdown is relatively thin in northernmost Grant and Haskell Counties and in western Grant County, is thin or absent south of the Cimarron River in Morton, Stevens, and Seward Counties, but it is much thicker toward the east.

Age and correlation.—The Kingsdown silt overlies unconformably the Pleistocene Meade formation and is uppermost Pleistocene to Recent as indicated by its stratigraphic position. Fossils collected from the Kingsdown deposits by Hibbard (Frye and Hibbard, 1941, p. 420, and Hibbard, 1944b, pp. 749-752) also indicate late Pleistocene and Recent age. A few snails have been collected from a thin bed of silty clay underlying dune sand in the SE¼ NE¼ sec. 3, T. 27 S., R. 31 W., in the northeastern part of Haskell County and have been identified by A. B. Leonard of the University of Kansas:

Mollusks collected from a bed of silty clay in the SE¼ NE¼ sec. 3, T. 27 S., R. 31 W., Haskell County

Aquatic forms	Terrestrial forms
Menetus exacuous (Say)	*Succinea grosvenori* Lea
Gyraulus cristatus (Linnaeus)	*Vertigo* cf. *morsei* Sterki
Gyraulus cf. *hirsutus* (Gould)	*Pupilla muscorum* (Linnaeus)
Gyraulus parvus (Say)	*Vollonia* cf. *costata* (Muller)
Lymnea parva (Lea)	*Discus anthonyi cronkhitei* (Pilsbry)
Lymnea palustris (Muller)	
Lymnea humilis (Say)	
Lymnea caperata (Say)	
Pisicium species	

This fauna is believed by Leonard (personal communication) to compare more closely with the fauna of Smith's *Jones Ranch beds* than with any other Pleistocene fauna from southwestern Kansas; hence these beds probably are equivalent in age to the Kingsdown.

Water supply.—The Kingsdown silt lies wholly above the water table in the Grant-Haskell-Stevens area and therefore does not yield water to wells. It is partly saturated at a few places in Meade County where it yields small quantities of water to a few wells (Frye, 1942, p. 110).

Terrace deposits

Smith (1940, pp. 126, 153) reported two or possibly three terraces along the Cimarron Valley in southwestern Kansas, including a high-level terrace north of Elkhart in Morton County about 70 to 75 feet above the flood plain, at levels of 20 and 55 feet above the flood plain in northwestern Stevens County, and terraces at levels of 20, 55, and 80 feet above the flood plain in Seward County.

Frye and Hibbard (1941, p. 420) reported a prominent terrace that attains a maximum height of 100 feet or more above the level of the Cimarron River. The beds of sand and gravel underlying this terrace are reported to be channeled into the Meade and Ogallala formations.

Several terraces have been observed in the Cimarron Valley by Hibbard and the writer during recent studies in southwestern Kansas, but their altitudes have not been determined and correlation between outcrops is difficult. The high terrace reported by Smith in southwestern Morton County is at an altitude of approximately 3,480 to 3,490 feet above sea level, whereas the altitude of the stream bed 2 miles northwest of the outcrop is about 3,380 feet;

thus, the terrace is at least 100 feet above river level and is about 50 feet below the level of adjacent upland areas. The gravel underlying this terrace contains very coarse pebbles and cobbles of water-worn fragments of sandstone which probably were derived from Mesozoic rocks. In addition, there are numerous fragments of reddish vesicular basalt which are characteristic of terrace deposits along the Cimarron Valley.

Another terrace deposit crops out in Morton County in a road cut north of Wilburton. This deposit is about 20 feet above stream level and is similar lithologically to the high terrace mentioned above except that it contains fewer fragments of sandstone and is much finer-grained. This deposit contains many fragments of red siltstone and sandstone which probably were derived from outcrops of redbeds at Point of Rocks and farther west.

The terrace deposits exposed in Morton County in a road cut at the north approach to the Rolla bridge probably are no more than 30 feet above stream level and may be equivalent to the terrace deposits north of Wilburton. The gravels in these deposits are channeled into beds that are believed to be a part of the Rexroad formation.

In southeastern Seward and southwestern Meade Counties are many outcrops of terrace deposits. The highest terrace deposits in southeastern Seward County are 30 to 50 feet below the upland surface and are approximately 200 feet above stream level. The deposits consist of coarse sand and gravel derived from both igneous and sedimentary rocks, and include many water-worn blocks of sandstone more than 6 inches long. The deposits also contain cobbles of reddish vesicular lava which resemble closely those found underlying the high terrace in Morton County. Some of these boulders are more than 12 inches in diameter. Water-worn fragments of "mortar beds" also have been found, some of which contain small water-worn pebbles of caliche.

The highest terrace deposits form a prominent bench of the sides of the Cimarron Valley where they are channeled into the upper part of the basal sand and gravel of the Meade formation and into the overlying reddish silt and sand. They are exposed typically in a small draw in the south-central part of Sec. 17, T. 34 S., R. 31 W., Seward County.

Another prominent terrace is at a much lower level in the Cimarron Valley in Meade and Seward Counties. The deposits underlying the terrace are at least 50 feet above stream level and are channeled into Laverne and Rexroad (?) deposits. In the vicinity of the Liberal and Arkalon bridges, terraces also have been observed at levels of about 40 or 50 feet above the stream. The deposits forming these terraces are channeled into the basal sand and gravel of the Meade formation and into the Rexroad (?) formation.

Frye and Hibbard (1941, p. 420) report that teeth of *Paraelephas columbi* (Falconer) have been taken from the high-terrace deposits in the Cimarron Valley south of Meade. The remains of fossils and the fact that the terrace deposits are channeled into the Meade formation indicate that this terrace was formed during very late Pleistocene time and that almost all the downcutting in the Cimarron Valley was during late Pleistocene and Recent time.

The terrace deposits lie wholly above the water table and yield no water to wells in the Grant-Haskell-Stevens area.

RECENT SERIES

Alluvium

Recent alluvium occurs along the floor of the Cimarron Valley (Pl. 12) and along some of its tributary valleys, including North Fork Cimarron Valley and Lakin Draw, but the alluvium was mapped only along Cimarron River (Pl. 1). The principal constituents in the alluvium are sand, silt, and gravel containing lesser amounts of clay. Very little is known about the thickness of the alluvium in this area, for during the investigation only one test hole was drilled into the alluvium of Cimarron River in southern Grant County (log 28) and it penetrated 70 feet of alluvium.

Alluvium yields water to a few domestic and stock wells in the Cimarron Valley, North Fork Cimarron Valley, and Lakin Draw, but the yield of these wells generally is small. One well (46), however, supplied water for irrigation in Lakin Draw, but no data on the yield are available. Water in the alluvium generally is hard but can be used for most domestic and farm purposes (see analyses 106 and 119).

Dune sand

Most of Stevens County and small parts of Grant and Haskell Counties are underlain by dune sand that probably is of Recent age (Pl. 1). The dune sand overlies parts of the Meade and Kingsdown formations and in northwestern Stevens County it overlies the alluvium of the Cimarron River Valley. The sand contains uniform medium-grained well-rounded quartz grains and in places it contains a small amount of silt and clay.

Two types of topography are recognized in the sand-dune areas in Grant, Haskell, and Stevens Counties (Pl. 1) which are reflections of the stage or phase of erosion of the sand dunes. The first type is characterized by typical dune-sand topography wherein the sand dunes generally are grass-covered moderately steep irregular hills between which are small valleys and undrained basins. This type is best exposed in northernmost Grant and Haskell Counties and in northwestern Stevens County near the Cimarron River. The second type of dune-sand topography comprises broad subdued swells and swales and has a thicker soil which is extensively cultivated. This type is most common in areas south of the Cimarron River.

Smith (1940, pp. 159-165) described an ideal dune cycle in his discussion of sand dunes in southwestern Kansas. The cycle consists of two phases: (1) an eolian or active phase during which the dune is built up, and (2) an eluvial or passive phase during which vegetation prevents further growth and the dune is subdued by weathering and creep. He divides the eluvial phase into stages of youth, maturity, and old age. In the youth stage the soil zone is formed and slopes are reduced. The dune becomes mature when its profile is smooth and regular and when its soil becomes thicker and more stable. Old age is reached when the dune form is indistinguishable. He states that the eluvial phase in any stage may be interrupted by rejuvenation.

Most of the sand dunes in the Grant-Haskell-Stevens area are in the eluvial phase of the dune cycle although a few dunes are in the eolian or active phase (Pl. 11). The types of dune sand mapped in Grant, Haskell, and Stevens Counties are (1) those that produce a typical sand-dune topography and which are in the youthful and mature stages of the eluvial phase of the dune cycle, together with the few dunes that are in the eolian phase of the cycle, and (2) those that produce a relatively flat topography and which are in the old-age stage of the eluvial phase of the dune cycle. The boundaries between the two types and between the old-age dunes and areas not covered by dunes are indistinct in many places; hence they are shown on Plate 1 by dashed lines.

The thickness of the dune sand in the Grant-Haskell-Stevens area is not known, but it probably does not exceed 50 or 60 feet. Where the dunes have reached the old-age stage the deposits are relatively thin. Where the dunes are in a younger stage the deposits are thick at the crests of the dunes but are thin in areas between crests.

The age of the dune sand is not known, but most of it probably was laid down in Recent time. In northwestern Stevens County the dune sand covers all of the southern part of the Cimarron Valley from the upland to the edge of the river channel; hence it overlies the terrace deposits and the alluvium (Pl. 12). Inasmuch as the dune sand in that vicinity is younger than the alluvium, it probably is of Recent age. In some places, however, there may be dune sand of Pleistocene age, for Smith (1940, p. 128) reports an older dune sand in the railroad cut southwest of Kismet in Seward County which is moderately well indurated and is separated from overlying younger less consolidated dune sand by a well-defined soil zone.

The dune sand lies above the water table in Grant, Haskell, and Stevens Counties and, therefore, yields no water to wells; however, it forms ideal catchment areas for rainfall and hence assists in the recharge of underlying formations.

WELL RECORDS

Information pertaining to water wells in Grant, Haskell, and Stevens Counties is tabulated in the following pages (Tables 18, 19, and 20). The numbers in the first column correspond to the well numbers on the map (Pl. 2) and in the tables of analyses (Tables 11, 12, and 13). The numbers in the first column that are in parentheses indicate wells from which samples of water were taken for analysis.

TABLE 18.—*Records of wells in Grant County, Kansas*

on 2)	LOCATION	Owner	Type of well (2)	Depth of well (feet) (3)	Diameter of well (in.)	Type of casing (4)	Principal water-bearing bed: Character of material	Principal water-bearing bed: Geologic subdivision [a]	Method of lift (5)	Use of water (6)	Measuring point: Description	Measuring point: Distance above (+) or below (−) land surface (feet)	Measuring point: Height above sea level (feet)	Depth to water level below measuring point (feet) (7)	Date of measurement	Remarks (Yield given in gallons a minute; drawdown in feet)
	T. 27 S., R. 35 W.															
1	SW NW sec. 3	Mr. Carkener	Dr	133.0	5	GI	Sand and gravel	Rexroad and/or Meade	N	N	Top of casing, west side	+1.7	3,036.5	123.49	7-18-41	Abandoned, formerly a domestic and stock well.
2	SE NE sec. 5	J. R. Neese	Dr	149.0	4	I	do	do	C,W	N	Top of casing, south side	+ .6	3,061.8	143.28	7-25-41	Do
3)	SW SW sec. 6	J. A. Richards	Dr	135	4.5	I	do	do	C,W	D,S	Land surface	0		120		
4	NW SW sec. 16	Craig Howard	Dr	182.0	6	I	do	do	C,W	N	Top of casing, east side	+ .7	3,084.9	175.75	5-27-41	Abandoned, formerly a stock well.
5)	SE SE sec. 16	School district	Dr	170	(?)	(?)	do	do	C,W	C	Land surface	0		160		
6	SW SW sec. 17	Cecil W. Sturgeon	Dr	184.3	(?)	(?)	do	do	C,H	N	Base of hole in pump head, west side	+2.0	3,092.8	177.21	7-24-41	Abandoned, formerly a domestic well.
7	NW SE sec. 22	Mary Neese	Dr	180.6	4	I	do	do	N	N	Top of casing, north side	+2.3	3,072.8	176.03	7-28-41	Abandoned, formerly a domestic and stock well.
8	NE NE sec. 24	J. W. Baughman	Dr	160.4	5	I	do	do	C,W	N	do	+ .3	3,028.3	145.05	7-18-41	Abandoned, formerly a stock well.
	T. 27 S., R. 36 W.															
9	SE NE sec. 2	O. E. Garrison	Dr	137.2	4	I	do	do	C,W	N	Top of hole in steel pipe clamp, north side	+2.5	3,072.1	129.16	7-24-41	Abandoned, formerly a domestic and stock well.
0	SE SW sec. 3	Mary Richardson	Dr	175.8	5	I	do	do	C,W	N	Top of casing, east side	+1.6	3,109.1	162.83	7-17-41	Do
1	NE NE sec. 4	Donald Davis	Dr	186.7	5	I	do	do	C,W	N	Top of casing, west side	+ .3	3,111.8	155.85	7-24-41	Do
2	NW NW sec. 5	A. C. Moore	Dr	163.3	4.5	I	do	do	C,W	N	Top of casing, north side	+4.5	3,095.4	123.99	10-24-39	Do
3	NW NW sec. 8	S. J. Coleman	Dr	137.9	5	GI	do	do	C,W	N	Top of casing, south side	0	3,093.2	126.58	7-14-41	Do

14	SE SE sec. 17	R. A. Phelps	Dr	159.7	6	GI	do	do	B,H	D	Top of casing, north side	+ .2	3,102.6	154.14	7-23-41	
15	NW NE sec. 18	Rosine Smith	Dr	144.2	5	I	do	do	C,W	N	Top of wooden pipe clamp, north side	+1.0	3,089.8	122.70	7-22-41	Do
16	SE NE sec. 34	D. F. Southard	Dr	193.6	5	GI	do	do	C,W	N	Top of casing, north side	+ .4	3,104.8	182.93	7-17-41	Do
	T. 27 S., R. 37 W.															
(17)	SW SW sec. 1	Ridley Howard	Dr	160	(?)	(?)	Sand	do	C,W	D,S	Land surface	0		110		
18	SE SE sec. 4	C. L. Jury	Dr	78.0	6	I	do	do	C,W	N	Top of casing	+ .4	3,070.3	67.40	5-14-41	Do
19	NW SW sec. 18	Hattie Anderson	Dr	86.3	4	I	do	do	C,W	N	Top of casing, west side	+2.1	3,093.0	50.09	7-21-41	Do
20	SW NW sec. 25	School district	Dr	120.9	5	I	do	do	C,H	C	do	+ .8	3,059.9	79.28	7-18-41	
(21)	SE NE sec. 28	Charles Smith	Dr	60	(?)	(?)	do	do	C,W	D,S	Land surface	0		40		
22	SE SE sec. 30	F. C. Williams	Dr	57.0	6	GI	do	do	C,W	N	Top of casing, west side	+ .5	3,077.9	44.88	5-14-41	Abandoned, formerly a stock well.
	T. 27 S., R. 38 W.															
23	SE NE sec. 1	A. Stahl	Dr	56.9	4	I	do	do	C,W	N	Top of casing, north side	+1.7	3,086.6	43.37	7-23-41	Do
24	SE SE sec. 9	Flossie J. Andes	Dr	99.0	8	GI	do	do	C,W	N	Top of 8-inch hole in concrete, south side	+ .7	3,150.0	88.22	5-14-41	Abandoned, formerly a domestic and stock well.
25	SE SE sec. 17	R. Waldie	Dr	55.8	5	I	do	do	C,W	S	Top of casing, east side	+3.0	3,115.3	36.88	7-16-41	
(26)	SE NE sec. 20	do	Dr	100	(?)	(?)	do	do	C,W	D,S	Land surface	0		40		
27	NW SW sec. 23	Leonard Hohner	Dr	(?)	18	I	Sand and gravel	Rexroad and Meade	T,G	I	Top of pump base, north side	+ .6		41.75	3- 9-43	Reported yield 1,200; drawdown 63.
28	NE NE sec. 26	J. B. Shorier	Dr	60.0	6	GI	Sand	Rexroad and/or Meade	C,W	N	Top of casing	0	3,096.3	46.05	5-14-41	Abandoned, formerly a domestic and stock well.
29	SE SE sec. 31	Joe Jungferman	Dr	317	16	I	Sand and gravel	Rexroad and Meade	T,NG	I	Top of casing, north side	0		57.85	8-25-41	Measured yield, 1,184; drawdown 23.94.
30	SW NW sec. 32	George Coffey	Dr	300	16	I	do	do	T,G	I	Top of casing, south side	+2.0	3,123.1	51.66	11-29-40	Measured yield, 1,122; drawdown 23.03.
31	NW SW sec. 33	W. L. Pucket	Dr	288	16	I	do	do	T,NG	I	Land surface	0		49		Measured yield, 967.
32	NE NE sec. 34	J. H. Jarvis	Dr	54.7	(?)	(?)	Sand	Rexroad and/or Meade	C,W	N	Top of wooden block, east side	+1.0	3,112.1	48.43	7-21-41	Abandoned, formerly a domestic and stock well.

TABLE 18.—Records of wells in Grant County, Kansas—*Continued*

on 2)	LOCATION	Owner	Type of well (2)	Depth of well (feet) (3)	Diameter of well (in.)	Type of casing (4)	Principal water-bearing bed: Character of material	Principal water-bearing bed: Geologic subdivision [a]	Method of lift (5)	Use of water (6)	Measuring point: Description	Measuring point: Distance above (+) or below (—) land surface (feet)	Measuring point: Height above sea level (feet)	Depth to water level below measuring point (feet) (7)	Date of measurement	Remarks (Yield given in gallons a minute; drawdown in feet)
	T. 28 S., R. 35 W.															
3	NW SW sec. 1	L. O. Stanley	Dr	267.3	6	I	Sand	Rexroad	C,W	N	Top of casing, southwest side	+0.4	3,081.3	216.07	7-19-41	Abandoned, formerly a domestic and stock well.
14	NE NW sec. 6	Warren Strong	Dr	241.8	4	I	do	do	N	N	Top of casing, north side	+ .2	3,123.8	231.25	7-24-41	Do
15)	NW NW sec. 15	V. S. Higginbotham	Dr	220	4.5	I	do	do	C,W	D,S	Land surface	0		212		
16	SW SW sec. 16	H. A. Kahn	Dr	241.6	5	GI	do	do	C,H	N	Top of casing, south side	+ .3	3,074.5	215.38	7-25-41	Do
17	SE SW sec. 24	J. P. Kaufman	Dr	220.1	(?)	(?)	do	do	C,W	N	Top of 5-inch hole in iron cover, west side	+0.3	3,033.7	212.14	7-19-41	Do
	T. 28 S., R. 36 W.															
18)	SE SE sec. 3	G. D. Hampton	Dr	220	(?)	(?)	do	do	C,W	D,S	Land surface	0		192		
19	NW SW sec. 7	H. W. Basler	Dr	50.9	6	GI	do	Rexroad and/or Meade	N	N	Top of casing, south side	+ .9	3,007.9	41.99	7-14-41	Do
10	NE NE sec. 15	Connie Hampton	Dr	285.1	5	I	Sand and gravel	Rexroad	C,W	N	Top of casing, north side	+1.4	3,091.8	198.79	7-17-41	Do
11	NE NE sec. 25	Fry brothers	Dr	214.3	4	I	Sand and silt	do	C,W	N	Top of casing	+ .9	3,074.7	160		Do
12	NE SW sec. 31	Dorothy Walker	Dr	300+	7	I	Sand and gravel	do	N	N	Top of casing, east side	+1.1	3,092.3	131.57	5-30-41	Abandoned, formerly used to provide water for drilling gas well.
13)	SE SW sec. 36	Ethel W. Hoffman	Dr	91.0	6	I	Sand	do	C,W	S	Top of casing, north side	+ .9	3,041.9	83.03	5-27-41	
	T. 28 S., R. 37 W.															
14	SW SW sec. 2	Attila Hinson	Dr	89.8	(?)	(?)	do	Rexroad and/or Meade	C,W	N	Top of galvanized-iron plate over casing, north side	+ .5	3,078.5	80.61	7-18-41	Abandoned, formerly a domestic and stock well.

45	SW SE sec. 5	Rosine Smith	Dr	300	16	I	Sand and gravel	Rexroad and Meade	T,G	I	Top of hole in pump base, south side	+ .9	3,073.6	52.88	11-29-40	Reported yield, 700; drawdown 74.
46	NE NE sec. 14	C. F. Patterson	Dr	34.7	(?)	(?)	do.	Rexroad and/or Meade	N	N	Top of iron bar over pit	0	2,983.4	9.34	7-18-41	Abandoned, formerly an irrigation well.
47	do.	do.	Dr	160	(?)	(?)	do.	do.	F	S	Top of 1-inch discharge pipe	+3			4-26-43	Measured flow 1¼.
48	SW SW sec. 18	A. Burnham	Dr	139.4	7	I	do.	do.	N	N	Top of casing, south side	+1.0		42.36	10-10-41	Abandoned, formerly used to provide water for drilling gas well.
49	SW SE sec. 20	Grant Co. State Bank	Dr	66.2	6	GI	Sand	do.	C,W	N	Top of casing, north side	0	3,077.4	50.94	7-14-41	Abandoned, formerly a domestic and stock well.
50	SW SE sec. 22	L. T. Helmly	Dr	132.1	6	I	do.	do.	N	N	do.	+2	3,042.3	47.61	8-25-41	Abandoned, formerly used to provide water for drilling gas well.
51	NE SW sec. 27	B. G. Robinson	Dr	77.0	6	GI	do.	do.	N	N	do.	0	3,052.7	72.26	5-28-41	Abandoned, formerly a domestic well.
(52)	SW SW sec. 27	City of Ulysses	Dr	290	12	I	Sand and gravel	Rexroad and Meade	T,NG	P	Land surface	0		57		Reported yield 150.
53	do.	do.	Dr	290	12	I	do.	do.	T,NG	P	do.	0		57		Reported yield, 200; drawdown 28.
54	SE SW sec. 27	A. T. & S. F. Rwy. Co.	Dr	289	12.5	I	do.	do.	C,E	R	do.	0		50		Reported yield, 51 to 78 in a 24-hour test in 1922.
(55)	NE NE sec. 35	Joe Jungferman	Dr	165	4.5	I	Sand	do.	C,W	D,S	do.	0		13		The very hard shallow water is cased off.
	T. 28 S., R. 38 W.															
56	NW NW sec. 4	Earl Brookover	Dr	317	16	I	Sand and gravel	do.	T,NG	I	Top of casing, south side	+ .7	3,118.0	44.50	11-29-40	When new, reported yield, 1,210; drawdown 44.5 feet after 10 hours of pumping. In September, 1942, measured 863; drawdown 48 after three hours of pumping.
(57)	NW SE sec. 4	do.	Dr	55	4.5	I	do.	do.	C,W	D,S	Land surface	0		45		
58	SW SW sec. 4	do.	Dr	285	15.5	I	do.	do.	T,NG	I	Top of casing, west side	+1.8		43.88	7-24-41	Reported yield, 1,400; drawdown 56.
59	NW NE sec. 5	R. R. Wilson	Dr	285	16	I	do.	do.	T,NG	I	Top of casing, east side	0		52.63	10-12-42	Reported yield, 1,400; drawdown 77.
60	NW NW sec. 8	O. P. Williams	Dr	288	16	I	do.	do.	T,NG	I	Top of casing, north side	+1.5	3,128.6	53.33	8-23-40	Measured yield, 1,435; drawdown 31.17.
61	SW SE sec. 8	A. G. Dyck	Dr	52.0	6	GI	Sand and silt	Rexroad and/or Meade	C,W	N	Top of casing, south side	+ .7	3,119.4	46.30	5-14-41	Abandoned, formerly a stock well.

TABLE 18.—Records of wells in Grant County, Kansas—*Continued*

. on . 2 1)	LOCATION	Owner	Type of well (2)	Depth of well (feet) (3)	Diameter of well (in.)	Type of casing (4)	Principal water-bearing bed		Method of lift (5)	Use of water (6)	Measuring point			Depth to water level below measuring point (feet) (7)	Date of measurement	Remarks (Yield given in gallons a minute; drawdown in feet)
							Character of material	Geologic subdivision [a]			Description	Distance above (+) or below (—) land surface (feet)	Height above sea level (feet)			
62	SW NW sec. 9	R. R. Wilson	Dr	280	16	I	Sand and gravel	Rexroad and Meade	T,NG	I	Top of casing, north side	+0.5	....	45.92	3-9-43	Reported yield, 1,000; drawdown 84.
63	SE SE sec. 13	W. O. Howby	Dr	67.8	4	I	Sand	Rexroad and/or Meade	C,W	D	Top of 4-in. pipe, north side	+1.5	3,098.8	61.91	10-10-41	
64	SE SW sec. 26	J. A. Hoffman	Dr	69.0	4	I	do	do	C,H	N	Top of casing, south side	+ .2	3,101.1	47.43	5-28-41	Abandoned, formerly supplied a school.
65	SE SE sec. 27	W. H. and C. E. Leigh	Dr	49.0	(?)	(?)	do	do	C,W	N	Top of hole in metal plate	+ .3	3,101.7	44.35	5-28-41	Abandoned, formerly a domestic and stock well.
66	NW NW sec. 30	T. W. Pudge	Dr	54.6	(?)	(?)	do	do	C,W	N	Top of board over casing	—1.9	3,138.8	48.36	7-23-41	Do
	T. 29 S., R. 35 W.															
67	SW SW sec. 7	Hazel Cantrell	Dr	146.2	5	I	Sand and gravel	do	C,W	S	Top of casing, west side	+ .4	3,031.9	133.39	8-7-41	
(68)	SE SW sec. 12	W. B. Miller	Dr	234	(?)	(?)	do	Rexroad	C,W	D,S	Land surface	0	....	226	.....	
69	NW NW sec. 24	G. D. Blackwelder	Dr	257.9	6	I	do	do	N	N	Top of casing, west side	—2.6	3,032.4	234.19	8-25-41	Abandoned, formerly used to provide water for drilling gas well.
70	SE SE sec. 25	United Carbon Co.	Dr	367	(?)	GI	do	do	PI,G	C	Top of casing	0	3,030.2	237	....	
71	NW NE sec. 33	E. O. Stuart	Dr	77.0	4	I	do	Rexroad and/or Meade	N	N	Top of casing, south side	+ .8	2,953.5	59.83	5-27-41	Abandoned, formerly a stock well.
	T. 29 S., R. 36 W.															
(72)	NW NE sec. 4	School district	Dr	113.4	4	I	Sand and silt	do	C,W	C	Top of hole in pump base	+0.8	3,058.7	93.87	7-15-41	
73	NW NE sec. 5	Fred Powell	Dr	119.0	4	I	do	do	N	N	Top of casing, east side	+ .5	3,064.0	107.05	5-30-41	Do
74	SW SW sec. 18	School district	Dr	37.5	4.5	I	do	do	C,H	C	Top of pump, south side	+3.0	2,986.3	35.65	7-12-41	

75	SE NW sec. 24	L. W. Stevenson	Dr	205.9	7	I	do	do	N	N	Top of casing, west side	+2.6	3,021.4	111.52	8-26-41	Abandoned, formerly used to provide water for drilling gas well.
(76)	NE NW sec. 25	O. T. Deyoe	Dr	119	(?)	(?)	do	do	C,W	D,S	Land surface	0	....	97	......	
77	NW NE sec. 27	O. O. Strickling	Dr	34.7	5	GI	do	do	N	N	Top of wooden platform	+ .4	2,934.6	13.79	7-30-41	Abandoned, formerly a domestic and stock well.
78	NE NW sec. 29	Ernest Keller	Dr	61.9	4	I	do	do	C,W	N	Top of casing, south side	+ .7	3,001.5	48.50	7-28-41	Abandoned, formerly a stock well.
	T. 29 S., R. 37 W.															
79	NW NW sec. 3	J. D. Riggs	Dr	26.8	4.5	I	do	do	C,W	N	Top of casing, west side	-1.0	....	14.72	7-11-41	Do
80	SE SW sec. 14	J. M. Thomason	Dr	100.3	4	I	do	do	C,W	N	do	+ .4	3,064.2	77.78	7-28-41	Abandoned, formerly a domestic and stock well.
81	SE NE sec. 18	John Neufield	Dr	90	4.5	GI	do	do	C,H	N	Top of casing	0	....	72	......	Do
82	SE SW sec. 20	Perry Campbell	Dr	82.0	5	I	do	do	N	N	Top of casing, southeast side	+ .1	3,090.6	74.16	5-30-41	Do
83	SW SW sec. 21	School district	Dr	80.3	4	I	do	do	C,H	C	Top of casing, north side	+ .4	3,086.8	75.07	8- 7-41	
(84)	SW SW sec. 22	Verlan Johnson	Dr	80	(?)	(?)	do	do	C,W	D,S	Land surface	0	....	60	......	
85	SW NW sec. 34	Edith Alford	Dr	76.5	5	GI	do	do	C,H	N	Top of casing, west side	0	3,066.7	67.30	7-11-41	Do
	T. 29 S., R. 38 W.															
(86)	NE NE sec. 16	A. G. Redinger	Dr	150	(?)	(?)	do	do	C,W	D,S	Land surface	0	....	60	......	
87	SE SE sec. 18	L. A. Smith	Dr	75.8	(?)	(?)	Sand and gravel	do	C,W	N	Top of wooden block, level with base of pump	+1.3	3,145.5	64.95	7-14-41	Abandoned, formerly a stock well.
88	NE NW sec. 26	School district	Dr	40.2	6	GI	do	do	C,H	C	Top of casing, north side	+ .5	3,073.0	29.86	8- 4-41	
(89)	NE NE sec. 27	P. H. Jantz	Dr	25	(?)	(?)	do	do	C,H	D,S	Land surface	0	....	20	......	
90	NW SW sec. 29	H. W. Loewen	Dr	63.4	5	I	do	do	C,W	N	Top of hole in 3-in. pipe	+2.8	3,115.2	32.87	8- 5-41	Abandoned, formerly a domestic and stock well.
91	SW NW sec. 30	F. C. Williams	Dr	93.0	6	GI	do	do	C,W	N	Top of pipe coupling, southeast side	+1.0	3,159.4	68.39	8- 9-39	Do
92	SW NE sec. 35	E. A. Kepley	Dr	240	12	GI	do	Rexroad and Meade	T,D	I	Top of air-gage hole in pump base, west side	+2.0	....	72.25	9-22-42	Measured yield, 456; drawdown 22.8.
	T. 30 S., R. 35 W.															
(93)	SW SE sec. 2	W. P. Haddican	Dr	240	(?)	(?)	do	Rexroad	C,W	D,S	Land surface	0	....	225	......	
94	SE SE sec. 3	C. E. Smith	Dr	195.6	5	GI	do	do	C,W	N	Top of casing, south side	+ .6	2,987.5	193.39	7-11-41	Do

TABLE 18.—Records of wells in Grant County, Kansas—*Continued*

). on 1.2 .1)	LOCATION	Owner	Type of well (2)	Depth of well (feet) (3)	Diameter of well (in.)	Type of casing (4)	Principal water-bearing bed: Character of material	Principal water-bearing bed: Geologic subdivision [a]	Method of lift (5)	Use of water (6)	Measuring point: Description	Measuring point: Distance above (+) or below (—) land surface (feet)	Measuring point: Height above sea level (feet)	Depth to water level below measuring point (feet) (7)	Date of measurement	Remarks (Yield given in gallons a minute; drawdown in feet)
95	SW SW sec. 4	R. P. Thoma	Dr	68.8	5	GI	Sand and gravel	Rexroad and/or Meade	C,W	N	Top of casing, west side	—1.2	2,906.3	67.54	7-16-41	Abandoned, formerly a stock well.
96	NW NE sec. 13	Estella Stevens	Dr	189.4	(?)	(?)	do	Rexroad	C,G	S	Top of pipe clamp, east side	+ .2	2,971.0	183.62	8-26-41	
97	NW NW sec. 16	Riverview State Bank	Dr	85.7	5	GI	do	Rexroad and/or Meade	C,W	S	Top of casing, east side	+ .4	2,884.4	76.46	7-17-41	
98	NE NW sec. 20	C. D. Hickok	Dr	177.2	5	GI	do	Rexroad	C,W	N	Top of casing, west side	0	2,998.8	155.47	7-16-41	Do
99	SW SW sec. 22	Hugh Hooper	Dr	69.4	4	I	do	Rexroad and/or Meade	C,W	N	Top of 2-inch pipe, west side	+9.0	2,878.9	55.91	8- 7-41	Do
100	NE SW sec. 24	Scott Holding Co.	Dr	67.6	5	GI	do	do	N	N	Top of casing, south side	+ .2	2,849.7	63.10	7-11-41	Abandoned, formerly a domestic and stock well.
101	SW SW sec. 35	Frank Fleming	Dr	139.4	5	GI	do	do	C,W	N	Top of casing, west side	+ .4	2,915.7	126.04	7-17-41	Do
	T. 30 S., R. 36 W.															
102)	SW SE sec. 1	Clara B. Hall	Dr	140	(?)	(?)	do	do	C,W	D,S	Land surface	0	....	130	....	
103	NW NW sec. 2	Iowa Alford	Dr	48.1	(?)	(?)	do	do	C,W	N	Top of 1½-inch pipe, east side	+4.5	2,955.1	45.98	7-21-41	Do
104)	NW NW sec. 5	J. W. Alford	Dr	125	(?)	(?)	do	do	C,W	D,S	Land surface	0	....	115	....	
105	SW SW sec. 10	J. W. Teeters	Dr	168.4	6	GI	do	do	C,W	N	Top of casing, south side	0	3,027.2	119.47	7-30-41	Abandoned, formerly a stock well.
106)	SE SE sec. 23	do	Dr	25	5	I	do	Alluvium	C,W	S	Land surface	0	....	20	....	
07	SW SW sec. 24	do	Dr	54.6	6	GI	do	do	N	N	Top of casing, west side	+ .5	3,910.9	21.47	7-11-41	Do
08	NE NW sec. 26	G. E. Gordon	Dr	20.7	5	GI	do	do	C,W	D	Top of iron pipe clamp	+2.7	2,912.0	15.97	8- 1-41	

109	NW NW sec. 27	Clarabelle Young	Dr	135.4	(?)	(?)	do.	Rexroad and/or Meade	N	N	Top of 2-inch pipe, south side	+3.1	3,028.5	99.38	7-30-41	Abandoned, formerly a domestic and stock well.
110	SW SE sec. 31	C. W. Eidson	Dr	111.8	(?)	(?)	do.	do.	C,W	N	Top of concrete slab over well	— .5	3,059.1	96.18	7-30-41	Do
	T. 30 S., R. 37 W.															
111	NW NW sec. 1	Georgia Limper	Dr	117.9	5	GI	do.	do.	C,W	N	Top of 5-inch hole in concrete base	0	3,083.4	113.20	7-28-41	Do
112	NW NE sec. 4	W. H. Hilderbrand	Dr	87.8	5	GI	do.	do.	C,H	N	Top of casing, south side	+ .4	3,087.2	85.36	7-11-41	Do
113	NW SW sec. 15	H. H. Tuttle	Dr	287	18	GI	do.	do.	T,G	I	Top of casing, southeast side	+ .5	3,101.2	119.94	8-29-41	Water level was reported to have been 114.6 feet below land surface before the well was pumped. Reported yield, 850.
(114)	NE NE sec. 16	do.	Dr	120	(?)	(?)	do.	do.	C,W	D,S	Land surface	0	....	94	......	
115	NW SW sec. 20	John Lewis	Dr	335	16	GI	do.	do	T,G	I	Top of casing, east side	0	3,124.0	114.40	8-8-41	Measured yield, 681; drawdown 23.42.
116	NW SE sec. 21	E. F. Fowler	Dr	193.2	6	I	do.	do.	N	N	Top of casing, west side	+ .8	3,093.7	103.00	8-25-41	Abandoned, formerly used to provide water for drilling gas well.
117	NW SW sec. 24	C. L. Carlock	Du	25	(?)	(?)	do.	Alluvium	P,H	N	Top of galvanized-iron cover over well	+ .1	2,970.8	21.67	7-30-41	Abandoned, formerly a domestic well.
118	SE SE sec. 25	C. J. Brollier	Dr	122.9	(?)	(?)	do.	Rexroad and/or Meade	C,W	N	Top of iron pipe clamp, west side	+ .2	3,053.5	105.54	7-30-41	Abandoned, formerly a domestic and stock well.
(119)	SW NW sec. 27	Harry Joyce	Dr	25	8	GI	do.	Alluvium	C,W	D,S	Top of casing	+2.0	....	15	......	
120	do.	do.	Dr	16.0	6	GI	do.	do.	N	N	Top of casing, north side	0	2,983.5	11.49	5-28-41	Do
121	SW SW sec. 31	L. M. Pope	Dr	40.6	6	GI	do.	Rexroad and/or Meade	C,W	N	Top of casing, west side	0	3,051.1	33.00	8-5-41	Do
122	NE NE sec. 33	M. T. Joyce	Dr	31.9	5	I	do.	Alluvium	C,W	N	Top of casing, north side	+2.1	3,002.1	20.62	8-2-41	Do
123	NW SE sec. 33	J. F. Parsons	Dr	71.7	8	I	do.	do.	C,W	S	do.	+1.3	3,018.84	23.61	8-2-41	
124	SW NW sec. 36	Harry Joyce	Dr	317	12	GI	do.	Rexroad and/or Meade	T,NG	I	At air-gage hole in pump base, south side	+1.0	3,064.35	81.68	7-11-41	Reported yield, 1,000; drawdown 13.
	T. 30 S., R. 38 W.															
125	SE NE sec. 9	School district	Dr	137.1	5	I	do.	do.	C,W	C	Top of casing, south side	+ .8	3,148.3	86.41	7-15-41	
(126)	SE SE sec. 10	Elmer Hennigh	Dr	140	4.5	I	do.	do.	C,W	D,S	Land surface	0	....	92	......	
127	NW NE sec. 15	Grant Co. State Bank	Dr	96.9	(?)	(?)	do.	do.	C,W	N	Top of galvanized-iron plate over casing	+ .7	3,139.4	84.61	7-15-41	Abandoned, formerly a stock well.

TABLE 18.—Record of wells in Grant County, Kansas—*Concluded*

No. on Pl. 2 (1)	Location	Owner	Type of well (2)	Depth of well (feet) (3)	Diameter of well (in.)	Type of casing (4)	Principal water-bearing bed: Character of material	Principal water-bearing bed: Geologic subdivision [a]	Method of lift (5)	Use of water (6)	Measuring point: Description	Measuring point: Distance above (+) or below (—) land surface (feet)	Measuring point: Height above sea level (feet)	Depth to water level below measuring point (feet) (7)	Date of measurement	Remarks (Yield given in gallons a minute; drawdown in feet)
28	NE NE sec. 33	H. F. McCall	Dr	111.4	(?)	(?)	Sand and gravel	Rexroad and/or Meade	C,W	N	Top of galvanized-iron plate over casing	—1.9	3,153.9	92.69	8- 2-41	Abandoned, formerly a domestic and stock well.
29	SW SE sec. 34	Gustav Witt	Dr	118.7	(?)	(?)	do	do	C,W	N	do	—.3	3,152.3	101.81	8- 2-41	Do

a. For Rexroad read Rexroad (?).
1. Well number in parentheses indicates that analysis of water is given in Table 11.
2. Dr, drilled; Du, dug.
3. Measured depths given in feet and in tenths of a foot; reported depths given in feet.
4. GI, galvanized iron; I, iron or steel.
5. Pumps: C, cylinder; F, natural flow; N, none; P, pitcher; Pl, plunger; T, turbine. Power: D, diesel engine; E, electric motor; G, gasoline engine; H, hand; N, none; NG, natural-gas engine; W, wind.
6. C, community; D, domestic; I, irrigation; N, none; P, public supply; R, railroad; S, stock.
7. Measured water levels given in feet and in tenths and hundredths of a foot; reported water levels given in feet.

TABLE 19.—*Records of wells in Haskell County, Kansas*

. on . 2 1)	LOCATION	Owner	Type of well (2)	Depth of well (feet) (3)	Diameter of well (in.)	Type of casing (4)	Principal water-bearing bed: Character of material	Principal water-bearing bed: Geologic subdivision [a]	Method of lift (5)	Use of water (6)	Measuring point: Description	Measuring point: Distance above (+) or below (–) land surface (feet)	Measuring point: Height above sea level (feet)	Depth to water level below measuring point (feet) (7)	Date of measurement	Remarks (Yield given in gallons a minute; drawdown in feet)
	T. 27 S., R. 31 W.															
.0	SE SE sec. 9	School district	Dr	86.4	4.5	GI	Sand and gravel	Rexroad and/or Meade	C,W	C	Top of casing, south side	+0.2	2,814.2	76.66	9- 6-41	
1	NE SE sec. 12	Ole Hoskinson	Dr	72.9	5	GI	do	do	C,W	N	Top of casing, west side	+ .8	2,794.7	68.46	9- 5-41	Abandoned, formerly a domestic and stock well.
2	SE NE sec. 19	Leah Nichols	Dr	104.6	5	GI	do	do	C,W	N	Top of casing, east side	+ .6	2,846.5	102.52	9-10-41	Do
33)	NE NE sec. 22	E. W. Frank	Dr	100	(?)	(?)	do	do	C,W	D,S	Land surface	0	....	81	....	
4	NW NE sec. 36	Dale Moore	Dr	197.8	16	GI	do	do	T,G	I,S	Top of hole in pump base, north side	+ .3	....	135.02	4-24-43	Reported yield, 500; drawdown 5.
	T. 27 S., R. 32 W.															
35)	NW SW sec. 6	J. A. Nichols	Dr	119.3	4.5	I	do	do	C,W	D,S	Top of casing, west side	+2.7	2,906.5	109.64	9-12-41	
6	NE NE sec. 14	Mary E. Carey	Dr	97.0	6	GI	do	do	C,W	C	Top of casing, northwest side	+ .2	2,848.3	86.08	7-24-41	
7	SW SW sec. 16	J. C. Lemon	Dr	109.8	4	(?)	do	do	C,W	N	Top of 4-inch hole in concrete platform	+ .3	2,883.7	107.17	9- 3-41	Abandoned, formerly a domestic and stock well.
18)	SW NW sec. 19	C. A. Tapely	Dr	120.0	6	I	do	do	C,W	S	Top of casing, west side	+1.1	2,895.0	110.73	9-17-41	
19)	SW NW sec. 24	C. E. Miller	Dr	127	(?)	(?)	do	do	C,W	D,S	Land surface	0	....	101	....	
	T. 27 S., R. 33 W.															
0	NE NE sec. 2	W. M. Garey	Dr	119.8	6	GI	do	do	C,W	N	Top of casing, northeast side	+1.3	2,919.5	112.71	9- 3-40	Do
1	NE NW sec. 13	E. A. Davis	Du	113.0	(?)	(?)	do	do	C,W	N	Top of pipe	+ .9	2,905.4	109.94	6-24-41	Do
2)	SE SW sec. 18	George S. Frey	Dr	160	4.5	I	do	do	C,W	D,S	Land surface	0	....	140	....	

TABLE 19.—Records of wells in Haskell County, Kansas—*Continued*

	Location	Owner	Type of well (2)	Depth of well (feet) (3)	Diameter of well (in.)	Type of casing (4)	Principal water-bearing bed		Method of lift (5)	Use of water (6)	Measuring point			Depth to water level below measuring point (feet) (7)	Date of measurement	Remarks (Yield given in gallons a minute; drawdown in feet)
							Character of material	Geologic subdivision [a]			Description	Distance above (+) or below (—) land surface (feet)	Height above sea level (feet)			
3	NE NE sec. 31	Harry B. Lyman	Dr	220.0	4	I	Sand and gravel	Rexroad	C,G	N	Top of casing, northeast side	+1.0	2,997.9	191.72	6-26-41	Abandoned, formerly a domestic and stock well.
	T. 27 S., R. 34 W.															
4	NW NW sec. 21	William Dreyer	Dr	167.0	6	GI	do	do	C,W	N	Top of casing, south side	0	3,019.9	151.92	7-31-41	Do
	T. 28 S., R. 31 W.															
.5	SW SW sec. 2	E. H. Schmidt	Dr	300	18	GI	do	do	T,G	I	Top of hole in casing, west side	— .3	2,884.4	161.43	9- 6-41	Reported yield, 800; on April 24, 1943, measured drawdown 6.26.
.6	NW SW sec. 8	H. J. Cornwell	Dr	209.4	5	GI	do	do	C,H	N	Top of casing, north side	— .4	2,915.2	183.22	9- 6-41	Abandoned, formerly a domestic and stock well.
.7	NE NW sec. 9	F. S. Henry	Dr	181.8	5	GI	do	do	C,W	N	Top of casing, northeast side	+ .5	2,892.0	164.93	9- 6-41	Do
48)	NW NW sec. 15	Earl H. Phillips	Dr	180	(?)	(?)	do	do	C,W	D,S	Land surface	0	....	172	......	
	T. 28 S., R. 32 W.															
9	SW SW sec. 3	J. H. Schuette	Dr	174.2	4.5	I	do	do	C,W	N	Top of casing, north side	0	2,918.5	165.45	9- 8-41	Abandoned, formerly a stock well.
50)	SW SE sec. 6	A. E. Hawes	Dr	185	4	I	do	do	C,W	D,S	Land surface	0	....	172	......	
51)	SW SE sec. 13	O. C. Derby	Dr	220	(?)	(?)	do	do	C,W	D,S	do	0	....	190	......	
2	NE NE sec. 25	Ida DeFresse	Dr	216.7	(?)	(?)	Silt	do	C,W	N	Top of hole in concrete platform, west side	0	2,928.1	201.79	9-18-41	Abandoned, formerly a domestic and stock well.
3	SE NE sec. 29	Dean Nelson	Dr	206.0	10	I	do	do	C,W	N	Top of 6-inch pipe	+ .8	2,937.9	198.45	6-27-41	Abandoned, formerly a stock well.

54	SW NE sec. 32	Peter Specht	Dr	298.2		GI	do	do	C,W	N	Top of 12-inch hole in concrete platform	+ .5	2,921.0	185.63	9- 4-41	Abandoned, formerly a domestic and stock well.
	T. 28 S., R. 33 W.															
55	SE NE sec. 10	Ray Bateman	Dr	213.7	(?)	(?)	do	do	C,W	N	Top of iron pipe clamp, south side	+ .3	2,974.3	201.99	9- 8-41	Do
56	NW NE sec. 18	R. N. Henage	Dr	292.3	4.5	I	do	do	C,W	N	Top of casing, west side	+ .7	3,005.7	234.59	9- 2-41	Do
57	NE SE sec. 21	Conn. Life Ins. Co.	Dr	221.0	6	GI	Sand and silt	do	C,W	N	do	0	2,968.8	202.84	9-17-41	Abandoned, formerly a stock well.
(58)	SE SW sec. 22	J. C. Barbee	Dr	231.8	4.5	I	do	do	C,W	N	Top of casing, north side	+1.3	2,963.7	213.66	9- 2-41	Abandoned, formerly a domestic and stock well.
59	SW SW sec. 31	H. F. Murphy	Dr	207.6	4	I	do	do	C,W	S	do	+ .7	2,967.7	195.91	8-22-41	
	T. 28 S., R. 34 W.															
(60)	NW NW sec. 9	H. W. Mace	Dr	262.1	4	I	Sand and gravel	do	C,W	N	Top of casing, west side	+0.8	3,088.5	247.18	9- 3-41	Do
61	SE SE sec. 21	Peter Plett	Dr	260.4	4.5	I	Sand and silt	do	C,W	D,S	Top of casing, south side	+1.3	3,033.5	248.88	8-17-41	
62	NE NE sec. 26	Frank McCoy	Dr	288.7	4	I	do	do	N	N	Top of casing, east side	+1.0	2,987.6	210.46	9- 3-41	Do
(63)	SE SE sec. 30	H. E. Winsted	Dr	210	(?)	(?)	do	do	C,W	D,S	Land surface	0		205		
64	NE SE sec. 31	Alda F. Trahern	Dr	202.7	(?)	(?)	do	do	C,W	N	Top of hole in pipe clamp, east side	0	2,999.8	196.46	8-29-41	Do
65	NW NW sec. 33	M. H. Eubank	Dr	234.0	6	I	do	do	C,W	N	Top of casing, east side	+1.2	3,015.9	222.82	7-31-41	Do
66	SW SE sec. 34	W. H. Davis	Dr	212.8	4	I	do	do	C,W	N	Top of casing, south side	+ .5	2,989.7	204.06	8-29-41	Do
	T. 29 S., R. 31 W.															
(67)	NE SE sec. 3	C. E. Ward	Dr	180	5	GI	Sand and gravel	do	C,W	D,S	Land surface	0		160		
68	NW NE sec. 7	C. G. Dennis	Dr	185	5	GI	Sand and silt	do	N	N	Top of casing, north side	−1.4	2,890.8	176.72	9- 9-41	Do
69	SE SE sec. 9	School district	Dr	173.4	5	GI	Sand and gravel	do	C,WH	C	do	0	2,856.8	156.17	9- 6-41	
70	NE NE sec. 11	Copeland State Bank	Dr	178.0	5	GI	do	do	N	N	Top of hole in casing, east side	+ .6	2,854.4	156.75	6-27-41	Do
71	NE NE sec. 20	C. D. Jennings	Dr	173.0	4	GI	do	do	N	N	Top of casing, east side	+ .2	2,860.4	161.31	6-27-41	Abandoned, formerly a domestic well.
(72)	SE NE sec. 20	do	Dr	172	(?)	(?)	do	do	C,WH	D,S	Land surface	0		162		
	T. 29 S., R. 32 W.															
73	SE NE sec. 2	H. L. Damm	Dr	188.9	5	GI	Sand and silt	do	C,W	N	Top of casing, east side	+ .3	2,902.3	189.62	9- 8-41	Abandoned, formerly a domestic and stock well.

TABLE 19.—Records of wells in Haskell County, Kansas—*Continued*

. on .2 1)	LOCATION	Owner	Type of well (2)	Depth of well (feet) (3)	Diameter of well (in.)	Type of casing (4)	Principal water-bearing bed: Character of material	Principal water-bearing bed: Geologic subdivision [a]	Method of lift (5)	Use of water (6)	Measuring point: Description	Measuring point: Distance above (+) or below (—) land surface (feet)	Measuring point: Height above sea level (feet)	Depth to water level below measuring point (feet) (7)	Date of measurement	Remarks (Yield given in gallons a minute; drawdown in feet)
'4	SW SE sec. 3	Ira Tain	Dr	193.2	(?)	(?)	Sand and silt	Rexroad and/or Meade	C,W	N	Top of pipe, west side	+3.9	2,914.2	191.09	8-13-41	Abandoned, formerly a stock well.
'5	NE NW sec. 6	Maggie Deewall	Dr	202.3	(?)	(?)	Sand and gravel	do.	C,W	N	Top of galvanized-iron plate over casing	0	2,932.9	196.59	8-13-41	Abandoned, formerly a domestic and stock well.
'6	SW NW sec. 7	W. D. Kuykendall	Dr	212.9	4	I	do.	do.	C,W	N	Bottom of 1-inch hole in 3-inch pipe	+3.0	2,929.6	200.58	8-22-41	Do
'7	NE NE sec. 9	Myrtle Hall	Dr	198.5	5	I	Sand and silt	do.	C,W	N	Top of pipe, north side	+2.0	2,914.8	187.06	8-13-41	Do
'8	SW SE sec. 12	G. F. Trager	Dr	188.6	5	GI	Silt and sand	do.	C,H	N	Top of casing, west side	+ .6	2,891.0	176.43	9- 9-41	Do
79)	SW SW sec. 15	E. D. Dennis	Dr	213	4.5	I	Coarse gravel	do.	C,W	D,S	Land surface	0		197		
30	NW SW sec. 26	D. E. McClure	Dr	205.3	5	I	Sand and gravel	do.	C,W	N	Top of wooden pipe clamp, west side	+1.6	2,897.8	192.17	9- 2-41	Abandoned, formerly a stock well.
31	SW SW sec. 27	M. M. Frazier	Dr	205.4	4.5	GI	do.	do.	N	N	Top of casing, west side	— .2	2,905.3	196.54	8-21-41	Abandoned, formerly a domestic and stock well.
32	SW NE sec. 32	A. T. & S. F. Rwy. Co.	Dr	211	5	(?)	do.	do.	C,W	R	Land surface	0		196		
83)	do.	City of Sublette	Dr	290	6	I	do.	do.	T,E	P	Top of casing	0		201		Reported yield, 100.
34	NE SW sec. 32	do.	Dr	275	24	I	do.	do.	T,E	P	do.	0		202		Reported yield, 175.
	T. 29 S., R. 33 W.															
35	NW SW sec. 5	E. M. Watkins	Dr	195	4	I	Sand	do.	C,W	D,S	do.	+ .5		187		Abandoned, formerly a domestic and stock well.
86)	SW SE sec. 12	Sarah Rowland	Dr	202	(?)	(?)	do.	do.	C,W	D,S	Land surface	0		198		

187	NE NE sec. 25	H. M. Daniel	Dr	221.5	4.5	I	do	do	C,W	D,S	Top of casing, east side	+ .2		201.94	10-26-42	
188	SW SE sec. 28	F. E. Murphy	Dr	241.7	(?)	(?)	Sand and gravel	do	C,W	S	Top of metal pipe clamp, north side	+ .2	2,950.9	200.74	8-22-41	
(189)	SW SW sec. 30	E. H. Elliott	Dr	222	4	I	do	do	C,W	S	Top of casing, west side	+1.6	2,973.0	212.61	8-22-41	
	T. 29 S., R. 31 W.															
190	SW SE sec. 1	C. M. Light	Dr	205.8	5	I	do	do	C,W	N	Top of casing, south side	0	2,958.0	183.10	8-22-41	Abandoned, formerly a stock well.
(191)	NE NE sec. 16	F. Owens	Dr	210	5	I	do	do	C,W	D,S	Land surface	0		202		
192	SW SW sec. 16	Laura Hickman	Dr	213.4	4	I	do	do	C,W	N	Top of hole in pipe clamp	+ .5	2,990.5	200.79	9-17-41	Abandoned, formerly a domestic and stock well.
193	SW SW sec. 28	R. L. Hall	Dr	212.6	4	I	do	do	C,W	N	Top of casing, west side	−1.0	2,992.0	208.90	8-22-41	Do
194	SW NE sec. 30	A. J. Collingwood	Dr	300+	6	I	do	do	N	N	Top of casing, east side	+ .9	3,010.6	220.44	8-25-41	Abandoned, formerly used to provide water for drilling gas well.
(195)	NE SE sec. 31	Ill. Bank. Life Assur. Co.	Dr	230	(?)	(?)	do	do	C,W	D,S	Land surface	0		220		
196	SE NW sec. 32	G. A. Harper	Dr	300±	6	I	do	do	N	N	Top of casing, east side	+1.0	3,008.5	222.85	8-25-41	Do
	T. 30 S., R. 31 W.															
197	NE NE sec. 2	James Wilson	Dr	166.4	5	GI	do	do	C,W	N	Top of hole in steel block, west side	0	2,843.9	161.64	8-12-41	Abandoned, formerly a domestic and stock well.
(198)	NE NE sec. 3	H. E. Luther	Dr	180	(?)	(?)	do	do	C,WH	D,S	Land surface	0		163		
199	NE NE sec. 10	John Schmidt	Dr	180.4	4.5	(?)	do	do	C,W	N	Top of 4½-inch hole in concrete platform	0	2,843.6	162.42	9-9-41	Do
200	SW NW sec. 17	W. J. Gleason	Dr	165.7	5	GI	do	do	C,W	N	Top of casing, east side	+0.4	2,847.0	163.06	9-9-41	Do
201	SW SW sec. 22	School district	Dr	183.9	5	GI	do	do	C,H	C	do	0	2,844.6	172.18	8-12-41	
(202)	SW SE sec. 22	G. W. Trahern	Dr	180	(?)	(?)	do	do	C,W	D,S	Land surface	0		170		
(203)	SE SW sec. 36	Homer Vail	Dr	160	(?)	(?)	do	do	C,W	D,S	do	0		152		
	T. 30 S., R. 32 W.															
204	NW NW sec. 2	Etta McCoy	Dr	196.0	6	I	do	do	N	N	Top of casing, east side	+1.1	2,890.3	188.60	6-28-41	Abandoned, formerly a stock well.
205	NE NE sec. 7	Ethel McCoy	Dr	209.3	5	I	do	do	C,W	N	Top of pipe, east side	+3.8	2,919.5	203.93	8-13-41	Do
206	SW SW sec. 11	Sybil Smith	Dr	198.0	6	GI	do	do	N	N	Bottom of iron pipe clamp	+ .3	2,878.5	180.76	7-24-41	Abandoned, formerly a domestic and stock well.

TABLE 19.—Records of wells in Haskell County, Kansas—*Concluded*

. on . 2 1)	LOCATION	Owner	Type of well (2)	Depth of well (feet) (3)	Diameter of well (in.)	Type of casing (4)	Principal water-bearing bed: Character of material	Principal water-bearing bed: Geologic subdivision [a]	Method of lift (5)	Use of water (6)	Measuring point: Description	Measuring point: Distance above (+) or below (—) land surface (feet)	Measuring point: Height above sea level (feet)	Depth to water level below measuring point (feet) (7)	Date of measurement	Remarks (Yield given in gallons a minute; drawdown in feet)
)7)	NE NE sec. 12	G. H. Walton	Dr	185.6	4.5	I	Sand and gravel	Rexroad and/or Meade	C,W	N	Top of casing, northwest side	+0.5	2,865.3	171.86	9-9-41	Abandoned, formerly a domestic and stock well.
8	SE SE sec. 18	F. W. Leonard	Dr	195.2	5	GI	do	do	C,W	N	Top of hole in pipe clamp, east side	0	2,907.6	191.78	8-13-41	Do
9	SE SW sec. 20	L. C. Leonard	Dr	198.0	6	GI	do	do	C,W	N	Top of galvanized-iron plate over casing	0	2,893.0	184.64	7-24-41	Do
0	NE SE sec. 24	Sophia Watson	Dr	178.5	(?)	(?)	do	do	C,W	S	Top of wooden pipe clamp, east side	+ .2	2,850.3	165.26	8-12-41	
1	NE NE sec. 28	G. W. Avery	Dr	181.3	4.5	I	do	do	C,W	N	Top of casing, east side	+ .6	2,870.4	171.70	9-2-41	Do
12)	NW NW sec. 31	J. C. Lemon	Dr	195	4	GI	do	do	C,W	D,S	Top of casing	0	....	188	......	
	T. 30 S., R. 33 W.															
3	SW SE sec. 5	Eunice Winsted	Dr	217.9	4	I	do	do	C,W	N	Top of casing, east side	+ .4	....	205	......	Do
4	SE SE sec. 14	D. E. Roberts	Dr	210.4	4	I	do	do	C,W	N	Top of pipe, east side	+3.0	2,930.0	208.84	8-12-41	Do
	T. 30 S., R. 34 W.															
5	SE NW sec. 5	H. P. Rooney	Dr	244.6	7	I	do	do	N	N	Top of casing, south side	+1.1	2,997.4	213.00	9-17-41	Abandoned, formerly used to provide water for drilling gas well.
6	SW NE sec. 13	A. T. & S. F. Rwy. Co	Dr	311	11	(?)	do	do	C,E	R	Land surface	0	....	220	......	Drilled to 258 feet in 1912, and deepened to 280 feet in 1931, and to 311 feet in 1936.
7	NW SE sec. 13	Bessie Custer	Dr	210.0	(?)	(?)	do	do	N	N	Top of 1-inch board over casing	0	2,963.1	207.68	6-30-41	Abandoned, formerly a domestic well.
18)	NE SW sec. 13	City of Satanta	Dr	280	8	I	do	do	T,E	P	Top of casing	0	....	200	......	Reported yield, 150.

219	do	do	Dr	280	8	I	do	do	T,E	P	do	0		200		Reported yield, 325; drawdown 40.
220	NE NW sec. 15	John Siddens	Dr	217.3	5	I	do	do	C,W	N	Top of hole in pump base	+ .4	2,972.3	202.80	8-20-41	Abandoned, formerly a domestic and stock well.
221	SW SE sec. 16	Arthur Vail	Dr	204.7	(?)	(?)	do	do	C,W	N	Top of metal pipe clamp, west side	+ .6	2,968.5	193.53	8-22-41	Do
222	SW SE sec. 18	Ill. Bank. Life Assur. Co.	Dr	207.5	(?)	(?)	do	do	C,W	N	Top of wooden pipe clamp, south side	0	2,983.9	200.63	8-20-41	Abandoned, formerly a stock well.
(223)	NE NW sec. 20	Ella McLain	Dr	210	(?)	(?)	do	do	C,W	D,S	Land surface	0		195		
224	NE NW sec. 23	Emil Schnellbacher	Dr	211.4	7	GI	do	do	N	N	Top of casing, east side	+ .6	2,961.6	197.51	8-20-41	Abandoned, formerly a domestic and stock well.
225	NE SE sec. 30	Scott Holding Co.	Dr	50.1	5	GI	do	do	C,W	N	Top of casing, north side	+1.4	2,824.3	44.43	8-20-41	Do
226	SE NE sec. 31	Ira O. Scott	Dr	78.4	4	I	do	do	N	N	Top of 2-inch pipe, south side	+ .4	2,844.9	63.37	8-20-41	Do
227	SE NW sec. 33	Eli Stoops	Dr	61.0	10	I	do	Alluvium	C,W	N	Top of pipe, north side	+5.8	2,828.9	55.67	6-30-41	Abandoned, formerly a stock well.

a. For Rexroad read Rexroad (?).
1. Well number in parentheses indicates that analysis of water is given in Table 12.
2. Dr, drilled; Du, dug.
3. Measured depths given in feet and tenths of a foot; reported depths given in feet.
4. GI, galvanized iron; I, iron.
5. Pumps: C, cylinder; N, none; T, turbine. Power: E, electric motor; G, gasoline engine; H, hand; N, none; NG, natural-gas engine; W, wind.
6. C, community; D, domestic; I, irrigation; N, none; P, public supply; R, railroad; S, stock.
7. Measured water levels given in feet and in tenths and hundredths of a foot; reported water levels given in feet.

TABLE 20.—*Records of wells in Stevens County, Kansas*

No. on Pl. 2 (1)	LOCATION	Owner	Type of well (2)	Depth of well (feet) (3)	Diameter of well (in.)	Type of casing (4)	Principal water-bearing bed: Character of material	Principal water-bearing bed: Geologic subdivision [a]	Method of lift (5)	Use of water (6)	Measuring point: Description	Measuring point: Distance above (+) or below (−) land surface (feet)	Measuring point: Height above sea level (feet)	Depth to water level below measuring point (feet) (7)	Date of measurement	Remarks (Yield given in gallons a minute; drawdown in feet)
	T. 31 S., R. 35 W.															
228	SW NE sec. 12	Minor Beardsley	Dr	291.0	6	I	Sand and gravel	Rexroad	N	N	Top of casing, north side	+0.9	2,971.6	194.90	8-24-42	Abandoned, formerly used to provide water for drilling gas well.
(229)	NE NE sec. 17	Adelia Shuler	Dr	199.5	5	GI	do	do	C,W	S	Top of casing, east side	−.3	2,999.3	193.59	8-24-42	
230	SW SE sec. 19	Central Life Assur. Co.	Dr	215.5	5	GI	do	do	N	N	do	0	3,121.8	182.65	8-21-42	Abandoned, formerly a domestic and stock well.
231	SE SE sec. 28	Moses Kauffman	Dr	223.0	5	GI	do	do	C,W	N	Top of galvanized-iron plate over casing	+.2	3,004.0	213.78	8-31-42	Do
(232)	SW SW sec. 35	R. A. Barton	Dr	225	(?)	(?)	do	do	C,W	S	Land surface	0	....	210	....	
	T. 31 S., R. 36 W.															
233	NE SE sec. 2	Lee L. Gilbert	Dr	169.0	5	GI	do	Rexroad and/or Meade[a]	C,W	D,S	Top of casing, south side	+.7	3,008.3	143.09	7-31-41	
(234)	NW NW sec. 7	J. W. Broiller	Dr	107	(?)	(?)	do	do	C,W	D,S	Land surface	0	....	98	....	
235	SW NW sec. 9	I. N. Shriver	Dr	124.5	5	GI	do	do	C,W	N	Top of casing, north side	−.5	3,026.6	100.40	8-22-42	Do
236	SE NE sec. 15	J. W. Stewart	Dr	174.5	5	GI	do	do	C,G	S	do	0	3,043.8	149.08	8-22-42	
237	NW NW sec. 25	W. A. Rapp	Dr	175.0	5	GI	do	do	N	N	Top of casing, west side	+.5	3,141.3	151.77	8-21-42	Abandoned, formerly a stock well.
238	SW NW sec. 26	A. T. & S. F. Rwy. Co.	Dr	182	11	(?)	do	do	C,E	N	Land surface	0	....	135	....	Abandoned, formerly used as a railroad supply.
(239)	SE NW sec. 26	City of Moscow	Dr	290	6	I	do	do	C,E	P	do	0	....	140	....	Reported yield, 10.

240	NE NW sec. 28	R. V. Thurow	Dr	132.5	5	GI	do	do	C,W	N	Top of casing, north side	+ .2	3,055.5	105.92	8- 6-42	Abandoned, formerly a stock well.
241	SE SW sec. 28	O. A. Teeter	Dr	149.5	5	GI	do	do	C,W	N	do	+ .4	3,075.3	124.07	8- 6-42	Abandoned, formerly a domestic and stock well.
242	NW NE sec. 34	C. E. Dudley	Dr	136.0	5	GI	do	do	C,W	N	Top of casing, south side	0	3,068.5	132.44	7-28-42	Do
	T. 31 S., R. 37 W.															
243	SE SE sec. 2	John Q. Adams	Dr	107.2	5	GI	do	Rexroad and Meade	C,W	N	Top of casing, east side	+ .6	3,071.4	96.58	8- 7-42	Do
244	SW NW sec. 4	J. F. Parsons	Dr	302	16	I	do	do	T,NG	I	Top of casing, southwest side	......	3,101.5	106.62	9-23-42	Measured yield, 1,092; drawdown 12.54.
245	NE NE sec. 9	B. W. Parsons	Dr	121	7	I	do	do	C,G	S	Top of casing, north side	0	3,078.6	87.03	7-26-42	Formerly used to provide water for drilling gas well.
246	SE SE sec. 9	M. E. McCreery	Dr	100.0	5	I	do	do	C,W	N	Top of pump base	+ .4	3,080.5	89.35	7-27-42	Abandoned, formerly a domestic and stock well.
247	SW NE sec. 10	B. W. Parsons	Dr	275	16	I	do	do	T,NG	I	Top of hole in pump base, northeast side	+1.3	3,069.5	80.70	9-24-42	Measured yield, 1,326; drawdown 14.31.
248	SW SW sec. 12	E. E. Breitheisen	Dr	100.0	(?)	(?)	do	do	C,W	N	Top of galvanized-iron plate over casing	+ .5	3,072.9	97.51	8- 7-42	Abandoned, formerly a domestic and stock well.
(249)	SW SE sec. 29	R. W. Grubbs	Dr	165	5	GI	do	Rexroad and/or Meade	C,W	D,S	Land surface	0	......	148	......	
	T. 31 S., R. 38 W.															
250	NW SE sec. 20	A. T. Spikes	Dr	111.5	(?)	(?)	do	do	C,W	N	Top of wooden pipe clamp, west side	-1.0	3,167.3	107.22	7-25-42	Do
251	NE NW sec. 27	W. H. Leonard	Dr	106.0	5	GI	do	do	C,W	N	Top of casing, east side	+ .6	3,144.6	103.76	8-18-42	Do
(252)	SW SW sec. 27	J. A. Showalter	Dr	114	(?)	(?)	do	do	C,W	D,S	Land surface	0	......	104	......	
(253)	SE NE sec. 29	Stevens County	B	21	(?)	(?)	do	Alluvium	P,H	C	Top wooden platform over well	+1.8	3,073.7	7.53	7-11-42	
254	SW NW sec. 30	R. L. Smith	Dr	114	5	GI	do	Rexroad and/or Meade	C,W	N	Top of 1½-inch pipe, north side	+4.3	3,191.6	112.08	7-25-42	Do
255	NW NE sec. 35	John Zimmerman	Dr	231.0	6.5	I	do	do	N	N	Top of casing, south side	+9.0	3,135.4	117.61	7-11-42	Abandoned, formerly used to provide water for drilling gas well.
	T. 31 S., R. 39 W.															
256	NW NW sec. 2	L. J. Pettijohn	Dr	97.0	6	GI	do	do	C,W	N	Top of casing, west side	0	3,184.5	86.25	8- 5-41	Abandoned, formerly a stock well.
257	NE SE sec. 34	C. T. Palmer	Dr	104.0	8	I	do	do	N	N	Top of casing, south side	+1.0	3,218.2	100.66	8-18-42	Abandoned, formerly used to provide water for drilling gas well.
258	NE NE sec. 35	School district	Dr	109.0	5	GI	do	do	C,W	C	Top of casing, west side	0	3,186.3	88.94	8-18-42	

TABLE 20.—Records of wells in Stevens County, Kansas—*Continued*

on 2	LOCATION	Owner	Type of well (2)	Depth of well (feet) (3)	Diameter of well (in.)	Type of casing (4)	Principal water-bearing bed: Character of material	Principal water-bearing bed: Geologic subdivision [a]	Method of lift (5)	Use of water (6)	Measuring point: Description	Measuring point: Distance above (+) or below (—) land surface (feet)	Measuring point: Height above sea level (feet)	Depth to water level below measuring point (feet) (7)	Date of measurement	Remarks (Yield given in gallons a minute; drawdown in feet)
	T. 32 S., R. 35 W.															
9	SW SW sec. 5	Hitch Land and Commission Co.	Dr	155.0	5	GI	Sand	Rexroad and/or Meade	N	N	Top of casing, west side	—1.0	3,031.3	130.83	8-12-42	Abandoned, formerly a domestic and stock well.
50)	NW NW sec. 16	Minnie Brown	Dr	142.5	5	GI	do	do	C,W	S	Top of casing, east side	— .7	3,012.9	133.81	8-12-42	
1	NW SW sec. 19	Oliver Jones	Dr	156	(?)	(?)	do	do	C,W	D,S	Land surface	0	3,031.4	126	....	
2	SW SW sec. 31	J. E. Mann	Dr	131.0	6	GI	Sand and gravel	do	N	N	Top of 10-inch outer casing, west side	— .3	3,017.8	110.70	8-12-42	Do
3	NE SE sec. 32	Cent. Life Assur. Assn.	Dr	115.5	(?)	(?)	do	do	N	N	Top of board over casing, west side	+ .2	2,988.9	105.18	8-12-42	Do
4	SW NW sec. 35	Charles Niebauer	Dr	139.0	(?)	(?)	Sand	do	C,W	N	Top of rubber cover over casing	+ .3	2,949.0	128.94	8-11-42	Do
	T. 32 S., R. 36 W.															
5	NE NE sec. 10	Eunice Batman	Dr	153.0	5	GI	Sand and gravel	do	C,W	N	Top of casing, east side	0	3,058.0	121.78	7-28-42	Do
6	NW NE sec. 17	Carrie Winter	Dr	123.0	5	GI	do	do	N	N	do	0	3,072.3	118.74	7-28-42	Abandoned, formerly a stock well.
7	NW NE sec. 22	W. H. Tilford	Dr	134.0	5	GI	do	do	N	N	Top of casing, south side	— .7	3,052.7	115.22	8-21-42	Abandoned, formerly a domestic and stock well.
8	NE NE sec. 24	Cent. Life Assur. Assn.	Dr	145.5	5	GI	do	do	C,W	N	Top of casing, north-east side	+1.1	3,029.7	116.41	8-27-42	Do
9	SE SW sec. 30	William Robinson	Dr	143.0	(?)	(?)	do	do	C,H	N	Top of metal cylinder around pipe	+ .5	3,096.8	123.74	8-31-42	Do
	T. 32 S., R. 37 W.															
0	NE SE sec. 3	A. B. Riney	Dr	139.5	5	GI	do	do	C,W	N	Top of casing, north side	0	3,106.3	120.04	8-14-42	Do
	NW NW sec. 6	Isabelle Shepherd	Dr	148.0	5	GI	do	do	C,W	N	Top of casing, south side	—1.0	3,153.6	131.87	8-18-42	Do

272	SE SW sec. 8	E. C. Mingenback	Dr	188.5	5	I	do.	Rexroad	C,W	N	Top of casing, west side	0	3,172.2	159.59	8-14-42	Do
(273)	NE SE sec. 18	J. E. Hill	Dr	145	(?)	(?)	do.	Rexroad and/or Meade	C,W	D,S	Land surface	0	....	136	......	
274	SE NE sec. 20	R. L. L. Barnstable	Dr	146.0	5	GI	do.	do.	N	N	Top of casing, west side	+ .5	3,149.6	127.85	8-18-42	Do
275	SW NE sec. 26	M. Jane White	Dr	126.5	5	GI	do.	do.	N	N	Top of casing, south side	+1.0	3,111.1	114.81	7-30-42	Do
276	SE SE sec. 33	R. R. Stebleton	Dr	100.0	5	GI	do.	do.	C,W	N	Top of casing, southeast side	+1.0	3,120.3	97.88	7-30-42	Do
	T. 32 S., R. 38 W.															
277	SW SW sec. 2	Missouri Supt. of Ins.	Dr	168.0	5	GI	do.	do.	N	N	Top of casing, north side	0	3,180.3	136.49	7-31-42	Abandoned, formerly a stock well.
278	SE SW sec. 21	W. S. Currin	Dr	130.0	5	GI	do.	do.	C,W	N	Top of casing, west side	+1.0	3,220.1	125.26	8-24-42	Abandoned, formerly a domestic and stock well.
279	SW NW sec. 23	State Farm Life Insurance Co.	Dr	132.5	5	GI	do.	do.	C,W	N	do.	+ .7	3,177.9	117.50	7-31-42	Do
280	SE SW sec. 23	W. A. James	Dr	137.0	5	GI	do.	do.	C,W	N	Top of casing, east side	+ .5	3,185.0	126.58	7-31-42	Do
	T. 32 S., R. 39 W.															
281	NE NE sec. 14	A. V. Youngren	Dr	17.4	6	GI	do.	Alluvium	C,W	N	Top of casing, northeast side	+ .3	3,023.8	8.64	8-19-42	Abandoned, formerly a stock well.
	T. 33 S., R. 35 W.															
282	SE SE sec. 3	E. Frick	Dr	99.5	5	GI	Sand	Rexroad and/or Meade	N	N	Top of casing, east side	+1.2	2,943.2	77.85	8-11-42	Abandoned, formerly a domestic and stock well.
283	SE SE sec. 15	J. C. Lemon	Dr	112.3	5	GI	do.	do.	C,W	S	do.	+ .2	2,956.5	93.76	10-29-41	
(284)	SW SE sec. 16	O. W. Nix	Dr	111.4	5	GI	do.	do.	C,W	S	Top of casing, south side	+ .7	2,978.3	99.82	10-28-41	
285	SE SE sec. 33	Federal Farm Mtg. Co.	Dr	161.5	5	GI	do.	do.	C,W	N	Top of casing, east side	+1.0	2,988.9	110.13	9-1-42	Do
	T. 33 S., R. 36 W.															
286	SE SE sec. 6	B. W. Brubaker	Dr	92	5	GI	do.	do.	C,W	N	Top of casing, west side	0	3,157.5	90.16	4-13-42	Do
(287)	SW SW sec. 14	J. E. Flower	Dr	115	5	GI	do.	do.	C,W	D,S	Land surface	0	....	105	......	
288	SE SE sec. 15	Cent. Life Assur. Assn.	Dr	121.0	4.5	GI	do.	do.	C,W	N	Top of casing, northeast side	+ .3	3,030.2	106.30	7-28-42	Do
289	NW SW sec. 26	H. Brown	Dr	159.5	5	GI	do.	do.	N	N	Top of casing, southwest side	+ .3	3,037.1	122.21	8-6-42	Abandoned, formerly a stock well.
290	SE SE sec. 26	Rudolph Heger	Dr	360	16	I	do.	do.	T,G	I	Top of hole in pump base, north side	+ .1	....	131.05	9-28-42	Reported yield, 410; drawdown 30.
291	NE NW sec. 33	W. J. Paden	Dr	157.5	5	GI	do.	do.	C,W	N	Top of casing, west side	— .1	3,062.5	127.69	8-6-42	Abandoned, formerly a stock well.

TABLE 20.—Records of wells in Stevens County, Kansas—*Continued*

on 2)	Location	Owner	Type of well (2)	Depth of well (feet) (3)	Diameter of well (in.)	Type of casing (4)	Principal water-bearing bed: Character of material	Principal water-bearing bed: Geologic subdivision [a]	Method of lift (5)	Use of water (6)	Measuring point: Description	Measuring point: Distance above (+) or below (−) land surface (feet)	Measuring point: Height above sea level (feet)	Depth to water level below measuring point (feet) (7)	Date of measurement	Remarks (Yield given in gallons a minute; drawdown in feet)
	T. 33 S., R. 37 W.															
2	NW SW sec. 1	N. J. Madden	Dr	106.0	5	GI	Sand	Rexroad and/or Meade	C,W	N	Top of casing, north side	+1.8	3,090.6	96.05	8-31-42	Abandoned, formerly a stock well.
3	SE SW sec. 13	R. L. Smith	Dr	115.5	5	GI	do	do	C,W	N	do	+ .2	3,087.0	100.17	7-29-42	Abandoned, formerly a domestic and stock well.
4	NW NE sec. 15	F. H. Crump	Dr	84	5	GI	do	do	C,W	N	Top of casing, west side	+ .5	3,105.4	81.45	4-13-42	Do
5	SW SW sec. 16	A. T. & S. F. Rwy. Co.	Dr	334	10	(?)	Sand and gravel	Rexroad and Meade	T,E	R	Land surface	0	....	74	......	Reported yield, 207; drawdown 64.
)6)	SW NE sec. 16	City of Hugoton	Dr	308	12	I	do	do	T,E	P	Top of casing	0	....	80	......	Reported yield, 130; drawdown 80 after 30 hours of pumping.
7	do	do	Dr	300	18	I	do	do	T,E	P	do	0	....	85	......	Reported yield, 230; drawdown 160 after 28 hours of pumping.
8	NW SW sec. 21	T. P. Patterson	Dr	115	4.5	GI	Sand	Rexroad and/or Meade	C,W	D,S	Top of wooden pipe clamp, south side	+ .3	3,121.7	82.95	10- 1-42	
9	do	do	Dr	375	16	I	Sand and gravel	Rexroad and Meade	T,NG	I	Top of hole in pump base, north side	0	3,120.8	82.79	10- 1-42	Measured yield, 552; drawdown 82.8.
0	SE NW sec. 22	City of Hugoton	Dr	120.5	(?)	(?)	Sand	Rexroad and/or Meade	C,W	C,I	do	+ .3	3,114.3	104.40	8- 4-42	
)1)	SW SW sec. 28	A. C. Moorehead	Dr	107	5	GI	do	do	C,W	D,S	Land surface	0	....	90	......	
2	NW NE sec. 34	W. C. Brubaker	Dr	128.0	5	GI	do	do	N	N	Top of casing, north side	0	3,107.4	96.48	8- 4-42	Abandoned, formerly a stock well.
	T. 33 S., R. 38 W.															
)3)	NW SW sec. 2	W. W. Guyer	Dr	120		GI	Sand and silt	do	C,WH	D,S	Land surface	0	....	102	......	

304	SE NE sec. 3	Federal Land Bank	Dr	118.5	5	GI	do.	do.	C,WH	N	Top of casing, east side	— .5	3,162.8	105.65	7-31-42	Abandoned, formerly a domestic and stock well.
(305)	SE NE sec. 6	School district	Dr	180.0	5	GI	do.	Rexroad and Meade	C,W	C	Top of casing, southwest side	—5.0	3,185.0	78.28	8-22-42	
306	SW SE sec. 8	Federal Land Bank	Dr	110	5	GI	do.	Rexroad and/or Meade	C,WH	N	Top of casing, northwest side	0	3,177.0	77.50	7-30-42	Do
307	SE NE sec. 10	E. L. Gaskell	Dr	220	10	I	do.	Rexroad and Meade	N	N	Top of casing, northeast side	+1.6	3,145.9	90.74	7-27-42	Abandoned, formerly used to provide water for drilling gas well.
(308)	NW NW sec. 21	Commissioner of Ins.	Dr	120	5	GI	do.	Rexroad and/or Meade	C,W	D,S	Land surface	0	....	90	....	
309	NW NW sec. 24	Panhandle Eastern Pipeline Co.	Dr	101.0	7	I	do.	do.	N	N	Top of casing, north side	+ .6	3,143.2	92.11	7-28-42	Abandoned, formerly a domestic well.
310	NE SE sec. 27	Jennie Lauteret	Dr	129.0	5	GI	do.	do.	N	N	Top of casing, east side	—2.3	3,171.1	109.63	8-21-42	Abandoned, formerly a domestic and stock well.
311	NW NE sec. 28	Mack Greenwood	Dr	153.0	4	GI	do.	do.	N	N	Top of casing, north side	+ .9	3,190.2	114.37	2-19-42	Do
312	NE NW sec. 30	T. H. Craig	Dr	114.0	(?)	(?)	Sand	do.	C,W	N	Top of wooden pipe clamp, north side	0	3,195.5	98.36	7-27-42	Do
313	NE SE sec. 30	J. A. Gregory	Dr	124.0	(?)	(?)	do.	do.	C,W	N	Top of pipe, north side	+ .5	3,200.0	116.71	3- 9-42	Do
	T. 33 S., R. 39 W.															
314	NE NE sec. 3	John Stone	Dr	213.7	8	I	Sand and gravel	Rexroad and Meade	N	N	Top of casing, west side	+1.6	3,225.5	85.80	8-11-42	Abandoned, formerly used to provide water for drilling gas well.
315	SW NW sec. 3	G. L. Hayward	Dr	92.9	4.5	GI	do.	Rexroad and/or Meade	C,W	N	Top of casing, north side	+ .6	3,228.4	79.54	7-28-39	Abandoned, formerly a domestic and stock well.
316	NW NW sec. 11	Helen Hall	Dr	97.0	5	GI	do.	do.	C,G	S	Top of casing, east side	0	3,211.8	80.45	8-11-42	
317	NW NW sec. 13	J. A. Christopher	Dr	300+	8	I	do.	Rexroad and Meade	N	N	Top of 3-inch pipe, north side	+4.0	3,207.2	88.04	8-22-42	Abandoned, formerly used to provide water for drilling gas well.
(318)	SE SE sec. 24	R. M. Crawford	Dr	111.0	5	GI	do.	Rexroad and/or Meade	C,W	S	Top of casing, west side	+ .8	3,198.3	92.33	7-27-42	
319	NE SE sec. 26	W. S. Morgan	Dr	106.0	4	GI	do.	do.	N	N	Top of casing, south side	+6.0	3,220.7	105.2	2-19-42	Abandoned, formerly a domestic and stock well.
	T. 34 S., R. 35 W.															
320	NW NE sec. 8	J. W. Barrett	Dr	164	5	GI	Sand	do.	C,W	D,S	Land surface	0	....	130	....	
321	SE SW sec. 16	Lon DeCamp	Dr	159.1	(?)	(?)	do.	do.	C,W	N	Top of 1½-inch pipe, west side	+2.8	3,013.1	125.98	9- 1-42	Do
322	SW NW sec. 26	Missouri Supt. of Ins.	Dr	136.0	5	GI	do.	do.	C,W	N	Top of casing, west side	—1.0	2,978.7	108.72	10-29-41	Do

TABLE 20.—Records of wells in Stevens County, Kansas—*Continued*

No. on pl. 2 (1)	Location	Owner	Type of well (2)	Depth of well (feet) (3)	Diameter of well (in.)	Type of casing (4)	Principal water-bearing bed: Character of material	Principal water-bearing bed: Geologic subdivision [a]	Method of lift (5)	Use of water (6)	Measuring point: Description	Measuring point: Distance above (+) or below (−) land surface (feet)	Measuring point: Height above sea level (feet)	Depth to water level below measuring point (feet) (7)	Date of measurement	Remarks (Yield given in gallons a minute; drawdown in feet)
23	NE NE sec. 32	B. A. Wonder	Dr	140.5	5	GI	Sand	Rexroad and/or Meade	C,W	N	Top of casing, west side	0	2,996.0	111.33	8-26-42	Abandoned, formerly a domestic and stock well.
(24)	SE SE sec. 34	Federal Land Bank	Dr	140	5	GI	do	do	C,W	D,S	Land surface	0	....	110	....	
25	NW SW sec. 35	George W. Rennick	Dr	138.0	5	GI	do	do	N	N	Top of casing, southwest side	+ .8	2,983.7	118.88	8-26-42	Do
	T. 34 S., R. 36 W.															
26	NE NW sec. 3	Ivan O. Moore	Dr	154.5	5	GI	do	do	N	N	Top of casing, north side	− .3	3,054.5	131.18	8- 6-42	Do
(27)	NW NE sec. 15	School district	Dr	171.5	5	GI	do	do	C,W	C	Top of casing, west side	0	3,062.2	140.66	8-17-42	
(28)	SW NW sec. 19	Albert Peachy	Dr	165	5	GI	do	do	C,W	D,S	Land surface	0	....	140	....	
29	SW SW sec. 23	S. C. Ellis	Dr	151.5	5	GI	do	do	N	N	Top of casing, west side	+ .9	3,046.1	130.07	8-17-42	Do
	T. 34 S., R. 37 W.															
30	SE NE sec. 3	W. F. McMichael	Dr	130.0	(?)	(?)	do	do	C,G	S	Top of wooden pipe clamp, northwest side	+1.0	3,018.7	116.04	8- 4-42	
31	NE SE sec. 10	William L. Cutter	Dr	143.5	5	GI	do	do	N	N	Top of casing, south side	+ .5	3,137.6	137.29	8- 5-42	Abandoned, formerly a stock well.
32	SE SE sec. 15	Cent. Life Assur. Assn.	Dr	158.0	5	GI	do	do	C,W	N	Top of casing, east side	+ .1	3,152.1	153.95	8- 4-42	Abandoned, formerly a domestic and stock well.
33	NE SE sec. 22	do	Dr	145.0	5	GI	do	do	N	N	do	0	3,127.1	130.19	8- 4-42	Do
34	NE NE sec. 24	School district	Dr	170.0	5	GI	do	do	C,W	C	Top of casing, west side	+ .5	3,111.4	142.43	....	
35	SW SW sec. 31	John Burrows	Dr	132.5	5	GI	do	do	N	N	Top of casing, east side	−1.8	3,163.3	124.50	8-14-42	Abandoned, formerly a stock well.

336	NE NE sec. 32	Missouri Supt. of Ins.	Dr	132.5	5	GI	do	do	N	N	Top of casing, north side	− .2		115.10	8- 4-42	Abandoned, formerly a domestic and stock well.
337	SW SW sec. 33	Maude Collingwood	Dr	148.0	6	GI	do	do	C,W	N	Top of casing, east side	+ .2	3,141.6	116.92	8-14-42	Do
338	SE SE sec. 34	School district	Dr	161.5	5	GI	do	do	C,W	C	Top of casing, west side	0	3,117.7	118.64	8-14-42	
	T. 34 S., R. 38 W.															
(339)	NE NE sec. 1	S. M. Liggett	Dr	120	5	GI	do	do	C,W	D,S	Land surface	0		100		
(340)	NE NE sec. 4	Carl Aeilts	Dr	166.5	5	GI	do	do	C,W	D,S	Top of casing, west side	+ .3	3,219.9	147.36	8-22-42	
341	SE SE sec. 9	American Nat. Bank, Hutchinson, Kan.	Dr	184.0	5	GI	do	Rexroad	C,W	N	Top of casing, east side	+ .7	3,247.3	178.30	8-21-42	Do
(342)	SE SE sec. 22	School district	Dr	168.0	5	GI	do	Rexroad and/or Meade	C,W	C	do	+ .2	3,205.3	150.43	8-21-42	
343	SW SW sec. 25	G. E. Beavers	Dr	157.5	5	GI	do	do	N	N	Top of casing, north side	− .5	3,183.9	135.25	8-20-42	Do
344	SE NE sec. 31	C. Brecheisen	Dr	202.5	5	GI	do	Rexroad	C,W	N	Top of casing, east side	+ .3	3,273.2	196.55	9- 1-42	Do
345)	SW SW sec. 31	R. Y. Gorman	Dr	210	5	GI	do	do	C,W	D,S	Land surface	0		195		
	T. 34 S., R. 39 W.															
346	SE SE sec. 11	T. G. Hicks	Dr	160.2	5	GI	do	Rexroad and/or Meade	N	N	Top of casing, north side	− .3	3,283.6	159.57	10- 2-42	Do
	T. 35 S., R. 35 W.															
7	SW SW sec. 2	A. L. Bowden	Dr	166	5	GI	do	do	C,W	D,S	Land surface	0		106		
48	SW SE sec. 5	Federal Land Bank	Dr	114.5	5	GI	do	do	C,W	N	Top of casing, west side	+ .6	2,967.0	105.27	8-26-42	Do
349	SW SW sec. 15	E. C. Hunter	Dr	114.0	5	GI	do	do	C,W	N	do	0	2,921.1	108.63	10-29-41	Do
350	NW NW sec. 17	Federal Land Bank	Dr	122.0	5	GI	do	do	C,W	D,S	Top of casing, east side	+ .8	2,994.0	105.73	10-29-41	
	T. 35 S., R. 36 W.															
(351)	NE NE sec. 3	A. L. Roehr	Dr	160	5	GI	do	do	C,W	D,S	Land surface	0		130		
352	SW SE sec. 4	L. D. Gooch	Dr	176.0	5	GI	do	do	C,W	N	Top of casing, west side	+ .3	3,047.8	126.75	8-17-42	Abandoned, formerly a stock well.
	T. 35 S., R. 38 W.															
353	SW SE sec. 2	School district	Dr	166.0	5	GI	(?)	do	C,W	C	Top of casing, south side	+ .8	3,195.0	148.86	8-20-42	
354	SE NE sec. 4	Charles Brecheisen	Dr	140.5	5	GI	(?)	do	C,W	N	do	+ .8	3,193.7	139.08	8-20-42	Do

TABLE 20.—Records of wells in Stevens County, Kansas—*Concluded*

No. on Pl. 2 (1)	Location	Owner	Type of well (2)	Depth of well (feet) (3)	Diameter of well (in.)	Type of casing (4)	Principal water-bearing bed: Character of material	Principal water-bearing bed: Geologic subdivision [a]	Method of lift (5)	Use of water (6)	Measuring point: Description	Measuring point: Distance above (+) or below (—) land surface (feet)	Measuring point: Height above sea level (feet)	Depth to water level below measuring point (feet) (7)	Date of measurement	Remarks (Yield given in gallons a minute; drawdown in feet)
(355)	SW SE sec. 4	W. Lowry	Dr	162	5	GI	(?)	Rexroad and/or Meade	C,W	D,S	Land surface	0		145		
	T. 35 S., R. 39 W.															
356	SW NW sec. 15	R. S. Phillips	Dr	200	(?)	(?)	Sand and gravel	do.	C,W	D,S	do.	0		188		

a. For Rexroad read Rexroad (?).
1. Well number in parentheses indicates that analysis of water is given in Table 18.
2. B, bored; Dr, drilled.
3. Measured depths given in feet and in tenths of a foot; reported depths given in feet.
4. GI, galvanized iron; I, iron.
5. Pumps: C, cylinder; N, none; P, pitcher; T, turbine. Power: E, electric motor; G, gasoline engine; H, hand; N, none; NG, natural-gas engine; W, wind.
6. C, community; D, domestic; I, irrigation; N, none; P, public supply; R, railroad; S, stock.
7. Measured water levels given in feet and in tenths and hundredths of a foot; reported water levels given in feet.

WELL LOGS

Listed in the following pages are the logs of 60 wells and test holes in Grant, Haskell, and Stevens Counties, including 46 test holes drilled by the State and Federal Geological Surveys (1-46), 13 water wells (47-59), and one gas-test well (60). The locations of the test holes are shown on Plate 3 and most of the water wells are shown on Plate 2. Test holes 1, 2, 3, 4, 5, 23, 35, and 38 were drilled as a part of the investigation of the geology and ground-water resources of adjacent counties.

1. Log of test hole 1 at the SW corner sec. 36, T. 26 S., R. 33 W., Finney County, drilled by State and Federal Geological Surveys, 1941. Surface altitude, 2,915 feet. (Authority, samples studied by Perry M. McNally and Bruce F. Latta.)

	Thickness, feet	Depth, feet
Soil, sandy, dark	3	3
Undifferentiated Pliocene and Pleistocene deposits		
Silt and sand, fine to coarse; tan; containing shell fragments	27	30
Gravel, fine to coarse, containing thin lenses of tan silt and sand	85	115
Silt and sand, fine; tan, brown, and gray	25	140
Sand, medium, to gravel, medium; brown	8	148
Sand, fine, brown	6.5	154.5
Sand, medium, to gravel, medium; brown	35	189.5
Silt, clayey and sandy, tan	7.5	197
Silt and sand, fine; medium gray; containing shell fragments	4	201
Silt and sand, fine; tan	3	204
Gravel, fine to coarse; containing silt and sand	40	244
Clay, silty and sandy, gray, blue gray, and tan	20	264
Sand, lime-cemented, hard, blue gray	8	272
Clay, silty, blue gray; containing shell fragments	8	280
Clay, silty and sandy, soft, blue black; containing gastropod fragments and ostracodes	10	290
Sand, coarse, to gravel, coarse; brown	23.5	313.5
Silt and sand, fine; limy; tan and light gray	7.5	321
Sand, medium, to gravel, medium; brown; containing light-gray sandy silt	10	331
Silt, clayey and sandy, tan and light gray; containing thin caliche beds	31	362
Sand, fine, tan to brown; containing some coarser sand and gravel	9	371
Sand and gravel; lime-cemented; light gray; and caliche, white	19	390
Clay, silty, tan and gray	20	410

	Thickness, feet	Depth, feet
Clay-shale, silty, tan and brown	41	451
Sand, medium, to gravel, fine; brown	18	469
Clay, silty, yellow tan	12.5	481.5
Dakota formation		
Shale, soft, yellow tan and light gray; containing thin beds of maroon-red sandstone	8.5	490
Sandstone, red, yellow tan, and red brown	7	497
Shale, silty, yellow tan	3	500

2. Log of test hole 2 at SE corner sec. 34, T. 26 S., R. 36 W. Kearny County, drilled by State and Federal Geological Surveys, 1941. Surface altitude, 3,091 feet. (Authority, samples studied by Perry M. McNally and Thad G. McLaughlin.)

	Thickness, feet	Depth, feet
Dune sand		
Sand, fine, tan to gray	30	30
Undifferentiated Pliocene and Pleistocene deposits		
Sand, fine to coarse, brown	18	48
Silt and sand, fine; tan to brown	35	83
Sand, fine, brown; containing clay and pebbles of caliche,	7	90
Sand, coarse, to gravel, coarse; brown	45	135
Gravel, fine to coarse, brown	5	140
Sand, coarse, to gravel, coarse; tan to brown	35	175
Sand, medium, to gravel, fine; brown	4	179
Sand, coarse, to gravel, coarse; brown	21	200
Sand, medium, to gravel, medium; brown	16	216
Clay, silty, gray to buff	7	223
Sand, medium, to gravel, fine; brown	101	324
Clay, silty, varicolored	10.5	334.5
Sand, coarse, to gravel, coarse; brown	10.5	345
Silt and sand, fine; tan to gray; and caliche	35	380
Silt and sand, fine; tan to gray; and clay, black	10	390
Sand, fine, to gravel, fine; brown	10	400
Clay, silty, tan to gray	6	406
Dakota formation		
Sandstone, dark brown, and clay, varicolored	1	407
Sandstone, white to gray	3	410

3. Log of test hole 3 at SE corner sec. 33, T. 26 S., R. 37 W., Kearny County, drilled by State and Federal Geological Surveys, 1941. Surface altitude, 3,074 feet. (Authority, samples studied by Perry M. McNally and Thad G. McLaughlin.)

	Thickness, feet	Depth, feet
Soil, sandy, brown	4	4
Undifferentiated Pliocene and Pleistocene deposits		
Clay, silty, greenish gray	6	10
Clay, silty to fine sandy, gray	5	15
Clay, silty and fine sandy; tan to gray	21	36
Sand, fine, and silt; tan	4	40

	Thickness, feet	Depth, feet
Clay, sandy, and silt; tan	30	70
Silt and sand; fine; tan	10	80
Silt, sand, and gravel	3	83
Silt and sand, fine; brown	19	102
Silt and sand, fine; tan; contains gravel	48	150
Clay, silty, tan, containing fine sand and gravel	22.5	172.5
Clay, silty and fine sandy, dark gray	47.5	220
Clay, silty, dark gray, containing lenses of sand and gravel	9	229
Silt, sand, and gravel; brown	11	240
Sand, medium, and gravel, fine	12	252
Silt, and sand, fine; light gray	12	264
Clay, silty and fine sandy; tan	56	320
Dakota formation		
Sandstone, white, containing concretions of ironstone	20	340

4. Log of test hole 4 at SE corner sec. 31, T. 26 S., R. 38 W., Kearny County, drilled by State and Federal Geological Surveys, 1941. Surface altitude, 3,203 feet. (Authority, samples studied by Perry M. McNally and Thad G. McLaughlin.)

	Thickness, feet	Depth, feet
Soil, sandy, brown	1	1
Undifferentiated Pliocene and Pleistocene deposits		
Silt and sand, fine; tan to gray	17	18
Sand and gravel; contains silt	15	33
Silt and sand, fine; tan	11.5	44.5
Sand, medium, to gravel, coarse; brown	30	74.5
Caliche, white	1.5	76
Sand, medium, to gravel, coarse; brown	6	82
Silt and sand, fine; tan to gray	39	121
Caliche, soft, light gray to white	14	135
Caliche, tan, containing fragments of brown sandstone	7	142
Dakota formation		
Sandstone, brown, and clay, yellow	3	145
Shale and sandstone; varicolored	8.5	153.5
Shale, sandy, blue gray, and sandstone, fine	1.5	155
Shale and sandstone, fine; varicolored	2.5	157.5
Sandstone, rusty brown	2.5	160

5. Log of test hole 5 at the NE corner sec. 31, T. 27 S., R. 30 W., Gray County, drilled by the State and Federal Geological Surveys, 1941. Surface altitude, 2,837 feet. (Authority, samples studied by Perry M. McNally and Bruce F. Latta.)

	Thickness, feet	Depth, feet
Soil, sandy, dark	2	2
Undifferentiated Pliocene and Pleistocene deposits		
Silt and sand, fine; tan	5	7
Sand, fine, to gravel, medium; brown	5	12

	Thickness, feet	Depth, feet
Silt and sand; tan; contains pebbles and nodules of caliche and some gravel in lower part	48	60
Sand, fine, to gravel, medium; silty; brown	18	78
Silt to sand, medium; limy; light gray and light tan	32	110
Sand, coarse, to gravel, coarse; brown	49	159
Silt and sand, fine; tan	1	160
Sand, coarse, to gravel, coarse; brown; lower 10 feet is partly cemented	66	226
Silt, sand, gravel, and caliche; poorly sorted; contains pebbles of "mortar beds"	14	240
Silt to sand, coarse; limy; tan and gray	3.5	243.5
Sand, coarse, to gravel, medium; brown	16.5	260
Silt, tan, containing a little sand and gravel	11	271
Sand, medium, to gravel, coarse; brown	26	297
Silt and sand, fine to coarse; gray and tan; containing gravel	53	350
Sand, fine to coarse, tan	19	369
Silt and sand, fine; tan	8	377
Sand and gravel, fine to medium; containing abundant pebbles of brown sandstone	27	404
Dakota formation		
Sandstone, concretionary, brown	3	407
Clay, gritty, yellow, light gray, and brown	3	410

6. Log of test hole 6 at the NE corner sec. 1, T. 27 S., R. 31 W., drilled by State and Federal Geological Surveys, 1942. Surface altitude, 2,793 feet. (Authority, samples studied by Oscar S. Fent and Thad G. McLaughlin.)

	Thickness, feet	Depth, feet
Soil, sandy, gray	2	2
Undifferentiated Pliocene and Pleistocene deposits		
Silt, blocky, gray	6	8
Sand, medium, red, containing fine gravel and soft red silt,	8	16
Sand, coarse to medium, brown, and gravel, fine; containing soft gray silt	7	23
Sand, coarse to medium, brown, and gravel, fine; containing caliche	5	28
Gravel, medium to fine, and sand, coarse to medium; brown	22	50
Gravel, coarse to fine, and sand, coarse	10	60
Gravel, medium to fine, and sand, coarse to medium	17	77
Silt, soft, buff; contains coarse to medium sand and coarse to fine gravel	5	82
Gravel, coarse to fine, and sand, coarse to medium; contains compact tan silt and caliche	8	90
Silt, compact, light tan, and sand, coarse to medium; contains medium-grained gravel	4	94
Gravel and sand; coarse to fine	6	100
Gravel and sand; coarse to fine; containing soft yellow silt,	15	115

	Thickness, feet	Depth, feet
Silt, clayey, white, and sand, coarse to medium	5	120
Gravel, medium to fine, and sand, coarse to medium; containing soft white silt	17	137
Silt, compact, buff, and sand, medium to fine; containing coarse to fine gravel and caliche	3	140
Silt, compact, white, and sand, medium to fine; containing medium gravel and caliche	6	146
Silt, compact, buff and white, and sand, medium to fine; containing coarse to fine gravel	18	164
Gravel, medium to fine, and silt, compact, buff and white; containing coarse- to medium-grained sand	6	170
Gravel, coarse to fine, containing caliche	7	177
Silt, compact, light tan, and sand, coarse to medium	3	180
Gravel, coarse to fine, and caliche	8	188
Silt, compact, light tan and white, and sand, medium	2	190
Silt, compact, gray to tan, and gravel, fine to coarse; containing medium sand and caliche	10	200
Silt, compact, light tan and gray, and sand, coarse to fine; containing coarse to medium gravel and caliche	10	210
Silt, compact, light tan and gray, and sand, coarse	8	218
Sand, medium to fine, and silt, soft, light tan; containing medium to fine gravel	12	230
Silt, compact; gray; contains medium sand, hard, blocky gray-green clay, coarse gravel and caliche	10	240
Sand, medium to fine, and silt, soft, buff, containing caliche	10	250
Sand, coarse to fine, containing soft buff silt and caliche,	10	260
Sand, coarse to medium, containing caliche and soft buff silt	12	272
Caliche and clay, soft, yellow, containing medium to fine sand	5	277
Graneros shale		
Shale, silty, gray to gray black	19	296
Shale, fissile, gray to blue gray; contains fine gray to white sandstone and pyrite	12.5	308.5
Dakota formation		
Sandstone, fine, hard, gray	2.5	311
Sandstone, very fine, poorly consolidated, light gray to gray, containing gray to brown clay	59	370
Sandstone, fine, calcareous, light gray, and clay, soft, gray,	10	380
Clay, light gray, and sandstone, gray; contains pyrite	10	390
Clay, light gray	10	400

7. **Log of test hole 7 at the SE corner sec. 24, T. 27 S., R. 34 W., drilled by State and Federal Geological Surveys, 1942. Surface altitude, 3,007 feet. (Authority, samples studied by Oscar S. Fent and Thad G. McLaughlin.)**

	Thickness, feet	Depth, feet
Soil, clayey, gray	1	1
Undifferentiated Pliocene and Pleistocene deposits		
Silt, soft, yellow gray, containing nodules of caliche	7	8
Sand, fine to coarse, brown, containing nodules of caliche,	24	32
Silt, soft, fine sandy, tan, containing caliche	16	48
Sand, fine to coarse, and gravel; tan	25	73
Silt, soft, sandy, and sand, coarse to medium; tan	9	82
Sand, coarse to fine, and gravel, fine; containing caliche and buff silt	34	116
Sand, coarse to fine, and gravel, coarse to fine; containing soft buff silt and caliche	244	360
Silt, clayey to sandy, tan to gray and white; contains medium to fine gravel and a little sand and caliche	80	440
Silt, medium to fine sandy, soft, compact, gray to tan and buff; contains a little fine gravel and caliche	80	520
Silt, clayey, compact, brown and gray green, containing much caliche	20	540
Clay, silty, compact, greenish yellow and brown	10	550
Silt, clayey, compact, greenish yellow and brown; contains reworked pebbles of sandstone	40	590
Kiowa shale		
Shale, fine sandy, dark gray to black	30	620
Shale, fine sandy, soft, gray, containing sandy nodules and pyrite	10	630
Shale, clayey to sandy, laminated, hard, gray to black	10	640

8. **Log of test hole 8 at the SW corner sec. 34, T. 27 S., R. 37 W., drilled by State and Federal Geological Surveys, 1942. Surface altitude, 3,068 feet. (Authority, samples studied by Oscar S. Fent and Thad G. McLaughlin.)**

	Thickness, feet	Depth, feet
Soil, silty to fine sandy, compact, tan to brown	1	1
Undifferentiated Pliocene and Pleistocene deposits		
Silt, fine sandy, compact, gray to dark gray and brown; contains a little fine gravel and caliche	9	10
Sand, fine, brown, containing silt	2.5	12.5
Silt and sand, fine; brown; containing gravel and caliche,	5.5	18
Silt, white to light gray and tan, containing fine to medium tan gravel and coarse tan sand	19	37
Sand and gravel, fine to coarse; brown; containing silt	3	40
Clay, compact, buff to tan, containing silt and fine sand	10	50
Silt and clay; sandy; compact; light gray, gray, grayish green, tan, and buff	70	120
Silt, sandy, light gray to tan, containing coarse gravel and a little caliche	20	140

	Thickness, feet	Depth, feet
Silt, sandy, compact, light gray to reddish tan, containing a little clay	73	213
Sand, fine to coarse, brown	7	220
Silt, sandy, white to tan, containing gravel and caliche	10	230
Gravel and sand; fine to coarse; dark gray to brown	35	265
Gravel, fine to coarse, and silt, sandy, white to tan	5	270
Silt, light gray to reddish tan, containing sand and caliche,	15	285
Dakota formation		
Sandstone, fine-grained, hard, and siltstone, soft; yellow brown	5	290
Sandstone, fine-grained, hard, and shale, soft; gray to yellow brown	10	300

9. Log of test hole 9 at the SE corner sec. 32, T. 27 S., R. 38 W., drilled by State and Federal Geological Surveys, 1942. Surface altitude, 3,118 feet. (Authority, samples studied by Oscar S. Fent and Thad G. McLaughlin.)

	Thickness, feet	Depth, feet
Soil, silty, gray	1	1
Undifferentiated Pliocene and Pleistocene deposits		
Silt, sandy, buff, containing gravel, sand, and clay	13	14
Clay, silty, compact, buff to tan	6	20
Silt, fine sandy, buff to tan	13	33
Silt, sand, and gravel; poorly sorted; gray to gray green, tan, and buff	33	66
Silt, sandy, gray to brown, containing caliche	4	70
Silt, sandy, gray and white, containing fine gravel	7	77
Silt, sandy, compact, buff, containing a little caliche	33	110
Sand and gravel, fine to coarse; light gray to buff; containing silt	30	140
Silt, fine sandy, buff and gray, containing gravel and a little clay	40	180
Silt, compact, dark tan to brown, containing fragments of charcoal	10	190
Gravel, fine to coarse, containing silt and fine sand; poorly sorted; buff to brown	40	230
Silt and gravel, fine; buff to tan; containing sand	24	254
Clay, compact, blocky, dark tan to brown; contains silt and a little charcoal	28	282
Silt and gravel, coarse; buff to white; containing sand and caliche	6	288
Silt, sandy to clayey, compact, dark tan, containing caliche,	2	290
Silt and gravel, medium to coarse; white to buff; containing sand, caliche, and clay	10	300
Dakota formation		
Sandstone, fine-grained to very fine-grained, varicolored, containing siltstone and clay	10	310
Clay, in part sandy, dark tan to brown and red, containing yellow-brown sandstone and ironstone	30	340

	Thickness, feet	Depth, feet
Sandstone, fine- to coarse-grained, fairly well cemented, yellow brown to dark rusty brown; contains siltstone and clay	10	350
Clay, soft, compact, varicolored; contains fine sandstone, silt, and ironstone	35	385
Clay, fine sandy, gray	15	400
Kiowa shale		
Shale, clayey, soft, fissile, gray to gray black, containing fragments of pyrite and charcoal	50	450
Shale, fine sandy, gray	30	480
Shale, soft, compact, fissile, gray black to black, containing fragments of white sandstone	22.5	502.5
Shale, clayey to fine sandy, soft, light gray and gray	7.5	510
Shale, clayey, gray black and black	10	520
Cheyenne sandstone		
Sandstone, fine- to coarse-grained, poorly cemented, well sorted, white	10	530
Sandstone, fine-grained, poorly cemented, white	33	563
Shale, clayey, soft, light gray and light green	7	570
Sandstone, fine-grained, poorly cemented, white	20	590
Sandstone, very fine-grained, well cemented, white	1.5	591.5
Shale, silty to clayey, soft, light gray and green; contains fragments of hard sandstone (Morrison (?) formation)	6.5	598
Permian redbeds		
Siltstone, soft, red	2	600

10. Log of test hole 10 at the SE corner sec. 25, T. 28 S., R. 31 W., drilled by State and Federal Geological Surveys, 1942. Surface altitude, 2,832 feet. (Authority, samples studied by Oscar S. Fent and Thad G. McLaughlin.)

	Thickness, feet	Depth, feet
Soil, silty, gray	2	2
Undifferentiated Pliocene and Pleistocene deposits		
Silt, soft, greenish gray, containing nodules of caliche	4	6
Silt, soft, brown	3	9
Silt, clayey, compact, buff, containing sand and nodules of caliche	11	20
Silt, clayey, soft, buff, containing fine to coarse sand, fine gravel, and caliche	20	40
Sand, fine to coarse, containing silt, fine gravel, and caliche	5	45
Silt, compact, pinkish tan, containing sand, fine gravel, and caliche	13	58
Sand, fine to coarse, and gravel, medium to coarse; containing tan and buff silt	4	62
Silt, compact, gray brown and white, containing caliche, sand, and gravel	19	81

	Thickness, feet	Depth, feet
Sand and gravel; fine to coarse; containing silt and fragments of caliche	69	150
Silt, compact, gray and buff, containing sand, gravel, and caliche	13	163
Sand and gravel; fine to coarse; containing fragments of silt	63	226
Silt, clayey, micaceous, soft, compact, blue gray to yellow brown; contains fine to coarse sand	4	230
Silt, clayey, blue gray to yellow brown; contains fine to medium sand	10	240
Silt and clay; in part micaceous; blue gray; contains fine to coarse sand and a little gravel	110	350
Gravel, medium to fine, and sand, coarse to fine; partly consolidated	12	362
Silt, compact, buff; contains fine gravel, fine to coarse sand, and caliche	68	430
Gravel, fine, and sand, coarse to fine; containing fragments of silt and caliche	46	476
Dakota formation		
Clay, in part laminated, soft, varicolored, containing ironstone and yellow-brown to red-brown sandstone	4	480
Silt, clayey, soft, yellow and gray, containing ironstone and fine-grained, hard, yellow and brown sandstone	10	490

11. Log of test hole 11 at the SE corner sec. 36, T. 28 S., R. 31 W., drilled by State and Federal Geological Surveys, 1942. Surface altitude, 2,838 feet. (Authority, samples studied by Oscar S. Fent and Thad G. McLaughlin.)

	Thickness, feet	Depth, feet
Soil, silty, gray brown	1	1
Undifferentiated Pliocene and Pleistocene deposits		
Silt, soft, gray brown, containing nodules of caliche	6	7
Silt, soft, buff to tan and white, containing very fine sand and nodules of caliche	23	30
Silt, soft, buff, containing fine to medium sand	7	37
Silt, soft, red brown, containing caliche and fine to coarse sand and gravel	23	60
Gravel, fine to coarse, and sand, coarse; containing buff silt	11	71
Silt, compact, tan, containing caliche and fine to coarse sand and gravel	9	80
Sand, coarse to medium, and silt, compact, buff; containing fine to coarse gravel	10	90
Gravel and sand; fine to coarse; in part cemented; containing buff and white silt, and fragments of caliche	47	137
Silt, compact, buff to tan, containing fine to coarse sand and gravel	13	150
Sand and gravel; fine to coarse; containing a few fragments of silt and caliche	240	390

12. **Log of test hole 12 at the NW corner sec. 6, T. 28 S., R. 32 W., drilled by State and Federal Geological Surveys, 1942. Surface altitude, 2,935 feet. (Authority, samples studied by Oscar S. Fent and Thad G. McLaughlin.)**

	Thickness, feet	Depth, feet
Soil, fine sandy, gray	1	1
Undifferentiated Pliocene and Pleistocene deposits		
Silt, soft, brown gray, containing fine sand	2	3
Silt, soft, blocky, yellow, containing fine sand and nodules of caliche	3	6
Silt, soft, red; contains fine to coarse sand, fine gravel, and nodules of caliche	8	14
Silt, soft, gray to light buff and tan, containing very fine to coarse sand and nodules of caliche	26	40
Sand, very fine to coarse, containing caliche and fine gravel	19	59
Sand, very fine to coarse, in part cemented, containing tan silt	15	74
Sand, very fine to coarse, and gravel, fine; containing buff silt	16	90
Silt, soft, buff, and sand, very fine to coarse; containing caliche and fine to medium gravel	15	105
Gravel and sand; fine to coarse; containing a little tan silt	64.5	169.5
Silt, clayey, yellow gray, containing fine to coarse sand	.5	170
Sand and gravel; fine to coarse; containing a little silt and caliche	80	250
Silt, clayey, in part laminated, gray to blue gray and buff, containing a little sand	116	366
Gravel, medium to fine, and silt, clayey, compact, laminated, blue gray and gray green; contains caliche	4	370
Gravel, medium to fine, and sand, coarse to medium; contains clayey, compact, laminated, blue-gray and gray-green silt	20	390
Gravel, medium to fine, and sand, coarse to medium; containing caliche and gray silt	50	440
Silt and clay; compact; buff and blue gray; contains medium to coarse sand, medium to fine gravel, and caliche	30	470
Gravel, fine, and sand, coarse; containing caliche	10	480
Silt, compact, buff, containing fine to coarse sand and fine to medium gravel	10	490
Silt, soft, light buff to tan, containing fine to very fine sand	27	517
Gravel, fine to medium, and sand, coarse to medium; containing caliche	20	537
Dakota formation		
Sandstone, light yellow brown to red brown, containing varicolored clay	33	570

13. **Log of test hole 13 at the SW corner sec. 31, T. 28 S., R. 32 W., drilled by State and Federal Geological Surveys, 1942. Surface altitude, 2,942 feet. (Authority, samples studied by Oscar S. Fent and Thad G. McLaughlin.)**

	Thickness, feet	Depth, feet
Soil, silty, brown	1.5	1.5
Undifferentiated Pliocene and Pleistocene deposits		
Silt, soft, light brown to yellow brown, containing very fine to coarse sand and fine gravel	14.5	16
Silt, clayey, compact, white to tan, containing fine sand and gravel	26	42
Sand, coarse to fine, containing silt and fine gravel	18	60
Silt, soft, brown, containing fine to coarse sand and fine gravel	14	74
Sand, fine to coarse	4	78
Silt, compact, brown, containing caliche and fine to coarse sand and gravel	3	81
Sand and gravel; fine to coarse	16	97
Sand, fine to coarse, and silt, soft, buff and tan; containing fine to coarse gravel	13	110
Sand and gravel; fine to coarse; containing a little caliche and buff silt	30	140
Sand and gravel; fine to coarse	50	190
Sand, fine to coarse, and gravel, fine to coarse; containing silt, clayey, yellow buff	9	199
Silt, clayey, soft, yellow to blue gray and greenish gray; contains caliche and fine to coarse sand and gravel	31	230
Clay, soft, compact, blue gray to tan; contains a little silt, sand, and gravel	130	360
Gravel and sand; fine to coarse; containing a little silt and caliche	82	442
Silt, soft, pinkish buff; contains fine to coarse sand, fine to medium gravel, and much caliche	58	500
Silt, soft, light yellow gray, containing fine to medium sand and caliche	24	524
Gravel, fine to medium, and sand, fine to coarse; containing caliche and yellow-gray silt	6	530
Sand, coarse to medium, and silt, compact, pinkish buff; containing caliche and medium gravel	10	540
Gravel, fine to medium, and sand, fine to coarse; containing caliche	40	580
Gravel, fine, and sand, fine to coarse; containing caliche and light-buff silt	17	597
Gravel, fine to coarse. Pebbles are water-worn fragments of varicolored sandstone	9	606
Dakota formation		
Clay, light gray to buff	4	610

14. Log of test hole 14 at the NW corner sec. 6, T. 28 S., R. 34 W., drilled by State and Federal Geological Surveys, 1942. Surface altitude, 3,062 feet. (Authority, samples studied by Oscar S. Fent and Thad G. McLaughlin.)

	Thickness, feet	Depth, feet
Soil, fine sandy, dark gray	2	2
Undifferentiated Pliocene and Pleistocene deposits		
Silt, soft, yellowish green, containing fine sand	5	7
Silt, soft, brown, containing fine to coarse sand and nodules of caliche	8	15
Silt, soft, white, and sand, fine	3	18
Sand, very fine to coarse, and silt, soft, gray brown	8	26
Silt, soft, tan, and sand, very fine to coarse, tan; containing caliche	28	54
Silt, soft, buff and white, and sand, fine to coarse; containing caliche and fine gravel	6	60
Sand, fine to coarse, and silt, buff	16	76
Silt, soft, compact, buff, and sand, fine to medium; containing caliche and fine to coarse gravel	20	96
Gravel, fine to coarse, and sand, coarse to medium; containing compact tan and buff silt	14	110
Sand, coarse, and gravel, fine to medium	12	122
Gravel, very coarse to fine, and sand, coarse	31	153
Silt, soft, buff to gray and white, and sand, coarse to fine; containing fine to coarse gravel	27	180
Sand, fine to coarse, and silt, soft, white to tan and buff; containing caliche and medium gravel	22	202
Gravel, medium, and sand, coarse to medium; containing soft buff silt	8	210
Sand, coarse to fine, and gravel, fine to medium; containing caliche and buff silt	20	230
Gravel, fine, and sand, medium to coarse; containing caliche and soft tan silt	7	237
Silt, soft, tan, and sand, medium; containing fine gravel	13	250
Sand, fine to medium, and silt, soft, gray and tan; containing fine gravel	20	270
Silt, soft, tan, and sand, fine to coarse; containing caliche and fine gravel	16	286
Gravel, fine to medium, and sand, fine to coarse; containing caliche and soft tan silt	14	300
Silt, soft, white and tan, and sand, fine to coarse; containing caliche and fine gravel	9	309
Gravel, fine to medium, and sand, medium to coarse; containing soft gray silt	21	330
Sand, medium to coarse, and gravel, fine to medium; containing caliche and soft white silt	32	362
Silt, soft, light gray to tan, containing caliche and fine to medium sand	38	400

	Thickness, feet	Depth, feet
Silt, compact, blocky, brown to tan and white, containing medium sand	98	498
Dakota formation		
Sandstone, yellow brown to red brown	12	510
Clay and silt; varicolored; containing very fine sand	10	520

15. Log of test hole 15 at the NW corner sec. 2, T. 28 S., R. 36 W., drilled by State and Federal Geological Surveys, 1942. Surface altitude, 3,119 feet. (Authority, samples studied by James B. Cooper and Thad G. McLaughlin.)

	Thickness, feet	Depth, feet
Soil, fine sandy, black	1.5	1.5
Undifferentiated Pliocene and Pleistocene deposits		
Silt, fine sandy, friable, brown, containing fine gravel and fragments of caliche	12.5	14
Silt, sandy, soft, gray and tan, and sand, fine to coarse; containing caliche and fine gravel	16	30
Silt, sandy, compact, tan to gray and white, containing caliche and fine gravel	32	62
Gravel, fine to very coarse, and sand, coarse to fine	29	91
Sand, fine to coarse, tightly cemented	2	93
Silt, sandy, soft, gray and yellow	17	110
Sand, fine to coarse, and gravel, fine; containing silt	10	120
Gravel and sand; fine to coarse	26.5	146.5
Caliche, hard, brittle, and clay, compact; light gray and white	3.5	150
Silt, soft, varicolored, containing fine to coarse gravel	10	160
Gravel and sand; fine to coarse	7	167
Gravel, fine to medium, and silt, sandy, soft, tan and gray; containing fine sand	23	190
Gravel and sand; fine to coarse	24	214
Sand, coarse, and silt, sandy, soft, red tan and yellow brown	8	222
Silt, sandy, compact, tan and light gray, containing coarse sand	18	240
Gravel, fine to medium, containing coarse sand	8	248
Silt, sandy, compact, gray, containing coarse sand	7	255
Gravel, fine to medium, containing coarse sand	15	270
Gravel, fine to medium, and sand, coarse; contains soft white silt	10	280
Silt, fine sandy, soft, blue gray to tan and yellow brown,	20	300
Sand, fine to coarse, and silt, soft, gray to tan and yellow brown	18	318
Sand, fine to medium, tightly cemented	4	322
Gravel and sand; fine to coarse	46	368
Gravel, fine to coarse, and sand, coarse; containing tan silt	20	388
Silt, sandy, soft, tan, containing fine gravel	8	396

	Thickness, feet	Depth, feet
Gravel and sand; fine to coarse	10.5	406.5
Clay, brown, containing limonite	3	409.5
Silt, sandy, compact, tan to white	30.5	440
Silt, clayey, compact, tan	10	450
Silt, sandy, tan, containing fragments of caliche	20	470
Silt, clayey, compact, tan	10	480
Dakota formation		
Siltstone, fine sandy, varicolored, and sandstone, hard, yellow and brown; containing fragments of ironstone,	10	490

16. Log of test hole 16 at the SW corner sec. 35, T. 28 S., R. 36 W., drilled by State and Federal Geological Surveys, 1942. Surface altitude, 3,052 feet. (Authority, samples studied by Oscar S. Fent and Thad G. McLaughlin.)

	Thickness, feet	Depth, feet
Soil, fine sandy, gray black	3	3
Undifferentiated Pliocene and Pleistocene deposits		
Silt, soft, gray brown	5	8
Silt, compact, blocky, gray green	2	10
Silt, soft, yellow brown	17	27
Silt, coarse sandy, soft, red brown	4	31
Silt, coarse sandy, soft, red brown, containing coarse gravel and nodules of caliche	12	43
Gravel, very coarse to fine, containing clayey gray-brown silt	17	60
Gravel, fine to coarse, and sand, coarse to medium	21	81
Clay, compact, light tan	19	100
Silt, sandy, soft, light tan	24	124
Sand, coarse to medium	7	131
Silt, clayey, compact, blocky, tan and buff to gray	68	199
Silt, clayey, soft, gray	11	210
Silt, compact, blocky, gray to brown, containing a little sand	30	240
Clay, compact, gray to gray green	40	280
Silt, fine sandy, light brown	20	300
Silt, clayey to sandy, compact, white to light brown, containing sand and gravel	40	340
Gravel, medium to fine, and sand, coarse to fine	5	345
Silt and clay; sandy; soft; light gray to white; containing sand and gravel	15	360
Gravel, fine, and sand, fine to coarse; containing caliche	16	376
Clay, laminated, hard, gray green	4	380
Sand, medium to fine, containing compact gray silt	20	400
Dakota formation		
Sandstone, soft, and clay; varicolored; containing ironstone	20	420

17. Log of test hole 17 at the SW corner sec. 34, T. 28 S., R. 37 W., drilled by State and Federal Geological Surveys, 1942. Surface altitude, 2,996 feet. (Authority, samples studied by James B. Cooper and Thad G. McLaughlin.)

	Thickness, feet	Depth, feet
Soil, sandy, brown to black	2.5	2.5
Undifferentiated Pliocene and Pleistocene deposits		
Gravel, fine to medium, containing silt and fine sand	5.5	8
Silt, compact, light tan to gray, containing fine sand and clay	2	10
Sand, fine to medium, tan	2	12
Silt, compact, light tan and buff, containing fine sand and clay	18	30
Sand, fine to coarse, red brown, containing buff silt	3	33
Silt, sandy, compact, containing buff clay	7	40
Silt, sandy, buff, and sand, fine to coarse; containing fine to coarse gravel	19	59
Sand, fine to coarse, containing fine gravel and buff silt	41	100
Silt, light gray, and sand, fine to coarse, brown	10	110
Sand, fine to coarse, brown	6	116
Silt, sandy, compact, gray to tan	44	160
Silt, clayey, compact, tan, containing sand	45	205
Gravel and sand; fine to coarse; containing silt and caliche	28	233
Silt, sandy, compact, gray and yellow tan; contains sand, fine to coarse gravel, and caliche	7	240
Gravel, fine to coarse, and sand, fine; contains soft red-tan silt	10	250
Silt, sandy, light gray to tan, containing caliche	40	290
Silt, clayey, compact, gray green and dark tan, containing caliche	11	301
Gravel, fine to medium, containing fine sand, silt, and caliche	18	319
Dakota formation		
Sandstone, fine-grained, rusty brown to yellow, containing ironstone and varicolored clay	11	330

18. Log of test hole 18 at the SE corner sec. 36, T. 29 S., R. 31 W., drilled by State and Federal Geological Surveys, 1942. Surface altitude, 2,823 feet. (Authority, samples studied by Oscar S. Fent and Thad G. McLaughlin.)

	Thickness, feet	Depth, feet
Soil, gray	..	..
Undifferentiated Pliocene and Pleistocene deposits		
Silt, soft, tan, containing nodules of caliche	3	6
Silt, blocky, brown, containing coarse gravel	4	10
Silt, clayey, compact, white to buff, containing fine sand and nodules of caliche	11	21

	Thickness, feet	Depth, feet
Sand, coarse to fine, containing silt, soft, buff	4	25
Silt, soft, buff to reddish tan, containing sand, gravel, and nodules of caliche	33	58
Gravel, medium to fine, and sand, coarse to medium	13	71
Silt, compact, white and gray buff, containing fine to medium sand, coarse gravel, and caliche	11	82
Silt, clayey, compact, gray green and tan, containing sand and caliche	8	90
Silt, compact, yellow tan, containing fine gravel and fine to coarse sand	8	98
Gravel and sand; fine to very coarse; containing a little soft buff and yellow-gray silt	129	227
Silt, soft, buff and gray, containing caliche and very fine to medium sand	13	240
Clay and silt; soft; light gray to blue gray and buff	100	340
Silt, soft, gray, containing fine to coarse sand and medium to fine gravel	13	353
Silt, compact, gray buff; contains fine gravel, fine to coarse sand, and caliche	5	358
Gravel, fine to medium, and sand, fine to coarse	22	380
Gravel, medium to fine, and sand, coarse to fine; containing soft buff silt and caliche	16	396
Silt, compact, buff, containing fine to coarse sand and fine gravel	4	400
Gravel, fine, and sand, coarse to fine; containing caliche and soft gray silt	12	412
Caliche, sandy, white, and silt, compact, white; containing fine to coarse sand	6	418
Dakota formation		
Clay, silty, soft, yellow	2	420
Sandstone, fine-grained, hard, yellow brown, and clay, soft, gray brown	10	430
Clay, varicolored, and sandstone, very fine-grained, yellow to red brown; containing ironstone	10	440
Clay, silty, yellow gray, containing fine-grained to very fine-grained brown sandstone and ironstone	30	470
Clay, yellow gray, containing brown siltstone	9	479
Sandstone, very fine-grained, very hard to soft, dark gray; containing soft clay	11	490
Kiowa shale		
Shale, soft, dark gray, containing very fine sand, in part consolidated	20	510
Shale, sandy, very hard, dark gray, and clay, soft, gray black to black	10	520
Shale, soft, thinly laminated, gray and black, containing pyrite	24	544

	Thickness, feet	Depth, feet
Shale, soft, light gray, containing fine-grained gray-white and white sandstone	31	575
Permian redbeds		
Siltstone, soft, clayey, dull red to light gray	25	600

19. Log of test hole 19 at the SE corner sec. 36, T. 29 S., R. 33 W., drilled by State and Federal Geological Surveys, 1942. Surface altitude, 2,935 feet. (Authority, samples studied by Oscar S. Fent and Thad G. McLaughlin.)

	Thickness, feet	Depth, feet
Soil, silty, gray brown	2	2
Undifferentiated Pliocene and Pleistocene deposits		
Silt, soft, yellow gray, containing fine to coarse sand	4	6
Silt, soft, tan, containing nodules of caliche	2	8
Silt, soft, buff, containing fine to medium sand and nodules of caliche	19	27
Silt, clayey, compact, tan	3	30
Silt, soft to compact, tan and white, containing fine to coarse sand and caliche	30	60
Sand, coarse to fine, and silt, soft, gray and buff; containing caliche and fine gravel	20	80
Silt, soft, gray buff, containing fine to coarse sand and nodules of caliche	2	82
Sand and gravel; fine to coarse; contains caliche and soft gray and gray-buff silt	40	122
Silt, soft, buff, containing fine to medium gravel and fine to coarse sand	4	126
Gravel, coarse to fine, and sand, coarse to medium; containing soft buff and white silt	21	147
Silt, compact, buff and tan, contains fine to coarse sand, fine to medium gravel, and caliche	27	174
Gravel, medium to fine, and sand, coarse to fine, containing soft buff and white silt and caliche	24	198
Silt, clayey, soft, white to light blue and buff, containinch caliche and coarse to medium sand	11	209
Gravel, coarse to fine, and sand, coarse to medium	126	335
Silt, clayey, soft, blue gray to white and buff, containing caliche	25	360
Clay, silty, compact, blue gray, containing caliche	10	370
Silt, clayey, soft, laminated, blue gray	53	423
Gravel, fine, and sand, coarse to fine; containing caliche.	17	440
Gravel, fine, and sand, coarse to fine; containing soft buff silt and caliche	21	461
Dakota formation.		
Sandstone, very fine-grained, containing soft yellow to brown clay	19	480

20. Log of test hole 20 at the NE corner sec. 1, T. 29 S., R. 35 W., drilled by State and Federal Geological Surveys, 1942. Surface altitude, 3,013 feet. (Authority, samples studied by James B. Cooper and Thad G. McLaughlin.)

	Thickness, feet	Depth, feet
Soil, sandy, dark brown	1	1
Undifferentiated Pliocene and Pleistocene deposits		
Silt, sandy, compact, buff to dark brown, containing fine to coarse gravel and blue-gray clay	9	10
Silt, fine sandy, soft, light brown to buff, containing fine to coarse gravel and caliche	2	12
Silt, sandy, soft, brown to buff and white, containing fine to coarse gravel and caliche	31	43
Sand, fine to coarse, and gravel, fine; contains sandy brown silt and nodules of caliche	7	50
Sand and gravel; coarse to fine	88	138
Silt, sandy, compact, buff to gray and white	22	160
Clay, compact, blocky, yellow buff and gray	110	270
Gravel, fine to coarse, and sand, medium to coarse	100	370
Sand, fine to coarse, and gravel, fine; containing silt	5	375
Silt, sandy, compact, white to dark gray, containing compact tan clay	5	380
Gravel, fine, and sand, fine to coarse	40	420
Dakota formation		
Clay and silt; varicolored; containing fragments of sandstone and ironstone	31	451
Silt, compact, dark brown	9	460
Clay, soft, yellow to white and gray, containing hard yellow-brown siltstone and fine-grained hard yellow-brown sandstone	40	500
Clay, fine sandy, hard, gray, containing yellow-brown siltstone	10	510
Kiowa shale		
Shale, clayey, dark gray to black, containing sandy gray shale	112	622
Shale, clayey, soft, gray	21	643
Cheyenne sandstone		
Sandstone, very fine-grained, soft, in part cemented, white to gray	46	689
Permian redbeds		
Siltsone, clayey, soft, brick red	11	700

21. Log of test hole 21 at the SW corner sec. 35, T. 29 S., R. 36 W., drilled by State and Federal Geological Surveys, 1942. Surface altitude, 2,933 feet. (Authority, samples studied by Oscar S. Fent and Thad G. McLaughlin.)

	Thickness, feet	Depth, feet
Soil, fine sandy, gray brown	1	1
Undifferentiated Pliocene and Pleistocene deposits		
Silt, tan, containing nodules of caliche	4	5
Silt, soft, dark gray	2	7
Silt, compact, blocky, grayish green to greenish brown	3	10
Sand, fine to coarse, brown	17	27
Gravel and sandstone; brown; containing brown and light-buff silt and caliche	13	40
Sand, coarse to fine, dark brown	3	43
Silt, compact, buff, containing caliche	3	46
Clay, compact, buff to white and pink, containing silt and a little sand	34	80
Volcanic ash, brittle, partly indurated, white to gray and pink brown	7	87
Clay, compact, gray green and brown	4	91
Clay, silty to fine sandy, gray to dark buff, containing caliche	21	112
Sand, silt, and clay; compact; gray and tan	8	120
Silt, sandy, pink, and clay, silty, gray green	10	130
Clay, silty to fine sandy, buff; contains clay, fine gravel, and caliche	28	158
Sand, silt, and clay, compact, tan and gray to brown	12	170
Silt, coarse sandy, soft, buff and gray, containing hard blocky gray-green clay	20	190
Silt, compact, tan, and sand, medium to fine, brown	10	200
Sand, coarse to fine, brown, and silt, compact, tan to white,	20	220
Gravel, coarse to fine, and silt, fine sandy to clayey, buff and white; containing caliche	20	240
Silt, clayey, buff to gray and green gray; contains sand, gravel, and caliche	10	250
Caliche, and silt, sandy, gray to buff; containing sand and gravel	10	260
Sand, medium, and silt, light buff to tan and gray green; containing caliche	30	290
Silt, sandy, soft, light buff to gray green and tan, containing caliche	10	300
Clay, compact, blocky, green brown	11	311
Sand, medium to fine, in part cemented	15	326
Clay, compact, blocky, dark tan	24	350
Silt, tan, containing fine gravel and fine to coarse sand	10	360
Sand, coarse to medium, gray brown, containing light-tan silt	61	421
Dakota formation		
Sandstone, fine-grained, varicolored, containing ironstone,	91	512
Permian redbeds		
Shale, silty, brick red	8	520

22. Log of test hole 22 at the NW corner sec. 33, T. 29 S., R. 38 W., drilled by State and Federal Geological Surveys, 1942. Surface altitude, 3,115 feet. (Authority, samples studied by James B. Cooper and Thad G. McLaughlin.)

	Thickness, feet	Depth, feet
Soil, sandy, brown, containing fine gravel	2	2
Undifferentiated Pliocene and Pleistocene deposits		
Silt, sandy, light gray to light brown, containing coarse sand	11	13
Silt, sandy to clayey, compact, light gray to tan	13	26
Sand, medium to coarse; contains coarse gravel, yellow and light-gray sandy silt, and compact clay	14	40
Silt, sandy, soft, white and yellow brown	3	43
Gravel, medium to coarse, and sand, fine to coarse	5	48
Silt, clayey, compact, tan	12	60
Silt, sandy, tan and light gray, containing coarse gravel and caliche	8	68
Gravel, medium to coarse, containing silt and fine to coarse sand	17	85
Silt, sandy, compact, tan	15	100
Silt, clayey, compact, gray and tan to red tan, containing sand and caliche	52	152
Gravel, fine to medium, and sand, fine to coarse; containing silt	22	174
Silt, sandy, soft to fairly compact, gray and white to red tan, containing sand and gravel	76	250
Gravel and sand; fine to coarse; containing gray to brown silt and caliche	92	342
Silt, sandy, compact, gray, and gravel, fine to medium; containing fine sand and caliche	30	372
Sand, fine to coarse, and gravel, fine to medium; containing tan silt	8	380
Silt, sandy, compact, tan gray, containing fine to medium gravel and coarse sand	30	410
Silt, fine sandy, compact, gray and yellow	13	423
Gravel, medium to very coarse, containing water-worn pebbles of ironstone and sandstone	5	428
Dakota formation		
Sandstone, fine-grained, very hard, varicolored, containing red and yellow clay and fragments of ironstone	22	450

23. Log of test hole 23 at the NW corner sec. 6, T. 31 S., R. 30 W., Meade County, drilled by State and Federal Geological Surveys, 1940. Surface altitude, 2,795± feet. (Authority, samples studied by Perry M. McNally and John C. Frye.)

	Thickness, feet	Depth, feet
Soil, brown	1	1
Undifferentiated Pliocene and Pleistocene deposits		
Silt and sand; fine, gray tan	7	8
Sand, fine to medium, brown	4	12

	Thickness, feet	Depth, feet
Sand, fine, and silt; containing gray-tan caliche	79	91
Sand and silt; brown; cemented caliche	6	97
Sand and gravel; brown	11	108
Silt, fine sand, and caliche	2	110
Sand and gravel; brown and tan	232	342
Sand, fine, silt, and caliche; gray	18	360
Silt, fine sand, and caliche; gray	31	391
Sand, gray	21	412
Sand, fine, silt, and caliche; pink tan	8	420
Sand, brown	11	431
Sand and silt; cemented with caliche	19	450
Silt, fine sand, and caliche; tan	20	470
Sand, fine, silt, and caliche; gray; contains remains of plants	20	490
Silt, caliche, and fine sand; tan and gray	23	513
Caliche, silt, and fine sand; yellow; contains thin beds of sandstone and beds of pink-red clay	17	530

24. Log of test hole 24 at the SW corner sec. 31, T. 30 S., R. 32 W., drilled by State and Federal Geological Surveys, 1943. Surface altitude, 2,897 feet. (Authority, samples studied by James B. Cooper, Oscar S. Fent, and Thad G. McLaughlin.)

	Thickness, feet	Depth, feet
Undifferentiated Pliocene and Pleistocene deposits		
Silt, clayey to sandy, dark brown to red brown, containing caliche	8	8
Silt, soft, white and gray, containing fine to medium sand,	9	17
Silt, sandy, compact, dark tan and gray, containing fine gravel	4	21
Silt, soft, brown, containing fine to medium sand	2	23
Silt, compact, white and gray, containing caliche	4	27
Silt, gray to light tan and brown, containing fine to medium sand and caliche	10	37
Sand, red brown, containing fine to coarse gravel and silt,	11	48
Silt, red brown and gray, containing caliche and very fine sand	3	51
Sand, red brown, containing fine gravel and silt	5	56
Silt, soft, red brown, containing fine to medium sand	4	60
Sand and gravel; coarse to fine	28	88
Silt, compact, gray, containing coarse gravel and caliche	8	96
Sand, yellow brown, containing fine to coarse gravel	4	100
Gravel, fine to coarse, containing silt	10	110
Sand, coarse to fine, containing fine to medium gravel	13	123
Sand, coarse to fine, containing fine to medium gravel and silt	117	240
Gravel, fine to coarse, and sand, coarse to medium; containing soft light-gray silt	6	246
Silt, soft, light gray, containing coarse to medium sand	2	248
Gravel, medium to fine, and sand, coarse to medium	9	257

	Thickness, feet	Depth, feet
Silt, soft, yellow gray, containing coarse to fine sand.....	3	260
Gravel, fine to coarse, and sand, coarse to medium; containing soft gray and tan silt........................	13	273
Silt, clayey, soft, yellow brown and light gray, containing medium to fine sand	7	280
Sand and gravel; coarse to fine; containing a little silt and caliche	113	393
Silt, soft, white and gray to buff and brown, containing fine to coarse sand and gravel and nodules of caliche...	47	440
Clay, blocky, tan, containing caliche....................	10	450
Silt, soft, white, and gravel, fine; containing fine to coarse sand and tan blocky clay	10	460
Sand, coarse to medium, consolidated, containing soft light-gray silt	11	471
Silt, soft, blue gray to gray buff and yellow buff, containing fine to coarse sand	24	495
Dakota formation		
Clay, silty, soft, yellow, and sand, very fine; containing fine-grained yellow and brown sandstone.............	5	500
No sample recovered	10	510

25. Log of test hole 25 at the SE corner sec. 36, T. 30 S., R. 32 W., drilled by State and Federal Geological Surveys, 1943. Surface altitude, 2,837 feet. (Authority, samples studied by James B. Cooper, Oscar S. Fent, and Thad G. McLaughlin.)

	Thickness, feet	Depth, feet
Soil, sandy, gray black	1.5	1.5
Undifferentiated Pliocene and Pleistocene deposits		
Silt, micaceous, soft, yellow gray......................	3.5	5
Silt, micaceous, soft, red brown, containing fine sand and caliche	5	10
Silt, compact, buff and tan; contains fine to coarse sand, caliche, and fine gravel	39	49
Sand, medium to fine, containing soft tan silt and caliche,	6	55
Clay, compact, light buff, containing fine sand...........	9	64
Silt, compact, red tan; contains fine to coarse sand, fine gravel, and caliche	18	82
Sand and gravel; coarse to fine; containing soft gray to tan and yellow-brown silt and caliche	50	132
Silt, soft, yellow brown	3	135
Gravel, fine to coarse, and sand; medium to coarse......	5	140
Silt, clayey, soft, yellow buff, containing coarse to fine sand and caliche	14	154
Sand and gravel; coarse to fine; containing soft buff and yellow-gray silt	63	217
Silt, soft, gray, containing medium to fine sand.........	9	226
Sand, coarse to fine, containing fine to medium gravel and soft gray silt	24	250

	Thickness, feet	Depth, feet
Clay and silt; soft; blue gray; containing fine sand.....	23	273
Sand, coarse to fine, gray, containing medium to fine gravel	5	278
Clay and silt; compact; partly laminated; blue gray to gray and buff; containing fine sand	67	345
Sand, coarse to fine, and gravel, medium to fine; containing caliche	31	376
Silt, soft, white to pink, containing coarse to fine sand and caliche	14	390
Caliche and silt, soft, light brown; containing medium to fine gravel and coarse to fine sand	27	417
Clay, compact, tan, containing pyrite and fine to medium sand	27	444
Sand, fine-grained, consolidated, containing caliche......	26	470
Silt, fine sandy, partly consolidated, cream-colored to tan, containing caliche	25	495
Sand, fine to medium, partly cemented, containing a little silt	21	516
Permian redbeds		
Siltstone, brick red	14	530

26. Log of test hole 26 at the NW corner sec. 6, T. 30 S., R. 34 W., drilled by State and Federal Geological Surveys, 1942. Surface altitude, 3,011 feet. (Authority, samples studied by James B. Cooper and Thad G. McLaughlin.)

	Thickness, feet	Depth, feet
Soil, compact, brown....................................	3	3
Undifferentiated Pliocene and Pleistocene deposits		
Silt, sandy to fine sandy, compact, white to tan and light brown, containing fine gravel and fine to medium sand,	33	36
Sand, fine to coarse, and gravel, fine; containing tan silt..	4	40
Sand, fine to coarse, containing fine gravel..............	20	60
Sand, coarse, containing silt...........................	10	70
Silt, sandy, compact, light brown to buff and white; contains fine to medium sand, fine gravel, and caliche....	20	90
Gravel, fine to coarse, and sand, fine to medium; containing a little tan silt................................	27.5	117.5
Silt, fine sandy, compact, light brown and yellow buff, containing caliche	9.5	127
Gravel, fine to coarse, and sand, medium to coarse.......	76	203
Silt, sandy to fine sandy, yellow buff to brown and gray, containing a few fragments of ironstone.............	17	220
Silt, clayey, soft, gray to yellow and buff................	13	233
Silt, sandy to clayey, gray to yellow and brown, containing coarse gravel	7	240
Clay, compact, blocky, gray and buff, containing soft light-brown and gray silt............................	45	285

	Thickness, feet	Depth, feet
Gravel, fine, brown, and sand, coarse; containing yellow siltstone	5	290
Gravel and sand; fine to coarse; containing a little rusty-brown and yellow siltstone	173	463
Clay, silty to fine sandy, light yellow to yellow buff and pink	37	500
Dakota formation		
Siltstone, clayey, compact, yellow to yellow brown, containing yellow sandstone	10	510
Clay, compact, light gray, containing yellow to yellow-brown siltstone and buff to yellow sandstone	12	522
Sandstone, fine-grained, soft, white to yellow and buff, containing ironstone and a little silt	86	608
Permian redbeds		
Siltstone, clayey, soft, brick red	7	615

27. Log of test hole 27 at the NW¼ sec. 32, T. 30 S., R. 34 W., on the west side of county road about 0.27 mile south of railroad crossing, drilled by State and Federal Geological Surveys, 1943. Surface altitude, 2,842 feet. (Authority, samples studied by Oscar S. Fent and Thad G. McLaughlin.)

	Thickness, feet	Depth, feet
Dune sand		
Sand, medium to very fine, containing soft brown silt	4	4
Undifferentiated Pliocene and Pleistocene deposits		
Sand, coarse to medium, and gravel, fine to coarse; containing nodules of caliche	13	17
Silt, soft, buff	2	19
Sand, coarse to fine, containing nodules of caliche	7	26
Silt, soft, gray to black, containing fine to coarse sand and fine gravel	11	37
Sand, coarse, and gravel, fine to coarse	23	60
Silt, micaceous, soft, gray, containing fine sand and caliche	3	63
Gravel, fine to coarse, and sand, coarse	35	98
Silt, soft, buff, containing sand, coarse to medium	.5	98.5
Gravel, coarse to fine, and sand, medium to coarse; containing a little caliche and silt	161.5	260
Silt, soft, buff, containing fine to coarse sand and gravel and a little caliche	12	272
Gravel, medium to fine, and sand, coarse to medium	8	280
Gravel, medium to fine, and silt, soft, buff; containing coarse to fine sand	7	287
Silt, soft, buff, containing fine to coarse sand and fine gravel	16	303
Sand, coarse to medium, and silt, soft, buff; containing fine to medium gravel and caliche	23	326

	Thickness, feet	Depth, feet
Dakota formation		
Sandstone, fine-grained to very fine-grained, yellow to brown, containing ironstone, silt, and yellow to buff clay	14	340
Silt, clayey, soft, white to light yellow, containing very fine-grained yellow to red-brown sandstone	10	350

28. Log of test hole 28 at the NW corner sec. 35, T. 29 S., R. 36 W., drilled by State and Federal Geological Surveys, 1942. Surface altitude, 2,897 feet. (Authority, samples studied by James B. Cooper and Thad G. McLaughlin.)

	Thickness, feet	Depth, feet
Road fill	5	5
Alluvium		
Silt, fine sandy to clayey, compact, dark buff	3	8
Sand, coarse to fine, and gravel, fine	3	11
Silt, fine sandy, dark gray to black	3	14
Silt, clayey, brownish gray	5	19
Sand, fine to coarse, and clay, sandy, grayish brown; containing fine gravel and caliche	31	50
Gravel, coarse to fine, brown, containing clay and nodules of caliche	4	54
Clay, compact, gray to yellow buff and tan, containing fine sand	16	70

29. Log of test hole 29 at the SE corner sec. 35, T. 30 S., R. 36 W., drilled by State and Federal Geological Surveys, 1942. Surface altitude, 2,954 feet. (Authority, samples studied by Oscar S. Fent and Thad G. McLaughlin.)

	Thickness, feet	Depth, feet
Soil, sandy, gray brown	1.5	1.5
Undifferentiated Pliocene and Pleistocene deposits		
Silt, sandy, red brown, containing caliche	5.5	7
Silt, sandy to clayey, blocky, light gray green, containing caliche	3	10
Silt and clay; sandy; compact; gray green and brown; containing caliche	16	26
Clay, compact, buff pink	2	28
Silt, red, and sand, coarse to fine; containing compact buff-pink clay	2	30
Silt, sandy to clayey, buff to pink, containing caliche	14	44
Silt, compact, gray and buff, containing gravel and caliche	6	50
Gravel, coarse to fine, slightly cemented, and silt, gray green to yellow and brown	18	68
Sand and gravel; coarse to fine; cemented with calcium carbonate to form "mortar beds"	2	70
Gravel, coarse to fine, and sand; containing gray-buff to buff and tan silt and caliche	20	90

	Thickness, feet	Depth, feet
Clay, compact, yellow gray and tan	20	110
Clay and silt; tan and blue; containing a little caliche	16	126
Silt, compact, gray brown and tan green to blue, containing caliche	34	160
Gravel, coarse to fine, and sand, coarse to medium; containing clayey silt	30	190
Silt, sandy, gray and brown, and gravel, coarse to fine; containing coarse to fine sand	10	200
Gravel, coarse to fine, and sand, coarse; containing silt and clay	20	220
Silt, clayey, compact, tan and blue, containing caliche	30	250
Dakota formation		
Siltstone, compact varicolored containing sandstone and clay	20	270

30. Log of test hole 30 at the NW corner sec. 3, T. 30 S., R. 37 W., drilled by State and Federal Geological Surveys, 1942. Surface altitude, 3,074 feet. (Authority, samples studied by Oscar S. Fent and Thad G. McLaughlin.)

	Thickness, feet	Depth, feet
Soil, sandy, black	3	3
Undifferentiated Pliocene and Pleistocene deposits		
Silt, fine sandy, gray brown, containing caliche	3	6
Sand and silt; gray brown to tan; containing caliche	13	19
Sand, medium to fine, partly consolidated	6	25
Silt, compact, tan and white, containing caliche	15	40
Silt, sandy, light tan to tan, containing caliche	10	50
Silt, clayey, compact, tan and buff, containing fine sand and caliche	88	138
Gravel, coarse to medium	5	143
Silt, sandy, and gravel	13	156
Gravel, medium to fine, and sand, coarse to fine; containing sandy, soft, pink and buff silt	27	183
Silt, sandy, soft, gray	2	185
Gravel, coarse to fine, and sand, coarse to medium; containing caliche	13	198
Silt, sandy, soft, buff to gray, containing sand and gravel,	12	210
Silt, clayey to sandy, compact, buff	15	225
Sand, coarse to fine, containing coarse gravel and sandy compact buff silt	25	250
Gravel and sand; coarse to fine; containing a little caliche and silt	60	310
Silt, sandy, tan and gray, containing a little gravel	10	320
Gravel, coarse, and silt, sandy, tan and gray	10	330
Silt, sandy, tan and gray, containing a little coarse gravel,	20	350
Sand, fine, and silt, fine sandy, white and light gray to buff; containing caliche	18	368

	Thickness, feet	Depth, feet
Dakota formation		
Sandstone, fine-grained, yellow to brown, containing clayey gray-green and blue-gray silt	22	390
Clay, varicolored, and sandstone, soft, yellow to red	10	400
Sandstone, fine-grained, soft, yellow, containing fine sandy silt and varicolored clay	10	410
Silt, sand, and clay; light blue gray and brick red; containing ironstone	10	420
Sandstone, fine-grained, soft, white to yellow and brown; containing varicolored clay	100	520
Permian redbeds		
Shale, clayey, brick red	10	530

31. Log of test hole 31 at the SE corner sec. 32, T. 30 S., R. 38 W., drilled by State and Federal Geological Surveys, 1942. Surface altitude, 3,173 feet. (Authority, samples studied by James B. Cooper and Thad G. McLaughlin.)

	Thickness, feet	Depth, feet
Soil, silty, brown and gray, containing caliche	3	3
Undifferentiated Pliocene and Pleistocene deposits		
Silt, fine sandy, light tan and brown, compact, containing sand, fine gravel, and caliche	15	18
Silt, sandy to clayey, light gray to buff; contains sand, a little gravel, and fragments of caliche	78	96
Silt, sandy, white to buff and brown, and caliche; containing sand and gravel	24	120
Silt, sandy, brown and gray, containing caliche and thin beds of cemented sand and gravel	10	130
Gravel and sand; coarse to fine; partly consolidated near top; containing a little clay	80	210
Silt, gray, sandy, compact; contains sand, gravel, caliche, and a little clay	25	235
Gravel and sand; fine to coarse; containing sandy tan to brown silt and caliche	5	240
Gravel and sand; coarse to fine; poorly sorted; containing silt and clay	32	272
Silt and clay; sandy; varicolored; containing caliche	11.5	283.5
Silt, sandy, compact, reddish tan	16.5	300
Gravel, coarse to fine, and sand, coarse to medium; containing silt and clay	136.5	436.5
Dakota formation		
Sandstone, fine-grained, yellow to rusty yellow and brown, containing varicolored clay and fragments of ironstone	93.5	530
Clay, silty, varicolored, containing gray to yellow and red sandstone and fragments of ironstone	9	539
Permian redbeds		
Siltstone, in part clayey, brick red	21	560

32. Log of test hole 32 at the SE corner sec. 25, T. 31 S., R. 35 W., drilled by State and Federal Geological Surveys, 1943. Surface altitude, 2,967 feet. (Authority, samples studied by Oscar S. Fent and Thad G. McLaughlin.)

	Thickness, feet	Depth, feet
Soil, sandy, gray black	2	2
Undifferentiated Pliocene and Pleistocene deposits		
Silt, soft, gray to yellow gray and buff, containing fine to medium sand	22	24
Sand, fine, containing silt, soft, gray buff	4	28
Silt, soft, gray buff and buff, containing fine to medium sand and a little caliche	7	35
Silt, clayey, yellow buff and buff; contains fine gravel, fine to coarse sand, and caliche	8.5	43.5
Silt, soft, buff to light gray and pink; contains fine to coarse sand, fine to medium gravel, and a little caliche,	37.5	81
Clay, silty, light tan, containing fine sand	9	90
Silt, in part clayey, white to buff and pink, containing fine to coarse sand and gravel and caliche	44	134
Gravel, coarse to fine, and sand, coarse	22	156
Silt, soft, yellow gray; contains fine gravel, fine to coarse sand, and caliche	9	165
Gravel, fine to medium, and sand, coarse to medium	17	182
Silt, soft, buff and gray	1	183
Gravel, fine to medium, and sand, coarse to medium	9	192
Silt, soft, yellow and light gray, containing very fine sand and caliche	13	205
Gravel, fine to coarse, and sand, coarse to medium; containing a little silt	33.5	238.5
Silt, soft, gray, containing medium to fine gravel and coarse to fine sand	7.5	246
Gravel, fine to medium, and sand, coarse to fine; containing a little silt and caliche	41	287
Silt, soft, light gray, containing fine to coarse sand	.5	287.5
Gravel, medium to fine, and sand, coarse to fine; containing caliche	20.5	308
Silt, soft, containing fine sand	1	309
Gravel, fine, and sand, coarse	4	313
Silt, soft, buff, containing coarse to fine sand and caliche,	4	317
Gravel, medium to fine, and sand, coarse	5.5	322.5
Silt, soft, buff and gray; contains fine to coarse sand, fine to coarse gravel, and caliche	81.5	404
Silt, white to blue gray and buff, containing fine to coarse sand and caliche	70	474
Dakota formation		
Siltstone, soft, yellow buff, containing fine-grained yellow sandstone and ironstone	6	480
Sandstone, fine-grained, soft, and silt, compact; white and yellow; containing ironstone	10	490

	Thickness, feet	Depth, feet
Silt, light yellow and white, containing very fine-grained white sandstone	7	497
Sandstone, fine-grained to very fine-grained, hard, and silt, soft; white and yellow	3	500
Siltstone, in part clayey, soft, and sandstone, fine-grained to very fine-grained; white to yellow; containing ironstone	17	517
Clay, varicolored, containing yellow and red siltstone and very fine-grained sandstone	29	546
Permian redbeds		
Clay, dark red	4	550
Shale, hard, dark red, containing a little blue-gray shale,	10	560

33. Log of test hole 33 at the NE corner sec. 9, T. 31 S., R. 37 W., drilled by State and Federal Geological Surveys, 1942. Surface altitude, 3,062 feet. (Authority, samples studied by James B. Cooper and Thad G. McLaughlin.)

	Thickness, feet	Depth, feet
Soil, silty, containing sand, medium, and gravel, fine; black	2	2
Undifferentiated Pliocene and Pleistocene deposits		
Silt, compact, gray and brown; contains fine gravel, medium sand, and caliche	2	7
Silt, sandy, light brown and tan to gray and white, containing fragments of caliche	14	21
Sand, fine to coarse, tan, and silt, sandy, gray and brown,	6	27
Silt, sandy, white and light gray to tan and red, containing caliche	31	58
Silt, clayey, compact, brown, containing caliche	12	70
Silt, sandy, gray and brown, containing fine to coarse tan sand and fragments of caliche	3	73
Gravel and sand; fine to coarse; partly cemented; containing brown silt	7	80
Silt, clayey, compact, tan, containing caliche	3	83
Gravel, coarse, and sand, medium, containing tan silt...	4	87
Silt, fine sandy to clayey, compact, tan, containing fine to coarse gravel and medium sand	3	90
Gravel, fine to coarse, tan and brown, and sand, medium; containing gray sandy silt	8	98
Silt, clayey, compact, tan	2	100
Gravel and sand; fine to coarse; containing tan silt....	18	118
Silt, compact, tan, containing medium sand and fragments of caliche	6	124
Gravel, fine to medium, and sand, fine to coarse	56	180
Gravel, fine to medium, and sand, fine to coarse; containing yellow and tan silt	15	195
Silt, fine sandy, compact, gray and tan, containing compact yellow to tan clay	12	207

	Thickness, feet	Depth, feet
Gravel, fine to coarse, containing medium sand and fragments of ironstone and sandstone	23	230
Silt, fine sandy, gray and brown	16	246
Gravel, medium to coarse, containing coarse, tan sand	94	340
Gravel, medium to very coarse, containing coarse sand and fragments of ironstone, sandstone, and red clay	23	363
Dakota formation		
Sandstone, soft, brown and yellow	30	393
Siltstone, clayey, hard, red and yellow, containing yellow sandstone	10	403
Sandstone, soft, white and yellow	7	410
Siltstone, fine sandy, soft, yellow tan and gray	10	420
No sample recovered	10	430

34. Log of test hole 34 at the SE corner sec. 33, T. 31 S., R. 37 W., drilled by State and Federal Geological Surveys, 1943. Surface altitude, 3,130 feet. (Authority, samples studied by Oscar S. Fent and Thad G. McLaughlin.)

	Thickness, feet	Depth, feet
Soil, clayey, dark gray to black	5	5
Undifferentiated Pliocene and Pleistocene deposits		
Silt, soft, blocky, yellow gray, containing fine sand	2	7
Silt, soft, brown to cream colored and buff, containing fine to coarse sand and nodules of caliche	33	40
Sand, medium to fine, and silt, soft, buff	2.5	42.5
Clay, silty, compact, buff	7.5	50
Silt, clayey, compact, light gray to buff, containing caliche and fine to coarse sand	19	69
Gravel, very coarse to fine, and sand, coarse to medium	23	92
Silt, compact, buff, containing caliche and fine to coarse sand	60	152
Sand, coarse to medium, and gravel, fine; containing caliche	10	162
Silt, soft, buff, containing sand, gravel, and caliche	18.5	180.5
Gravel, medium to fine, and sand, fine to coarse; containing caliche and soft buff silt	27.5	208
Silt, soft, cream to reddish tan; contains fine gravel, fine to coarse sand, and caliche	19	227
Gravel, medium to fine, and sand, coarse	9	236
Gravel and sand; consolidated	4	240
Gravel, medium to fine, and silt, soft, tan; containing medium to coarse sand	7	247
Silt, soft, tan, containing fine gravel, fine to coarse sand, and caliche	23	270
Silt, compact, blocky, brown	40	310
Silt, compact, blocky, brown, containing a little gravel and caliche	9.5	319.5

	Thickness, feet	Depth, feet
Silt, soft, buff and brown, containing medium to fine sand and caliche	10.5	330
Silt, compact, blocky, brown, and silt, soft, gray; containing fine to coarse sand and a little caliche	200	530
Silt, soft, light greenish gray and brown, containing fine to medium sand and a little caliche	32	562
Permian redbeds		
Siltstone, brick red, containing a little compact greenish-gray silt	8	570

35. Log of test hole 35 at the NW corner sec. 4, T. 31 S., R. 39 W., Morton County, drilled by State and Federal Geological Surveys, 1940. Surface altitude 3,193 feet. (Authority, samples studied by Perry M. McNally and Thad G. McLaughlin.)

	Thickness, feet	Depth, feet
Loam, brown to black	3	3
Undifferentiated Pliocene and Pleistocene deposits		
Clay, silty to fine sandy, light brown	5	8
Silt, fine sandy, brown	3	11
Silt, fine sandy, light brown	2	13
Sand, fine, brown, containing caliche and clay	4	17
Silt, light brown and gray, and caliche	8	25
Silt, fine sandy, brown	4	29
Clay, silty, light brown, and caliche	12	41
Silt, light gray, fine sandy	2	43
Silt, fine sandy, light brown	3	46
Sand, fine, reddish brown	8	54
Silt, fine sandy, brown, and caliche	10	64
Clay, silty, light brown	5	69
Sand, fine, and silt; brown	4	73
Silt and caliche	5	78
Sand, fine, brown, and caliche	9	87
Sand, fine, light brown to gray, and caliche	10	97
Sand, fine, brown	11	108
Silt, light gray to white	6	114
Sand, fine, brown to gray	23	137
Sand, medium, brown	4	141
Silt, fine sandy, brown	6	147
Sand and gravel; brown	11.5	158.5
Silt, sandy, brown	6.5	165
Sand and gravel; brown	11	176
Silt, caliche, and sand	4	180
Sand and gravel; brown	10	190
Sand and gravel; coarse	10	200
Sand, fine, brown, and silt	10	210
Silt, brown, and loose sand	13	223
Silt, brown and gray	5	228
Sand, fine to coarse, brown	9	237

	Thickness, feet	Depth, feet
Sand and gravel	11.5	248.5
Silt, brown, sandy	7.5	256
Silt, sand, and gravel	5.5	261.5
Dakota formation		
Sandstone, brown, and clay; varicolored	8.5	270

36. Log of test hole 36 at the SE corner sec. 24, T. 32 S., R. 35 W., drilled by State and Federal Geological Surveys, 1943. Surface altitude, 2,974 feet. (Authority, samples studied by Oscar S. Fent and Thad G. McLaughlin.)

	Thickness, feet	Depth, feet
Dune sand		
Sand, medium to fine, containing light-gray to dark-gray silt	6	6
Undifferentiated Pliocene and Pleistocene deposits		
Silt, in part clayey, soft, buff to greenish gray and gray, containing a little caliche and fine to medium sand	20	26
Sand, medium to fine, containing soft gray-white silt and a little caliche	3	29
Silt, soft, buff and light tan, containing fine to coarse sand and a little caliche	21	50
Sand, medium	3.5	53.5
Clay, silty, yellow gray	6.5	60
Sand, coarse to fine, containing fine gravel and soft gray silt	6	66
Silt, soft, yellow gray, containing fine to medium sand	10	76
Sand, coarse to fine, and silt, soft, gray; containing caliche	4	80
Sand and gravel; coarse to fine	13	93
Silt, clayey, buff, containing fine sand, pink-buff clay, and caliche	17	110
Clay, silty, buff	7	117
Gravel and sand; coarse to fine; containing a little soft white silt	19	136
Silt, clayey, buff, containing fine sand and a little caliche	4	140
Silt, compact, buff and pink, containing fine to coarse sand and caliche	35	175
Gravel, medium to fine, containing soft buff silt and fine to coarse sand	14.5	189.5
Silt, gray, containing fine gravel, fine to coarse sand, and caliche	10.5	200
Gravel, medium to fine, and sand, coarse; partly consolidated	20	220
Gravel, medium to fine, and sand, coarse; consolidated	3	223
Silt, soft, gray brown, containing fine to coarse sand	11	234
Sand, coarse to medium, and gravel, fine	5	239
Silt, soft, yellow gray to tan and buff, containing fine to medium sand and caliche	31	270
Clay, compact, blocky, brown and blue gray, containing caliche	10	280

	Thickness, feet	Depth, feet
Silt, clayey, buff to yellow gray and tan, containing very fine to medium sand, and caliche	30	310
Clay, compact, laminated, light blue gray, containing soft tan silt and a little caliche	70	380
Silt, soft, buff and tan, containing fine sand	40	420
Sand, coarse to fine; contains yellow-buff silt, fine to medium gravel, and caliche	30	450
Silt, gray and buff, containing fine to medium sand and a little caliche	20.5	470.5
Gravel, fine, and sand, coarse to fine	6.5	477
Silt, soft to compact, light pink to buff, containing fine to coarse sand and a little caliche	15	492
Silt, clayey, red and buff, containing sand and caliche	5	497
Permian redbeds		
Siltstone, clayey, dark red	13	510

37. Log of test hole 37 at the SW corner sec. 27, T. 32 S., R. 37 W., drilled by State and Federal Geological Surveys, 1943. Surface altitude, 3,123 feet. (Authority, samples studied by Oscar S. Fent and Thad G. McLaughlin.)

	Thickness, feet	Depth, feet
Dune sand		
Sand, medium to fine, containing silt, soft, gray and tan	10	10
Undifferentiated Pliocene and Pleistocene deposits		
Silt, clayey, compact, buff and tan; contains fine to coarse sand, fine gravel, and caliche	19	29
Sand, coarse to medium, and gravel, fine	7	36
Silt, compact, tan, containing fine to coarse sand and a little caliche	7	43
Sand, coarse to medium, and gravel, medium to fine	6	49
Silt, soft, tan, containing coarse to medium sand	10	59
Gravel, medium to fine, and sand, coarse; containing soft buff silt	6	65
Silt, buff to yellow gray, and sand, coarse to fine; containing coarse to fine gravel and a little caliche	25	90
Sand, coarse to fine, and silt, soft, buff	4	94
Silt, soft, dark gray and buff; contains fine to coarse sand, fine to coarse gravel, and caliche	6	100
Gravel, coarse to fine, and sand, coarse to medium; consolidated	11	111
Silt, clayey, pinkish buff, containing fine to coarse sand and a little caliche	35	146
Silt, soft, buff to light gray and yellow gray; contains fine to coarse sand, fine to medium gravel, and caliche	44	190
Silt, clayey, compact, buff, containing fine to coarse sand and a little caliche	32	222

	Thickness, feet	Depth, feet
Silt, soft, gray and tan, containing fine to coarse sand and a little caliche	8	230
Silt, soft, reddish tan; contains fine to very fine sand, blue-gray compact silt, and caliche	90	330
Silt, soft, reddish tan and blue gray, containing fine to very fine sand and a little caliche	50	380
Silt, soft, red and buff, containing very fine to medium sand and a little caliche	40	420
Silt, clayey, compact, blocky, blue gray, containing fine to coarse sand and a little caliche	10	430
Silt, soft, red and pink, containing very fine sand and caliche	70	500
Silt, soft, light gray to gray green, containing fine to medium sand and caliche	30	530
Silt, compact, red and pink, containing fine sand and caliche	10	540
Silt, soft, gray white, containing fine sand and a few pebbles of sandstone	10	550
Silt, soft, red and pink, containing fine to medium sand and gravel	9	559
Permian redbeds		
Siltstone, brick red, containing very fine sand	11	570

38. Log of test hole 38 at the SW corner sec. 18, T. 33 S., R. 34 W., Seward County, drilled by the State and Federal Geological Surveys, 1942. Surface altitude, 2,936 feet. (Authority, samples studied by James B. Cooper and Frank E. Byrne.)

	Thickness, feet	Depth, feet
Dune sand		
Sand, fine to medium, containing some silt, brown	6	6
Undifferentiated Pliocene and Pleistocene deposits		
Sand, silt, clay, and fine gravel; calcareous; pinkish gray	4	10
Sand, fine to coarse, containing fine gravel; calcareous; gray brown; coarser toward base	17	27
Clay, silt, and sand, coarse; brown gray; calcareous	3	30
Sand, medium and coarse, brownish gray	10	40
Sand, silt, clay, and fine gravel; calcareous; pink brown; much coarser in basal part	20	60
Gravel, coarse, to sand, coarse; gray brown	10	70
Sand, fine, to gravel, medium; containing numerous fragments of caliche	25	95
Gravel, medium, to sand, fine; lime-cemented	5	100
Sand, silt, and clay; containing a little fine gravel; gray brown, highly calcareous	10	110
Sand and some silt; tan to pinkish gray; lime-cemented	30	140
Sand, coarse, to silt, gray brown	10	150
Sand and some silt; tan to pinkish gray; lime-cemented	10	160
Silt, sand, and clay; tan to pinkish gray	10	170

	Thickness, feet	Depth, feet
Silt, clay, and some sand; gray brown; highly calcareous,	4	174
Sand, fine, to gravel, medium; calcareous; light brown...	16	190
Gravel, fine, and sand, coarse; light brown...............	30	220
Sand, fine to coarse, containing a little fine gravel; light brown; slightly calcareous...........................	20	240
Sand, coarse, and gravel, fine; light brown...............	20	260
Sand, fine to coarse, containing a little fine gravel; slightly calcareous; tan gray.........................	10	270
Sand, fine to coarse, slightly calcareous, brownish gray..	20	290
Sand, coarse, and gravel, fine; brownish gray............	20	310
Sand and gravel; reddish gray.........................	10	320
Sand, fine to coarse, containing a little gravel; light brownish gray	10	330
Sand and a little gravel; reddish gray..................	10	340
Silt, clay, and sand; tan brown to yellow gray..........	13	353
Sand, medium, to gravel, fine; light brownish gray.......	27	380
Silt and clay; tan brown	3	383
Sand, medium, to gravel, fine; light brownish gray.......	7	390
Sand and gravel; containing small fragments of ironstone,	10	400
Sand, medium, and gravel, fine	10	410
Sand, medium, to gravel, fine; light brownish gray.......	46	456
Shale, compact, tan brown and red	4	460
Sand and gravel; brownish gray	20	480
Shale, compact, tan, brown, red, and gray green........	10	490
Sand and gravel; brownish gray	20	510
Sand, light brown, and shale, red and brown; interbedded,	17	527
Shale, compact, hard, brown	3	530
Sand, brownish gray, and shale, compact, brown and red; interbedded	90	620
Shale, compact, tan brown	78	698
Permian deposits		
Shale, silty, slightly calcareous, bright red	22	720

39. Log of test hole 39 at the SW corner sec. 18. T. 33 S., R. 35 W., drilled by State and Federal Geological Surveys, 1943. Surface altitude, 3,005 feet. (Authority, samples studied by Oscar S. Fent and Thad G. McLaughlin.)

	Thickness, feet	Depth, feet
Soil, sandy, gray	1.5	1.5
Dune sand		
Sand, medium to fine, reddish buff	5.5	7
Undifferentiated Pliocene and Pleistocene deposits		
Silt, reddish, containing medium to fine sand and caliche,	7	14
Sand, medium to fine, red, containing reddish-buff and white silt	24	38
Silt, clayey, white to yellow, containing fine to medium sand	12	50

	Thickness, feet	Depth, feet
Gravel, medium to fine, and sand, coarse to fine; containing soft buff silt	15	65
Silt, soft, buff, containing sand and gravel	5	70
Sand, coarse to fine	4	74
Silt, soft, light gray to greenish gray, containing sand, gravel, and caliche	16	90
Sand, medium to coarse, and gravel, medium to fine	10	100
Silt, gray buff to buff, containing fine to coarse sand and caliche	24	124
Sand, coarse to medium, containing caliche and buff to white silt	17	141
Silt, buff, containing medium to fine sand and caliche	16.5	157.5
Silt, soft, white, and caliche	3.5	161
Gravel, fine, and silt, compact, buff	7	168
Silt, compact, gray, containing fine to coarse sand and caliche	22	190
Silt, soft, greenish gray to tan, contains fine to coarse sand, fine gravel, and caliche	34	224
Sand, coarse to fine, and gravel, fine; containing caliche	34	258
Silt, soft, gray buff, containing coarse to fine sand and caliche	3	261
Sand, coarse to fine, containing fine gravel and caliche	12	273
Silt, soft, pink tan to gray buff and brown, containing coarse to fine sand, medium to fine gravel, and caliche	27	300
Sand, coarse to fine, and gravel, fine to medium, containing a little silt and caliche	126.5	426.5
Silt, clayey, soft to compact, white to blue gray and varicolored, alternating with beds of pink clay; containing very fine to medium sand and caliche	230.5	657
Gravel, medium to fine, and sand, coarse to fine	46	703
Permian redbeds		
Silt, soft, orange red	17	720
Silt, soft, orange red, and siltstone, hard, red	10	730
Shale, silty, dark red, containing a little limestone and gypsum	10	740

40. Log of test hole 40 at the NW corner sec. 20, T. 33 S., R. 36 W., drilled by State and Federal Geological Surveys, 1943. Surface altitude, 3,061 feet. (Authority, samples studied by Oscar S. Fent and Thad G. McLaughlin.)

	Thickness, feet	Depth, feet
Soil, very sandy, gray black	2	2
Dune sand		
Sand, medium to fine, containing gray and buff calcareous silt	8	10
Sand, medium, containing a little fine and coarse sand and reddish-buff silt	18	28

	Thickness, feet	Depth, feet
Undifferentiated Pliocene and Pleistocene deposits		
Silt, compact, gray, containing medium to fine sand	2	30
Silt, soft, buff, containing gravel in lower part	10	40
Gravel, medium to fine, and sand, medium to coarse	23	63
Silt, soft, yellow buff, interbedded with sand and gravel	7	70
Silt, clayey, soft, grayish green and buff, containing coarse to fine sand and a little gravel and caliche	40	110
Silt, compact, buff and pink, containing fine to coarse sand and caliche	11	121
Silt, soft, buff and white, containing much medium to fine sand and caliche	29	150
Sand, coarse to fine, and silt, soft, gray brown, containing caliche	10	160
Gravel, fine to medium, and sand, coarse to fine; containing soft buff silt and a little caliche	47	207
Silt, soft, gray to pink and buff; contains fine to coarse sand, fine to coarse gravel, and caliche	33	240
Gravel, medium to fine, and sand, fine to coarse; containing silt and caliche in upper part	18.5	258.5
Silt, soft, buff and gray; contains medium to fine gravel, coarse to fine sand, and caliche	21.5	280
Clay, compact, laminated, blue gray and yellow gray, containing red silt and caliche	33	313
Gravel and sand; coarse to fine; containing soft buff silt and a little caliche	2	315
Clay, silty, laminated, gray to dark blue gray, containing gray-green silt and a little sand	85	400
Silt, compact, brown gray, containing a little sand	10	410
Clay, silty, compact, blue gray and gray green; contains silt, sand, gravel, and caliche	30	440
Silt, soft, yellow buff and gray, containing fine to coarse sand and fine to medium gravel	20	460
Clay, compact, blocky, yellow to blue gray and black	20	480
Clay, silty, compact, blocky, blue gray and gray, containing a little fine to coarse sand	10	490
Silt, clayey, compact, gray, containing a little very fine sand	8	498
Gravel, fine, and sand, coarse	2	500
Silt, compact, clayey, partly micaceous, blue gray to gray and yellow	36	536
Permian redbeds		
Siltstone, hard, bright red to dark red	14	550

41. Log of test hole 41 at the SW corner NW¼ sec. 21, T. 33 S., R. 37 W., drilled by State and Federal Geological Surveys, 1943. Surface altitude 3,120 feet. (Authority, samples studied by Oscar S. Fent and Thad G. McLaughlin.)

	Thickness, feet	Depth, feet
Soil, sandy to silty, dark gray	2.5	2.5
Dune sand		
Sand, fine, and silt, soft, light gray	2.5	5
Undifferentiated Pliocene and Pleistocene deposits		
Silt, light gray, blocky	2	7
Sand, medium to fine, containing silt, red	13	20
Sand, medium to fine, containing silt, gray white	10	30
Sand, coarse to medium, stained orange red	7	37
Silt, soft, reddish tan, containing caliche	.5	37.5
Gravel, very coarse, to sand, fine; containing soft buff silt and a little caliche	46.5	84
Silt, soft, buff, containing coarse to fine sand and caliche,	16	100
Clay, silty, white, containing sand and gravel which are partly cemented by calcium carbonate	10	110
Silt, calcareous, white and pink, containing medium to fine sand	9	119
Silt, hard, blocky, gray	5	124
Silt, soft, gray to buff and tan; contains fine to coarse sand, fine to medium gravel, and caliche	61	185
Gravel, medium, to sand, fine; containing soft buff silt,	6	191
Silt, soft, tan, containing fine gravel, fine to coarse sand, and caliche	11	202
Caliche, silty, hard, light pink, containing soft red silt and very fine sand	8	210
Gravel, fine, containing soft red and white silt and caliche,	10	220
Silt, very soft to partly cemented, red, containing very fine to coarse sand and fine gravel	40	260
Silt, micaceous, very soft, white to yellow and pink, containing much very fine sand and a little caliche	10	270
Silt, soft, partly clayey, white and yellow, containing very fine to coarse sand and fine gravel	17	287
Gravel, fine to medium, and sand, fine to very fine; containing soft yellow and light-gray silt and caliche	3	290
Silt, clayey, soft, gray to buff and red, containing coarse to medium gravel and coarse to very fine sand	22	312
Gravel, coarse to medium, and sand, coarse to fine	8	320
Silt, soft, tan to white; contains fine to coarse sand, fine to coarse gravel, and caliche	70	390
Gravel, fine	20	410
Gravel and sand; fine to coarse; containing soft buff silt and caliche	10	420
Silt, soft, tan to buff; contains fine to very fine sand; fine gravel, red and yellow silt, and caliche	70	490

	Thickness, feet	Depth, feet
Silt, micaceous, soft, light yellow to buff and light red, containing a little gravel	10	500
Silt, partly cemented, buff and light red	34.5	534.5
Gravel, medium, to sand, coarse; containing soft buff silt,	5.5	540
Gravel, fine to medium, containing caliche	24	564
Permian redbeds		
Siltstone, clayey, dark red	11	575

42. Log of test hole 42 at SE corner sec. 16, T. 33 S., R. 38 W., drilled by State and Federal Geological Surveys, 1943. Surface altitude, 3,165 feet. (Authority, samples studied by Oscar S. Fent and Thad G. McLaughlin.)

	Thickness, feet	Depth, feet
Dune sand		
Sand, medium to fine, containing dark-gray silt	9	9
Undifferentiated Pliocene and Pleistocene deposits		
Sand, coarse to medium, containing blocky gray-green and tan silt and caliche	19	28
Clay, silty, tan, containing fine to coarse sand and caliche,	10	38
Sand, coarse, and gravel, fine	9.5	47.5
Silt, soft, tan, containing very coarse to fine gravel and coarse to fine sand	2.5	50
Sand, medium, to gravel, fine	3	53
Silt, compact, yellow gray, containing coarse to fine sand and caliche	7	60
Sand, medium, to gravel, fine	2	62
Silt, soft, light tan and red tan; contains fine to coarse sand; fine to coarse gravel, and a little caliche	10.5	72.5
Silt, compact, buff, and sand, coarse to fine; containing caliche	12.5	85
Clay, silty, gray buff, containing fine to medium sand and caliche	25	110
Silt, clayey, gray buff to tan and white, containing coarse to fine sand and caliche	70	180
Silt, soft, buff and tan, containing fine to medium sand and a little caliche	10	190
Silt, soft, greenish gray; contains fine to coarse sand, fine to medium gravel, and caliche	17	207
Gravel, medium, to sand, fine; containing soft buff silt	19	226
Silt, soft, greenish gray to gray and buff; contains fine to coarse sand, fine gravel, and caliche	52	278
Silt, soft, light tan, and gravel, medium to fine; containing fine to coarse sand and caliche	15	293
Gravel, coarse, to sand, fine; containing soft buff to tan and gray silt and caliche	167	460
Silt, soft, buff, containing fine to coarse sand	6	466
Gravel, medium, to sand, medium	10	476

	Thickness, feet	Depth, feet
Silt, soft, buff; contains fine to medium sand, medium gravel, and caliche	11	487
Gravel, coarse, to sand, coarse; containing caliche	13	500
Gravel, medium to fine, containing buff to yellow and red silt and caliche	8	508
Permian redbeds		
Clay, silty, brick red	12	520

43. Log of test hole 43 at NW corner sec. 22, T. 33 S., R. 39 W., drilled by State and Federal Geological Surveys, 1943. Surface altitude, 3,235± feet. (Authority, samples studied by Oscar S. Fent and Thad G. McLaughlin.)

	Thickness, feet	Depth, feet
Dune sand		
Sand, medium to fine, containing gray silt and a little caliche	10	10
Undifferentiated Pliocene and Pleistocene deposits		
Sand, coarse to fine, containing soft buff silt and nodules of caliche	8	18
Silt, soft, buff tan, containing fine to medium sand and caliche	2	20
Sand, coarse to fine, containing soft buff silt and caliche	4	24
Silt, compact, buff; contains fine gravel, fine to coarse sand, and caliche	4	28
Gravel, coarse, to sand, fine; containing soft tan to buff and gray silt	36	64
Silt, compact, tan, containing coarse to fine sand and gravel and caliche	6	70
Silt, soft, buff and red, containing fine to coarse sand and caliche	30	100
Silt, soft, gray and tan, containing fine to coarse sand and caliche	34	134
Sand, medium to fine, and silt, soft, gray	4	138
Silt, soft, yellow gray and pink, containing fine to coarse sand and caliche	5	143
Gravel, coarse, to sand, coarse; containing soft buff silt and caliche	15	158
Silt, white and buff, containing fine to medium sand and caliche	13	171
Silt, clayey, brown, containing fine to medium sand	9	180
Silt, soft, buff and tan; contains fine to coarse sand, a little fine gravel near base, and caliche	98	278
Sand, coarse to fine, interbedded with tan and greenish-yellow silt; containing a little fine gravel and caliche	12	290
Silt, clayey, compact, blocky, dark tan to greenish yellow, containing fine to medium sand	13	303
Gravel, fine, to sand, fine	5	308
Silt, clayey, tan and greenish yellow, containing fine to medium sand	4	312

	Thickness, feet	Depth, feet
Sand, coarse to fine	4	316
Silt, compact, blocky, tan and greenish yellow, and silt, soft, buff; containing fine to medium sand	24	340
Sand, coarse to fine, and silt, tan and buff	11	351
Silt, white to tan, and sand, coarse to fine; consolidated; containing a little fine to coarse gravel	9	360
Gravel, sand, and clay, varicolored. Gravel consists of water-worn pebbles of sandstone	30	390
Permian redbeds		
Clay, silty, red, containing maroon and light-gray sandstone	20	410
Sandstone, very fine-grained, soft, maroon red, and clay, silty, pink; containing a little white sandstone in the middle	41	451
Shale and siltstone; dark red	4	455

44. Log of test hole 44 at the SE corner sec. 36, T. 34 S., R. 35 W., drilled by State and Federal Geological Surveys, 1943. Surface altitude, 2,950± feet. (Authority, samples studied by Oscar S. Fent and Thad G. McLaughlin.)

	Thickness, feet	Depth, feet
Dune sand		
Sand, medium to fine, containing soft gray to gray-black silt	5	5
Sand, medium to fine, red	9	14
Undifferentiated Pliocene and Pleistocene deposits		
Silt, soft, buff, containing medium to fine sand	4	18
Silt, clayey, green, containing medium to fine sand	5	23
Silt, soft, buff to white, containing medium to fine sand and caliche	7	30
Sand, medium to fine, and silt, soft, buff	4	34
Silt, soft, light gray, containing medium to fine sand	4	38
Sand, coarse to fine	22	60
Silt, soft, buff to gray white, containing medium to fine sand and caliche	10	70
Silt, compact, light yellow tan, containing medium to fine sand and caliche	20	90
Sand, coarse to fine, containing soft buff white silt	14	104
Silt, clayey, buff, containing coarse to fine sand and caliche	2	106
Gravel and sand; coarse to fine	29	135
Silt, soft, buff, containing medium to fine sand and a little gravel	10.5	145.5
Silt, compact, light tan, containing medium to fine sand and caliche	14.5	160
Silt, soft, white and buff, containing coarse to fine sand and caliche	30	190
Silt, clayey, buff and light tan, containing coarse to fine sand and caliche	15	205

	Thickness, feet	Depth, feet
Silt, soft, gray and buff; contains fine to coarse sand, fine gravel, and caliche	15.5	220.5
Gravel, fine, to sand, medium	2.5	223
Silt, soft, light brown, containing medium to fine sand and caliche	6	229
Sand, fine, to gravel, fine; containing caliche	23	252
Silt, soft, tan, containing medium to fine sand and caliche	28	280
Sand, coarse to fine	20	300
Silt, soft, tan, containing fine sand and caliche	4	304
Silt, soft, light greenish gray and brown, and sand, very fine	6	310
Silt, soft, white to greenish gray and light gray buff, containing coarse to fine sand and a little caliche	50	360
Silt, clayey, white to yellow and brown, containing dense blue-white caliche	20	380
Silt, very soft, gray white and yellow brown, and sand, fine; containing hard white to yellow-brown sandstone and concretions of hard brown siltstone	50	430
Silt, very soft, gray white and yellow brown, containing concretions of sandy hard brown siltstone	38	468
Gravel, fine, to sand, medium	2	470
Silt, very soft, light buff to yellow brown and gray white, containing coarse to very fine sand	100	570
Silt, soft, gray buff to blue gray, and sand, medium to fine; containing concretions of ironstone	20	590
Silt, soft, light gray and yellow brown, containing medium to fine sand	10	600
Silt, very soft, gray buff and yellow brown, containing coarse to find sand and fine gravel	20	620
Silt, soft, light gray buff, containing medium to fine sand,	60	680
Gravel, fine, to sand, medium	8	688
Permian redbeds		
Silt, blocky, light orange red	2	690
Silt, clayey, light orange red	30	720

45. Log of test hole 45 at the SE corner sec. 17, T. 34 S., R. 37 W., drilled by State and Federal Geological Surveys, 1943. Surface altitude, 3,169 feet. (Authority, samples studied by Oscar S. Fent and Thad G. McLaughlin.)

	Thickness, feet	Depth, feet
Dune sand		
Sand, medium to fine, containing a little silt	3	3
Undifferentiated Pliocene and Pleistocene deposits		
Silt, containing a little coarse to fine sand	3	6
Silt, clayey, greenish gray, containing medium to fine sand,	3	9
Silt, soft, yellow gray, containing fine sand	4	13
Sand, medium to fine, containing red silt	3	16

	Thickness, feet	Depth, feet
Silt, compact, red and gray, containing medium to fine sand	4	20
Sand, medium to very fine; contains red silt, white clay, and caliche	15	35
Silt, clayey, soft, buff, containing fine sand and caliche	15	50
Sand, fine, to gravel, medium; containing soft buff silt and caliche	37	87
Silt, compact, buff, containing coarse to fine sand and caliche	1	88
Sand, coarse to medium, and gravel, coarse to fine; containing gray and buff silt and caliche	33	121
Silt, soft, gray to greenish gray and tan, containing fine to coarse sand and a little gravel and caliche	51	172
Gravel, medium to fine	4	176
Silt, soft, yellow gray to white; contains much medium to fine gravel near the top, fine to coarse sand, and much caliche near the base	25	201
Sand, medium to fine, and silt, soft, gray to tan; containing caliche	9	210
Silt, soft, gray to light brown and greenish gray; contains fine gravel, fine to coarse sand, and caliche	30	240
Gravel, fine, to sand, fine; containing soft brown silt and caliche	27	267
Silt, soft, white to pink brown and buff, containing coarse to fine sand, fine gravel, and caliche	103	370
Silt, clayey, laminated, blue gray and yellow buff to red brown, containing a little caliche	20	390
Silt, pink, containing medium to fine sand and caliche	40	430
Silt, compact, flaky, red brown to brown and gray brown, containing a little caliche	100	530
Silt, compact, blue gray and brown, containing caliche	30	560
Silt, compact, brown, containing clay, buff, and caliche	20	580
Silt, compact, brown, containing caliche	21	601
Sand, medium, to gravel, fine	12	613
Silt, soft, gray to buff and pink, containing coarse to fine sand	47	660
Silt, clayey, pink	10	670
Silt, clayey, light red and buff	17	687
Permian redbeds		
Siltstone, brick red and white	13	700
Siltstone, brick red, containing gypsum	10	710

46. Log of test hole 46 at the SE corner sec. 17, T. 35 S., R. 37 W., drilled by State and Federal Geological Surveys, 1943. Surface altitude, 3,155 feet. (Authority, samples studied by Oscar S. Fent and Thad G. McLaughlin.)

	Thickness, feet	Depth, feet
Road fill	3	3
Dune sand		
Sand, medium to fine, and silt, calcareous, soft, gray buff,	4	7
Sand, medium to fine, red	27	34
Undifferentiated Pliocene and Pleistocene deposits		
Caliche, soft, containing fine gravel and fine to coarse sand	5.5	39.5
Sand, coarse to fine, partly cemented, containing soft buff and gray silt	10.5	50
Sand, coarse to fine, containing fine gravel and soft buff to gray silt; partly cemented	22	72
Silt, compact, tan, and caliche; containing fine sand	8	80
Sand, coarse to fine, and silt, soft, tan; containing caliche,	10	90
Sand, coarse to medium, containing caliche	7	97
Silt, soft, light gray to tan, containing coarse to fine sand and caliche	83	180
Silt, soft, tan, and caliche; containing fine gravel and coarse to fine sand	10	190
Sand, fine, to gravel, medium; containing buff and red to pink silt and a little caliche	66	256
Silt, soft, light red to dull red, containing fine to coarse sand, fine gravel, and caliche	56	312
Sand, medium, to gravel, medium; containing a little caliche in lower part	18	330
Sand, coarse to fine, containing soft pink-buff silt and caliche	30	360
Silt, compact, red, containing coarse to fine sand and caliche	10	370
Sand, fine, to gravel, fine	70	440
Sand, coarse to fine, containing gray and red silt and caliche	20	460
Silt, soft, pink to brown; contains very fine sand, concretions of siltstone, and caliche	10	470
Silt, soft, gray and yellow brown, containing very fine sand and concretions of siltstone	10	480
Silt, clayey, blue gray, containing very fine sand and a little caliche and pyrite	10	490
Silt, soft, gray and blue gray, and sand, very fine; containing compact laminated red and yellow silt	10	500
Silt, soft, gray to blue gray, containing very fine sand and a little caliche	30	530
Silt, soft, gray to blue gray and red, containing medium to fine sand and caliche	20	550

47. Log of railroad well (54) at Ulysses in SE¼ SW¼ sec 27, T. 28 S., R. 37 W., drilled in 1922. Surface altitude, 3,047 feet. (Authority, Atchison, Topeka and Santa Fe Railway Company.)

	Thickness, feet	Depth, feet
Undifferentiated Pliocene and Pleistocene deposits		
Clay, sandy, yellow	87	87
Sand and clay, yellow	52	139
Clay, sandy, yellow	129	268
Sand, coarse	12	280
Clay, yellow	9	289

48. Log of railroad well (182) at Sublette in SW¼ NE¼ sec. 32, T. 29 S., R. 32 W. (Authority, Atchison, Topeka and Santa Fe Railway Company.)

	Thickness, feet	Depth, feet
Undifferentiated Pliocene and Pleistocene deposits		
Clay, sandy	190	190
Sand, dry	6	196
Sand, water bearing	15	211

49. Log of railroad well (216) at Satanta in SW¼ NE¼ sec. 13, T. 30 S., R. 34 W., drilled in 1912. (Authority, Atchison, Topeka and Santa Fe Railway Company.)

	Thickness, feet	Depth, feet
Soil	10	10
Undifferentiated Pliocene and Pleistocene deposits		
Rock, hard (probably consolidated sand or silt)	5	15
Clay, gray	15	30
Clay, white	20	50
Sand, coarse	50	100
Sand, fine	30	130
Clay, sandy	45	175
Cement gravel (probably consolidated sand and gravel)	10	185
Sand and gravel	15	200
Sand, coarse	45	245
Clay, white	13	258
Clay, blue	2.5	260.5
Sand, coarse	49.5	310
Clay, hard, yellow	1	311

50. Log of railroad well (295) at Hugoton in NW¼ NW¼ sec. 16, T. 33 S., R. 37 W., drilled in 1929. (Authority, Atchison, Topeka and Santa Fe Railway Company.)

	Thickness, feet	Depth, feet
Dune sand		
Sand, soft	3	3
Undifferentiated Pliocene and Pleistocene deposits		
Dirt, black (probably silt or clay)	7	10
Sand, clayey, red	11	21
Sand, soft	23	44
Sand, consolidated	10	54

	Thickness, feet	Depth, feet
Sand, soft	11	65
Sand, hard	23	88
Clay, white	82	170
Sand, soft	27	197
Sand, containing clay, red	10	207
Sand, hard	12	219
Sand, soft	10	229
Sand, clayey, red	12	241
Clay, red	15	256
Sand, soft	78	334

51. Log of railroad well (238) at Moscow in SW¼ NW¼ sec. 26, T. 31 S., R. 36 W., drilled in 1931. (Authority, Atchison, Topeka and Santa Fe Railway Company.)

	Thickness, feet	Depth, feet
Soil	5	5
Undifferentiated Pliocene and Pleistocene deposits		
Clay, brown	10	15
Marl	30	45
Sand, brown	20	65
Clay, white and yellow	75	140
Sand, brown	40	180
Clay, blue	2	182

52. Log of municipal supply well (296) No. 1 of the city of Hugoton in SW¼ NE¼ sec. 16, T. 33 S., R. 37 W. (Authority, driller.)

	Thickness, feet	Depth, feet
Soil	2	2
Undifferentiated Pliocene and Pleistocene deposits		
Clay	6	8
Clay, sandy	10	18
Clay	6	24
Clay, sandy	7	31
Sand, fine	11	42
Clay, sandy	4	46
Sand	35	81
Sand and gravel; coarse	17	98
Clay	3	101
Caliche and clay	11	112
Clay, sandy	12	124
Clay and caliche	10	134
Caliche	6	140
Clay, sandy	12	152
Sand, fine	8	160
Sand, coarse	38	198
Clay	2	200
Caliche	5	205
Clay	4	209

	Thickness, feet	Depth, feet
Rock (probably consolidated sand or silt)	2	211
Sand	4	215
Rock (probably consolidated sand or silt)	1	216
Caliche	2	218
Clay and caliche	30	248
Sand and gravel; coarse	6	254
Clay, containing sand and gravel	13	267
Rock (probably consolidated sand or silt)	3	269
Clay	4	273
Clay, sandy	30	303
Rock (probably consolidated sand or silt)	1	304
Clay	4	308

53. Log of municipal supply well (297) No. 2 of the city of Hugoton in SW¼ NE¼ sec. 16, T. 33 S., R. 37 W., drilled in 1931. (Authority, driller.)

	Thickness, feet	Depth, feet
Soil	2	2
Undifferentiated Pliocene and Pleistocene deposits		
Clay	18	20
Clay, sandy	20	40
Sand	18	58
Sand, hard	4	62
Sand	15	77
Sand and gravel	2	79
Sand, coarse	3	82
Sand	8	90
Sand and gravel	2	92
Gravel	11	103
"Magnesia rock" (probably calcareous sand or silt)	16	119
Clay, sandy	7	126
Clay	8	134
Clay, sandy	46	180
Clay and gravel	15	195
Clay, caliche, and gravel	14	209
Sand and clay	16	225
Sand and gravel	25	250
Clay, sandy, and gravel	12	262
Rock (probably consolidated sand or silt)	2	264
Clay	10	274
Rock (probably consolidated sand or silt)	2	276
Sand, containing gravel	9	285
Clay, sandy	13	298
Gravel, consolidated	1	299
Clay	1	300

54. Log of well (29) of Joseph Jungferman in SE¼ SE¼ sec. 31, T. 27 S., R. 38 W. (Authority, driller.)

	Thickness, feet	Depth, feet
Undifferentiated Pliocene and Pleistocene deposits		
Sand	90	90
Clay, sandy, containing alternating beds of sand	165	255
Gravel, coarse	27	282
Rock (probably consolidated sand or silt)	3	285
Gravel	10	295
Clay	3	298
Clay and sand	11	309
Clay, sandy	8	317

55. Log of well (244) of J. F. Parsons in SW¼ NW¼ sec. 4, T. 31 S., R. 37 W. (Authority, driller.)

	Thickness, feet	Depth, feet
Undifferentiated Pliocene and Pleistocene deposits		
Clay and sand	115	115
Sand, fine	45	160
Sand and gravel, coarse	142	302

56. Log of well (247) of B. W. Parsons in SW¼ NE¼ sec. 10, T. 31 S., R. 37 W. (Authority, driller.)

	Thickness, feet	Depth, feet
Undifferentiated Pliocene and Pleistocene deposits		
Clay and sand	75	75
Sand	10	85
Clay	5	90
Sand, fine	20	110
Sand, coarse	30	140
Clay	40	180
Gravel, coarse	10	190
Clay	30	220
Gravel, coarse	55	275

57. Log of State well in NW¼ NW¼ sec. 36, T. 29 S., R. 37 W., drilled in 1895. (Cited by Haworth, 1897.)

	Thickness, feet	Depth, feet
Soil	2	2
Undifferentiated Pliocene and Pleistocene deposits		
Clay and gypsum (probably clay and caliche)	6	8
Ashy (probably silt or very fine sand)	8	16
Sand, hard, red	5	21
Gypsum, very hard (probably caliche)	14	35
Sand, red	35	70
Clay and gypsum, very hard (probably clay and caliche),	7	79
Sand, hard, red	12	91
Sand, soft, gray	2	93
Sand, hard, red	7	100

	Thickness, feet	Depth, feet
Sand, soft, red	9	109
Clay, sandy, hard	11	120
Clay	24	144
Clay, hard, red	4	148
Sand, red	5	153
Clay, hard, red	1	154
Gypsum, hard (probably caliche)	3	157
Sand	8	165
Clay	5	170
Sand, coarse	2.5	172.5
Clay, red	12.5	185
Sand	14	199
Clay	3	202
Sand	10	212
Rock (probably consolidated sand or silt)	8	220
Clay, blue	11	231

58. Log of well used to supply water for drilling Republic Natural Gas Company No. 1 Sherwood well in sec. 33, T. 33 S., R. 37 W. (Authority, driller.)

	Thickness, feet	Depth, feet
Soil	4	4
Undifferentiated Pliocene and Pleistocene deposits		
Clay, yellow	31	35
Sand	9	44
"Redbed" (probably red silt, clay, or fine sand)	2	46
Sand	24	70
"Redbed" (probably red silt, clay, or fine sand)	4	74
Sand and clay, consolidated	26	100
Sand	6	106
Sand and clay, consolidated	2	108
Sand	20	128
Sand and clay, consolidated	57	185
Sand	7	192
Clay, yellow	24	216

59. Log of well used to supply water for drilling Republic Natural Gas Company No. 1 Laura Porter well in SW¼ sec. 27, T. 32 S., R. 37 W. (Authority, driller.)

	Thickness, feet	Depth, feet
Dune sand		
Sand	6	6
Undifferentiated Pliocene and Pleistocene deposits		
Clay	14	20
Sand	25	45
Sand, coarse	22	67
Clay, yellow	6	73
Sand	43	116
Gravel	5	121

	Thickness, feet	Depth, feet
Clay, yellow	3	124
Sand	27	151
Clay, yellow	34	185
Sand	35	220
Sand and clay, consolidated	21	241

60. Partial log of gas well in sec. 34, T. 34 S., R. 38 W. (Authority, samples studied by H. T. U. Smith. Cited by Smith, 1940.)

	Thickness, feet	Depth, feet
Undifferentiated Pliocene and Pleistocene deposits		
Sand, silt, and clay	18	18
Sand, medium to coarse, clean	61	79
Sand, fine to medium, dirty, dark buff, and limestone, compact, gray buff	30	109
Limestone chips and medium to coarse sand and grit	92	201
Sand, grit, calcareous sandstone, and chips of limestone. Stained red between depths of 231 and 262 feet	91	292
Sand, medium to coarse, dirty, containing a little gravel and clay	31	323
Grit, gravel, and clay	30	353
Grit, gravel, and clay; containing sand	31	384
Grit, gravel, and clay; containing buff calcareous clayey silt	61	445
Grit, clayey, dirty, containing fragments of red mudstone and a little gravel	61	506
Sand and grit; reddish; dirty; containing clay	30	536
Sand and grit; containing clay	30	566
Sand, reddish, dirty, containing a little gravel	31	597
Permian redbeds		
Sand and silt, light reddish	30	627

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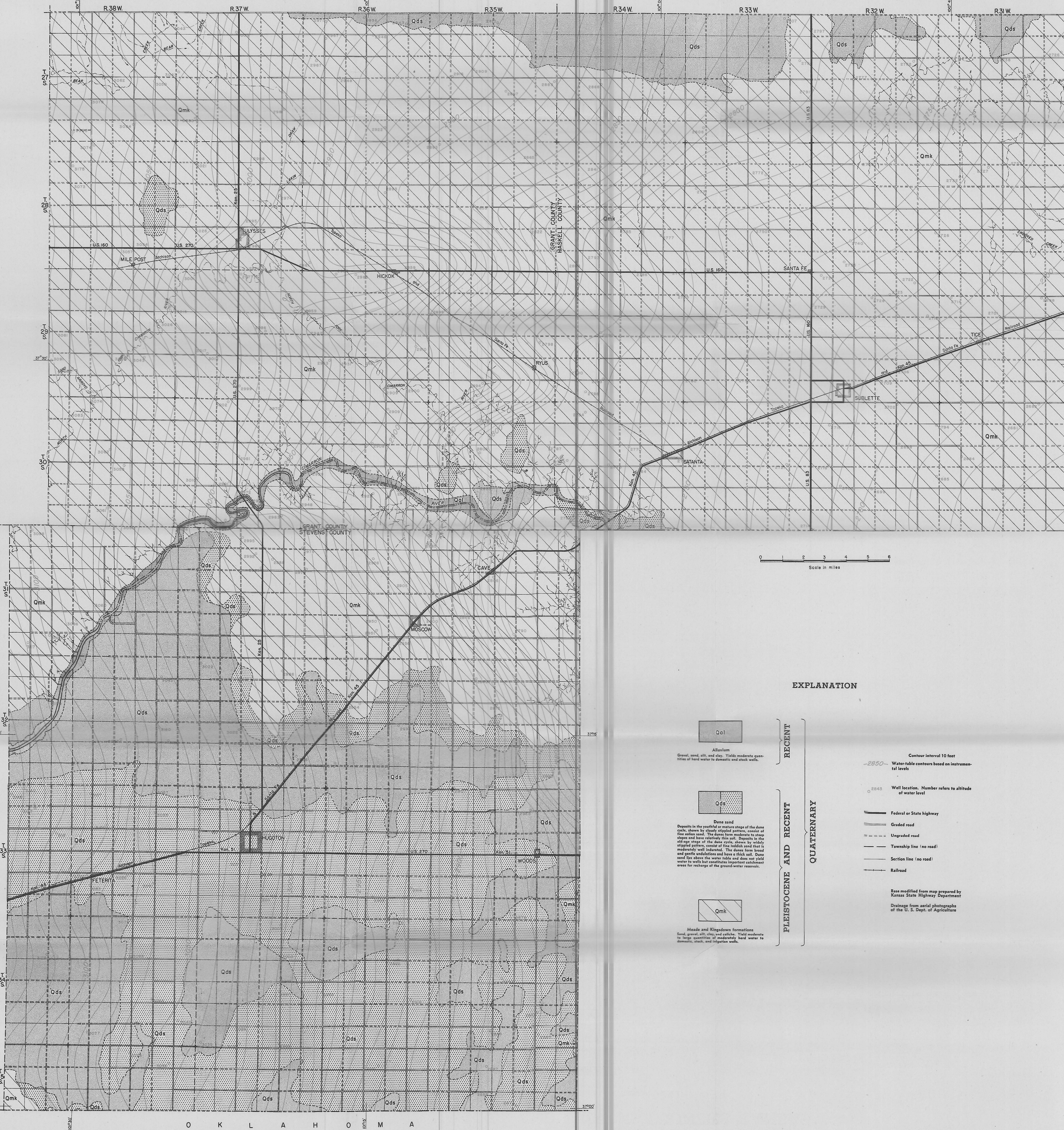

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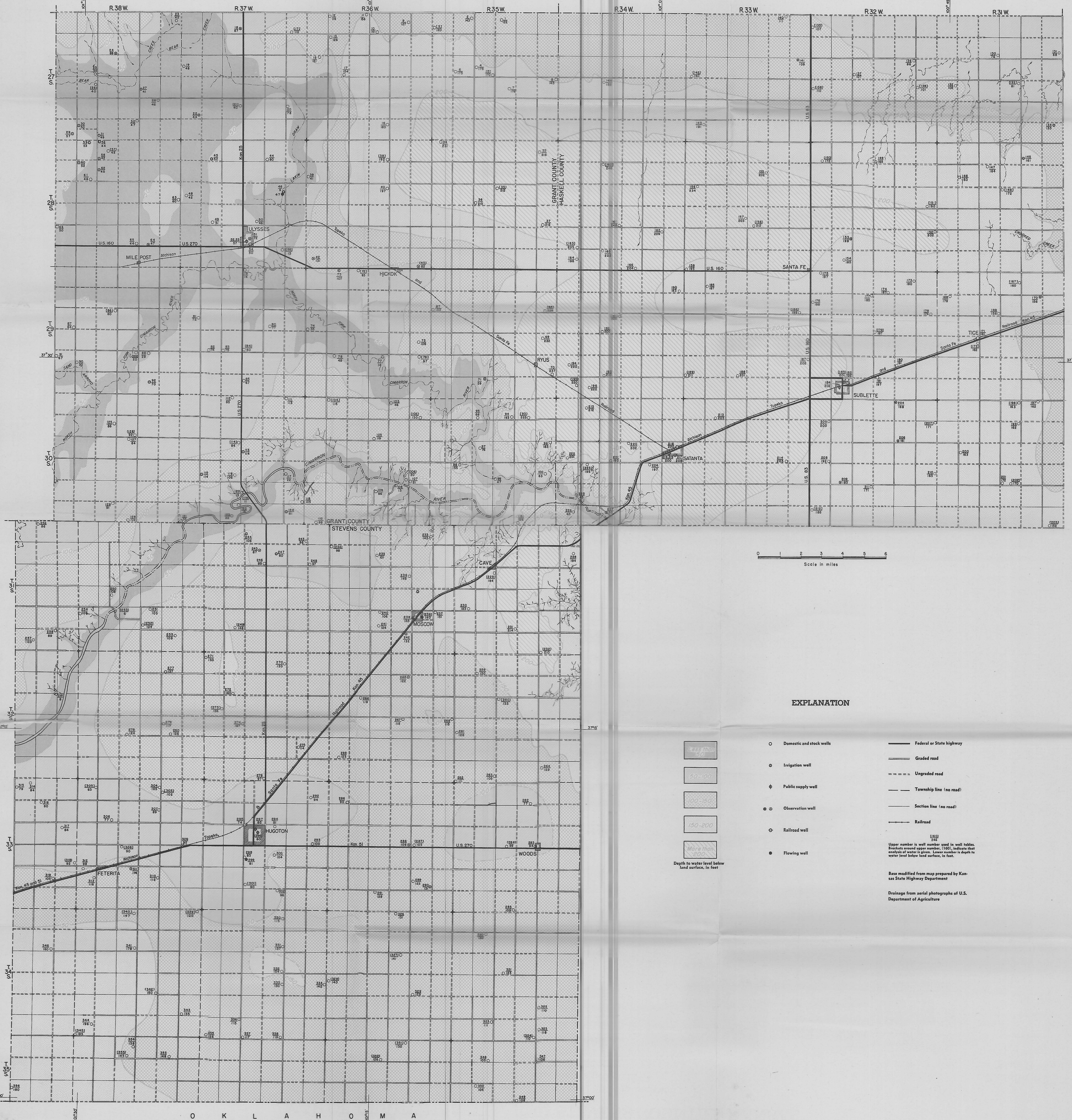

DIAGRAMMATIC CROSS SECTION OF GRANT, HASKELL, AND STEVENS COUNTIES, KANSAS